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In Ancient Fossils, Seeds of a New Debate on Warming

By WILLIAM J. BROAD

In recent years, scientists have made sizable gains in what was once considered an impossible art — reconstructing the history of Earth's atmosphere back into the dim past. They can now peer across more than a half billion years.

The scientists have learned about the changing makeup of the vanished gases by teasing subtle clues from fossilized soils, plants and sea creatures. They have also gained insights from computer models that predict how phenomena like eroding rocks and erupting volcanoes have altered the planet's evolving air. "It's getting a lot more attention," Michael C. MacCracken, chief scientist of the Climate Institute, a research group in Washington, said of the growing field.

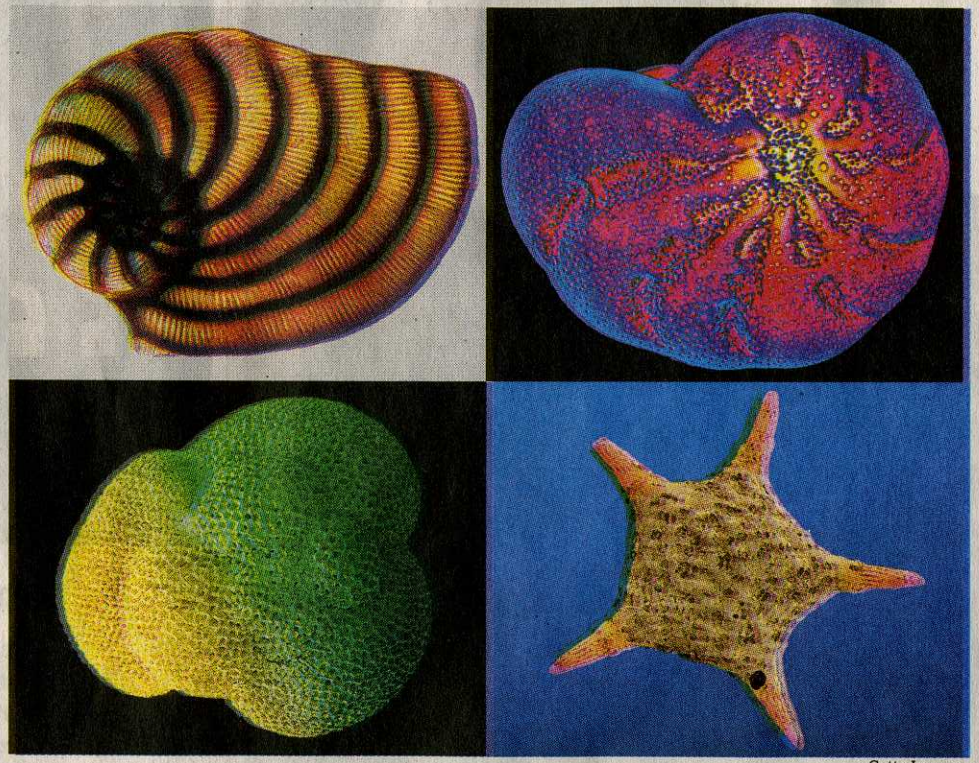
For the first time, the Intergovernmental Panel on Climate Change, a United Nations group that analyzes global warming, plans to include a chapter on the reconstructions in its latest report, due early next year.

The discoveries have stirred a little-known dispute that, if resolved, could have major implications. At issue is whether the findings back or undermine the prevailing view on global warming. One side foresees a looming crisis of planetary heating; the other, temperature increases that would be more nuisance than catastrophe.

Perhaps surprisingly, both hail from the same camp: scientists who study the big picture of Earth's past, including geologists and paleoclimatologists.

Most public discussions of global warming concentrate on evidence from the last few hundred or, at most, few thousand years. And some climate scientists remain unconvinced that data from the deep past are solid enough to be relevant to the debates.

But the experts who peer back millions of years, though they may debate what their work means, do agree on the relevance of their findings. They also agree that the eon known as the Phanerozoic, a lengthy span from the present to 550 million years ago, the dawn of complex life, typically bore concentrations of carbon dioxide that were up to 18 times the levels present in the short reign of Homo sapiens.



Getty Images

SEA CREATURES Fossils like these tiny Foraminifera yield clues about past climates.

The carbon dioxide, the scientists agree, came from volcanoes and other natural sources, as on Mars and Venus. The levels have generally dropped over the ages, as the carbon became a building block of many rock formations and all living things.

Moreover, the opponents tend to agree on why the early Earth's high carbon dioxide levels failed to roast the planet. First, the Sun was dimmer in its youth. Second, as the gas concentrations increase, its heat trapping capacity slows and reaches a plateau.

Where the specialists clash is on what the evidence means for the idea that industrial civilization and the burning of fossil fuels are the main culprits in climate change. The two sides agree that carbon dioxide can block solar energy that would otherwise radiate back into space, an effect known as greenhouse warming. But they differ sharply on its strength.

Some argue that CO_2 fluctuations over the Phanerozoic follow climate trends fairly well, supporting a causal relationship between high gas levels and high temperatures. "The geologic record over the past 550 million years indicates a good correlation," said Robert A. Berner, a Yale geologist and pioneer of paleoclimate analysis. "There are other factors at work here. But in general, global warming is due to CO_2. It was in the past and is now."

Other experts say that is an oversimplification of a complex picture of natural variation. The fluctuations in the gas levels, they say, often fall out of step with the planet's hot and cold cycles, undermining the claimed supremacy of carbon dioxide.

"It's too simplistic to say low CO_2 was the only cause of the glacial periods" on time scales of millions of years, said Robert Giegengack, a geologist at the University of Pennsylvania who studies past atmospheres. "The record violates that one-to-one correspondence."

New clues about gases and computer models lead to new questions.

He and other doubters say the planet is clearly warming today, as it has repeatedly done, but insist that no one knows exactly why. Other possible causes, they say, include changes in sea currents, Sun cycles and cosmic rays that bombard the planet.

"More and more data," Jan Veizer, an expert on Phanerozoic climates at the University of Ottawa, said, "point to the Sun and stars as the dominant driver."

Highlighting the gap, the two sides clash

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on how much the Earth would warm today if carbon dioxide concentrations double from preindustrial levels, as scientists expect. Many climatologists see an increase of as much as 8 degrees Fahrenheit. The skeptics, drawing on Phanerozoic data, tend to see far less, perhaps 2 or 3 degrees.

In the Phanerozoic (the term is Greek for visible life), complex organisms arose. If its countless ages were compressed into a single year, fish would have appeared in January, land animals in March, dinosaurs in June, monkeys in December and humans late on New Year's Eve.

The Phanerozoic dispute, fought mainly in scholarly journals and scientific meetings, has occurred in isolation from the public debate on global warming. Al Gore in "An Inconvenient Truth" makes no mention of it.

Some mainstream scientists familiar with the Phanerozoic evidence call it too sketchy for public consumption and government policy, if not expert deliberations.

"In my view, the uncertainties are too great to draw any conclusions right now," Michael Oppenheimer, a professor of geosciences and international affairs at Princeton, said. "It could be that when the dust settles some insight will emerge that will be germane to the current problem — how do we keep the climate from spinning out of control."

Skeptics say CO_2 crusaders simply find the Phanerozoic data embarrassing and irreconcilable with public alarms. "People come to me and say, 'Stop talking like this, you're hurting the cause,' " said Dr. Giegengack of Penn.

Robert A. Rohde, a graduate student in geophysics at the University of California, Berkeley, may represent a neutral voice. The evidence, he said, "is that CO_2 is just one of many influences."

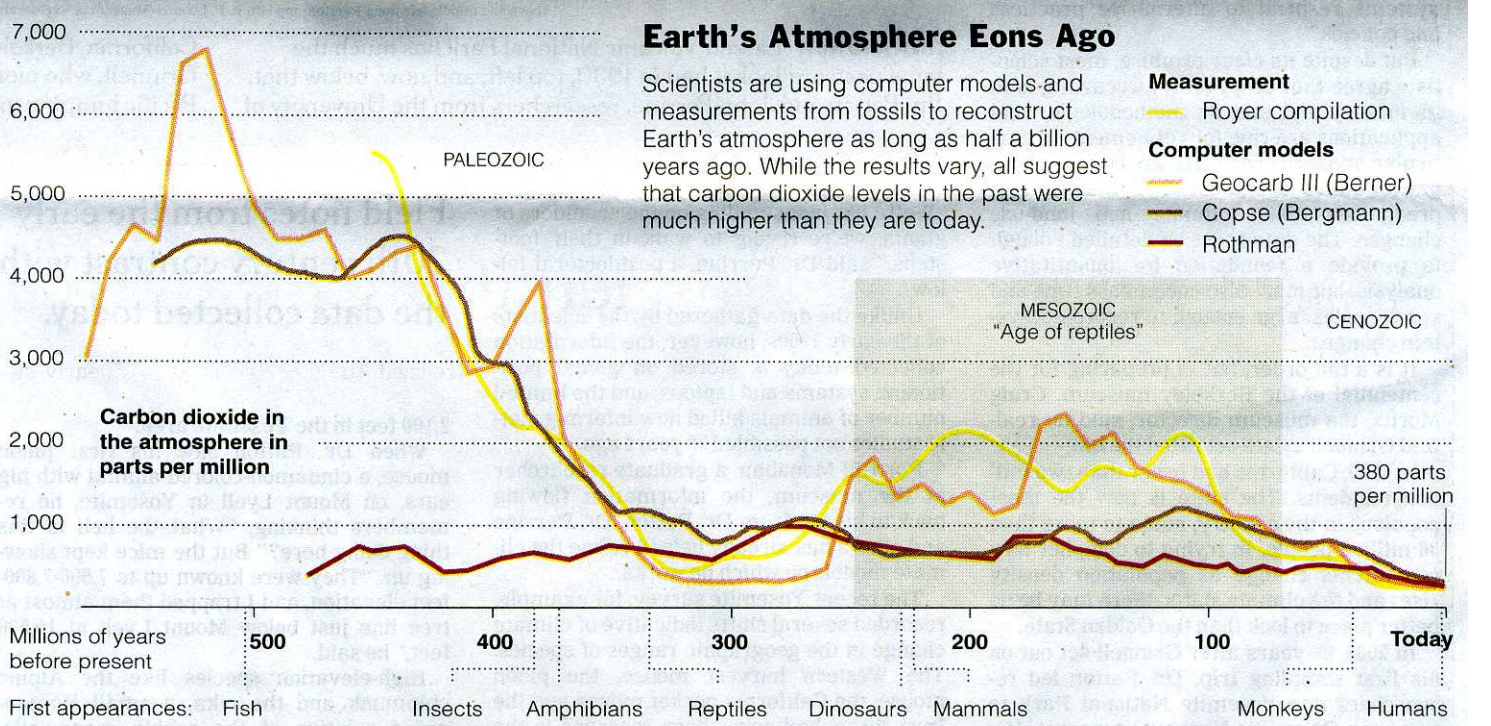
For Wikipedia, Mr. Rohde recently drew up graphic overviews of Phanerozoic carbon dioxide, en.wikipedia.org/wiki/Image:Phanerozoic-Carbon-Dioxide.png, and climate swings, en.wikipedia.org/wiki/Image:Phanerozoic-Climate-Change.png.

For nearly two centuries, scientists have known that the ancient Earth went through ice ages and other climate upheavals. Their explanations included changes in land forms, ocean flows, solar intensity and Earth's orbit around the Sun.

The new argument dates from 1958, when scientists began to track carbon dioxide in the air, finding its levels low, 0.0315 percent, but increasing. They knew that excess gas could in theory trap more heat from the Sun, warming the planet and providing a new explanation for climate change.

The greenhouse theory rose to prominence in the 1980's as carbon dioxide continued to increase and as global temperatures started to increase. While scientists tracked many greenhouse gases, including ozone, methane and water vapor, they focused on carbon dioxide because its concentrations seemed to be rising quite rapidly.

Keen to put the threat in perspective, they sought to compare modern CO_2 levels to those of the past. Ice cores from the frozen regions turned out to harbor tiny air bubbles that showed carbon dioxide concentrations going back hundreds of thousands of years. Scientists found the preindustrial levels averaging 280 parts per million, down from 315



Source: Robert A. Rohde, University of California at Berkeley

Chart does not include margins of error.

parts per million, or 0.0315 percent, in 1958.

Scientists suspected that the concentrations were once much higher, especially in hot eras of little or no polar ice. Eager to push beyond the cores, which went back just a half million years or so, scientists looked for ways to peer further back.

Dr. Berner of Yale focused on computer models. His studies of the Phanerozoic analyzed factors such as how some ages produced many volcanoes and much atmospheric carbon dioxide and others spawned mountains, extensive weathering of fresh rock and, by that mechanism, considerable uptake of atmospheric carbon dioxide.

From the start, he consistently reported close ties between carbon dioxide and climate swings. For instance, in the explosion of plant life from 400 million to 300 million years ago, he found a sharp drop in the gas, occurring as the earth entered an ice age.

"These results," Dr. Berner wrote in the journal Science in 1990, "support the notion that the atmospheric CO_2 greenhouse mechanism is a major control on climate over very long time scales."

Other scientists looked for clues among fossilized soils, plants and sea creatures, assuming that fluctuating climates had altered their growth patterns. In time, the ancient specimens yielded a bonanza of subtle evidence, some confirming aspects of Dr. Berner's modeling.

Claudia I. Mora and two colleagues at the University of Tennessee found that ancient soils verified the steep decline in carbon dioxide between 400 million and 300 million years ago.

Other scientists found conflicting evidence. In 1992, a team from the University of New Mexico reported that ancient soils showed extremely high levels of carbon dioxide 440 million years ago, an age of primitive sea life before the advent of land plants and animals. The carbon dioxide levels were roughly 16 times higher than today. Surprisingly, the scientists said, this appeared to coincide with wide glaciation, an analysis, wrote Crayton J. Yapp and Harald Poths in the journal Nature, that "suggests that the climate models require modification."

Throughout the 1990's, reconstruction papers offered evidence on both sides of the debate about the effects of carbon dioxide. Starting in 2000, the attacks intensified as Dr. Veizer of Ottawa questioned the CO_2-climate link across the whole Phanerozoic. He and two Belgian colleagues, writing in Nature, based their doubts on how two ice ages — 440 million and 150 million years ago, in the age of dinosaurs — apparently had very high carbon dioxide levels.

In 2002, Daniel H. Rothman of the Massachusetts Institute of Technology also raised sharp Phanerozoic questions after studying carbon dioxide clues teased from marine rocks. Writing in The Proceedings of

If CO_2 levels have fallen, should we be preoccupied with greenhouse gases?

the National Academy of Sciences, he said that with one exception — the recent cool period of the last 50 million years — he could find "no systematic correspondence" between carbon dioxide and climate shifts.

In 2003, Dr. Veizer joined Nir J. Shaviv, an astrophysicist at the Hebrew University of Jerusalem, to propose a new climate driver. They envisioned slow movements of the solar system through the surrounding galaxy as controlling the cosmic rays that bombard Earth's atmosphere. A reduction, they argued, would lessen cloud cover and Earth's reflectivity, warming the planet. The reverse would cause cooling. The Phanerozoic record of cosmic-ray bombardment showed excellent agreement with climate fluctuations, trumping carbon dioxide, they wrote.

In 2004, Dr. Berner of Yale and four colleagues fired back. While saying cosmic rays were possibly "of some climatic significance," they argued that such an effect was much less than that of carbon dioxide.

In the debate, opponents can differ not only on the contours of past CO_2 fluctuations but also on defining hot and cold eras. Although Dr. Veizer sees a cold period 150 million years ago, a time of increased ice at sea but not on land because the continents had shifted from the poles, Dr. Berner, in his modeling, disregards it. Such differences can muddy the dispute.

Today, each side claims new victories. Dr. Veizer says he has a comprehensive paper on the cosmic-ray theory coming out soon. Dr. Berner recently refined his model to repair an old inconsistency.

The revision, described in the May issue of The American Journal of Science, brings the model into closer agreement with the fact of wide glaciation 440 million years ago, yielding what he sees as stronger evidence of the dominant role of carbon dioxide then.

Dr. Yapp, once a carbon dioxide skeptic, concurred, saying, "The data complied in the last decade suggests that long-term climate change correlates pretty well with CO_2 changes."

Some climatologists view the Phanerozoic debate as irrelevant. They say the evidence of a tie between carbon dioxide and planetary warming over the last few centuries is so compelling that any long-term evidence to the contrary must somehow be tainted. They also say greenhouse gases are increasing faster than at any other time in Earth history, making the past immaterial.

Carbon dioxide skeptics and others see the reconstructions of the last 15 years as increasingly reliable, posing fundamental questions about the claimed powers of carbon dioxide. Climatologists and policy makers, they say, need to ponder such complexities rather than trying to ignore or dismiss the unexpected findings.

"Some of the work has been quite meticulous," Thure E. Cerling, an expert at the University of Utah on Phanerozoic climates, said. "We are likely to learn something."