chain. The higher beam current translates into an increased average laser power.

Santa Barbara's accelerator was built by National Electrostatics Corporation (NEC), Middletown, Wisconsin. Tests of the recirculation scheme last year, when the machine was at the factory being modified for free electron laser use, demonstrated an average beam recovery of 97 percent. Moreover, the accelerated beam current reached 1.2 amperes, as compared to the tens of microamperes typical of this kind of accelerator.

With the undulator and other elements of the free electron laser at Santa Barbara, beam recovery is currently 83 percent, according to Ramian. "We are hoping for the upper 90's, when everything is working properly," he says. Unexpected was the observation of a recirculation threshold for lasing, as it was originally thought that recirculation was not necessary. So far, at least 70 percent beam recovery is needed before lasing begins.

One limitation of using the electrostatic accelerator is that the low beam energy confines the laser radiation to the far infrared. This is not necessarily a disadvantage, as there is much interest among physicists, materials scientists, chemists, and biologists in this wavelength region. Another free electron laser project that has been under way at AT&T Bell Laboratories for some time is designed explicitly for this purpose.

However, Elias proposed some years back a way to reach the near infrared without a high-energy accelerator. With the upgraded free electron laser system, including the 6-MeV accelerator and a higher capacity power supply, the idea will be tested next year.

Elias calls his plan a two-stage free electron laser. The first stage operates in the ordinary way, producing far infrared radiation. The second stage does not use an external undulator. Instead, it uses the electromagnetic field of the far infrared radiation as an extremely short-period undulator that interacts with the electron beam to generate near infrared. A new undulator is under construction for this demonstration.

A crucial aspect of the two-stage free electron laser is the quality of the electron beam, which is expressed by the spread in energy of the electrons and by a quantity called the emittance. Both should be as low as possible. In particular, the emittance, which is a measure of the diameter of the electron beam and of the velocity component of the electrons normal to the beam direction, should be close to the theoretical minimum value. Measurements last year at NEC indicate that this is indeed the case.

Eventually, Santa Barbara would like to operate the free electron laser as a user facility, where visiting scientists could come to do experiments, as at national synchrotron radiation centers. The present hope is to acquire a $2-million building with laboratory and office space that would be adjacent to that housing the free electron laser, for which Santa Barbara spent $5.5 million over 5 years.

In the meantime, the first experiments will begin as soon as the laser quality is better characterized. One of the first studies, by Jaccarino and his associates, will be to investigate nonlinear lattice vibration effects in the semiconductor indium antimonide. As there is room in the laser building for only one experiment at a time, there will be limited opportunities for outside collaborators at first.—ARTHUR L. ROBINSON

The Paleoclimatic Magic Numbers Game

Examination of major events in the climatic and faunal records begins to identify environmental change as an engine of evolution

There is a widely held belief among biologists that the environment—specifically environmental change—drives evolution. This very reasonable assumption has, however, been only little tested in any systematic, large-scale manner. Individual researchers have, of course, noticed apparent correlations between assumed climatic events and evolutionary pulses in many different faunal groups. The first attempt to bring together such examples and to see how they match up with data on global climatic history was held recently at the Lamont-Doherty Geological Observatory, New York.* The meeting concentrated on the faunal record in Africa and southern Eurasia from the beginning of the Neogene Period, which started 25 million years ago, onwards.

The gathering illustrated the very different nature and quality of data available to those who would reconstruct climatic history and those who seek to track the history of life, even over relatively short time intervals. Drawing on the fruits of the National Science Foundation's Deep Sea Drilling Program, it is possible to obtain rather detailed and continuous records of putative temperature changes over many millions of years. By contrast, a move onto the continent offers a faunal record that at present is at best fragmentary and at worst misleading.

For instance, one can easily be seduced into recording a pattern of apparent first and last appearances of a faunal group that in reality reflects just a restricted window onto the group's history offered by a single, temporally limited site. The mood of the meeting was, however, one of optimism, as it became apparent that individually these windows may in some cases expand and collectively may eventually be coalesced to offer a relatively uninterrupted view of the major features of faunal history during the Neogene.

Nevertheless, even with the continental evidence so far available it proved possible to identify times of apparent evolutionary activity since the beginning of the Neogene that coincided with strong signals of global cooling in the climatic record. The most striking correlations were at around 15 million and 2.4 million year ago, with something clearly happening at around 5 million years before present too. One proposal that might eventually allow a much finer grained pattern to be perceived was that when the deep-sea drilling ship is next in the Indian Ocean, some time in 1987, a core should be taken close to the East African coast.

A long core taken in this locality with the new hydraulic piston technology would provide an unparalleled opportunity for tying in the detailed chronology and temperature record from the deep sea with the volcanic ash–layered, fossil-

*Workshop on Neogene Paleoclimates and Evolution, Lamont-Doherty Geological Observatory of Columbia University, 11 to 13 September 1984.

bearing sediments of East Africa's Great Rift Valley. "This core itself would have made the meeting a success," comments James Kennet, of the University of Rhode Island. Kennet's words were echoed by deep-sea and continental experts alike, and a formal proposal is now on its way to the National Science Foundation.

The biological world is in general a very conservative place, as evidenced by the persistence of basic body plans right through the history of life. Change—evolution—will therefore occur only when a substantial push is applied, contends Elizabeth Vrba, of the Transvaal Museum, Pretoria, South Africa. That push comes in the form of shifts in environment—such as alteration of vegetation cover—which are driven by climate changes (*1*).

The transformation of, for instance, once continuous tree cover into a mosaic of woodland and open grassland not only places severe selection pressure on forest-orientated fauna but also fragments their populations into small, isolated pockets, a process that is thought to be important in the origin of new species. The fact that such a vegetational transformation can come about through a general global cooling and through tectonic events, such as the continental "doming" that occurred in East Africa in the second half of the Miocene Epoch, 16 million years ago onwards, means that the picture of evolution in the face of environmental change has more layers of complexity to it than might at first appear.

For the paleontologist who is trying to discern the outlines of the picture, there is the often rather difficult requirement of differentiating in the fossil record between the simple migration of a species into a new area in response to the changing environment and the origin of a new species in that area. Waves of migration between, for instance, the African continent and Eurasia have clearly occurred at identifiable points in the past and are undoubtedly good potential indicators of global warming and cooling cycles. But tectonics can again complicate matters, as the two landmasses were in fitful contact with each other through the early Miocene, 25 to 16 million years ago, until "permanent" union was finally established.

So, although species migrations may be the most obvious response to—and indicator of—climatic change, the subject of principal interest here is speciation under these same conditions. "If we eventually are able to establish a good time resolution with the continental record, I expect to be able to discern synchronous pulses of evolution that involve many groups of fauna and flora," says Vrba. "Many different lineages in the biota will respond by synchronous waves of speciation and extinction to global temperature extremes and attendant environmental changes. This is my starting hypothesis." Vrba was one of the prime movers in organizing the Lamont workshop, which is planned as the first of three such gatherings over the next 3 years.

Experts in deep-sea cores and continental glaciation records were at the Lamont meeting to provide the climatic backdrop to Vrba's prediction. Although the continental paleontologists were impressed—some thought overimpressed—with the climatic data, there are clearly many uncertainties in this backdrop. For instance, there is still room for dispute over the interpretation of $^{16}O/^{18}O$ data from diatoms in deep-sea cores—some see shifts in the ratio as indicating sharp temperature curves while others attribute a major portion of the change to the volume of polar ice. The linkage between Northern and Southern hemisphere glaciation remains unclear, as do the specific climatic effects of the ice sheets. Numerical modeling is, however, likely to impinge significantly on this latter problem in the near future.

"Many different lineages in the biota will respond by synchronous waves of speciation and extinction to global temperature extremes and attendant environmental changes."

The broad-brush picture, however, goes something like this. The relatively balmy days of the Paleogene, 65 to 25 million years ago, were brought to an end mid-Period by the northward drift of Australia. The result of this continental movement was the isolation of Antarctica by the development of the circum-Antarctic current, which is now the most voluminous current of all the oceans. The upshot was the intensification of global cooling some 40 million years ago, with a sharpening of the temperature gradient between the poles and the equator.

First signs of Antarctic ice appear by 30 million years ago (*2*), with the definite formation of a significant ice sheet (the eastern ice sheet) 14 million years later. The western ice sheet probably formed at the end of the Pliocene, 5.5 million years ago, which event coincided with the transient drying of the Mediterranean. The first good evidence for northern polar ice comes at 2.4 million years ago (*3*), with the ice ages of 0.9 million years onwards being a major feature of the Quaternary.

These major milestones in glaciation—16, 5.5, 2.4, and 0.9 million years ago—are reflected (in part at least) in the oxygen isotope and planktonic diversity data from the deep-sea cores. Part of the glaciation data indicate tremendous variation in extent of the Antarctic ice sheet. In addition to suggestions of unsuspected shrinkage within the past 3 million years, there were vast ice accumulations big enough to override most of the Transantarctic mountains, which rise to some 4600 meters, on at least three occasions in the last 15 million years, according to George Denton, of the University of Maine. As yet he has no dates for these events, but one would expect their effect to be imprinted on the world's biota, given their unusual extent.

The star data set among the faunal presentations undoubtedly is that from the Siwalik Hills in Pakistan. The virtually continuous sediments, which are built from the detritus of the uplifting Himalayas, are some 3 kilometers thick and span perhaps 18 to 1 million years before present. The paleontological work during the past decade, run by a joint U.S. and Pakistani team, is producing a profile that is beginning to record in some detail faunal events in this key geographic locality, as it stands at the crossroads between Africa and Eurasia. Paleomagnetic dating, once sparse and unpromising, is now looking very good. One outstanding event recorded in these deposits is the rather sudden disappearance of a diverse group of apes about 7 million years ago, which seems to coincide with the onset of a cooler, drier climate.

In Africa, the longest sequence, with notable gaps, comes from a region near to Lake Baringo in northern Kenya and spans 14 to 2 million years ago. Earlier time slices are to be had at Fort Ternan, in Kenya, and overlapping or later ones in Libya, Ethiopia, Tanzania, Kenya, and South Africa. It is a temporal and spatial jigsaw, in which many of the pieces remain to be located before the final structure can be assembled.

At the closing session of the meeting participants began to sketch in events—

climatic and faunal—on a large time chart. The relatively crisp picture contributed by the geophysical evidence was nicely corroborated by evidence from pollen and micromammal (rodents, rabbits and the like) data, both of which are excellent climatic indicators. But enthusiasm for adding a data set just because it existed quickly turned the chart into scatter of points, all but obscuring correlative events.

A greater selection of data is required, with emphasis given to faunal groups that contain many species and have tight environmental requirements, such as the bovids, which include antelopes, wildebeest, and their relatives. The bovid data from Africa already show bursts of speciation at the 2.4 and 0.9 million year events, and possibly around 5 million years too. The Lamont meeting has initiated the systematic assessment of other data sets that might match the quality of the bovids, the result of which will reveal just how synchronous the pulses of extinctions and speciations really are.

—ROGER LEWIN

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The Proper Display of Data

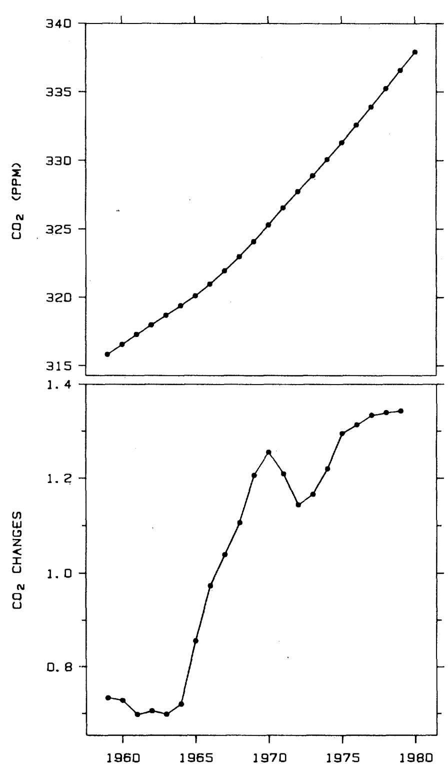
Two statisticians looked at graphs in scientific publications and they suggest means of improvement

A few years ago, William Cleveland of AT&T Bell Laboratories began looking through scientific journals to see how researchers use graphs. There had been a revolution in graphic methods in their own field of statistics as investigators began developing new ways of analyzing and presenting data and Cleveland thought that similar developments might have occurred in other areas of science. "I figured, 'Look, there's this incredible talent in science. Surely, there's all kinds of amazing techniques invented that those of us in statistics don't know about. Let's find out about them and bring them into our tool kit,' " he reasoned.

But, Cleveland remarks, "It didn't happen. I found just the opposite was true. I saw all kinds of errors and abuse [in the graphical display of data]."

In order to determine how common graphs are in scientific publications, Cleveland and Marylyn McGill of MEM Research in New Providence, New Jersey, surveyed 57 journals from 14 disciplines. Among these, the publication with the most graphs was the *Journal of Geophysical Research*, which devoted a third of its space to graphs. The median amount of space devoted to graphs was 6 percent and the journal with the fewest graphs in the group was the *Journal of Social Psychology*.

Then Cleveland and Robert McGill of AT&T Bell Laboratories chose to study *Science* in particular and looked through every issue of volume 207 (January to March 1980) carefully examining each of the 377 graphs there. They found generally familiar formats; furthermore, they report that 30 percent of the graphs contained at least one error. Less extensive analysis of other journals led them to conclude that the graph problem is widespread. But the tedious task of surveying journals had one beneficial result. It led Cleveland and McGill to ask what it is that makes some graphs better than others in displaying data and to devise guidelines that scientists can use to make their use of graphs far more effective. (Edward R. Tufte of Yale University did a similar analysis of graphs in the mass media and published his results in his book *The Visual Display of Quantitative Information* (Graphics Press, Santa Monica, California, 1983).



Slope is hard to judge

The visual impression from the top panel is that the rate of change of atmospheric CO_2 is constant from 1967 to 1980. But in the bottom panel, where the yearly changes are graphed, it can be seen that there is a dip in the rate of change around 1970.

After sifting through the journals, McGill and Cleveland began their research on how people visually decode the quantitative information in graphs. "The main thing we did was to sit and look at graphs and think very hard about what exactly are the elements that contain quantitative information," Cleveland explains. Then we got people and had them look at graphs, asking them questions that made them focus on very basic perceptual tasks, such as judging slopes of lines or areas." Although Cleveland and McGill tested subjects with a variety of backgrounds—scientists, high school students, university students, housewives—they learned that the different groups performed more or less the same.

Among the most difficult graphs to read are those that involve estimations of area. For example, a graph may show the amount of coal mined in different areas of England, with circles at each spot on the map of England where coal is mined and with the circles drawn so that their areas are proportional to the amount of coal mined at each place. Such a graph is very difficult to read, Cleveland and McGill find, and although scientists do not often use graphs that require estimates of area, such graphs are common in newspapers and magazines.

Slope is also difficult to judge, but scientists frequently require their readers to estimate it. Any time that a variable is graphed and readers need to know its rate of change, they must estimate