Science AAAS

Pinatubo, Diffuse Light, and the Carbon Cycle

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Science **299**, 1997 (2003);
DOI: 10.1126/science.1080681

extensive deformation of this specimen and the known cranial variation in early hominid species and among modern apes and humans (see the second figure), proclamations that it signals Pliocene hominid diversity seem premature at best.

Is there really a great diversity of hominid lineages waiting to be found and recognized in Africa? Was this diversity like that in extant *Anopheles* mosquitoes (about 500 species), Old World fruit bats (173 species), cercopithecid monkeys (94 species), or even African soft-furred rats (8 species)? Or did just a few demographically expansive and cosmopolitan hominid species expand their ranges and invade new habitats during the Pliocene (5.3 to 1.8 million years ago)?

As Mayr and Simpson appreciated, species recognition is at the core of the paleontological enterprise and is an essential component in building an accurate understanding of evolution. As the hominid fossil record expands, we should not forget their cautions about typological thinking. Confusing true biological species diversity with analytical mistakes (*15, 16*), preservational artifacts, diachronic evolution, or normal biological variation grossly distorts our understanding of human evolution. Past hominid diversity should be established by the canons of modern biology, not by a populist zeal for diversity.

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12. Leakey *et al.* (*8*) reported mesiodistal and buccolingual measurements of 11.4 mm by 12.4 mm for the right upper second molar of KNM-ER 40000 but did not comment on how that measurement was derived. Even accepting the published estimates for the single distorted crown available, it is extremely unlikely that this tooth's size was significantly different from a small *A. anamensis* to *A. afarensis* sample.
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ATMOSPHERIC SCIENCE

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In studies of the global carbon cycle, light has traditionally been characterized in terms of its intensity. However, as Gu *et al.* demonstrate on page 2035 of this issue (*1*), its geometry can also be important, with potentially global effects.

Visual artists know that subtle differences between light and shade are primarily a result of the geometry of the light source in relation to the subject (see the figure). The same principles also apply in photography: As we age we may prefer to be photographed in a "softer" light from a more diffuse source, which reduces shadows and hence hides wrinkles.

Outdoors, the reduction in shadows is readily observed on cloudy days, but can also happen for other reasons. After volcanic eruptions like that of Mount Pinatubo in 1991, there is a sudden increase in the proportion of diffuse sunlight and hence a reduction in shade. The atmospheric CO_2 concentration usually decreases after volcanic eruptions (*2*); isotopic data suggest that the CO_2 anomaly observed after the Pinatubo eruption was a terrestrial response (*3*). Gu *et al.* (*1*) report how the net exchange of CO_2 by a hardwood forest changed as a result. They show that the increased diffuse light observed under cloudless conditions immediately after the Pinatubo eruption resulted in a sink for CO_2 because of an increase in gross photosynthesis.

The idea that whole-canopy photosynthesis is sensitive to the geometry of light is not new (*4*). It arises because leaf photosynthesis has a saturating response to light intensity. Hence, photosynthesis is typically greater if two leaves receive moderate light than if one receives bright light while the other is in deep shade. On a bright, sunny day, light is concentrated in a beam and the sky is relatively dark elsewhere, resulting in a lot of deep shade within the canopy. In contrast, on a cloudy day, more of the sky is bright—it is a more diffuse source—and hence leaves lower in the canopy are more likely to "see" some relatively bright sky than they would on a sunny day.

Canopy-scale gas exchange measurements have confirmed that such effects are important (*5*). But although the importance of diffuse light has long been recognized in the agricultural community (*6*), its effects have yet to be incorporated in large-scale terrestrial primary production models. Hence, when Pinatubo erupted, the resulting dramatic slowdown in the rise of atmospheric CO_2 concentrations was widely attributed to the effects of temperature on plant and soil respiration (*2, 7*). However,

View of Vetheuil (1880), Claude Monet. Claude Monet wrote that "The subject of my painting is not light and shade, but the painting placed in light and shade."

CREDIT: METROPOLITAN MUSEUM, NEW YORK

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rough calculations suggest that a sizable increase in productivity resulted from the increase in diffuse light (*8*). The mechanisms are not mutually exclusive.

Importantly, Gu *et al*. report measured changes in net CO_2 exchange following the Pinatubo eruption. Aided by records of direct and diffuse sunlight and of temperature changes, they demonstrate an increase in canopy photosynthesis on cloud-free days during summer, caused by the increase in diffuse light, and separate these changes in photosynthesis from changes in respiration. The paper reminds us of the scientific value of long-term environmental records.

More work is needed for a comprehensive assessment of the impacts of volcanic eruptions on the global carbon cycle. One important issue is that under cloudy skies, the diffuse light is often roughly isotropic. In contrast, after volcanic eruptions it is anisotropic, with much more forward scattering than usual. If the increased diffuse light following Pinatubo was so extremely forward-scattered that it hardly brightened the sky away from the Sun, then the advantage for photosynthesis would disappear. The data of Gu *et al*. suggest that this is unlikely. Nevertheless, for a complete assessment of the effects of volcanic eruptions on the global carbon cycle, descriptions of photosynthesis that take into account the irradiance from different parts of the sky (*9*, *10*) must be integrated with the appropriate phase functions that describe the scattering of light (*11*).

Over the past 50 years there has been a general decrease in solar radiation at Earth's surface, despite a relatively constant irradiance at the top of the atmosphere (*12*). This global dimming and the associated increase in the diffuse fraction of sunlight over much of the world imply a generally brighter sky, except near the solar disk. This has consequences for primary production and for the evaporative power of the atmosphere over land (*13*). Volcanoes and pollution reduce surface light and temperature directly, whereas greenhouse gas emissions increase temperature and possibly reduce light. The key feature is that volcanoes, pollution, and greenhouse gases may all increase diffuse light.

It is fitting that the term climate originates from the Greek verb klinen (to tilt), characterizing the angle of the solar rays (*14*). This can be interpreted in terms of latitude (*14*). However, taking a literal interpretation, a change in climate would mean a change in the tilt of the solar rays—neatly summarizing the fundamental importance of diffuse sunlight.

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MATERIALS SCIENCE

Not Too Hot to Handle

John Kieffer

Lava streaming from an erupting volcano or liquid steel being cast into a mold is fascinating to observe. But the properties of such high-temperature melts are little explored because they are too hot to handle, difficult to contain, and chemically too aggressive to warrant the survival of most examination tools.

On page 2047 of this issue, Sinn *et al.* (*1*) show how the use of inelastic x-ray scattering on levitated samples allows these problems to be overcome. Their approach has two important advantages: It eliminates physical contact with container and probe, and it directly interrogates the atomic-scale mechanisms underlying the dynamics of liquids. The method provides rich and detailed information relating the structure of molten materials to their properties.

Some liquids exhibit extraordinary behaviors at high temperatures. For example, the most common glass-forming oxides—SiO_2, GeO_2, and B_2O_3 (see the figure)—become stiffer at the molecular scale with increasing temperature, in contrast to most materials, which soften when heated. The behavior of B_2O_3 is most striking: At more than 1000°C above the melting point of crystalline B_2O_3, the elastic moduli still show positive temperature dependence, that is, molten B_2O_3 becomes more rigid when heated (*2*). At these temperatures, it is unexpected that liquid B_2O_3 exhibits a resistance to oscillatory shear deformation at all, let alone that it increases with temperature. Another stunning observation was made by Aasland *et al*., who discovered that Y_2O_3-Al_2O_3 melts spontaneously separate into two chemically identical but structurally different liquid phases (*3*).

These behaviors demonstrate how little we understand the structure of molten inorganic compounds. Because liquids exhibit a high degree of disorder and lack translational symmetry, diffraction experiments yield little insight into their structure. Researchers have long resorted to less direct approaches to characterizing liquids (*4*). For example, structural descriptions of a liquid may be derived from knowledge of how its molecular constituents move, rearrange, and dynamically adapt to external constraints. The necessary information is obtained from spectroscopic techniques.

The inelastic x-ray scattering measurements with high energy resolution reported by Sinn *et al.* (*1*) are the most recent addition to the cadre of spectroscopic techniques used to investigate the structural dynamics of liquids. Related methods based on inelastic scattering of light and neutrons have been used by researchers since the 1960s. In each case, the measurement is based on the exchange of energy and momentum between radiation and a particular excitation in the specimen. To study structural dynamics, one needs to access collective excitations such as sound waves (acoustic phonons) that involve the motion of groups of atoms. These excitations have relatively low energies, and because neutrons can be generated with energies closely matching those of phonons, they have been the method of choice.

Conversely, electromagnetic radiation, such as light and x-rays, can match the wavelengths of phonons while traveling at much higher speed. This type of radiation is therefore more sensitive to the spatial character of sound waves, including their propagation and damping. However, it is difficult to resolve the small relative energy changes between scattered and incident radiation during inelastic scattering events (ranging from 10^{-5} for visible light to 10^{-7} for x-rays). For visible light, such small energy shifts can be detected relatively easily with interferometric techniques. But for x-rays, reaching the desired resolution is more difficult. Spectral filtering can be achieved with in-line angle-tuned monochromator crystals, but the efficiency of this technique is poor. It has only become viable with the

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