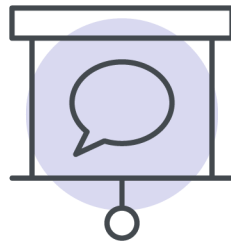

Waterloo

ERTH 2401
MIDTERM EXAM
STUDY GUIDE



Lecture Notes

ERTH 2401 – Lecture #1

Fossils And Their Place In Evolution

- Cryolophosaurus – found somewhere cold; Antarctica which does not have the environment to support any reptile life now indicating there was a much warmer climate before during the dinosaur age
- Slide 1; print time scale for geological period
- Precambrian (610 MYA) --> Cenozoic
- Age of the earth is 4.5 billion years old
- Changes to earth's geography; 1 supercontinent, 1 large ocean – this allows migration to continue along the entire world b/c there are no oceans to stop migration routes like there is now
- Blue line – sea level; which has fluctuated tremendously during the geological time scale; when sea level is low there is more land, when sea level is high the continents are flooded
- The sudden drops in sea level are due to ice ages and expose a lot of land as water is frozen – exposure of land causes erosion and therefore loss of sedimentary levels (which are crucial in the preservation of fossils) – erase time and therefore do not know how much time is lost (sharp dips) – high water levels preserve these sedimentary layers
- Glaciers and ice caps exist now – there were time where no ice existed at all; high sea levels and flooded continents
- Mass extinctions – there were many mass extinctions not just dinosaurs
- Raising of mountains; affect movement of life
- The evolution of life was affected by all see factors at the different geological times
- Explosion of life and # of genera in early Cambrian time Cambrian explosion – very primitively life, explosion of life
- 600 MYA: 1 continent, southern polar region had an ice cap
- As earth changes so did life – evolution?
- There were distinct periods of times here diverse life existed
- Climate curve; climate is always changing, changing at a more rapid rate in the last 200 years than ever before, natural climate change was much slower
- “Green house phases” & “ice house phases”
- Different geographical periods; flooding of continents vs supercontinent and polar ice cap in the south
- Continental sea ways can influence everything
- Planet earth 3 billion years ago: stromatolites – first organisms (gamma sedimentary structures), organic layers, sediment stuck to these layers – “domes” also with sedimentary layers – lived 3.7 billion years ago maybe more – very resistant organisms as they are still visible today
- The presence of stromatolites mean the area where they were present was flooded
- Ediacara metazoan fossils – multicellular organisms, single cell organisms
- “Resting structures” – leaf type organisms, looks like a leaf – fell into soft sediment

- Not a body fossil but rather a ichnofossil (trace fossil) – gives an idea of life structure, texture, behaviours, foot prints, actions, preserves organisms without bones/ other hard structure – very confident for these organisms without hard structures because if this did not exist they would never be identified – trace can tell a lot if body cannot be preserved
- Always important to look at body body and ichnofossils if possible
- At the time of Cambrian explosion; nature experiment – extinct at end of Cambrian
- Pikaia – our oldest ancestor (first organism with notochord)
- Sea level; red line = present sea level compared to the geological time sea levels
- The sea during these time periods was never lower than it is now – was always the same or higher (few exceptions)
- Remember sea level drop = lots of erosion, loss of records = unconformities (unsure about the drop)
- 450 MYA: stromatolites come out of period
- Some life forms
- Life originated in the sea; original fish; Dunkleosteus
- End of Paleozoic – start to fuze together – Pangea; land to be populated, Carboniferous coal forest
- As more land was exposed animals needed to explore therefore evolved limbs; e.g. The lobe-finned fish (which was similar to the early amphibian)
- However, like fish, amphibians rely on water for reproduction (site to hatch eggs)
- Step in evolution: the amniotic egg (in a shell) – animals no longer require water for reproduction and can reproduce on land b/c the shell of this newly evolved egg protects offspring before they are born
- Permian (280 MYA): Pangea, 1 large super continent – in the middle of this continent was a mountain range (the north and south plate collided producing a mountain), ice cap in southern hemisphere, we know this existed because the same fossils were found on opposite sides of the world, how could they have gotten there without the entire world being once connected?
- Reptiles present; e.g. Dimetrodon – which has a “sail-looking” fin which helped regulate their body temperature
- Early Triassic (237 MYA): Pangea type continent – first appearance of dinosaurs (later on in the Triassic), Pangea about to break up which would create valleys (still dry in this period)
- E.g. East African River Valley; important b/c early humans were found here
- Volcanism puts ash into the air which is full of different molecules; carbon, CO₂, phosphates and silica – silica particles when settled in to the ground or water can actually preserve organisms making them available to us today in fossilized form
- Coelphysis: early, small dinosaur
- Late Jurassic (152 MYA): split of southern and northern hemisphere, looking at European region; wonderful fossils found here – very large Dino period
- Anoxic basins – no oxygen in these basins therefore when organisms fall in the soft sedimentary layer and sink down into the basin their remains are persevered; e.g. Organisms giving birth, other animals, bugs, shrimp etc.

- Live births were discovered as well as the existence of eggs (live births captured in these anoxic basins)
- Jurassic reefs and Jurassic lagoons – lagoons are high in salinity, low predators therefore preserving specimens – e.g. Imprint of jellyfish found (very rare b/c jelly fish are soft bodied)
- Archaeopteryx lithographica – bird similar to dinosaurs (could be the transition bird from bird to dinosaur – compsognathus)
- Cretaceous period (105 MYA): warm planet, unusual time, high sea levels – western interior sea

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The Mesozoic Landscape Where Dinosaurs Roamed

- Dinosaurs evolved greatly over the time period that they were alive – 160 MY – means that their species were successful
- Due to the changing earth, dinosaurs were forced to change as well
- Canada = the best sites for dinosaur bones/fossils – e.g. Alberta Badlands (can actually walk over bones here)
- There are specific structures in the Badlands that help protect the dinosaur evidence and geological landscapes (see slides 3-5)
- Channels of rivers form these structures in the surrounding geography – water erosion is present as well in these areas – no vegetation (this is weird because it suggests that the earth was different before if it supported dinosaurs – e.g. herbivores were found in these areas therefore needed vegetation to feed on) – the earth has changed
- Lush vegetation during the **Cretaceous Period – 90 MYA** – we can take evidence from the area to form pictures of what this period may have looked like (e.g. leaf fossils, other imprints) – assume that herbivores would feed on the plants and carnivores would feed on the herbivores
- Analyzing fossils for organic matter – find pollen which can lead to what kind of plants existed at the periods of time – reconstruct vegetation
- There were many large earth changes during the dinosaur era which may have contributed to many factors of their lives (e.g. migration and variation)
- Dinosaurs lived from the end of the Triassic through the Jurassic and into the Cretaceous (extinction occurred at end of the Cretaceous period)

Moving Through Dinosaur Time:

Modern Day Earth

- Large, separate continents
- 2 polar ice caps
- Oceans (Atlantic and Pacific) clearly visible

Late Triassic (220 MYA)

- No ice caps indicating a warm climate
- Giant continent – some island but the land masses are generally connected to one another

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- Mountain range can be seen – could be problematic in terms of migration of the dinosaurs
- Generally, the configuration of this giant land mass allowed easy migration routes for the dinosaurs allowing them to spread put across the world
- Very dry area where North America (NA) would be located; volcanic systems

Early Jurassic (200 MYA)

- Continents on the verge of separating
- The ocean is moving in between the continents, pushing them apart (separating them by the new incoming ocean)
- European region is not visible – underwater
- Pacific Ocean pushing through

Middle Jurassic (170 MYA)

- Ocean still progressing between the continents – looks like there is only a single “land bridge” connecting the continents

Late Jurassic (150 MYA)

- **Tethyan Seaway**

Early Cretaceous (105 MYA)

- Dinosaur species separated by the separation of the continents – can now explore their own paths of evolution (have variation in the dinosaur species begin)
- African dinosaurs separated from the South American dinosaurs (SA)
- Species diversity
- NA now on own, Greenland on own
- European region still underwater
- Australia and Antarctica still connected
- Polar Sea approaching the NA continent from the north (see slide 19)
- Still no ice caps therefore can assume warm period of time

Late Cretaceous (90 MYA)

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- The earth's structure is similar to the earth's structure we know today
- Shallow seas and sea ways – see the shallow sea that separates NA
- Many new marine migration paths for marine organism to explore and expand into
- However, the land is very separate now – each species evolves on its own in different locations
- Sea level is much higher in this period
- Mowry Sea – comes from the Polar Sea and looks like it will connect with Tethyan Sea

Latest Cretaceous

- **Western Interior Seaway (WIS)** – connection of Mowry to the Tethyan
- Species that are adapted to warm water move up from the south into the WIS and species adapted to cold water move from the north into the WIS – therefore diversity in the middle
- This seaway is responsible for the lush environment experienced on either side – prime region for dinosaurs since it is humid, warm and lots of rain

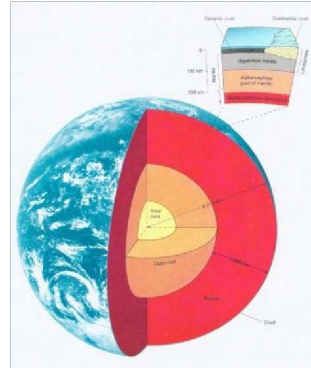
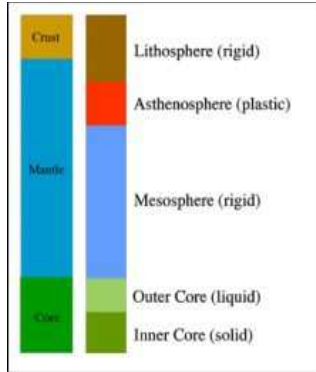
Cretaceous/Tertiary Boundary (66 MYA)

- Begin to lose dinosaurs and other species of plants and animals
- Mass extinction – some catastrophic event occurring at end of period
- Earth changes again
- From the NA view – seaway dries up in the middle leaving just small bays in the north and south – indicates climate change in NA

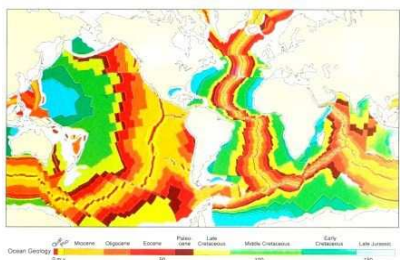
What Drives Changes to The Earth?

- Plate tectonics – different parts of the earth
- Major lithosphere plates defined by zones of seismicity

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- Asthenosphere – plastic layer that is not rigid, allows movement
- NA plate – into Atlantic – mid Atlantic ridge: Atlantic Ocean is considered growing ocean, Pacific is the decreasing ocean – there are large plates and small plates all that have contributed to the changing Earth
- There was no such thing as the Atlantic Ocean during Pangea – it was all connected as one body of water
- Atlantic Ocean started forming during dino-times
- East African Rift – eastern part of African splitting off from rest of continent
- As 2 continents separate the ocean flows in between
- Pterosaurs shown in pictures – when the ocean formed fully groups of these dinosaurs could have been separated or they could have flown very long distances
- Age of sea floor – as we move away from the origin of the ocean, it is older and older near the edges however there is nothing older than the later Jurassic period b/c the earth is not constantly expanding – plates go under each other

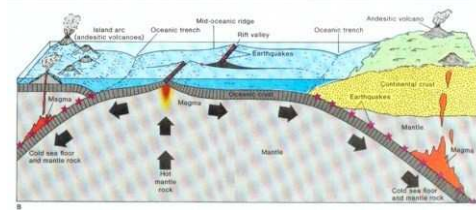
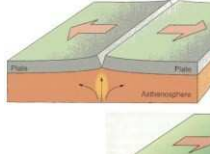


- Pacific side – pacific and south American plate (Andes) – large subduction zone – oceanic crust goes under continental crust – when plate goes underneath, magma rises to the earth (volcanos erupt)

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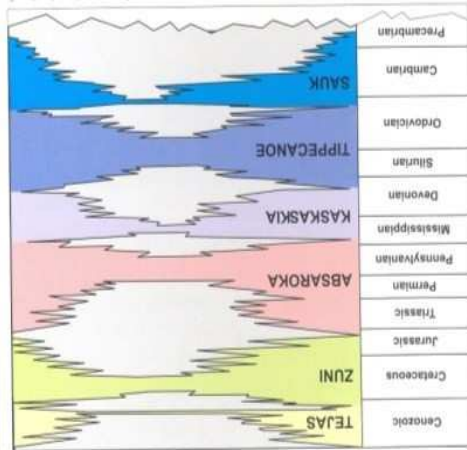
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- West coast: mount St. Helens – pacific side; active volcano
- Also in the Pacific Ocean lies ring of fire volcanic system – collision of oceanic plates – lots of seismic activity



- Diverging, colliding/convergent and translational boundaries
- Examples of each; diverging = mid Atlantic ridge, colliding/convergent = western coast and translational = seismic activity
- Higher sea levels much of the time during past geological time
- Sea levels rise intensely towards cretaceous
- Tectonic processes contribute to sea level increase/decrease – deepest at subduction zones/trenches – drop in sea level with these subduction zones (as it is a big hole the water fills it first before increasing the rest of the seal level). Ocean ridges increase sea level b/c of the displacement of the water – reason why sea level was high in cretaceous
- Since there was no ice in these time periods, the melting of ice did not contribute as there was no ice to melt
- Cratonic sequences; 6 major sequences – geological evidence of sea level rising/falling – deposits of sediments along craton during each time period creating a sequence which can be studied – fun fact: there are limestones in Kingston that are part of this sequence

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- Transgression/regression – **transgression** = shoreline moves landward; high sea levels cause water to move into the shore toward the land (**highstand**); **regression** = shoreline moves toward the shore (**lowstand**) – sea level is low during regression; **stand still** = intermediate pause between rise and fall
- Great lakes exist b/c of melted ice sheets that used to cover our area
- Sea level change: these changes have shaped the earth and influenced life on earth
- **Eustatic sea level change** – global sea level changes vs relative sea level change – **local/regional change**
- **Unconformities** are large time gaps between sea level changes – loss of time; no evidence of either high or low sea levels – we don't know what happened during these unconformities
- Sequence boundaries – bound by unconformities
- Land relief dictates response to sea-level change; Netherlands are under sea level where BC is above sea level; different areas can be affected in different ways by rise/fall of the sea

Causes of Sea Level Change1) **Eustatic (Global)**

- **Volume:** changes amount of water in the ocean
- **Glacial eustasy;** fluctuating continental glacier – if they melt sea level will rise
- Desiccation of basins – for example when the Mediterranean dried up (large salt deposits found to show this event)
- Changes in oceanic temperatures

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- **Tectono eustasy;** growth of ocean ridges
- Change volumes of ocean basins
- Formation of ocean trenches – shallow ocean water
- Sedimentation – when sediment is pushed into the ocean – deltas (e.g. the Nile)
- Example: Mid-Atlantic ridge – took space out of an ocean basin therefore sea level increased

2) **Relative (Regional/Localized)**

- **Regression (shallowing)** – regional uplift and faulting in tectonically active areas – post glacier rebound (as glaciers melt, ocean rise), depositional progradation – lots of sediment out, pushing sea level back (e.g. progradation of Mississippi delta - rapid sedimentation caused local regression – overall worldwide transgression b/c sea level rise but Mississippi does the opposite b/c of sedimentation) – regressive shoreline, sedimentation counteracts transgression
- **Transgression (deepening)** – region subsidence, sinking along hinge line of postglacial uplift, thermal subsidence of crust – volcanic islands, sinking of coastal areas due to compaction of underlying sediment, coastal retreat due to erosion – water moves in and destroys lands and homes
- Example: transgressive shoreline in Australia – pushing further and further inland due to sea level rise

Sea Level Change and Sedimentation

- **Transgressive facies:** continuous shift of environment and their sedimentary and biological products inward (landward) – shoreline moved back, shrinkage of land area precede by erosional unconformity, landward shift of adjacent facies through time and ocean takes over the land, erosion occurs and sediments become finer

Mesozoic Climate

- Climate and ocean connected/related
- Ocean – fluid = fast heat distribution
- Warms and cools slowly, holding onto heat much longer than continents
- Continents warm quickly on surface
- Oceans balance and climate changes

Modern Ocean Climates

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- Equatorial currents – east to west along the equator connects to currents from the north and south – this connection is important otherwise the ocean would be very very very hot and could potentially dry up; important mixture of water – there is no marine life without this mixture
- There was a different ocean current system due to the arrangement of the continents (had to go around one giant continent at one point) – different circulation
- Summary: climate and sea level changes during the dino time

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Continuation from Lecture #2

Climate Indicators:

- Pollen can help us understand climate. Also trees, coal ends, sediments (evaporated), flora/fauna, glacial indicators – lakes, deep valley. Also, geochemical evidence – soils and isotopic data
- E.g. Picture of conifer log – indicator of climate change

Review of Geological Time

Early Triassic

- Super continent, Pangea
- Low sea level – increased exposure of land; lots of erosion
- No tectonic activity
- Change in ocean currents due to large land mass
- 1 large land mass, 1 large ocean – change in climate
- Continental effect; more extreme weather (cold winters, extremely hot summers) – rapid warming and cooling – dinosaurs had to adapt to the environment
- **Influence on Biota:** decrease in species diversity, opening of migration routes, similarity between biota (Biota: total collection of organisms in a geographic region at a period of time)
- Triassic Chinle Formation: white areas = volcanic ash built up; forming first rift phase – rifting leads to volcanic activity which produces ash; important b/c these ash piles are filled with datable minerals – can determine geochronological age

Late Triassic – Early Jurassic

- Hot and arid, sand dunes and evaporites (salt deposits)
- Strong seasonality
- Year-round dry belt at the equator (Equatorial) – not much to eat for the dinosaurs
- Strong seasonal rainfall in the north and south regions above/below the dry belt.
- Middle and upper latitude humid belt – migration to these areas for food
- Red beds form (iron oxide – turns sand red)
- End of Triassic: possible extinction – Manicouagan Crater indicates mass event (found in Quebec)

Jurassic

- Rising sea levels
- Marine inundation of NA
- Warm, shallow seas with tropical islands
- Rare terrestrial sediments from Middle Jurassic onwards – exception: in China; lots of Jurassic dinosaurs

- Jurassic formations: Sundance Sea approached NA from the west – no connection to the Tethyan Sea as it is blocked by mountain belt (mountains formed when NA and SA joined together in forming of Pangea), Morrison Formation – terrestrial; many dinosaurs from this formation (picture of Morrison Formation, Colorado)

Middle – Late Jurassic

- Most data from marine sequences
- No ice at northern latitudes
- Warm indicators such as fish and plants
- Low seasonality; no extreme climates – overall warm climate; due to epeiric seas
- Late Jurassic: Arid NA, Europe under tropical sea
- Tethyan goes all the way through

Mesozoic (Triassic, Jurassic & Cretaceous) Overview

- Time of slow continental break-up
- Initial rifting in Middle Jurassic
- Tethyan sea – evidence in Gulf Coast

Tethyan Seaway

- A west/east seaway
- First blocked by supercontinent and goes right through
- Ammonites --> evolved to --> Nautilus

Late Jurassic – Early Cretaceous

- Complete separation of SA and Africa (Laurussia and Gondwana)
- Sea level fall
- In the Cretaceous; continents become separated, epeiric seas change continental effect of hot dry summers and cold winters
- Stabilizing effect
- Western Interior Sea – separates Rockies – Canadian Shield; dinosaurs roamed on both sides of WIS

Cretaceous Climate

- Continents become separated
- Even climate due to lots of water – stabilizing
- Ice-free poles? Unsure if there was ice or not
- Temperature from 0 – 17 degrees C (decreased temperature diff. From today)
- Lots of volcanic activity – increased tectonics and spreading centres
- Very dynamic period – lots to know about dinosaurs
- High sea level due to epeiric seas

Picture: 3 globes

- Different sides of the world during Cretaceous
- Stable climates

- Increased volcanism
- Increased input of CO₂ into the atmosphere – more absorption of heat into the air
- Warmer global climates
- Expansion of subtropical and tropical belts

Middle Cretaceous

- Active tectonics
- Further rifting between Africa and SA – Proto Atlantic
- Separation of dinosaurs
- Sea level rises

Western Interior Sea

- Connected to the Boreal Sea (north) and Tethyan Sea (south)
- Separates the Cordillera and stable NA craton - mountains forming
- Configuration changed (WIS) – variable palaeogeography

Chalk deposits; e.g. Kansas – formed out of Cretaceous = fossils (plants, cytoplankton)

- Not found in CAN – in the USA b/c it was warmer
- Coccolithophore (calcareous algae); formed chalk; abundant, lots of surface productivity
- Chalk casts of southern England
- Lower Cretaceous marine sedimentations – dark shales (e.g. Dinosaur Lake)

End of Cretaceous

- Sea level drops
- Less qual conditions
- Increased seasonality
- Harsher climate conditions – dinosaurs not able to adapt
- Possible leads to extinction of the dinosaurs – Cretaceous extinction; extreme conditions vs Big Bang (meteor impact)
- Retreat of WIS

Lecture #3

Taphonomy: How do fossils form?

Fossil Record – dinosaurs are extinct 66MYA

- Fossil lagerstaetten – places of extraordinary preservation (Messa, Germany) – shows very good details of specimens (e.g. Specific features of birds – colour, features etc.)

Where to Find Fossils?

- Not in igneous rock as it forms from magma – would destroy the fossils – too hot
- Not metamorphic because the pressure and heat would distort the fossils
- Sedimentary is where you can find fossils b/c of layers; there is still some distortion however best preserves the fossil compared to other kinds of rocks

More Fossil Record

- Hard parts: fossils better preserve the hard parts than the soft parts; e.g. Teeth, bones, claws, shells and spines
- Poor fossil record of the soft parts of organisms: flesh, organs, blood vessels, and skin – they all decay as they are organic matter
- Finding a skull helps puts the organism in taxonomic order
- Invertebrates more abundant than vertebrates
- Coral fossils
- Amber: element/medium of preservation – stuck in sap from tree and preserves the entire specimen once the amber hardens

Taphonomy – process of forming fossils

- Life assemblage: biocenosis (group of species); before death, presence of soft bodied taxa, possible high species diversity of invertebrates; e.g. Reef assemblage: lots of symbiosis, large species diversity – e.g. Tidal pool – another example of life assemblage
- Death assemblage: thanatoenosis – first changes in organism structure, disarticulation (loss of structure), death by natural cause or predation, predators, scavengers, bacteria
- Transported death assemblage: taphocoenoses – erosion and renetworking; rivers, other animals, wind, gravity, ocean currents and waves; locality of bones/structures changes – e.g. Wave transported beach assemblage – when waves bring shells onto the beach

Diversity Change

- Diversity decreases, removal of soft bodied members, mixing of assemblages through transport

More Taphonomy

- Fossil assemblage: fodere = to bury, burial by sediments, a fast burial increases fossilization potential
- Burial of organisms; net accumulation of sediment – river (still water zone), desert (dunes), ocean, lake – erosion causing reworking (erosion is not good for fossilization) – need quick burials for good fossil specimens
- In-situ burial vs reworked; in-situ burial means organism died and is articulated and buried in the same place it dies (intact structures later to be found), reworked burials indicate structures have been moved and separate, different location and disarticulated – often scientists find these types of burials where it is just a bone or 2 in a specific location not the entire structure – important to look at cause; catastrophic or slow accumulation that caused the death of an organism
- Quick burials = well preserved, complete articulated specimen
- Slow burials if disarticulated/dismembered before burial and single bones are found

Body Fossil vs Ichnofossils/Tracefossil

- Body = organisms
- Ichnofossils = activity/function

- Ichnofossils: molds (original impression – e.g. Dino foot imprint), casts (material filling the mold to make a cast; casts fill in, molds open – very important; Ediacaran fauna – first multicellular organisms, without ichnofossils we would not be able to determine organism's existence)

Fossilization Processes After Burial

- 1) Chemical processes within soil and sediment
- 2) Destruction or enhancement of fossilization

Bones – calcium hydroxy apatite

- Porous, reaction to temperature and pressure, percolating fluids – cause permineralization (filling of porous bones with minerals)

Changes After Burial

- Recrystallization: dissolution of original bone material, precipitation – retaining original shape of bone and replacement by another mineral
- Pyritization vs calcite; very hard preservation, every detail is preserved (enhancement) – see examples from in class of nautilus – pearly outer shell is preserved in one example and the outer shell is not preserved but the chambers are filled with calcite (recrystallization)
- Carbonate environment – hardens things very quickly

September 20th/2016

ERTH 2401 T – Lecture #4

Lecture #3 Continuation

- Pyritization – form of fossilization – fills with pyrite to preserve the specimen (pyrite crystals)
- Carbonate (brain corals) – rain water hardens the carbonate organisms
- Dolomitized corals – magnesium replaces the calcium in the calcite
- Changes After Burial:
- Silicification - silica hardens; volcanism produces silica-rich ash and when it buries organisms/specimens it preserves them into fossils; in the Cretaceous (lots of volcanos = lots of silica) – very helpful in preserving the past
- Agate quartz replaced by petrified wood – due to Silicification
- Conclusion: the fossil record gives us a glimpse about what has once lived on this planet – we don't get to see entire ecosystems – only small amount based on what we find - try to rebuild the ecosystems
- Ichthyosaur preservation
- Lear preservation, bird preservation
- Paleontological resolution: 5-1 million species today, life originated 3.5 billion years ago – unsure about deep marine life and insects – 1-3 billion species have come and gone; 99% from past are extinct (less than 1% were fossilized) – only 10% have been discovered

Lecture #4 – Taxonomic Order in the Natural World

- Family tree
- Slime molds → flat worms → tape worms → (image)
- Classification system: Carlos Linnaeus; naturalist – came up with system which puts life into categories; these categories have different sizes and get smaller and smaller until at 1 species – used to compare species and groups of organisms
- E.g. Cat
- Domain: Eukaryota, Kingdom: Animalia, Phylum: Chordata, Class: Mammalia, Order: Carnivora, Family: Felidae, Genus: Felis, Species: domesticus
- E.g. Dinosaur
- Domain: Eukaryota, Kingdom: Animalia, Phylum: Chordata, Class: Reptilia, Order: Therapoda, Family: Tyrannosauridae, Genus: Tyrannosaurus, Species: rex
- Natural hierarchy expressed as a puzzle – starts off very large and works down smaller and smaller (e.g. living organism → mammals)
- Binomen: genus and species
- Type species: one specimen on which the species described is based – used to compare another species
- General and specific characters; general define larger groups and become more specific

Biological vs. Geological Classification

- Biologists can examine how a species reproduces

- A geologist cannot reproduce for example dinosaurs or other extinct animals – no concept for breeding to reproduce a fertile organism
- Geologists rely on external morphologies for classification – although there is not always perfect specimens as they change through fossilizations

Phylogeny

- History of the descent of organisms (family tree)
- Clade: branch on a family tree
- Glade: a horizontal slice through the tree
- Origination: a new type of organism appears
- Extinction: an organism disappears
- Divergence: one clade splits into 2
- Convergence: evolution of similar features in 2 unrelated clades – come together; 2 organisms develop similar qualities
- Phylogenetic relationships: how taxa are related to each other

Stratophenetic Phylogeny

- Early classification method – not used very often anymore
- Resemblance between descendant and ancestor taxa – descent younger than ancestor
- Problems: assumption that the fossil record is complete – however it isn't, there are many missing pieces to the fossil record; not all ancestors or descents are found particularly with vertebrates (many micro-fossils) – unsure of evolving members

Cladistics

- Another classification method which takes the incomplete fossil record into account
- Concentrates on similarities of characters
- No time range (can account for the missing time if time is not incorporated at all)
- Evolutionary novelties: inherited change from a previously existing structure
- Cladograms are built in cladistics
- Taxa that share a number of evolutionary novelties are forming branches on the cladogram – evolutionary novelties = specific characteristics

Monophyletic vs Polyphyletic

- Monophyletic: taxa that share a number of evolutionary novelties and having a common ancestor – have multiple elements in common, trace back to a common ancestor
- Polyphyletic: taxa which lack the common ancestor – different roots
- Example cladograms; see slides
- Convergence cladogram: straight parallel lines, similar in evolutionary novelties – no common ancestor (e.g. wing structure for birds, bats and a fly – similar structures but no common ancestor)
- Always looking for the most parsimonious characteristics – simplest cladogram that works in same direction as evolution

Evolution of Life

- Prokaryotes: single-cell organism without nucleus, simple
- Eukaryotes: single-cell organism with nucleus or even multi-celled
- Example: stromatolites (early signs of life)
- Protozoa: single cell, mainly aquatic, motile
- Foraminifera: hard shell, environmental indicators, fossil record
- Ediacara Fauna: first multi-celled organism (570 MYA) – ichno fossils found indicating multicellular life

Cambrian Explosion

- Explosion in diversity and number of genera in early Cambrian time
- More life become present
- Cambrian explosion occurs in Cambrian period (544-505 MYA); explosion of life, experimentation of life forms
- Modern phyla came from phyla
- E.g. Yoho National Park – B.C.
- Emerald Lake
- Burgess Shale – ancient Cambrian sea floor due to tectonic activity; fine laminated sediment pyrite rich – pyritized bed due to anoxic environment – leads to good preservation
- Depositional Setting: at the foot of an escarpment – leads to fast burial (better preservation)
- Experimental phase – many animals became extinct at the end of the Cambrian

Chordata

- Throat
- Presence of notochord – stiff rod running down the back of an animal
- Presence of a dorsal, hollow nerve cord
- E.g. Haikouichthys

Cephalochordates

- Next step
- Closest relatives to the vertebrates one specimen in Cambrian Period
- Modern representations had blood vessels
- E.g. lancet (little worm creature)
- Modern cephalochordates; nerve cord, notochord

Pikaia

- Earliest ancestor
- Notochord
- Invertebrate
- Possibly the earliest representative taxon of cephalochordates

Vertebrates – Uniting Features

- Calcified skeletal tissue (bone) – divided into segments

- Natural neural crest – cell formation
- Differentiation of cranial nerves (skull nerves)
- Eyes
- Presence of kidneys
- New hormonal systems
- Mouthparts

Gnathostomata

- Development of jaws – goes from small mouth to bones developing to form jaw
- Early fish: sharks, ray-finned fish, lobe-finned fish, lobe-finned fish with lungs (movement onto land)
- Originated in the water and then moved onto land once features were developed (creatures had to evolve to make it onto land)

Conquering Land (Developing Structures)

- Respiration (lungs)
- Permeability barrier – skin – protect skin from the elements (e.g. increased exposure to sun)
- Reproduction – amniotic egg
- Gravity – develop a skeleton to hold everything together under the pressure of gravity
- Feeding – actually eat food, no suction
- Locomotion – capability of moving on land
- Evolution of creatures to live on land; needed to develop feet to walk on land

Tetrapoda

- 4, feet (tetra-poda)
- 4 limbs
- Facilitating life on land vs the water
- Evolution: Ray-finned fish → limbs evolved and become stronger and stronger (see slide for further evolution)
- Hand bones; humerus, ulna and radius (facilitate life on land)
- Strong shoulder girdle
- Foot prints of early amphibian on Blue Beach, NS – help us determine size, stride lengths, speed etc.
- Cladogram: chordata → vertebrata → tetrapoda

Four Classes of Tetrapoda

- 1) Amphibia (frogs, salamanders, etc.)
- 2) Reptilia (crocodiles, turtles, snakes, lizards)
- 3) Aves (birds)
- 4) Mammalia

Diagnostic Features of Tetrapoda

- Backbone made of vertebrae

- Lower spool called centrum
- Spool contains the spinal cord
- Vertical splint; neural arch and spine
- Vertebrae have various processes for muscle and ligament attachment
- Spinal cord: centrum, neural arch, neural spine, neural canal

Function of Backbone

- Is more sophisticated than in ancestors
- Carries body out of water onto land
- Facilitates locomotion
- Running between the pelvic and pectoral girdle – shoulders and hips

Skull

- Can determine taxonomic placement
- At the anterior/cranial end
- Brain case
- Occipital condyle – knob connecting braincase to vertebral column
- Feeding apparatus
- Face

September 22nd/2016

ERTH 2401 T – Lecture #5 Notes

Lecture #4 Continuation

Skull Openings

- Picture: large eye socket – deep water habitat
- On side of the brain case there are openings for stapes (bones which transmit sound from the tympanic membrane (ear drum) to the brain)
- On the skull roof: orbit (eye socket) and nares (nostrils) – important openings on the skull
- The skull is important for classifying dinosaurs into taxonomic order
- Drawing of skull: important parts of the skull (don't need to know all the names – just important ones identified later)

Shared Tetrapod Features

- Monophyletic
- They share evolutionary novelties and a common ancestor

Important Evolutionary Step

- Amniotic egg (different features of the egg allowed survival and successful reproduction on land)
- Membrane: amnion retained moisture, keeping embryo bathed in liquid – the amnion surrounds the embryo (“sac” like)
- A shell
- Large yolk to feed embryo
- Special bladder to deal with waste
- All of these were important for surviving on earth vs living in aqueous environments
- By finding eggs, growth rate can be determined
- Sketch: amnion surrounding the embryo (different parts of the amniotic egg)
- Amphibians have to stay close to water for reproduction; reptiles, birds and primitive mammals however have eggs – can be on land

Faunal Change Over

- End of the Triassic: many non-amniotic tetrapods become extinct – move on to organisms only with amniotic eggs
- The dinosaurs evolved

Amniota

- Amniotic tetrapods
- 2 lineages: mammals (Synapsida) and reptiles (Diapsida and Anapsida)
- Photo: Differences in skulls between the Synapsida, Diapsida and Anapsida
- Split between both lineages took place 310 and 320 MYA
- 2 cladograms describing lineage; incorporating Tetrapoda → Amniota → Reptilia and Dinosauria (presented in different ways)

Lecture #5: Dinosaur Anatomy

Important: Many slides contain images (anatomy) that should be reviewed before the midterm/exam

Importance of the Skull Features

- Anapsid: eye orbit, fused plates (closed skull roof), nostril
- Synapsid: temporal opening, closed roof still, braincase visible through temporal opening (lower) – opening behind the eye, jaw muscles pass through to attach to upper part of skull roof

Skull Openings

- Supratemporal fenestra
- Orbit
- Lateral fenestra
- Mandibular fenestra
- Nostril
- Antorbital fenestra

30 Different Skull Bones

- See slide; not all need to be known
- Mandible is the lower jaw portion of the skull
- More terminology on following slide
- Braincase; we are interested in the size of the brain; can measure the braincase using paint and then fill with water to determine approx. size of dinosaur's brain
- We want to know how big the brain was in respect to the size of the body
- Tomography used to study brain skulls

Synapsida

- Early representation of Dimetrodon – from the Permian, cold blooded, the fan-like structures helped regulate body temperature
- 2 m long
- Carnivore
- Elongated neural spine
- Lived during late Paleozoic
- Synapsids were most dominant terrestrial vertebrates during early Mesozoic
- Followed by smaller mammals – living parallel to dinosaurs, not dominant (small mouse-like)
- After the dinosaurs is when the mammals flourished

Reptilia

- Anapsida (turtles)
- Fully roofed temporal region – no holes
- Diapsida (dinosaurs and pterosaurs)
- D for dinosaurs
- Recent: snakes, lizards, crocodiles
- Upper and lower temporal openings
- Light bones – for flying; lost easily in fossil record
- Anapsida: chelonian (turtles); other extinct forms – turtles exist since Late Triassic (210 MYA), large specimens during the cretaceous (See Archelon)
- Diapsida: 2 temporal openings in skull roof in addition to an upper and lower temporal fenestra
- 2 clades of diapsid reptiles; lepidosauromorpha: snakes, lizards, Ichthyosaurs, Plesiosaurs (marine animals) and Archosauromorpha: archosauria (crocodiles, birds, dinosaurs and pterosaurs)
- See cladogram
- Picture: Lepidosauromorpha; Ichthyosaur (giving birth to live young)
- Picture: Archosauromorpha; Pterosaur – large openings in the skull; lightens the skull for flying

Crocodyles

- Crurotarsi
- Flippers instead of legs for some – others have little legs, adapted to running on land (hunting dinosaurs)
- Carnivores or herbivores or piscivores (fish-eating)

- Picture: cladogram

Ornithodira

- 2 clades; dinosauria and pterosauria
- Erect posture – parasagittal (plane of legs are perpendicular to the plane of the torso)
- Legs are tucked under the body – fast runners
- Picture; structure
- Dinosaurs – Saurischia and ornithischia
- Comparison of pelvic bones; notice 3 important structures; ilium, pubis and ischium – run together to the posterior end for the Ornithischian pelvis – the Saurischian pelvis runs anteriorly and downwards and consists of same 3 structures

Bones Described

- Important terms: scapula, coracoid, humerus, radius, ulna, caudal vertebrae, femur, fibula, tibia, pubis, tarsals, phalanges, metatarsals

Limbs

- Consist of: one single upper bone, a joint and 2 lower bones

Hindlimbs

- Femur – upper bone
- Knee – joint
- Tibia and fibula – paired lower bone
- Elbow and knees are bent in opposite directions
- Hindlimb image: important: Cnemial crest – dinosaur feature

The Pectoral Girdle (Shoulder)

- Attachment for forelimbs
- Flat sheet of bone
- Scapulae – shoulder blades on both side of backbone (sing. Scapula)
- Sternum (breast bone) at the chest within the thoracic ribs

Forelimbs

- Humerus – upper bone
- Radius and Ulna – lower bones
- Elbow – joint in between

- Photo: shows the location for all these bones
- Photo: building plan in evolution; same bones are kept throughout evolution (e.g. pectoral girdle of lobe-fin fish and tetrapod)

Hand and Foot Bones

- Carpals – wrist bones
- Tarsals – ankle bones
- Metacarpals – pal bones
- Metatarsals – foot bone
- Together called metapodials
- Phalanges – bones allowing flexibility of hands and feet – fingers/toes – built a grasping hand that allowed grasping and climbing for example

Joints

- Joints only allow a linear articulation
- Forward and backwards
- No rotation as in humans
- Metatarsal joint
- Cursorial locomotion – moving on land

2 Groups of Dinosaurs

- Ornithischia (ornith = bird, ischia – hip)
- Saurischia (Saurus = lizard)
- Different pelvic structures (very important)

First Members of Dinosaurs (Early Dinosaurs)

- Iguanodon – ornithopod
- Megalosaurus - theropod
- Hylaeosaurus – ankylosaur (armoured dinosaur_)
- Early reconstruction of Iguanodon; not accurate – body is actually perpendicular to legs

Diphyletic vs Monophyletic

- First beliefs: Diphyletic however Bob Bakker proposed a monophyletic system (common ancestor system)
- Both groups united with birds

Characteristics Uniting Dinosaurs

- Corresponding pictures for all the characteristics are important
- 1) Three or more sacral vertebrae
- 2) Rear facing shoulder joint
- 3) Asymmetric hand with 2 smaller outer digits (opposite direction)
- 4) Open Hip socket (acetabulum)
- 5) Cnemial crest of tibia (on lower bone in the Hindlimbs)
- 6) Ascending process on Astragalus (bone in ankle)
- 7) Sigmoidal third Metatarsal (foot in the bone)

Search for Dinosaur Ancestors

- Features which will be shared
- Features which will be absent in ancestors; should be similarities and difference
- Some features might be present, but less evolved in ancestors
- Evolution drives for building on pre-existing structures
- E.g. bipedal dinos back to quadrupedal (what was the advantage of this evolution?)

Early Ancestors

- Lagosuchus from Middle Triassic found in Argentina – bipedal
- Dinosauromorpha – similarities but not yet a dinosaur
- More early dinosaurs; herrerasaurus and coelophysis – we know a lot about these animals

Shared Features with Dinosaurs

- 1) Sigmoidal vertebral column in neck region
- 2) Shortening of the forelimb
- 3) Several modifications of the ankle bones and metatarsals

Bipeds vs. Quadrupeds

- Earliest dinosaurs were bipedal
- Quadrupedal dinosaurs developed later; stegosaurus and ceratopsian
- Hind legs longer than front legs – stand on 4 legs

Evolution of Dinosaurs

- 245 MYA: synapsids inhabited earth

- 225 MYA: most synapsids become extinct with exception of small mammals
- Diapsida take over – dinosaurs, pterosaurs and crocodiles

The Competitive Edge

- Erect posture; adding speed, more effective walking, escape from predators
- Warm blooded – e.g. coelophysis

Question: In a complex ecosystem can we relate an evolutionary change to one factory only?

Rest Continued Next Lecture (September 27th/2016)

September 17th/2016

ERTH 2401 T

Lecture #6: Fossil Collection (Last Lecture Before Midterm)

- The process of collecting fossils from the field and being put into a museum (hard work)
- Valley of the Moon: Argentina – early dinosaurs (ancestors) found here

Prospecting

- Finding dinosaurs is a combination of luck and fulfilling a specific criterion for success
- Have to distinguish between terrestrial and marine sediments – what's an ocean vs what is land in geological time
 - o E.g. marine animal unlikely to be found as they were usually in deep oceans, marine reptiles are more likely to be found – close to shore
- Rocks between 228 – 66 MA could have dinosaur fossils (when the dinosaurs lived)
 - o Look at geological map and decipher through rock layers – rocks have to be within the Late Triassic and Cretaceous time periods in order for dinosaur fossils to be found
- Rocks must be sedimentary, not igneous or metamorphic – remember igneous rocks form b/c of volcanic activity therefore destroying any evidence of dinosaur life. Metamorphic rocks are formed because of pressure, which also would compromise the dinosaur evidence therefore must look at strictly sedimentary
- Good preservation conditions
- “Must have your nose to the ground” to be in this particular field; spot unusual things
- E.g. the Alberta Badlands (Dinosaur Provincial Park) – rich in fossils as it was on the edge of the WIS – very dinosaur abundant
- Picture: dunes; used to be very rich in vegetation – as it keeps eroding more fossils will appear
- Picture: Hadrosaur skin – southeast Alberta; skin was preserved which can tell us a lot about the texture and features of the dinosaurs

Paleogeography

- 100 Ma vs 8 Ma – we see the Cretaceous Western Interior Sea making its way through the continent down from the polar sea – dinosaurs were abundant on either side of the WIS – e.g. the Badlands were here – it was terrestrial which made a good environment for dinosaur life
 - o Fossils were better preserved along the western side due to the mountain range
- Picture (National Geographic): the dots present where fossils were found (fossil localities) – indication that there were lots of fossils found on the western side of WIS (see dots)

Stratigraphic Horizons

- Find fossils in layers of the horizons (if conditions were good – fossils would be preserved within the layers) – each layer is from a different geological time (lots of time between the top layers and the bottom layers)
- If you look at each horizon laterally and move along horizontally you remain in the same time span; above or below indicates younger or older
- How much time btw lowest and highest bed of sediment?
 - o Depends on sea-level, erosion – marine settings
 - o Deeper and deeper in marine setting indicates moving away from sediment source (little can be fossilized)
 - o Sedimentation rate/depositional rate – fast deep rate, not a lot of time, slow rate = lots of time – translates to evolution

Pictures: bone structures

Late Triassic Chinle Formation – Colorado Plateau

- Lots of dinosaurs found
- Beginning of dinosaur era
- Deinonychus – vicious/fast hunters – study of them changed the belief that dinosaurs aren't cold-blooded but actually warm-blooded and agile as well
- Has major claw, raised up when running - discovered by John Ostrom

Featured Dinosaurs

- Coming from China – preserved by ash-rich sediment (allows a lot of detail in the fossils)

Working in Sahara Desert

- Very remote
- Was not always a harsh desert

Egg Sites (Map) – Na, Asia etc. (see picture)

Observations That Are Notes in the Field

- Important: you can't just go into a location with dynamite and blow it up to find fossils, you must be careful and take detail notes of what is discovered – very time consuming and must have patience
- Every detail must be noted as it could be useful
- Look at evidence of fossils in life orientation – are they separated or are they in situ – buried right in the moment of what they were doing (intact)

- Degree of articulation – do we have an articulated skeleton or are they separated/individual bones that have been disarticulated?
 - o Tells us if there was a medium of transportation – and possible how they died
- Fragmentation of fragile to robust fossils – preserved or fragmented?
 - o E.g. If a sand storm occurred a specimen could suffocate and be well preserved by the sand
- Proportion of various skeletal elements
- Evidence of any preferred orientation – some evidence for the way it died
 - o E.g. Fast flowing river will change bone orientation – and therefore change the original site of death
- Relative degree and type of abrasion, bioerosion
 - o E.g. If exposed to air for a long period of time than the structures can change
- Presence of mineralogy of fillings and coatings
 - o E.g. Silification, Pyritization
- Evidence of early dissolution
- Special features and preservation should be noted as well
 - o E.g. enrolled trilobites – enroll and create a ball for protection against predators)
 - o E.g. Encrusting epibionts – attach and encrust

Found Bone Beds

- Build frame, take photographs, draw it in a grid – makes sure every specimen is accounted for
- Orientation: scattered – don't have a preserved orientation –
- Carnegie quarry = very large bone beds
- Bones and eggs found – moments of life; nesting site – breeding animal and its eggs – allows us to make some assumptions about the nesting habits

Taphonomic Facies

- Ideas about how the environment might have changed (conclusions from observation)
- A sedimentary rock unit, or association of units, characterized by the combination of preservational features of the fossils contained within it
- Looking at sedimentary rock units
- Description facie

- Combination of biostratigraphic (observations made when discovering fossils) and early diagenetic (chemical changes) data subdivides sedimentary sequences into **taphonomic facies**
- E.g. going from a wet environment → dry environment
- Looks at pollens as well
- This will help with the interpretation of:
 - Relative frequencies and intensity of disturbances - can tell about climate
 - E.g. sandstorms, floods etc.
 - Relative rates of background sedimentation – how much time is in sequence of sediments, what is causing the sediment
 - Degree of turbulence (e.g. prevailing currents) – preferred orientation connected to this
 - Oxygenation and geochemistry of bottom waters and upper sediments – marine environments = no oxygen
 - Water column is very stratified = major density change (temperature and salinity) – transfer of oxygen from surface to bottom waters is inhibited = anoxic environments (not many animals in these environments – need to breathe)
 - Animals are found at surface where there is oxygen however when they die they sink down and are very well preserved b/c there are no predators; baron of life and fine-grain sediment

Picture: Reconstruction – block of sediment; lots of bones preserved in the block – lots of specimens in the block (colour coated)

Collecting

- Uncovering bones requires attention to articulation – articulated vs disarticulated
- These bones are fragile therefore must be hardened with glue; protective jacket or glue
- Fully expose bones with protective matrix
- Protective jackets used; made out of toilet paper and burlap soaked in plaster – adds a lot of weight (huge packages created)
- Remote localities make large skeletons and transportation difficult (e.g. taken out by military helicopter) – walk fossils out or with helicopter (if very large)
- Found in remote locations – e.g. mountain side

Bones Softer Than Matrix

- Very very fragile – matrix can be very hard must harden it with chemical substance
- Carbowax is removable with heat

- Limestone; used for buildings – fossils found in limestone (e.g. plate of fossilized fish)
- Bioclastic horizons sometimes found (in the eastern sediment-starved shallow WIS) - accumulation of bone fragments – calcareous matrix; bone bed example – use acid (e.g. diluted vinegar) to dissolve calcareous material, bones left
- Bioclastic – tiny specimens within; identify ecosystem – tells us the story of ancient ecosystem – “bits”

Museum Preparation

- Removing bones from the matrix
 - o Sand blasting
 - o Carbide-tipped needles
 - o Air-powered zip scribes
 - o Acid etching (used depending on matrix)
- Picture: working in the lab; wear masks to protect from dust and chemicals
- Ghost Ranch – Coelophysis specimens – took 5 years using a microscope and dental pick to work through the fossil – Alex Downs

Making of a Bone Bed

- Example: Modern times; pack of specimens unable to cross a river – washed down the rivers on the river side – birds start picking at the carcass (tearing them apart)
- Drying out – predation continues
- Scattered bones – disarticulation – from predators
- Ready to be moved back – occurred in the dinosaur era
- Picture: bone bed put together with grid structure

Final Steps

- Studying bone morphology is easier when skeleton is unassembled
- Fully assembled skeletons usually are casts of the originals – fiber glass or resin duplicates (originals are too precious to drill into) – for displays
- Sometimes need rods to go through to hold up heavy vertebrate column (picture)
- Displays comes together and are put into a museum
- As we learn more and more about dinosaurs – their positions can be rearranged to be more accurate (e.g. t-rex specimen)
- E.g. heard of iguanodons found in coal mine - put on display

- Argentinosaurus (type sauropod) – 90 MY old, 38m long – one can be seen in ROM
- Skin preservation (picture)
- Sometimes get a dinosaur mummy – fleshy head crests sometimes found

Dinosaur Mummies

- E.g. Leonardo – juvenile Brachyophosaurus Canadensis
- Evidence of a bird-like cop, used to predigest food in Leonardo's neck
- Images of hear and liver
- Evidence that the dinosaur was bitten by a large predator shortly before it dies
- Evidence of more than 200 parasite burrows
- Stomach contents: material from ferns, conifers and magnolias
- Pollen from about 40 plant species was also found