



How do Geologists Analyze Time?

Relative Dating
is a system of *reasoning* that is used to determine the chronological sequence or order of a series of geologic events.

Radiometric Dating
uses the natural phenomenon of radioactive decay of radioactive isotopes within minerals to calculate their chronological age.

The Geologic Time Scale Summarizes Earth's History.

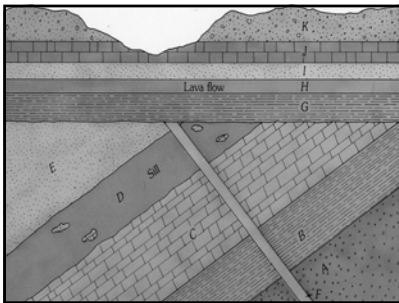
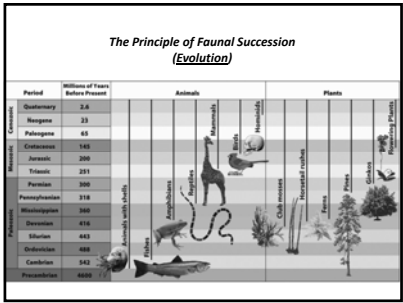
Time is divided into progressively shorter intervals defined by specific fossils and strata found in the Rock Record:

- Eons
- Eras
- Period
- Epochs

Major Time Age	Subdivisions Epochs	Periods	Eras	Eons
4.6 billion	Archaean eon	Proterozoic eon	Proterozoic eon	Proterozoic eon
2.5 billion	Proterozoic eon	Proterozoic eon	Proterozoic eon	Proterozoic eon
660 million	Proterozoic eon	Proterozoic eon	Proterozoic eon	Proterozoic eon
252 million	Proterozoic eon	Proterozoic eon	Proterozoic eon	Proterozoic eon
66 million	Proterozoic eon	Proterozoic eon	Proterozoic eon	Proterozoic eon
2.52 million	Proterozoic eon	Proterozoic eon	Proterozoic eon	Proterozoic eon
0	Proterozoic eon	Proterozoic eon	Proterozoic eon	Proterozoic eon

Five Fundamental Geologic Events are "ordered" by Relative Dating.

- Intrusion
- Erosion
- Deposition
- Faulting
- Rock Deformation



Earth's Age Is Measured Using Several Independent Observations.

Age of Earth

- Chondrites contain 4 lead isotopes but no U or Th.
- Chondrites record the original lead abundance of the solar nebula. Chondrites are thought to be the most primitive material in the solar system.
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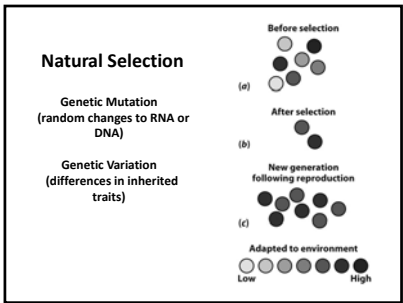
Lead Abundance

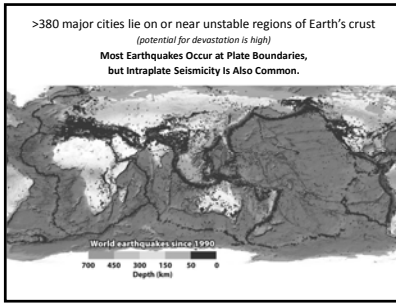
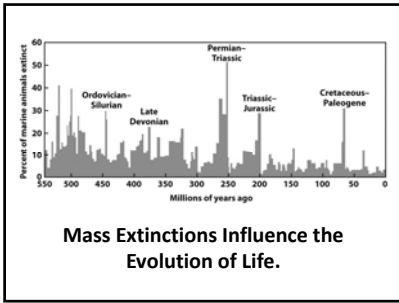
Pb^{208} , Pb^{207} , Pb^{206} - increasing amount on Earth due to thorium and uranium decay

Pb^{204} - constant amount on Earth since origin

Modern \leftarrow Time \rightarrow 4.6 billion years ago

- "Absolute" ages of primordial crust, Moon, and meteorites.
- Abundance of Lead Isotopes.
- Consistency between these observations.





Two types of wave groups generated –
Surface waves (two types: Rayleigh, Love)
 Travel along outer layer of crust at the surface causing ground roll like a water wave and lateral shifting...travel slowly and generate the most damage

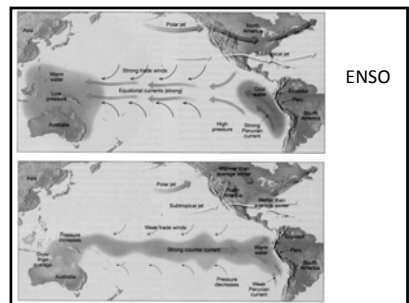
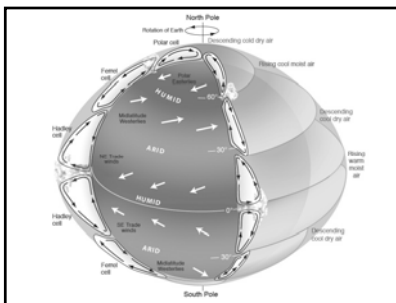
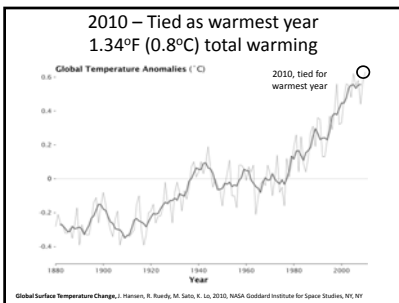
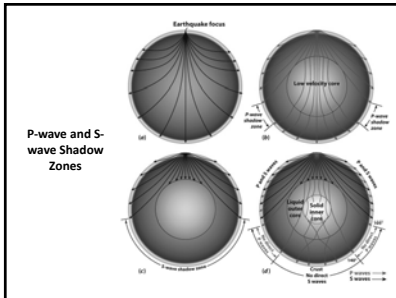
Body waves (two types)
Primary waves (P) – compress and pull (dilate) rocks in the direction of movement, changing the **volume** and **shape** of material...solids, liquids and gases resist compression and will spring back. Thus they propagate the waves forward.
P waves travel through all types of matter

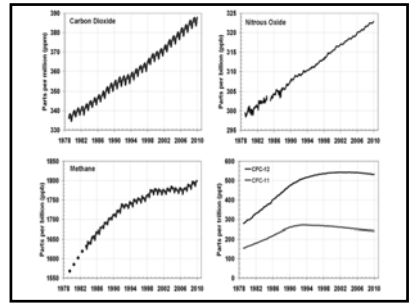
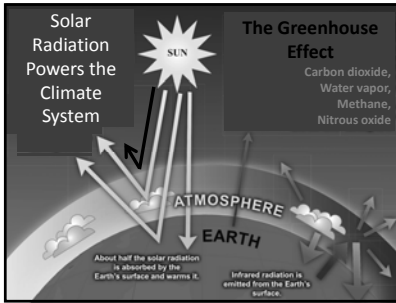
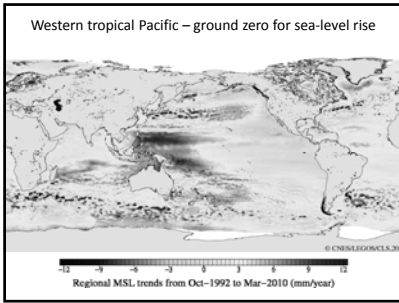
Fastest wave

(a) P wave

Secondary waves (S) – motion is 90 degrees to direction of propagation (up and down), involves only changing the **shape** of transmitting media...fluid and gas do not resist shape change hence they will not spring back and will not transmit the wave forward. **S waves travel only through solids.**
Second fastest wave

S wave



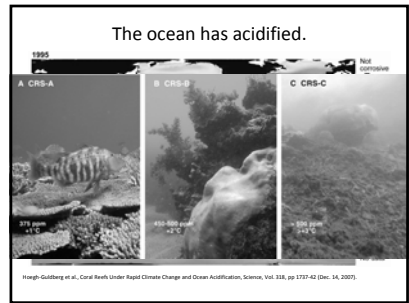
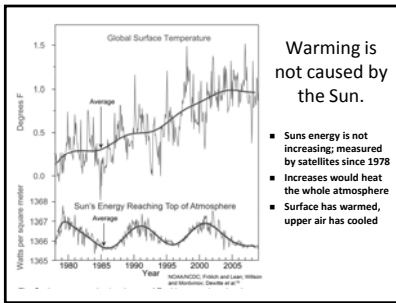
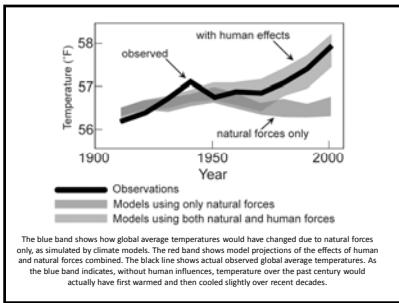


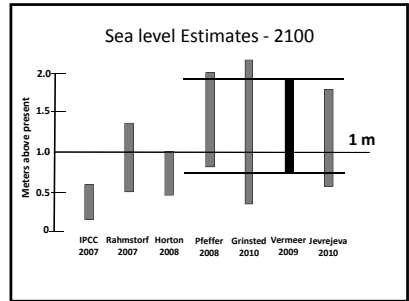
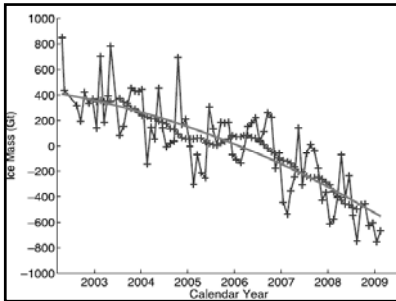
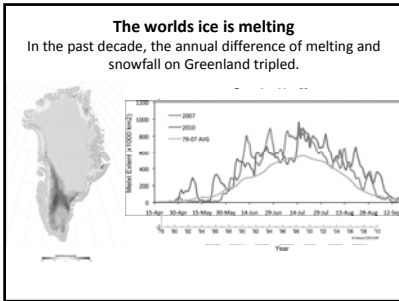
U.S. National Academy of Science and Engineering
May 29, 2010

Some scientific conclusions have been so thoroughly examined and tested, and supported by so many independent observations and results, that their likelihood of being found wrong is vanishingly small. Such conclusions are then regarded as **settled facts**. This is the case for the conclusions that the Earth system is warming and that much of this warming is very likely due to human activities.

Note: a scientist is prone to say "The Sun will very likely rise tomorrow."

Advancing the Science of Climate Change – National Academies: <http://americascimatechology.org/>





Pacific Island Climate is Changing

In Hawaii

- Rainfall (-15%) and stream discharge have decreased
- Air temperature is increasing (0.3°F/decade)
- Rainstorm intensity has increased (+12%)
- Sea surface temperature is rising (0.22°F/decade)
- Ocean has grown more acidic
- Sea level is rising

Alternative energy sources

Renewable, Electric/Hybrid mass transit

Collage of images illustrating alternative energy and mass transit. It includes wind turbines, solar panels, a water turbine, and a hybrid mass transit vehicle. A text box states: 'Electric/hybrid Mass transit $\lt; 1/4$ cost of gasoline, emissions -40%'.

Energy efficiency and conservation

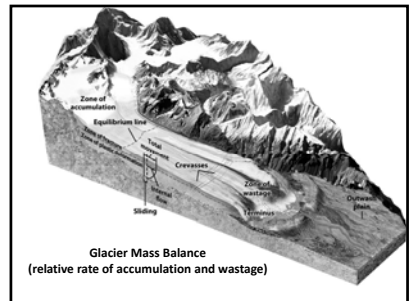
Urban Design, Building design, Reforestation (avoided deforestation)

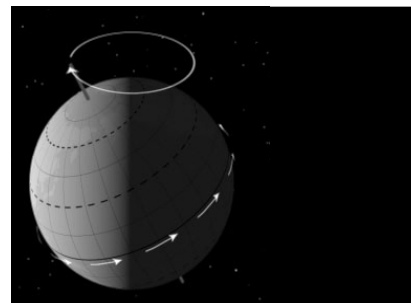
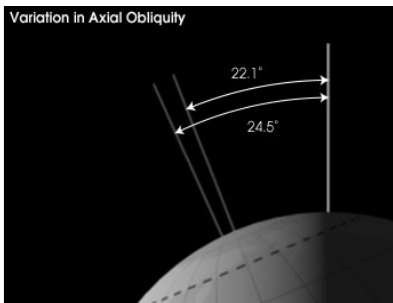
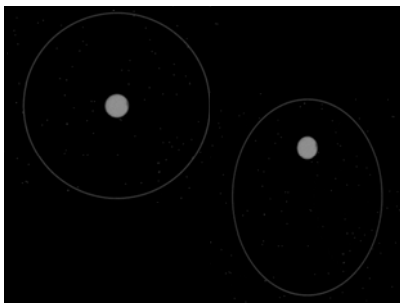
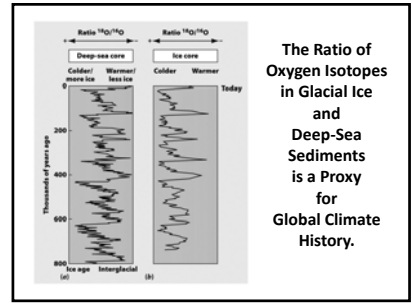
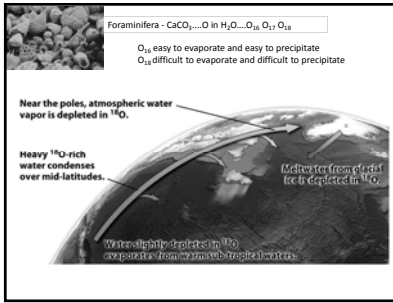
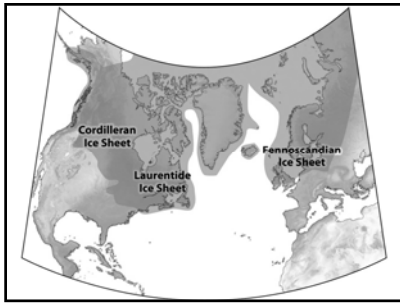
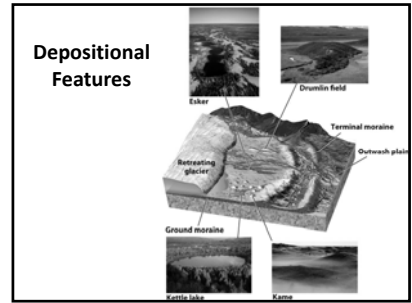
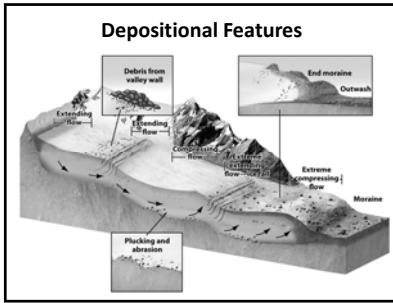
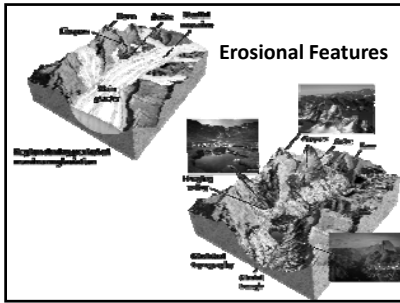
Collage of images illustrating energy efficiency and conservation. It includes urban design, a zero energy community, and land preservation. Text boxes state: 'Zero energy communities, Higher density, Local food' and 'Land preservation'.

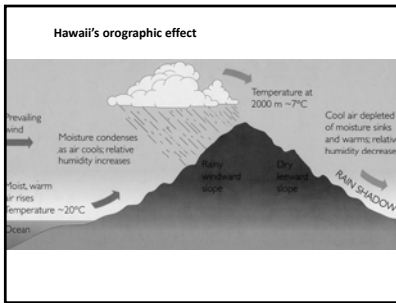
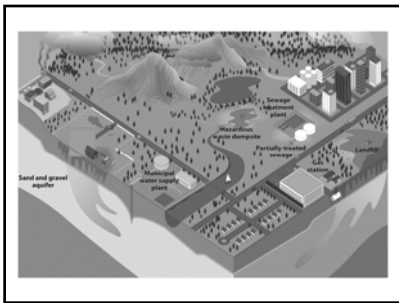
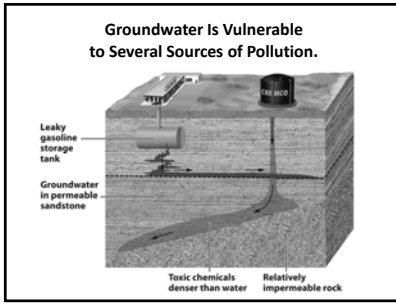
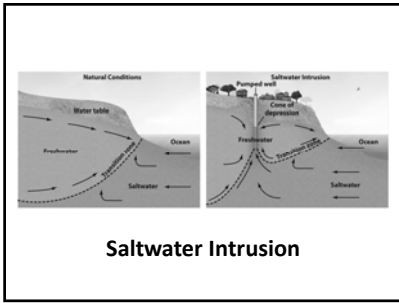
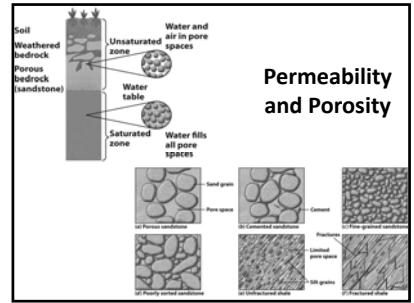
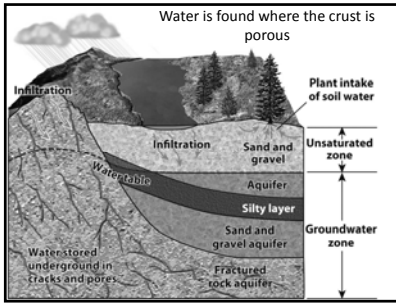
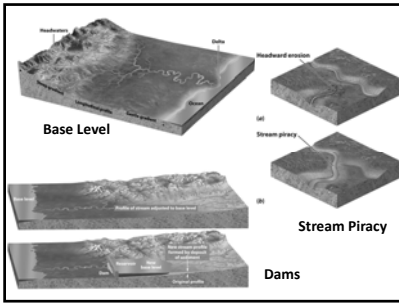
Adaptation

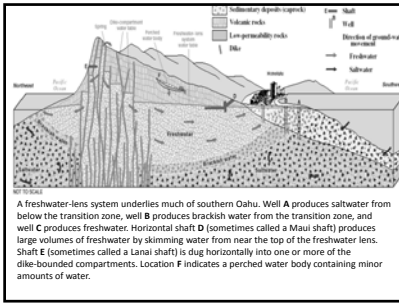
Enhancing adaptive capacity

Collage of images illustrating adaptation strategies. It includes raising roadbeds, community-based climate risk management, and climate proof infrastructure. A logo for 'Micronesia Challenge' is also present. Text boxes state: 'Raise awareness', 'Develop plans with climate theme', and 'Climate proof' infrastructure.

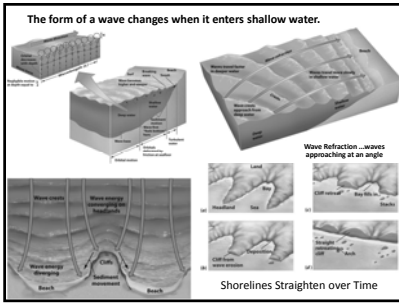
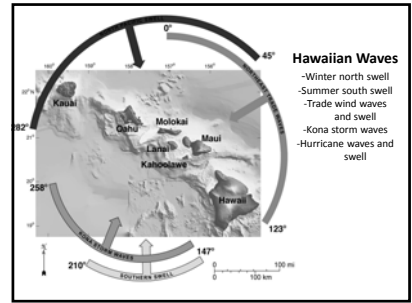








Coastal management has lagged behind the growth in population leading to problems with pollution...

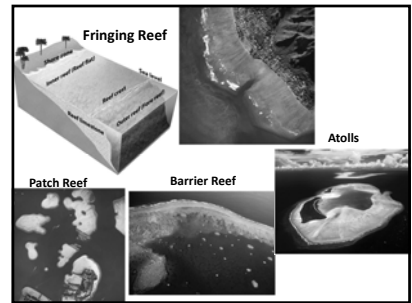
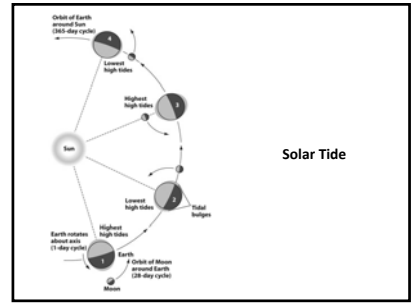


... Wave-Generated Currents occur in Shallow Water.

sea-level setup

Longshore Currents

and Rip Currents Transport Sediment in the Surf Zone.



Five Recognized Oceans and Three Largest Seas

Marine Geology Is the Study of Geologic Processes within Ocean Basins.

Oceanic Gyres deflected to right in northern hemisphere

The Continental Margin Consists of the Shelf, the Slope, and the Rise.

Calcareous Ooze

foraminifera

coccolithophores

Below the CCD (Carbonate Compensation Depth), CaCO_3 dissolves.

Pelagic Stratigraphy Reflects Dissolution, Dilution, and Productivity.

Ocean Sediments

- Calcareous ooze
- Siliceous ooze
- Abyssal clay
- Glacial sediments
- Terrigenous sediments
- Continental margin sediments

OCEANIC CRUST

Why does the source and composition of sediment change between the coast, shelf, rise, abyssal plain, and oceanic ridge?