they break up into their subunits, which allows the chromosomes to detach themselves from the nuclear membrane and line up on the mitotic spindle. The recent results make it seem likely that along with its other roles, cdc2 kinase is an essential element in this step, too.

Although cdc2 kinase and cyclin seem to play the central role in cell cycle regulation, growing evidence points to supporting roles for other players. Some of them don't send the cycle moving forward—they act as checkpoints to interrupt it if it has gone off the tracks. Ted Weinert, from the University of Arizona in Tucson, presented work with genes in the yeast ***Saccharomyces cerevisiae*** that appear to control one key "checkpoint" of the mitotic cycle.

In eukaryotic cells in which the DNA is damaged or incompletely replicated, the cycle comes to a halt and the cells do not proceed to mitosis. This checkpoint ensures the viability of the daughter cells, as well as the fidelity of the genome passed along to them. In earlier work, Weinert and his colleagues had found that in ***S. cerevisiae*** a gene called RAD9 is essential for this failsafe mechanism.

Weinert has now identified five additional genes that are involved in this damage-induced halt. He and his group are investigating how these genes act to stop the cell cycle in its tracks. He postulates that they are activated by a signal—as yet unidentified—sent out by the damaged DNA. At least in the case of the RAD9 gene, the action of the inhibitor does not depend on production of new protein—since the cell cycle is arrested even in the presence of a protein synthesis inhibitor. This suggests that activation of RAD9's function involves an alteration of a protein that has already been made, possibly by phosphorylation.

The details of how specific enzymes are phosphorylated or dephosphorylated is the kind of question cell cycle researchers are turning to now—having established the grand unifying "universal model." In Vienna, Nurse found a graphic way of illustrating the change the field is going through. During his talk, he had the front cover of the meeting program, featuring a line drawing of Vienna's St. Stephen's Cathedral, projected onto the screen. "All these different strands are coming together to a point, which is the universal model," he said. "And sitting at the top of the tower are cdc2 and cyclin." Then he flipped the image upside down, so the tower was at the bottom. "And this is a symbol of where the field is going. From the unified model into all the complexities." ■ **MICHAEL BALTER**

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The Stately Cycles of Ancient Climate

Drill holes sunk in New Jersey reveal a 200-million-year-old record of climate cycles with periods of up to 5 million years

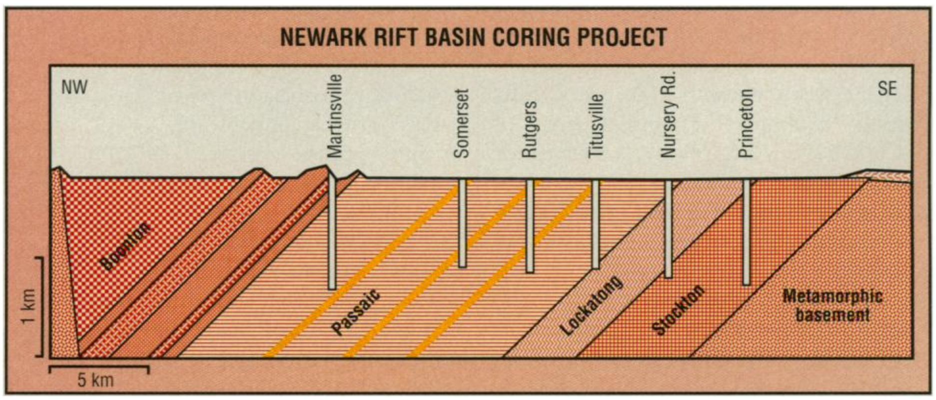
THE EARTH'S CLIMATE VARIES YEAR BY YEAR, millennium by millennium, eon by eon. Ice sheets grow and retreat, deserts bloom, and grasslands turn to dust. Some of these shifts are steady and irreversible, resulting from the uplift of mountains or the drifting of continents. But other climate changes have been periodic, varying in cycles of up to 100,000 years. Now, researchers examining core samples of rock drilled from such unlikely New Jersey sites as the campus of Rutgers University and the outskirts of Princeton have found that 200 million years ago the earth was in the grip of even longer climatic cycles, lasting as long as several million years.

The discovery underscores the importance of a fundamental pacemaker of climate change. Over the past 15 years, paleoclimatologists have recognized that many of the recent oscillations of climate have an astronomical source. They are driven by cyclic variations in the tilt and orientation of the earth's spin axis and in the shape of its orbit around the sun. These astronomical cycles, which take place on many different time scales, affect the distribution of sunlight around the globe and how it changes from season to season. The end result is a climate that varies in cycles of 20,000, 40,000, and—most dramatically of late—100,000 years, that last cycle having paced the repeated ice ages of the past million years. But although the astronomical cycles also have periods even longer than 100,000 years, there has been little evidence of a matching signal in recent climate history.

A 30-million-year climate record, preserved in sedimentary rock that accumulated in New Jersey 200 million years ago and more, has now confirmed that orbital variations can set up strong climate oscillations with a period of 400,000 years. The record also hints at even longer climate cycles, one lasting 2 million years and another 4 to 6 million years. These ancient climate cycles may serve as a point of comparison for researchers trying to understand the climate of the past few million years, when shorter oscillations have stood out.

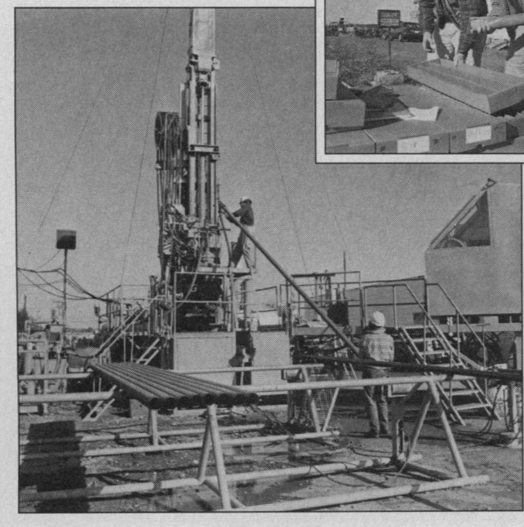
Paul Olsen and Dennis Kent, a paleontologist and a paleomagnetician at Lamont-Doherty Geological Observatory, took advantage of some favorable geology to extract their climate record. The Newark Basin, where the researchers did their drilling under the auspices of the revived Continental Scientific Drilling Program, is a paleoclimatologist's dream. The basin formed more than 200 million years ago as the crust of the supercontinent Pangaea was slowly pulled apart in the early stages of the formation of the Atlantic Ocean. The resulting rift valley, like the Great Rift Valley in Africa today, trapped a series of lakes, including one that was the size of Lake Tanganyika under present-day New Jersey.

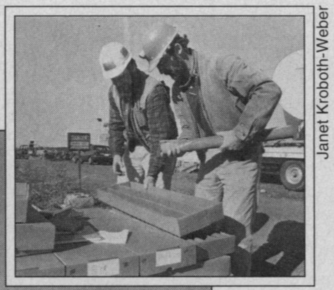
The site then lay near the equator, where monsoon rains draining into the basin turned the lake into a huge rain gauge. When the rains were heavy, the lake brimmed. But as Earth's climate varied under the influence of orbital cycles, the monsoon periodically faltered and lake levels fell.



An economical approach. *Tilted strata made it possible to retrieve a complete climate record from these ancient lake beds by drilling six shallow holes instead of one deep one.*

Hitting paydirt. *A modest drilling rig returned rock cores containing 30 million years of climate change.*





Janet Kroboth-Weber

The sediments accumulating on the lake bottom changed from black or gray organic-rich ooze when the water was deep to reddish cracked muds patterned with dinosaur footprints when the lake dried up.

These markers of the lake's repeated emptying and filling were laid down one on top of another like a deck of cards 7 kilometers thick, but tectonic forces have since tilted the deposit. Instead of needing a 7-kilometer hole to retrieve a complete sample of the deposit, Olsen and Kent could make do with a string of relatively shallow—and therefore inexpensive—holes, spread out so that each hole pierced a different part of the deposit (*Science*, 11 January, p. 158).

The drilling—six 1-kilometer holes in central New Jersey—was completed at the end of last month. This week Olsen, Kent, and Bruce Cornet of Lamont reported at the meeting of the American Geophysical Union in Baltimore that their cores showed climate periodicities aplenty operating between 200 million and 230 million years ago. The familiar 20,000- and 100,000-year cycles stood out in the first 4 million years of record they have analyzed. Even more prominent, though, was a 400,000-year cycle, which was evident in a pronounced intensification of the dry extremes of the 100,000-year cycle.

Olsen has not analyzed enough core to be very quantitative about even longer periodicities, but "it's clear by visual examination" of the cores that lake levels also varied with a period of about 1.6 million to 2 million years, he says. That's close to an orbital variation having a period of 2.3 million years. And about every 4 million to 6 million years the Newark Basin record shows a million-year period of extreme dryness. Andre Berger of the Catholic University of Louvain, Belgium, who calculates orbital variations, thinks that shorter orbital periods might interact to drive this longest climate cycle.

The appearance of all these stately climate cycles in the ancient record may be less surprising than what it underscores: their apparent absence in recent climatic history. It's not that researchers haven't looked for the expected longer periods. John Imbrie of Brown University, who in the 1970s helped demonstrate the link between orbital variations and recent climate changes recorded in deep-sea sediments, sees little evidence that the 400,000-year variation had any effect during the past 2 million years. If it did, he says, the effect was subtle, while "the 100,000-year period jumps out and shouts at you."

Imbrie suggests that the shorter period's recent dominance probably reflects the other dramatic differences between our world and the one Olsen and Kent are probing—in particular the ice sheets that now cover Antarctica and Greenland. Climatologists have assumed that the ice has somehow acted to amplify the 100,000-year period at the expense of the 400,000-year one—although so far all the suggested ice-related mechanisms act to amplify both periods equally. Imbrie calls this "the 400,000-year problem."

Olsen has a different view of the problem. "I think there may be more of a problem with the climate recorder than the climate system," he says. Rather than worrying about how the climate system could amplify one period and not the other, he says, paleo-oceanographers should be considering whether their marine sediments have faithfully recorded the 400,000-year cycle.

But if there really is a 400,000-year problem in recent climate history, the Newark Basin record may help researchers resolve it. If they can understand why the longest orbital cycles could drive climate oscillations in the ice-free, single-continent world of 200 million years ago, they may be able to understand why the cycles are absent or inconspicuous in our very different world.

The regularity of the cycles preserved in the Newark Basin drill cores may also make them useful as a timetable for other ancient events. Among them are reversals of Earth's magnetic field, which are recorded in tiny grains of magnetic minerals trapped in the ancient lake sediments. Measuring the duration of the reversals would fill in a major gap in the existing paleomagnetic timetable.

Kent intends to use the fleshed-out paleomagnetic record to date a giant impact that may have scattered debris across the lakes that filled the ancient Newark Basin. He hopes to find out whether the impact coincided with a mass extinction that took place about 205 million years ago (*Science*, 11 January, p. 161). Ironically, climate periodicities and extinction by impact are both subjects that were shunned until recent years as a bit too disreputable. How nice that the two outcasts might now help each other out. ■ RICHARD A. KERR

Finding DNA Sequencing Errors

The DNA sequence databases are chock full of errors, and investigators should clean up their act. That was the message delivered by molecular biologist Richard Roberts at a recent genome mapping and sequencing meeting at Cold Spring Harbor Laboratory, where he runs his lab. But Roberts did more than chide his colleagues for submitting error-ridden sequences to the databases: He offered a handy computer program to help them spot mistakes.

In doing so, Roberts waded right into a heated debate among human genome project researchers on just how accurate the sequence needs to be. Some have argued that, considering the huge expense of getting the sequence absolutely right, slightly sloppy sequences might be just fine. But Roberts clearly isn't buying that argument. "It is crazy not to get the basic set of genes right," said Roberts, referring to the 50,000 or so genes presumed to exist in the human genome. "It is worth spending extra money on, because it will save money downstream." Since searching the databases for related protein sequences is usually the first step in figuring out what a newly discovered gene does, inaccurate sequence data can mislead investigators or cause them to miss a match entirely, so that they end up not knowing what they have uncovered.

To David Lipman, who is setting up a massive new genome database at the National Library of Medicine, Roberts' call for cleaner data is right on the mark. "There is an incredible number of errors in the database. Real biology is being missed because of errors. What Rich is saying is, 'Wake up and realize there are things you can do that are actually fairly simple to help pick up