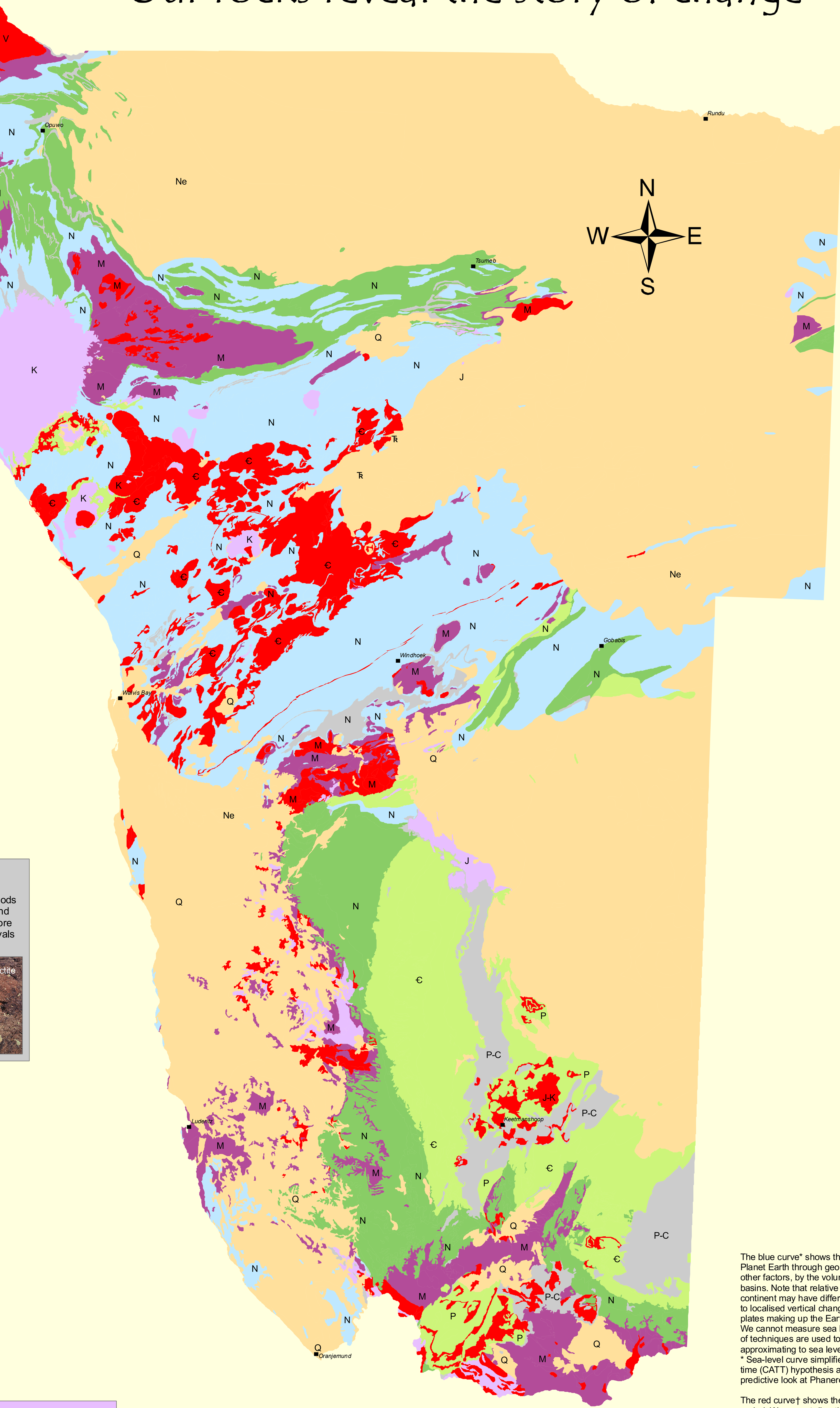
Climate Through Time

Our rocks reveal the story of change

Earth's climate is predicted to change rapidly with serious consequences for humanity. However, during its more than four billion years of existence, the climate on our planet has been changing continously, accompanied by more or less severe extinction events (for instance at the end of the Permian, some 250 million years ago, more than 85% of all lliving organisms on land and in the sea became extinct, due to a disastrous global warming caused among other factors by enormous volcanic eruptions). What is new today is, that while before the appearance of *homo sapiens* these climate changes had natural causes, and took place over long periods of time, in the present day human activity contributes considerably to the ill effects on our environment (including climate), as well as brings about change more quickly.

Rocks record the climate and conditions under which they originated and thus are a window to the geological past of Planet Earth. As environments are directly influenced by the prevailing climate, so are the sediments and rocks formed in them. On this poster each environment is represented by a particular colour to indicate the climatic changes that have led to the geology of Namibia, as we know it today. For example orange areas on the map show the location of modern and ancient deserts, while grey indicates the remnants of the various glaciations (ice ages), to which the region was subjected. Colours used on the map correspond to the geological timetable on the right as well as the insets below, showing the climatic development of Namibia and the southern African subcontinent, and examples of these palaeoenvironments and their products, respectively.

In some cases, however, rocks are created by geological processes regardless of climatic conditions. For example, igneous intrusions, shown here in red, are formed by the uprising of molten material from the Earth's interior, while metamorphic rocks (e.g. gneisses and related rock types here referred to as "Ancient Mountains") originate during episodes of tectonic activity or mountain building. Conversely large amounts of ash from volcanic eruptions, may accumulate in the atmosphere to such a degree as to effectively block out sunlight, and thus influence the climate.



0 50 100 200 300 400 Kilometers

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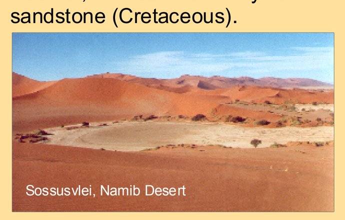
Deserts

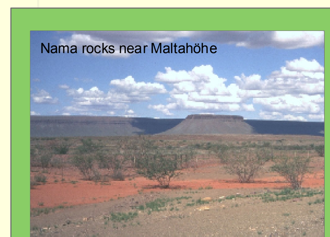

Twyfelfontein sandstone

Evidence: dunes are preserved as cross-bedded sandstones with a reddish colour. Mud cracks, salt and gypsum deposits also indicate a dry climate. Examples are the young deposits of the Kalahari and Namib Deserts, as well as the Twyfelfontein sandstone (Cretaceous).

Environment: hot, arid to semi-arid, with few seasonal rivers and lakes, wind-shaped sand dunes, and salt pans formed through evaporation.

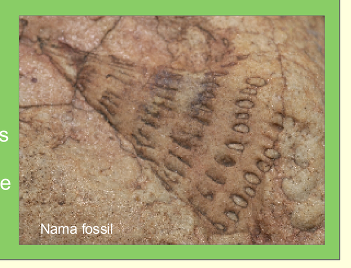

Sossusvlei, Namib Desert

Warm Seas


Nama rocks near Maltahöhe

Environment: Warm shallow to deep seas, where sand, mud and calcareous oozes are deposited, and reefs build up.

Evidence: sandstone, mudstone and limestone containing abundant plants and animals. Examples are the sedimentary rocks of the Nama Group, which contain some of the oldest known fossils on Earth.


Nama fossil

Subtropical swamps, rivers and seas


Cypress swamp

Environment: Tropical to subtropical swamps, rivers and sshallow seas. Sand and mud accumulate in layers, sometimes rich in fossils

Evidence: bedded sandstone and mudstone, containing the remains of alternating marine and freshwater organisms. Examples are the sedimentary rocks of the Karoo Sequence, in the Huab and main Karoo basins.

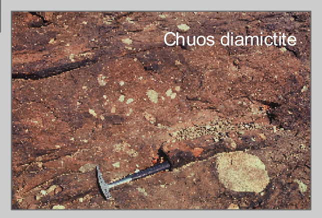

Petrified Forest near Khorixas

Ice Ages


Glacier

Environment: very cold periods with extensive ice sheets and glaciers, alternating with more temperate interglacial intervals

Evidence: grooved rock surfaces caused by moving ice; ill sorted rocks (tillites), with larger pebbles in a fine-grained groundmass. Examples are the Dwyka tillite (Carboniferous) and the Chuos Formation (Neoproterozoic).


Chuos diamictite

Cold to temperate seas


Fjord landscape

Environment: Coastal waters and deep seas in cold to temperate latitudes. Sand and mud accumulate on the sea bed in layers

Evidence: bedded sandstone and mudstone, alternating with thick sequences of carbonate rock. Most of the rocks of the Neoproterozoic Damara Sequence and Gariep Belt formed in this environment.


Kuiseb Canyon

Igneous Intrusions


Brandberg Intrusive Complex

Process: intrusion of molten rock (magma) into the Earth's crust from below, crystallizing slowly at depth. May produce geyers and hot springs at the surface.

Evidence: coarse-grained granites and gabbros are evidence that magma crystsallized slowly under the Earth's surface. Namibia has plenty intrusive rocks of varied composition and age which can be found all over the country.


Kobos Granite, Gamsberg area

Ancient Mountains


Namaqua gneiss, Ai-Ais

Process: ancient rocks of varied origin, deformed and baked under high pressures and temperatures, forming the roots of mountains ranges.

Evidence: schist and gneiss are formed by the metamorphism of existing rocks, which often involves the growth of new minerals, such as garnet. Examples are the Namaqua and Epupa Metamorphic Complexes, and other basement complexes throughout Namibia (Meso- to Palaeoproterozoic).

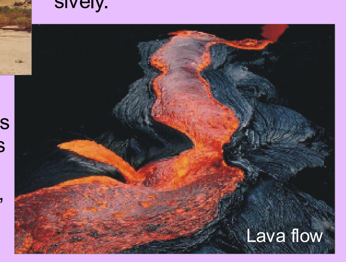

Garnet-bearing paragneiss

Volcanic Rocks

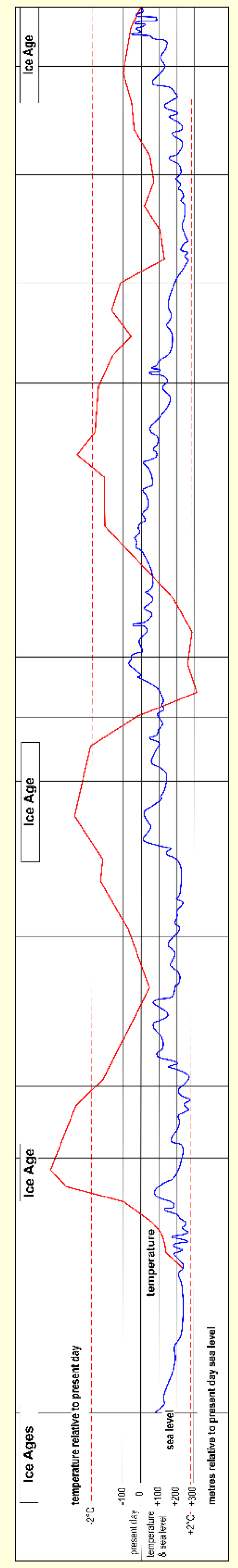

Flood basalts, Etendeka Plateau

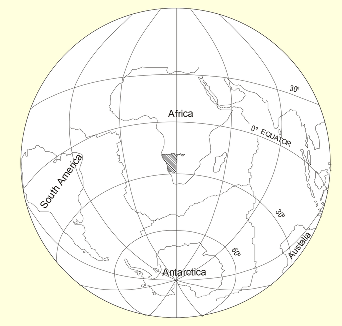
Process: molten rock pours out onto the Earth's surface as basalt lava. Stickier, silica-rich rhyolite lava erupts explosively.

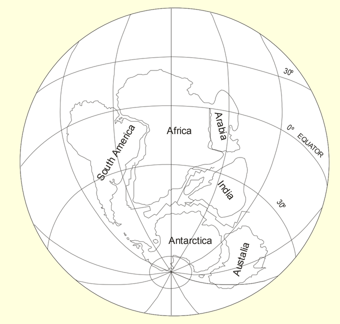
Evidence: basaltic to rhyolitic lava and ash. Fine-grained rocks indicate rapid cooling. Examples include the flood basalts of the Etendeka Plateau (Cretaceous), and the rhyolites of the Sinclair Sequence (Mesoproterozoic).

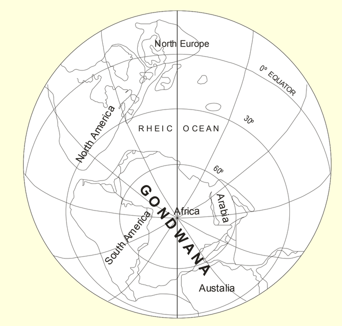

Lava flow

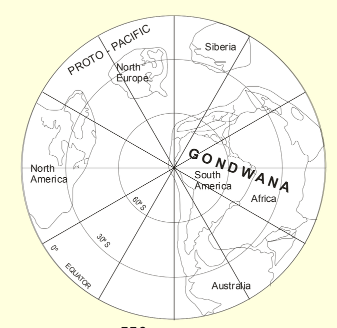
Temperature and sea levels through time	Position of the continents through time	Geological periods	Fossil evidence and palaeoenvironments



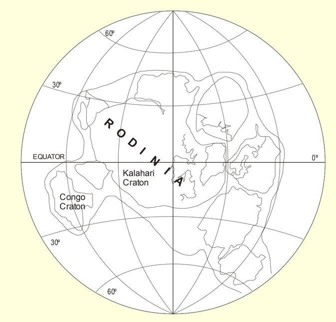

Present


115 m.y. ago - Breakup of Gondwana


350 m.y. ago - Southern continents are combined in Gondwana



550 m.y. ago - Formation of Gondwana



750 m.y. ago - Rodinia Supercontinent

Continental drift through the ages

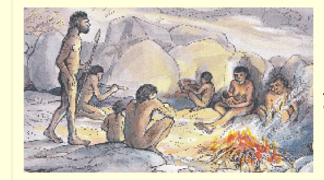
Quaternary (Q)
2 million years
Neogene (Ne)
23 million years
Palaeogene (G)
65 million years
Cretaceous (K)
145 million years
Jurassic (J)
200 million years
Triassic (₸)
251 million years
Permian (P)
299 million years
Carboniferous (C)
359 million years

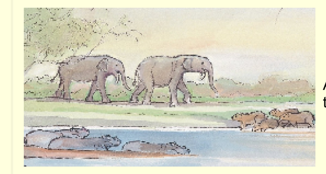
Time Gap Ordovician to Devonian

488 million years
Cambrian (€)
542 million years
Neoproterozoic (N)
635 million years
720 million years
Time gap
1000 million years
Mesoproterozoic (M)
Time gap
1600 million years
Palaeoproterozoic (V)
Time gap
2500 million years
Archaean (A)
4600 million years — Earth forms

Colours in the geological time table only indicate the predominant environment or processes; not drawn to scale

Phases of:
- Volcanic eruptions
- Igneous intrusions
- Mountain building


Archaic Homo sapiens, Orange River

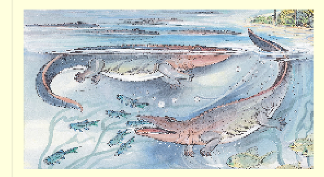

Arriesdrift in the Miocene

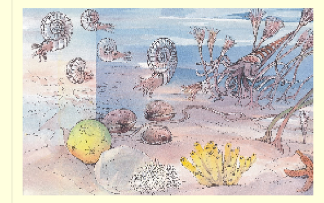

Tropical sea of the Eocene


Massospondylus, Etjo Desert

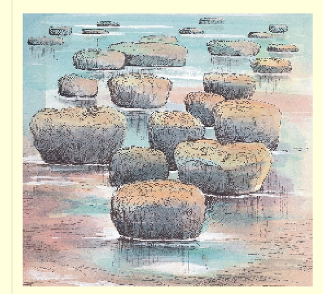

Kannemeyeria, Waterberg Plateau


Mesosaurus, Ecca swamp


Stereospondylus, Lake Gai-As


Molluscs of the Dwyka glaciation


Nama sea, southern Namibia


Stromatolites, Otavi Mountainland

Palaeoenvironments found in Namibia; drawings by C. Marais

The blue curve* shows the average sea level compared to today for the whole Planet Earth through geological time. This global sea-level is affected, among other factors, by the volume of water in the oceans and the shape of the ocean basins. Note that relative sea-level changes affecting the Southern African subcontinent may have differed markedly from this 'global' curve (for example due to localised vertical changes of the land surface caused by the interaction of the plates making up the Earth's crust, or the formation and melting of ice-sheets. We cannot measure sea level changes in the ancient past directly, and a variety of techniques are used to estimate it, such as erosion by the sea, and fossil reefs approximating to sea level.
* Sea-level curve simplified after Collins (2008), "The carbonate analogs through time (CATT) hypothesis and the global atlas of carbonate fields. A systematic and predictive look at Phanerozoic carbonate systems"

The red curve† shows the average global temperature back to the Cambrian period. We cannot directly measure past temperatures, instead we use evidence preserved in the rocks. One such method uses the proportion of the oxygen-18 isotope found in fossil shells - a high oxygen-18 content is associated with cold sea temperatures and times of glaciation. During ice ages (marked by white bars) ice caps covered the Earth's polar regions.
† Temperature curve after N.J. Saviv and J. Veizer (2003) "Celestial driver of Phanerozoic climate?"

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