Geology 2051
Assignment 5
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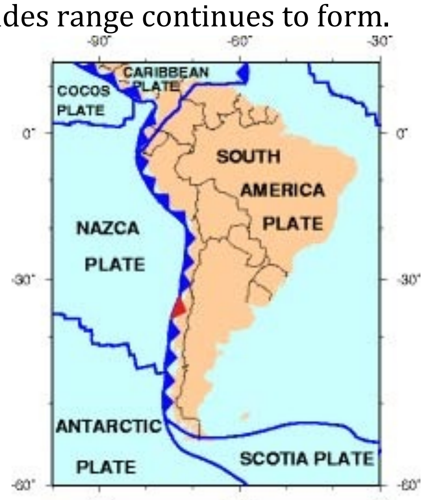
PART A

1. Before moving north during the Cenozoic, Australia and India rifted away from Gondwana. East Gondwana (made up of Anatarctica, Madagascar, India, and Australia) began to separate from Africa (early Crustaceous, approximately 140 Ma). East Gondwana began to break up when India moved northwest from Australia-Antarctica. Rifting between Australia and East Antarctica began when seafloor spreading started to occur.
2. The sediments of the Himalayan range were formed in the sea south of Asia (Paleozoic and Mesozoic age rocks) and thrust northward onto the Indian plate (Tibet). When the Indian plate collided with Asia, it resisted subduction because of its lower density (and similar density to the Eurasian plate) so it was underthrust beneath Asia for about 2000 km. This initiated uplift and crustal thickening at a rate of 5 centimetres per year. Sedimentary rocks that had accumulated on continental margins were thrust into great peaks.
3. The granitic rocks of the Andes range were in the form of plutons (igneous rock crystalized from slow-cooling magma below the surface) that intruded as the Cocos and Nazca plates move eastward to be subducted along the west coasts of Central and South America (South American plate). The converging of these Mesozoic and Cenzoic plates caused crustal thickening when sedimentary rocks became deformed and uplifted, and intruded by the granitic plutons that came from the volcanic activity and magma. The subduction creates seismic activity and volcanism in this area even today, as the Andes range continues to form.



4. During the Paleocene-Eocene Thermal Maximum, oceanic circulation was disrupted so warm water circulation from equatorial regions to the poles either diminished or stopped entirely. Sea floor sediment showed the deviation in the amount of ^{13}C. Deep ocean water became warmer which may have released methane from seafloor methane hydrate. This would

have released a greenhouse gas into the atmosphere causing a temperature increase. Volcanism may also have led to enough ocean warming to aggravate sea floor methane hydrate deposits. The following release of methane would have then caused more warming enough to create the ^{13}C anomaly. This anomaly caused the extinction of many deep-sea foraminifera.

5. Prior to the Pleistocene glaciation, the closure of the Tethys Sea (during the Oligocene) limited flow of warm water to higher latitudes, and the formation of an Antarctic ice sheet caused ocean water to become even colder, both possibly contributing to further glaciation. The Milankovitch Theory is now the widely accepted proposal, identifying three aspects of the Earth's orbit to the eventual Pleistocene Ice Age: eccentricity, tilt, (obliquity), and precession. Eccentricity (departure of Earth's orbit from circularity) alters the distance of Earth to the sun, changing the distance that the sun's short wave radiation must travel to reach Earth, Tilt (inclination of Earth's axis in relation to its plane of orbit around the sun) creates an angle variation. For example, more tilt increases the difference in radiation received between equatorial and polar regions. A smaller tilt would promote ice sheet growth: winter would be warmer so warmer air would hold more moisture causing more snowfall. Summer temperature would be cooler so winter accumulation would melt less, and finally precession (Earth's wobble as it spins on its axis) which, depending on which direction the axis is pointing, will create greater seasonal contrast. The three aspects of the Milankovitch Theory impact seasonality and location of solar energy around Earth, thus impacting contrast between seasons.
6. During the Oligocene, the C_4 photosynthetic process developed in response to decreased CO_2 levels. The first fossil evidence was at the start of the Miocene, 23 Ma). The C_4 (carbon fixation, or Hatch-Slack pathway) uses less water than the C_3 process, which gives plants that use this process a better survival chance during a drought or high temperatures. It is also more efficient when CO_2 levels are low. The additional steps in the C_4 process require more energy (ATP), but using this extra energy allows for the previously mentioned benefits. C_3 photosynthesis does not require the extra energy. It converts carbon dioxide and ribulose biphosphate (a carbon sugar) into 3-phosphoglycerate, in the first step of the Calvin-Benson cycle. Plants that use this method do well in moderately intense sunlight and moderate temperatures, with adequate CO_2 and enough groundwater. They, unlike their C_4 counterparts, cannot thrive in extremely hot areas because the C_3 process leads to limited growth from the plant having a net loss of carbon and nitrogen. (Some of the energy from photosynthesis is wasted).

Citation:

C_3 carbon fixation

C3 carbon fixation - Wikipedia

https://en.wikipedia.org/wiki/C3_carbon_fixation

C_4 carbon fixation
C4 carbon fixation - Wikipedia
https://en.wikipedia.org/wiki/C4_carbon_fixation

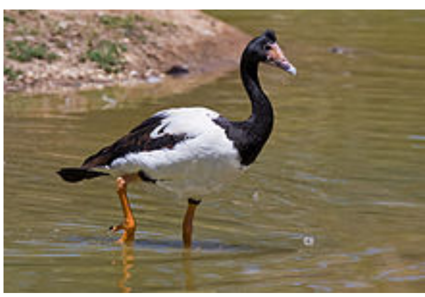
7. Examples of birds that evolved prior to the Cenzoic:

Passer domesticus (house sparrow)
Class: Aves
Order: Passeriformes
Family: Passeridae

Evolved from *Theropods*


house sparrow

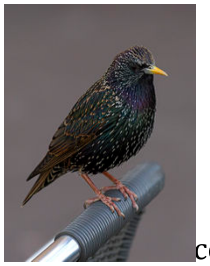
Anseranas semipalmata (Magpie goose)
Class: Aves
Order: Anseriformes
Family: Anseranatidae


Magpie goose

The Magpie goose is the only living species of the family Anseranatidae. It is a common water bird found in N. Australia and southern New Guinea. It has a tendency to wander so is sometimes found outside its home area.

Neoavians
(late Cretaceous-present)
example: Sturnus vulgaris (common starling)
Class: Aves
Infraclass: Neognathae

Clade: Neoaves

common starling

8. (a) Dolphins are related to the Mesonyx, which first appeared in the Eocene around 50 Ma. It was a wolf-like, quadrupedal animal with strong hind legs, hooves, fur, and sharp teeth. It hunted and fed in shallow water, close to where it lived on land. (b)Manatees are related to the clade of mammals called Tethytheria. They are a hoofed mammal from the Cenzoic (Paleocene-Holocene) and were small and rodent like in appearance. Tethytheria are suspected to have evolved from a group of primitive hoofed animals called condylarths that lived on the shores of the Tethys Ocean. Tethytheria includes Proboscidea (trunk animals) and sirenia (sea cows and manatees). (c) Seals are related to Puijila darwini, which lived during the late Oligocene to early Miocene (24-21 Ma). This extinct "seal" had minimal adaptions for swimming. There were no flippers and it was otter-like in appearance. Research indicates that the skull and teeth point to the fact that it was an "early seal". It was discovered in 2007, in an early Miocene lake deposit at Devon Island in Nunavut, Canada by Natalia Rybczynski. The area around this lake was once a forest community (boreal-conifer) with a cool, temperate coastal climate and moderate winters.
9. Horses increased in size from the Eocene to present, and most of their evolution took place in North America. At their beginning they were around 20-35 centimetres high, weighed about 20 kilograms, and had 4-toed front feet with 3-toed hind feet (each toe being covered by a hoof). Their diet began as browsers of rich nutrients and slowly shifted to high-fibre grasses with poor nutrients. These new grazers developed chewing teeth to accommodate this evolutionary change, which may have been connected to the spread of grasses during the Miocene. The grassland habitat did not provide much protection from predators so speed was necessary for survival. Therefore it is probable that this was the reason for the horse developing longer legs, and the toes becoming one, faster hoof. Longer legs would then require the development of a larger body to support them, which included a longer, straight back. A longer back and legs would also increase the animal's speed. The larger, more complex brain would also be helpful in survival against predators in the increasingly open-plain environment. So, the general increase in size was a general defense against predators in an environment with little protection. The diet shift was another component since horses can't process food as efficiently as the even-toed ungulates with

four-chambered stomachs-horses don't have the same energy efficiency per unit of mass. Larger animals are better able to conserve energy and can retain heat better, as well as the fact that an increase in body size would increase running speed and therefore safety from predators.

Citation for question 9
(in addition to textbook)

Evolution of the horse
Evolution of the horse | Fins to Feet
https://finstofeet.com/2011/11/05/634/

PART B: The Indian-Asia Collision

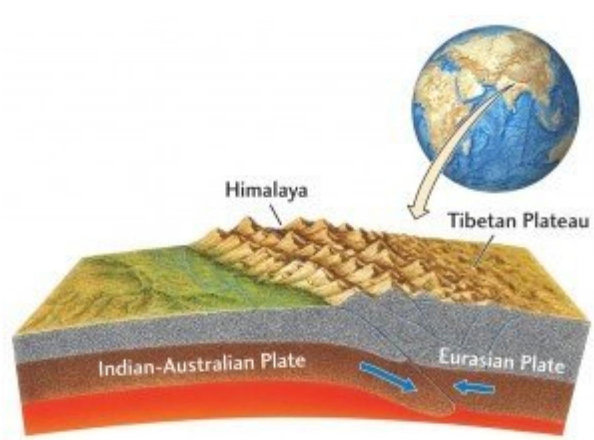
India rifted from Gondwana beginning in the early Crustaceous (approximately 140Ma) and began moving northward toward the southern part of the Asian (Eurasian) plate. Oceanic lithosphere met with a subduction zone at this southern margin. (The oceanic plate in front of the Indian plate was subducting beneath Asia). As the descending oceanic plate partially melted, it formed magma that formed a volcanic chain and large volcanic plutons (present day Tibet). When the Indian plate reached these volcanoes they were destroyed during the collision with Asia, joining two continental plates in what is named the Himalayan orogeny. Around 40-50 million years ago, the Indian plate's rate of drift decreased from 15-20 centimetres per year to 5 centimetres per year. This decrease likely marks the time when it collided with the Asian plate. The Indian plate does not subduct beneath Asia: they are both continental landmasses with similar densities. Continental crust is buoyant upon the mantle. The result of this: presently the Indian plate is moving NE 5 centimetres per year while the Eurasian plate is moving North 2 centimetres per year. The Eurasian plate is deforming and the Indian plate is compressing 4 millimetres per year.

Since the Indian plate doesn't subduct below Asia, the sedimentary rocks that had accumulated on the continental margins (along with blocks of older crustal rock) were thrust into huge peaks to form the Earth's highest plateau: The Tibetan Plateau, which is still rising today, and the Himalayan Peaks. The Tibetan plateau is a collection of terranes (lithospheric blocks with characteristics different from the surrounding area rocks) that were added to the continent during the Paleozoic and Mesozoic. The boundaries between the terranes contain characteristics of ocean lithosphere (where the oceanic plate met with Eurasia during the collision). The Himalayas are an accretionary wedge formed by the thrusting and folding of sediments that were scraped of the subducting (ocean) slab.

Another consequence of these two plates being of similar density is that the Indian plate was underthrust 2000 kilometres below Asia causing crustal thickening and uplift of about 5 centimetres per year. Sedimentary rocks formed in the sea south of Asia were thrust northward into Tibet. Two thrust faults also carried Paloezoic and Mesozoic rocks onto the Indian plate.

The results of this tectonic event produced the Himalayan Mountain Range that runs 3000 kilometres along the border of India and Tibet. This range contains the highest mountains in the world, including Mount Everest, which stands at 8,848 metres above sea level. The Tibetan plateau has an average elevation of over 4500 metres.

The climate of this region is also a result of the massive landform. The Tibetan plateau is a major water storage and flow control area, as it has tens of thousands of glaciers as well as headwaters of drainage basins for most of the streams in the surrounding areas. Global warming on this area would have an extreme impact. Also, the Tibetan plateau has been considered to be the main heat source for the south Asian Monsoons. Heavy rain lasts from June to September in this area, and while it provides much needed irrigation, is also causes devastation in the form of landslides. The Himalayan range prevents cold, dry winds from reaching south to the sub continent area, which keeps Asia warmer than similar regions on other continents. The mountains also stop the monsoon winds from travelling northward and played a part in forming Central Asian deserts like the Gobi.



There was no volcanism since the Indian plate does not penetrate deep enough to create any magma. However, seismic activity still continues, even today: the 2008 earthquake in China and the Gorkha earthquake of 2015 being examples.

directional movement of the India plate over time

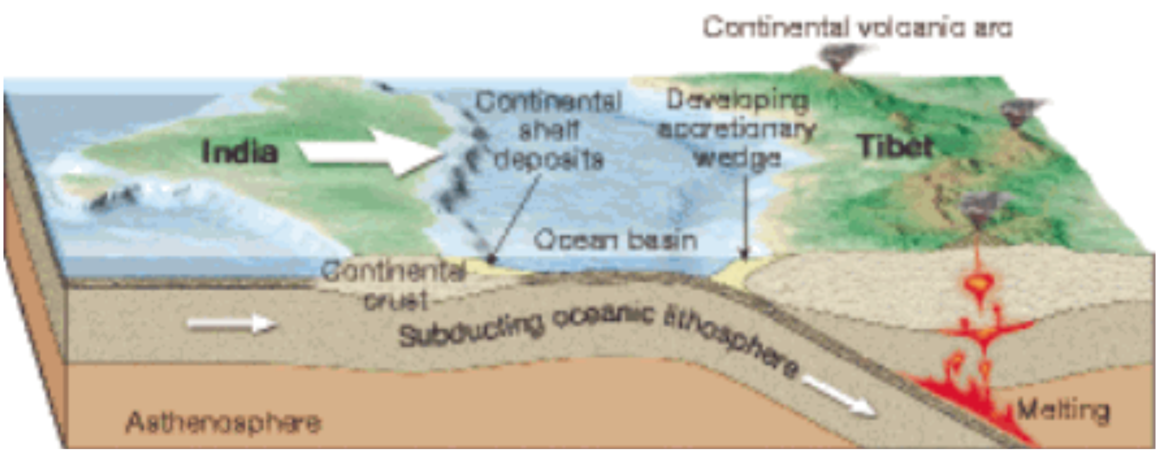


diagram showing subduction of oceanic lithosphere before the continents collided

Himalayas - Wikipedia
https://en.wikipedia.org/wiki/Himalayas

Geodynamics | Remarkable Regions – The India-Asia collision zone
https://blogs.egu.eu/divisions/gd/.../remarkable-regions-the-india-asia-collision-zone/

Tibetan Plateau - Wikipedia
https://en.wikipedia.org/wiki/Tibetan_Plateau

PART C: Milankovitch Cycles and Climate Feedbacks

Climate feedback exists when the result of an initial climate process triggers changes in a second climate process, and this second process, in turn, influences the first process. If the feedback is positive, the original process is increased or intensified, and if the feedback is negative, the original process is reduced. Basically, climate feedbacks are a result of a change in the climate system that expresses itself in either a positive or negative manner, and they can be either fast or slow.

The following are some major climate feedback mechanisms, with explanations as to how they function in correlation with the Milankovitch Cycles to accentuate a change in climate:

If the Milankovitch cycles initiate a reduction in insolation, greater seasonal differences (hotter summers/colder winters) will occur. Greater axial tilt would affect the duration of polar dark periods and colder winters (cooler atmosphere, condensation) would bring greater **CLOUD COVER.** This initial mechanism (cloud cover) would bring about a cooling climate feedback mechanism. Clouds also reflect away incoming solar radiation, further cooling the Earth. If this cooling continues, glacial melting would decrease giving existing glaciers a positive glacial budget.

Feedback "equation" for cloud cover:

Milankovitch cycles in favour of cooling—colder winters, increased cloud cover—decreased insolation—further cooling—glacial increase—if feedback continues, possible ice age (like Pleistocene Ice Age)

PERMAFROST and the melting of permafrost regions by warming trends initiated by Milankovitch cycles prompt climate feedbacks as well. Increased insolation and an even distribution of solar radiation bring about less of a difference between seasons. This would cause a warming trend, inducing the melting of permafrost regions (any rock/soil material remaining at a temperature of 0 degrees Celsius for 2 or more years). If permafrost regions begin to melt, it could result in release of methane. Much of the permafrost region in the Northern Hemisphere is covered by evergreen boreal forest which is a carbon sink (reservoir)/source. The Arctic currently stores nearly 1/3 of Earth's soil carbon; the majority of the northern ecosystems are carbon sinks.

The feedback to warming of the permafrost layer would be a warmer, dryer active layer (the layer that thaws and then refreezes every year) that would activate microbes (microorganisms 'bacteria' causing disease or fermentation) in the summer. A warmer winter and later freezing start time would further enhance microbe activity in the winter:

Feedback mechanism-Arctic/subarctic ecosystems are becoming a source of carbon dioxide instead of containing it in permafrost…
Feedback mechanism-areas of wet thermokarst (irregular land surface of marshy hollows from thawing permafrost) will develop as sources of methane, possible ground collapse or landslides…
Feedback mechanism-this swampy wetland will release methane (more powerful than CO_2)

(above are positive feedbacks in the increasing of global warming that could be consequences of warming-trend Milankovitch cycles)

Present day examples:

- Frozen peat bogs in Siberia began to bubble in the warm summer of 2006
- Studies of methane emissions at sites on Alaska's northern slope during two especially warm summers: increase of 3 times the methane in 1987 and 2 times the methane in 1989

ALBEDO , the amount of light reflected by a material, is sensitive to the sun's angle of incidence (incoming ray), especially on water. Since the Milankovitch cycles are connected to the amount of solar energy reaching the Earth, warming and cooling trends initiated by these cycles can initiate climate feedback mechanisms in connection with albedo of Earth's surface materials.

Research indicates that when the sun is at an angle of 40° and higher to the horizon, the albedo of water is consistent, but when the angle is less than 40°, the albedo of water increases. This could be affected if the Earth's eccentricity, tilt, and precession are increased or decreased in any way.

Examples of albedos of various Earth materials (% reflectance)

Entire planet Earth: 0.31
Ice/fresh snow: 0.90
Sand 0.35
Rain forest: 0.07-0.15
Water 0.06-0.10
Clouds 0.5-0.9
Grassland: 0.18-0.25
Forest areas: 0.09-0.18

The climate feedback mechanisms related to albedo could be as follows:
Melting initiated as a result of Milankovitch initiated warming would reveal "darker" areas of land surface and water (which is less reflective than ice/snow)-this in turn would absorb more heat from the sun's rays, leading to more warming, and again, more melting. This mechanism would perhaps continue until there is a change in the

Milankovitch cycle to initiate *a cooling mechanism that would "reverse"* the above-mentioned feedback "equation" (glacial development/onset of ice age).

Atmospheric vapour can also be considered in relation to Milankovitch-initiated warming and cooling trends. If climate feedback mechanisms such as cloud cover, permafrost, and albedo could potentially release CO_2 and methane into the atmosphere (on a warming trend), this would create a higher concentration of water vapour, which would further intensify the greenhouse effect. The opposite would stand true for a cooling trend.

Citation:

Climate Feedback
www.global-greenhouse-warming.com/climate-feedback.html

Bacteria primarily metabolize at the active layer/permafrost border in ...
https://link.springer.com/article/10.1007/s00300-017-2088-1
by YN Morgalev - 2017

PNNL: News - Permafrost's turn of the microbes
https://www.pnnl.gov/news/release.aspx?id=4183

PART D: CENZOIC FOSSILS

(photographs of sketches follow written component)

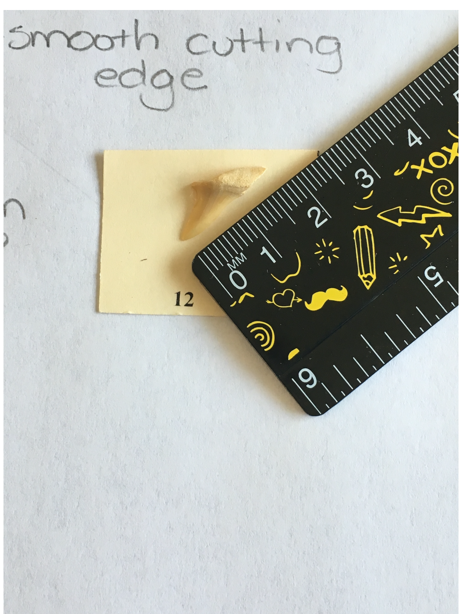
1. The Eocene gastropod (Turritella) is most similar in shape to the Cretaceous gastropod. Both have similar anatomical parts such as a spire, suture, body whorl, as well as the inner and outer lip of the canal at the anterior end. Both are elongated in shape, although the specimen of the Cretaceous gastropod is considerably larger than the Eocene gastropod. When comparing the Eocene gastropod to the Cretaceous (honeycomb) Oyster, the Eocene specimen is not a bivalve while the oyster is. The oyster is more of a rounded "honeycomb" shape with it's "snail-like coil" of the right valve being swirled and cupped to one side, the left valve being the more cupped, and without the swirl. The oyster has growth lines similar to the Turitella's suture but they are not as swirled and ridged as they are on the gastropod. Compared to the oyster's rounded swirl appearance, the Eocene gastropod's shape is elongated, swirled, and spire like.
2. Possible name for shark tooth specimen: Cosmopolitodus planus **(genus: Cosmopolitodus)**. The specimen matches the description given as follows: The tooth (blade) is triangular and slightly flattened with no serration. There are no secondary cusplets ("extra tooth stub") and there is a narrow line (scar) on the specimen between the root and tooth blade. The blade is

curved at the tip and overhangs the root (the specimen is missing a piece of root-this observation has been made based on the one root bulb in tact on the specimen).

Cosmopolitodus is an extinct genus of sharks, a Great White Shark, and was only found in the Pacific Ocean. It is thought to be a branch of Cosmopolitodus hastalis, but the *planus* upper teeth are narrower and more hooked than the hastalis, while the lower teeth are extremely similar.
Citation:
Cosmopolitodus planus - Elasmo.com
www.elasmo.com/heim/bh-i_pla.html

http://www.elasmo-research.org/education/evolution/guide_f.htm

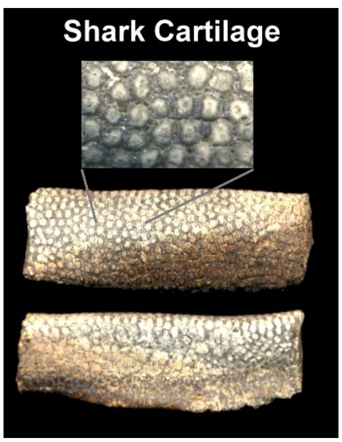
compared to specimen:



3. Shark teeth are usually the most common fossilized part of the shark because they are made of dentin, a calcified, hard tissue that does not decompose quickly. It is more dense than bone. The teeth usually take about 10,000 years to fossilize. The fossil specimens are usually not white because they

are covered in sediment that prevents oxygen and bacteria from decaying the tooth. The teeth are usually preserved in sedimentary rock after they fall out of the shark's mouth. The fossils will be more worn if they were moved around and re-deposited in different areas. It would also be possible to assume that shark teeth are abundant in the fossil record for the fact that sharks loose teeth at a rapid rate, so it would be logical to expect to find an abundant supply. It has been estimated that sharks loose between 25,000-50,000 teeth in a lifetime, which would support this hypothesis.

The shark skeletons are composed of cartilage, which is even softer than bone and does not usually surpass fossilization. This is the main reason than entire shark skeletons are not found as fossils. However, the centres of shark vertebrae will sometimes fossilize because they are the densest part of the skeleton. This is rare. While most of the shark will not fossilize because of softer tissues that will decay, there are some other parts that may be found as fossils, such as: jaw cartilage, nostril node in the snout, some skin that contains dentin, and spines in the fins.



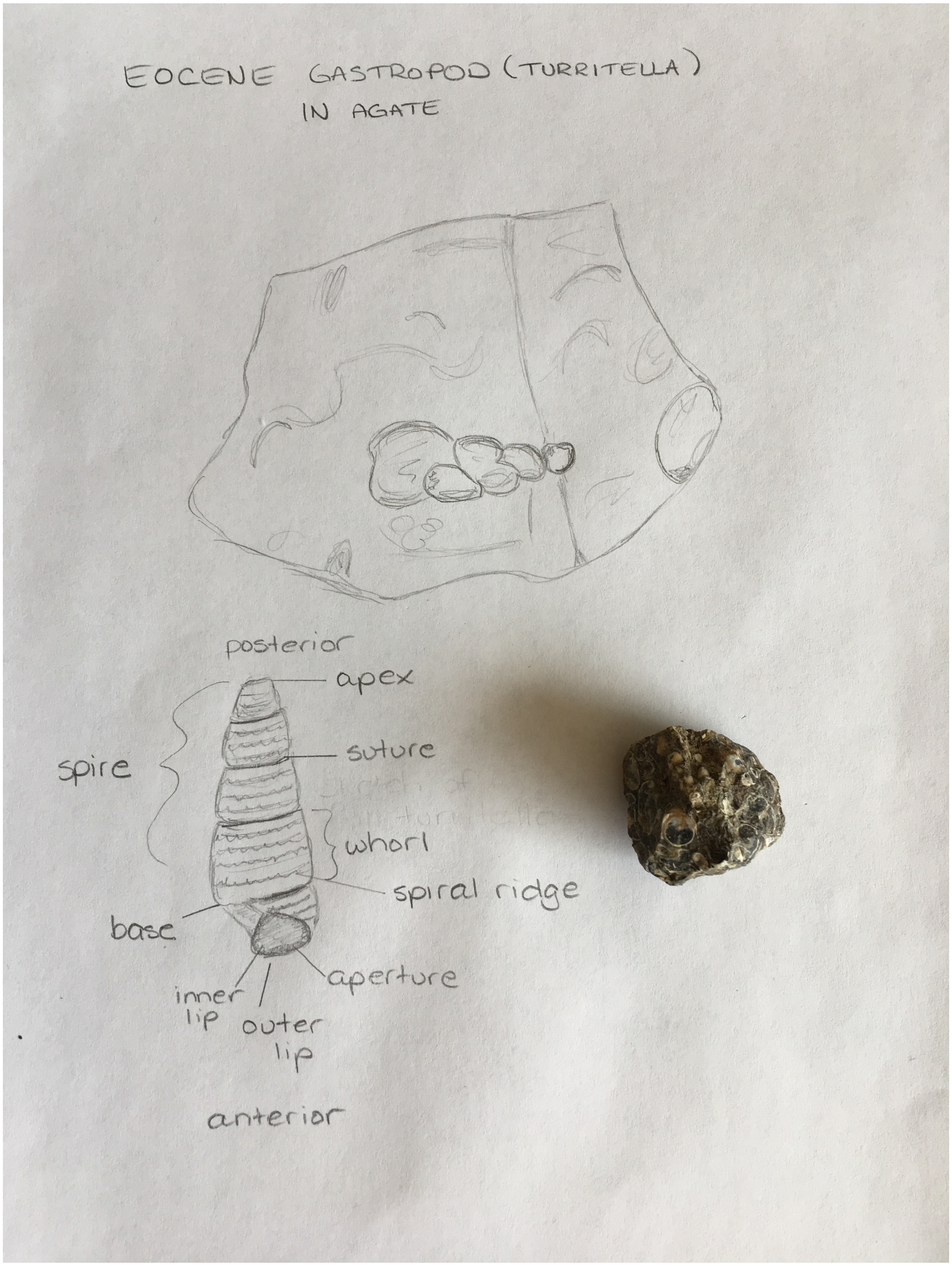
sample from shark jaw

fossilized vertebrae-softer tissues would have been in the holes

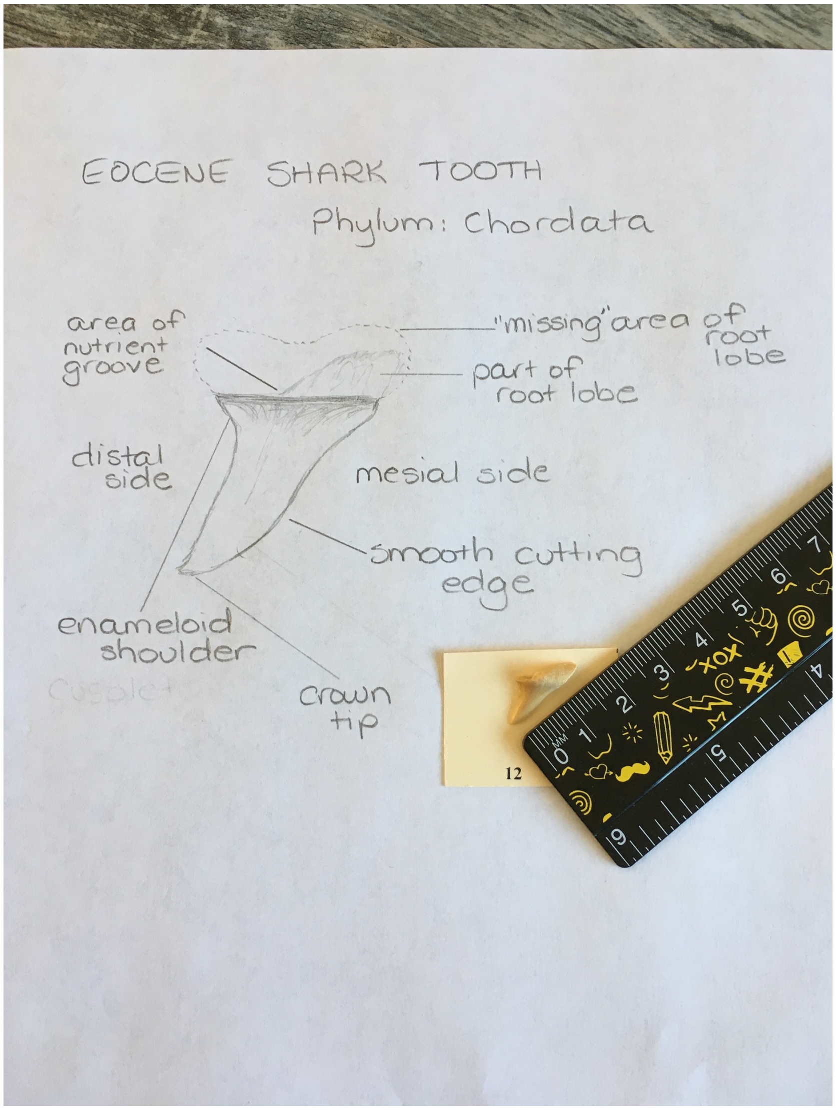
Citation(in addition to assignment link):
[Shark tooth - Wikipedia](https://en.wikipedia.org/wiki/Shark_tooth)
https://en.wikipedia.org/wiki/Shark_tooth

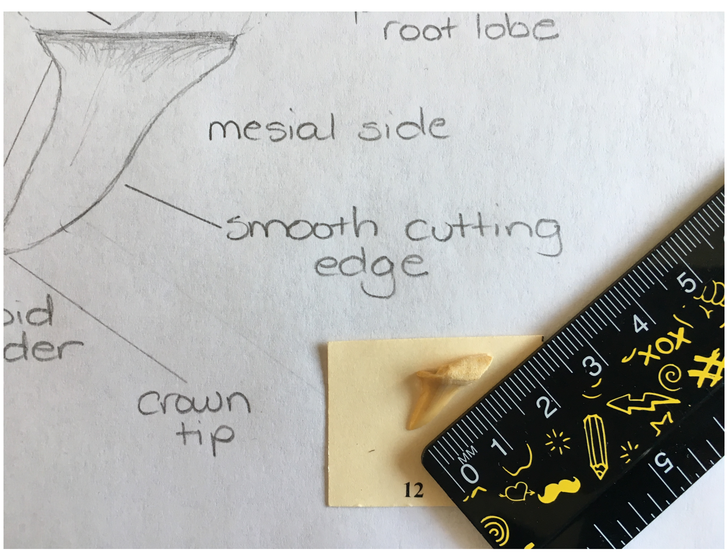
Shark Fossils Theres more than just Shark Teeth that ... - FossilGuy.com
www.fossilguy.com/gallery/vert/fish-shark/remnant.htm
(this site also used for the cartilage and vertebrae photos)

Sample Fossil Sketches:



Sample chosen for sketch


EOCENE SHARK TOOTH
Phylum: Chordata
area of nutrient groove
"missing" area of root lobe
part of root lobe
distal side
mesial side
smooth cutting edge
enameloid shoulder
crown tip
12


root lobe
mesial side
smooth cutting edge
crown tip
12

PART E:

Examination and Description of Fossiliferous Pleistocene Sediments (photos follow chart)

Organism	General Description	Number of specimens	Approximate average dimensions (mm)
Fragments of spine of identified urchin	Specimen: Fragment- excellent condition with grain and base visible, Spine of a sea urchin, a spiny, global-shaped animal 3-10 cm across. The spines are used for defence. Urchins live in all climates and oceans- inhabit marine areas from depths of 5000m to rocky shallow areas.	3	0.5mm x 4mm each
Serripes groenlandicus (Greenland cockle)	Specimen: Broken, weathered Species of bivalve mollusc, found on Atlantic (Greenland- Cape Cod) and Pacific coasts (Alaska- Washington)	6	5mm x 10mm
Clinocardium ciliatum (Iceland cockle)	Specimen: Broken, mildly weathered Species of bilvalve mollusc, currently found along the Atlantic coast of North America (Greenland- Massacheusetts)	4	2mm x 2mm
Nuculana fossa (Northern nutclam)	Specimen: Broken, weathered Species of bivalve mollusc, marine, (currently: Alaska-Puget Sound) fossils: Alaska- S. California	1	3mm x 1mm
Possible urchin tubercle (attaches the spine)	Specimen: Broken, weathered	1	3mm x 2mm

	Potentially-sea urchin, Echinoidea (location: see “urchin spine” cell) The tubercle attaches the spine to the body of the urchin. 3 spine samples were found in the collection. This tubercle is small, possibly coming from the smaller urchins that are around 3cm diameter		
Hiatella arctica (Arctic saxicave)	Broken, slightly weathered Species of saltwater clam Marine, Bivalve mollusc- rectangular shell Found in all oceans from shallow-800m, lives attached to hard or soft rock, sometimes kelp	1	3mm x 2mm
Macoma calcarea (Chalky macoma)	Specimen: Broken, weathered Species of bivalve mollusk, elongated shell has fawn coloured, chalky surface and is dull bottom dweller (fine sand and mud) from tidal areas to few hundred metres currently found: Northern Atlantic and Arctic areas, Europe (Iceland, Norway)	2	2mm x 2mm 12mm x 10mm
Chlamys sp. (Scallop)	Specimen:Broken, weathered Species of small scallop (bivalve mollusc) Name means “cloak” in Greek and refers to cloaks worn by Greek soldiers Widely distributed, marine only, capable of swimming (probably to escape predators)	1	4mm x 2mm

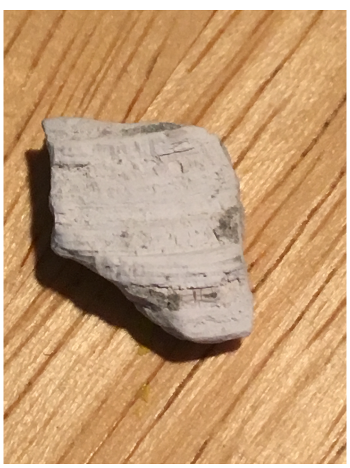
**also found with specimens: sedimentary rock specimen, 15mm x 8mm (angular gravel-sedimentary brecchia), greyish in colour, (most likely from the marine layer), grain visible.

Group photo of all samples (above)
(samples were extremely small and delicate-I did not physically group them after rinsing)

Individual/smaller group sample photos to follow:

Close up photos of various sample groups:


photo features possible sea urchin tubercle



This particular specimen faded after rinsing and being exposed. (macoma calcarea)

COMMENTS:

The climate of southwestern BC around 12,500 years ago was considerably cooler than it is now, as this was the end of the Pleistocene Era, the last glacial period. The most recent glaciation that affected North America, and British Columbia, was the Winconsinan Glaciation (75,000 – 11,000 years ago), when most of British Columbia was covered with ice. When the glaciers started to melt, the melt water would have logically been rather cold. Since the sample fossils are indicative of arctic specimens, it could be assumed that the water temperature of southwestern British Columbia was considerably cooler, and the general climate still considerably arctic. The fluvial layers at the Gabriola site would also support the idea of a cooler climate, since during times when the sea level is lower (during glaciation), rivers transported sediment across exposed continent shelves, and then onto continental slopes where the sediment assisted in the growth of submarine fans. As the glaciers melted and the waters rose, the deposits became marine and could account for the blue-grey layers of sediment at the Gabriola site. Research indicated that some of the fossils are widely distributed: it is possible that some of the cold water examples (such as the Nuculana fossa, Northern nutclam) have taken to deeper, cooler waters. Fossils have been found in S. California but the species is currently listed with a distribution for the Alaska (and Puget Sound) area, indicating once again that the southern climate was cooler 12,500 years ago.

GEOLOGICAL SIGNIFICANCE

History (pertaining to deposition of fossils):

The Nanaimo Group (thickness, nearly 5000m)

Clastic (fragments of pre-existing minerals or rock) sediments were deposited from south of Duncan, BC to north of Campbell River BC (late Cretaceous). Deposition probably started when micro-continent Wranglellia (consists of most of Vancouver Island) accreted onto North America. The Nanaimo Group consists of conglomerate, sandstone and mudstone (coal beds in some areas). It was originally thought that the rocks of the area were only deposited by rivers in continental environments but it is now believed that many of the sediments in the Nanaimo Group were deposited in a marine environment, specifically, submarine fan deposits:

Diagram explanation, next page:

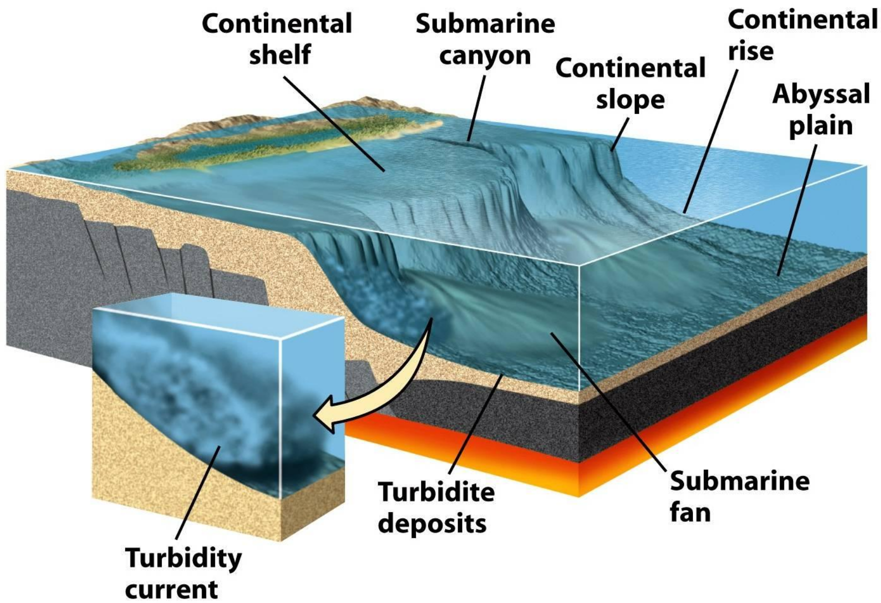


Figure 20.19a
Understanding Earth, Sixth Edition

This fossil deposit, located approximately 60 metres above sea level is evidence of higher sea levels due to glacial melt. When the Laurentian Ice sheet over North America started to melt around 19,000 years ago, the melt water flowed toward the sea, raising ocean levels. The fossils are marine, and of post-glacial age. The fossils of the Vancouver Island area have been found up to 200m above sea level[1]. The Gabriola site photo (figure E-2) indicates that fossils were found in the blue-grey silty sands, between layers of brown sand and gravel (terrestrial fluvial) above and below. The blue-grey is presumed to be of marine origin. It is suggested that 15,000 years ago the sea level in the Vancouver Island (specifically Nanaimo) was 100 metres higher than today, which would have placed the majority of Gabriola Island under ocean waters, thus helping to validate the marine fossils. By about 6000 years ago, post-glacial isostatic rebound of the crust had brought the ocean levels to be close to what they are today. Recession of the water allowed for the discovery of the previous marine environment.

Footnote:
1. **PDF]**Gabriola sea-level changes - Nick Doe
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