Water world

Colorado is a long way from Norway. But during the Late Cretaceous epoch it was a little closer, both geographically and geologically.

Robert W Williams (text and photos)

An outcropping of 94-million-year-old limestone along a railway cutting in central Colorado resembles rocks deposited simultaneously in many other parts of the world - including Norway.

It entombs similar plants and animals and records similar sea-level changes and seafloor environments. Although affected by local conditions in North America at the time, these strata would not seem much out of place had they occurred in southern England, central Tunisia or on the Norwegian continental shelf.

What happened 94 million years ago to make marine environments so similar across the globe? To explain this, it may help to see the Earth through a palaeontologist's eyes.

Analyse. Palaeontologists study sedimentary rocks in the same way that art historians analyse great works of art. The historian assesses a painting in the context of the era when the artist lived.

Medieval, Renaissance, Baroque - the periods of European art history reflect stages in our cultural evolution. Religion, ideas, technology and social conditions each play a role in shaping the artistic style of different periods.

That style is itself modulated by a variety of factors expressed in slightly different ways in the minds of different artists. Art influences culture and culture influences art in a complex interaction.

By examining motif, symbolism, style and painting techniques, the art historian gleans a wealth of information about the human condition which would otherwise remain hidden.

In a similar fashion, palaeontologists appreciate rocks and fossils in the context of when and where they were deposited. Each geological period is characterised by a particular "style" of biological evolution.

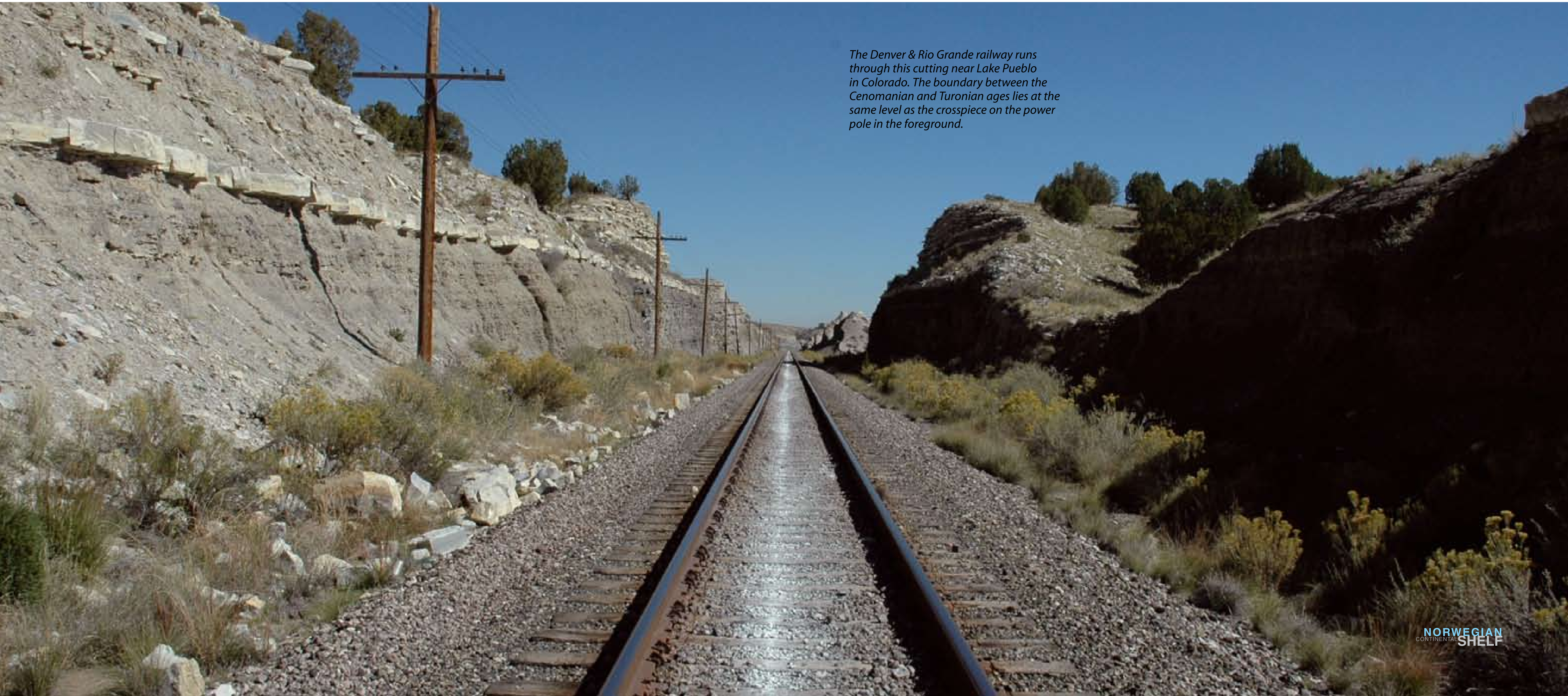
Climate, geography and available resources all play a role in shaping ecosystems and the organisms which occupy them. These factors again influence each other in a complex system of feedbacks.

By examining sediment characteristics, fossil content, palaeogeography and a host of other factors, palaeontologists glean a wealth of information about the Earth's history which would otherwise remain hidden.

Changing. In this perspective, those cliffs along the railway line take on new meaning. World geography in the Late Cretaceous was not what it is today. As always, it was a product of the ever-changing position and topography of continents, together with fluctuating sea levels and climate. Basically, the Earth was very warm and the continents were partially covered by seas.

The mechanism which controls these changes is plate tectonics: the slow drifting of plates that make up the thin, solid outer shell of the Earth.

Seafloor spreading occurs at ocean



The Denver & Rio Grande railway runs through this cutting near Lake Pueblo in Colorado. The boundary between the Cenomanian and Turonian ages lies at the same level as the crosspiece on the power pole in the foreground.

ridges, where heavy oceanic crust extrudes along the seams of large plates of basalt. The lighter, buoyant continents are just along for the ride, occasionally bumping into one another when their paths cross.

This bumping and shoving deforms continental boundaries, shaping mountain chains like the Himalayas.

Elsewhere, heavy oceanic crust is recycled in the melting pot of the planet's interior while descending along the edges of colliding plates. This creates island arcs such as the Aleutians and volcanic mountain chains like the Andes.

Continental drift directly affects global climate by altering ocean currents, atmospheric circulation and sea levels. Erosion is intensified by mountains formed during plate collisions.

The resulting increase in sedimentation induces chemical reactions which remove carbon dioxide from the air, lowering global temperature. Seafloor spreading also alters ocean chemistry, affecting ecosystems and biological evolution.

All these factors control where and how things live and sediment is deposited. Like the styles of trend-setting masters in the art world, sediments, living organisms and climate each influence the other through an array of interacting mechanisms.

Collisions. There were no major continental collisions during the Cretaceous, so mountain ranges were far fewer and eroded much lower than today. But seafloor spreading became intense during the Late Cretaceous, and mid-ocean ridges swelled upward as a result.

This reduced the volume of ocean basins, forcing shallow seas to cover much of what is today dry land. The unusually flat continental topography enabled encroaching seas significantly to alter global geography and climate. The Earth became a water world of inundated continents with warm marine climates.

North America shrank to three major islands about the size of India. One was a narrow strip of land which stretched from Central America to Alaska.

Central and eastern USA and parts of Manitoba, Ontario and Quebec formed another. The third island lay to the north and comprised Canada's Nunavut Territory.

In modern geographical terms, it would have been possible to sail from Nicaragua to the North Pole by striking a straight course through the Great Plains and western Canada.

A 5 000-kilometre ocean voyage from Colorado to Norway would have followed a north-easterly route over Nebraska and the Dakotas into Saskatchewan and Manitoba, turning east into Hudson Bay. After rounding the southern tip of Greenland, the North Sea was only 1 500 kilometres away.

Our rock layers by the railway tracks reveal that microplankton which thrived in the seas trisecting North America were similar to contemporaneous populations in the waters off Norway. The marine connection to northern Europe is the key.

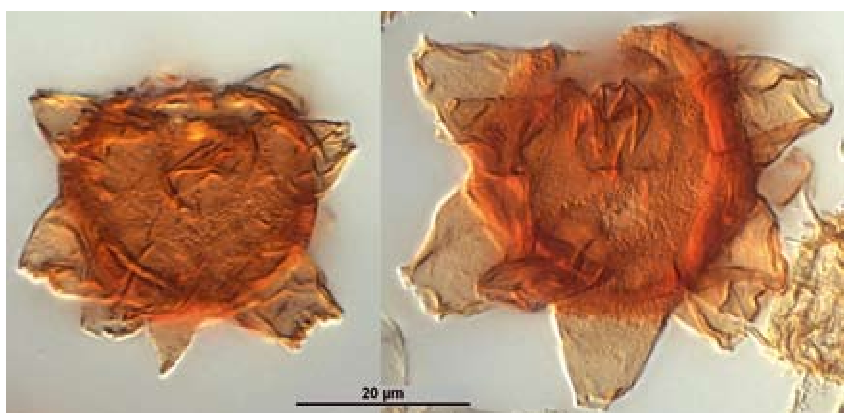
Similarity. These Colorado limestone layers show another remarkable similarity to coeval Norwegian sediments. The outcrop begins on the south side of the tracks with black, thinly laminated claystone.

The rock here splits into thin sheets because the mud layers were never disturbed by sediment-burrowing animals. When we dissolve the rocks in acid, what remains is a gelatinous, organic goo of algal microfossils.

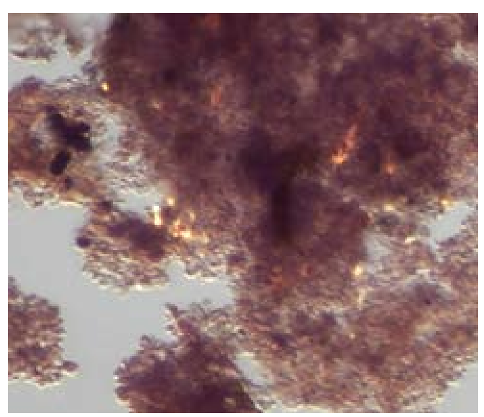
This is bacterially degraded microplankton, the raw material for hydrocarbons. The 94-million-year-old sediments are an important source rock for petroleum in many basins around the world.

The conditions which produced this algal-rich soup must have been very common in the oceans and inland seas at this time.

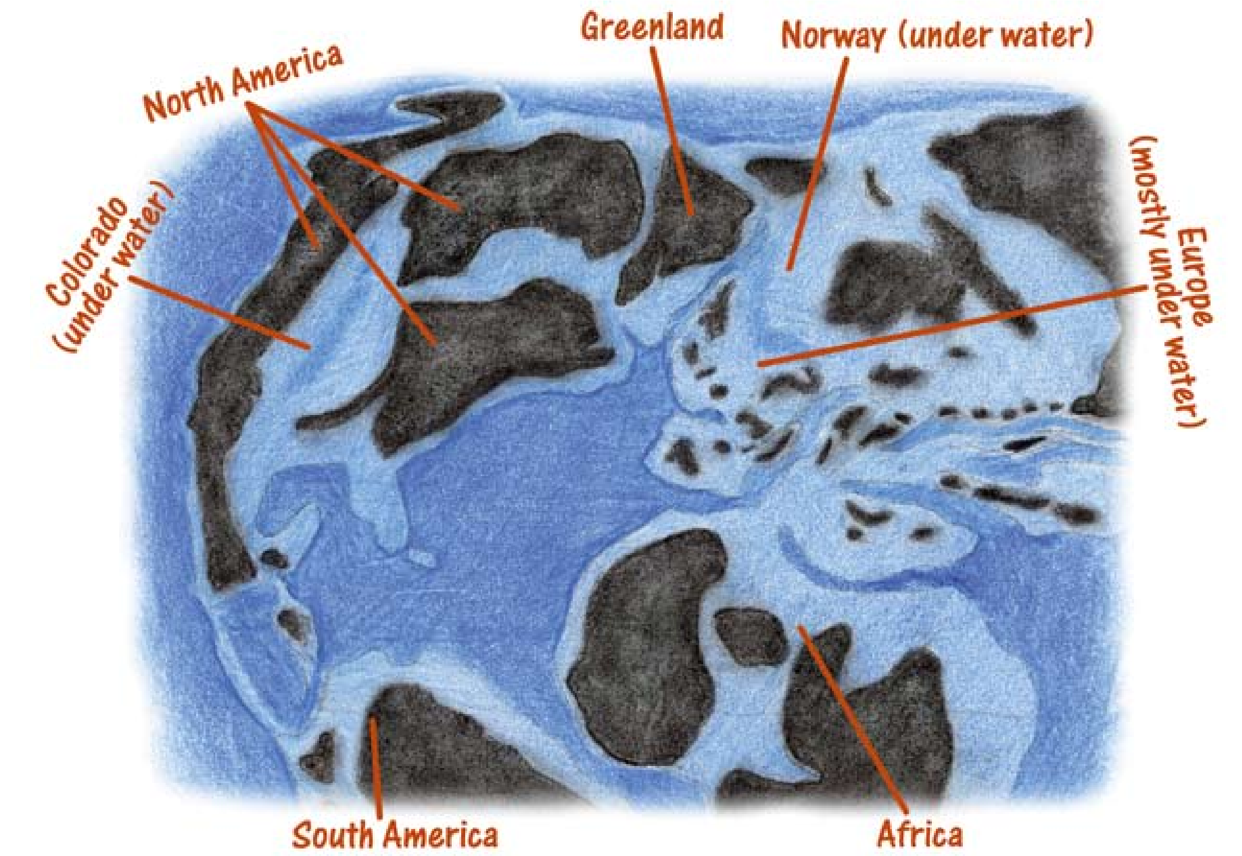
Bottom waters over vast areas of



Two specimens of 94 million year old Lithosphaeridium siphoniphorum, *a fossil dinoflagellate. The left specimen is from Colorado, the right from the Norwegian continental shelf. Scale bar = 0.02 millimetres.*



Organic material from the black claystone beds by the railway. This consists primarily of bacterially degraded microplankton remains.



Map of the world at the end of the Cenomanian Age, 94 million years ago

ocean floor were free of oxygen. Only bacteria of the sort which do not need oxygen could thrive on the dead plankton.

The answer to the mystery of oxygen depletion in Earth's oceans at the close of this Cenomanian age may have something to do with salt.

Oceans today are stirred even at their greatest depths by bottom currents, powered by density differences between cold, salty water and warm, less salty water.

The cold, salty water descends at high latitudes while the warm, less salty surface water flows north to replace it. This is how our present-day oceans distribute solar heat.

No ice. However, ocean circulation during the Late Cretaceous differed in many ways from that of today. There was no ice at sea level, for instance, so the generation of cold, saltier water at high latitudes did not occur.

There is evidence which indicates that the reverse was in fact the case. The global sea level was very high, so vast inland seas increased sea surface area and evaporation. Hypersaline tropical water may have sunk at low latitudes owing to cooling during the winter months.

Colder, high-density brines may have stratified the water column in deep oceans and shallow inland seas, thus preventing oxygenated surface water from mixing with bottom water.

The global occurrence of black claystone at the end of the Cenomanian age, 94 million years ago, could be the result of this naturally occurring ecological disaster.

Viewed from that perspective, the rocks of the railway cutting paint a dismal picture of this important event in our planet's history. ❇

Golden spike

The limestone strata outcrop along the Denver and Rio Grande railway cutting near Lake Pueblo in Colorado is important because of a decision made in 2003.

After assessing several well developed outcrops around the world, the International Commission on Stratigraphy chose to place the "golden spike" defining the boundary between the Cenomanian and Turonian ages in precisely this spot. So these strata have worldwide significance.

Microplankton

Marine palynology is a field of palaeontology which deals mainly with a large group of single-celled microplankton called dinoflagellates.

Many of these organisms go through a stage in their life cycle when they encapsulate themselves in a resistant, often beautifully decorated, shell of flexible organic polymer.

Appearing much like yellow and orange plastic trinkets, such dinoflagellate cysts are used to determine the age and depositional environments of sediments.