Letters

Cleanup of the Savannah River Plant

Because I have been directly involved for the past decade in the aggressive program for high-level waste immobilization at the Savannah River Plant, I was astounded to read Eliot Marshall's statement (News & Comment, 8 Aug., p. 613) that Congress compelled the Department of Energy to take action in 1983. The House virtually killed the program in 1982, and it was through the efforts of Senator Strom Thurmond (R–SC) during the "lame-duck session" that initial construction money was reauthorized. The House finally concurred in early 1983, and the program for waste glassification has been funded ever since.

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Response: As Hennelly points out, it was not DOE but members of Congress who opposed the waste glassification plant, regarding it as an unnecessary expense in the military budget. In this vein, Representative Butler Derrick (D–SC) also deserves mention. He persuaded the House Rules Committee to block action on the entire DOE defense bill in 1979 until other congressmen agreed to support preliminary work on a waste plant at Savannah River.

—ELIOT MARSHALL

Treatment of Depression

The article "Depression research advances, treatment lags" by Constance Holden (Research News, 15 Aug., p. 723) is an excellent review of the current status of research in depression and the problems with diagnosis and treatment. However, two areas require comment.

In the discussion of pharmacotherapy for depression, the statement is made that "monoamine oxidase inhibitors have few side effects but involve dietary restrictions." This is misleading, as anyone who has used these drugs clinically can testify. Monoamine oxidase inhibitors are powerful drugs that can produce severe adverse effects. In addition to the dietary restrictions they necessitate, they can interact disastrously with many other drugs ranging from over-the-counter cold medications to a wide variety of prescription drugs.

Second, the statement is made that "most depressed who seek help are treated by general practitioners for secondary symptoms." General practitioners are a relatively small group of physicians who comprise a subset of primary care physicians that includes general internists, family physicians, obstetricians-gynecologists, and pediatricians. The current literature supports the assertion that 80% of patients with depression consult primary care physicians initially.

On balance, the article is well written and correctly points out the problems in integrating current research and knowledge with effective diagnosis and therapy of depression.

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Mazel Tov!

Uwe Reinhardt's Navajo salute "Mazel-tov!" to Arnold Relman (News & Comment, 5 Sept., p. 1032) will be criticized by ardent Navajo linguists. The original Yiddish salute from whence it was derived means "congratulations" and not "good luck."

Leo Rosten (*1*) gives a most appropriate example of proper usage of the salute: "don't 'mazel tov'! a man going into the hospital; say 'mazel tov'! when he comes out!"

I personally hope we can say mazel tov! to Relman.

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Cretaceous Extinctions and Wildfires

Wendy S. Wolbach, Roy S. Lewis, and Edward Anders (Reports, 11 Oct. 1985, p. 167) have added interesting new data to the subject of Cretaceous extinctions: a layer of soot (21 milligrams per square centimeter) in the Cretaceous-Tertiary (K-T) boundary sediments. However, their suggestion that wildfires were the origin of this layer, while offering a novel but improbable (*1*) method of ignition, does not take into account the all-important dynamics of wildfire propagation. It is well known (*2*) that the spread of wildfire is usually terminated shortly after ignition (hours to days) by one or another unfavorable circumstance such as a large change of wind direction or a substantial rain. Wildfire spread is often slowed or stopped at the edges of rivers or lakes and, of course, at the edge of the forest. But above all, wildfire moves slowly (1.5 to 5 kilometers per hour) because of the low combustibility of green trees. The mode of ignition, in comparison to these factors, would seem to be of minor importance.

If several percent of the earth's biomass is assumed to have burned within one or a few years, it is necessary to propose a new factor in wildfire propagation, and just such a factor is at hand: the death of many of the earth's forests. If the worldwide dust cloud from an asteroid impact crater was sufficiently dense to depress nighttime temperatures by 10° to 20°C, there would have been extensive killing (but not necessarily extermination) of the tropical rain forests, and possibly also of other forests. Within months the dead vegetation would have been in a highly dessicated and flammable state. Among such tinder, lightning strokes would have been unusually efficient agents of ignition. Wildfires would have been more numerous, of larger extent, and faster burning than in green vegetation. Lightning would have started fires on every treed continent in both hemispheres, ensuring worldwide distribution of smoke sources.

This qualitative discussion leaves open the question of whether a dust cloud of impact origin could have been or was dense enough by itself to stop photosynthesis. Until that matter is settled it will be premature to say whether the newly discovered soot layer is a consequence of the great extinction, or one of its causes.

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REFERENCES AND NOTES

1. If one assumes with Wolbach *et al.* that the fireball could have started fires at a range of 1000 kilometers in suitable vegetation, it can be estimated that only about one in six impacts in the oceans would have been favorably located for ignition of a major wildfire.
2. C. Chandler, *Fire in Forestry* (Wiley, New York, 1983), vol. 1.

Wolbach *et al.* found anomalous abundances of graphitic carbon at three marine Cretaceous-Tertiary (K-T) boundary sites. Fluffy spheroidal clusters of carbon were described as being the product of combustion, and the interpretation was that the proposed "end of Cretaceous" impact event (*1*) triggered burning of vegetation or fossil fuels on a global scale. This report followed an earlier discovery of fire-consumed organic matter just above the K-T boundary at a nonmarine site in North America (*2*).

In an initially unrelated study (*3*), we investigated the phenomenon of spontaneous combustion in marine sediments recently exposed to subaerial weathering. This process is surprisingly common in reduced facies rocks containing abundant hydrocarbon, and is usually initiated through low-temperature oxidation of finely disseminated pyrite within the rock. A similar reaction is responsible for spontaneous combustion in lignite beds, underground coal seams, and even coal piles and storage bins (*4*).

While compiling a list of combustion metamorphism (CM) sites, we were struck by the frequency with which Middle to Upper Cretaceous black shales served as the host rock for self-combustion. Marine shales of this age are currently burning at numerous locations near the Beaufort Sea in northwest Canada (*5*) and in western Greenland (*6*). In the 19th century rocks of a similar age were observed burning at a number of locations in northern Alberta (*7*). Because rocks subject to this process are undergoing erosion, older CM zones are rarely preserved. One exception occurs in Israel, where Upper Cretaceous oil shales (a total volume of about 10 cubic kilometers) underwent burning 16.8 ± 2.0 million years ago in at least nine different basins (*8*). Bituminous shales of a similar lithology were common during the Middle to Late Cretaceous throughout the Arctic, in north-central North America, in the Middle East, from Deep Sea Drilling Project cores in the North Atlantic, and in northeast South America. The common occurrence of reduced facies marine rock of this age seems related to widespread conditions of deep water stagnation in the Mid- and Late Cretaceous oceans (*9*).

This abundance of combustion-prone bituminous rock of Late Cretaceous age raises a number of interesting questions about the K-T terminal event, particularly in light of the new preliminary evidence for a coincident global layer of soot. One widely accepted tenet about the latest Cretaceous is that it represented a time of sudden widespread uplift of former epicontinental seas, perhaps in response to a eustatic lowering of sea level following an increased rate of oceanic crust generation. This occurrence would have simultaneously exposed a large area of the Cretaceous black shales to subaerial erosion and potentially to the CM process. Profound ecological effects have been noted in lake waters adjacent to the Canadian Arctic burn areas in response to dramatically elevated levels of trace metals and acidity (*10*), two characteristics of K-T boundary clays. However it seems unlikely that sporadic combustion of the black shales accompanying erosion could account for the apparent brevity and synchronicity of the K-T extinction horizon without some fairly sudden triggering event (for example, a meteorite impact or volcanic eruptions). As an example, Jurassic oil shales in northwest Britain were apparently ignited by the extrusion of lavas in the early Tertiary (*11*). On the other hand, something as common as a midsummer drought in 1972 resulted in widespread combustion of peat bogs in the Soviet Union, which produced plumes of smoke stretching from Moscow to the Ural Mountains (*12*).

Historically active CM zones are recorded as having burned for sometimes tens of years, with the same outcrops periodically reigniting over centuries. This slow burning, often under conditions of restricted oxygen availability, might account for the high soot levels reported by Wolbach *et al.* Aluminosilicate spherules with fibroradial and dendritic crystalline structures, along with magnetic ferrite spherules, are commonly found in fossil fuel fly ash, but with a smaller sized distribution than similar spheres found at the K-T boundary (*13*). If burning of the Late Cretaceous black shales did at least partially contribute to the proposed K-T soot layer, geochemical evidence concerning the composition of the postulated extraterrestrial impacting body will have to be reexamined, as reduced sulfide-bearing sediments are known to have excess platinum metal abundances (*14*). Values as high as 30 parts per billion for iridium and 600 parts per billion for rhenium have been reported for black shales and oil shales in China (*15*) and the Soviet Union (*16*), and an iridium abundance of 600 parts per million has been measured in oxidized kerogen from an organogenic limestone (*17*).

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Wolbach *et al.* have presented results of chemical analyses that indicate to them the occurrence of a worldwide layer of soot at the Cretaceous-Tertiary (K-T) boundary. They interpret this result in terms of global wildfires. If correct, this is a spectacular finding; and indeed it was reported as a fact by many newspapers and magazines as well as radio and television stations throughout the country.

The data on which their far-ranging speculations are based are given in table 2 of their report. They measured elemental carbon at three K-T sections—Stevns Klint, Denmark; Woodside Creek, New Zealand; and Caravaca, Spain—with values of 3600, 5700, and 5800 parts per million, respectively. Only for the Danish section are additional measurements given for the section portions above and below the K-T boundary, with values of 1040 and 950 parts per million, respectively. The values for the New Zealand and Spanish sections are difficult to use, for there are no background values upon which a comparison can be made. Only the values for the Danish section can be used, and they indicate a concentration anomaly for the K-T boundary of 3.6 to 1 over background. These three data points are a very small sample upon which to make the conclusions given by the authors. It is not known what the natural variations of elemental carbon are throughout the section and whether the observed difference represents an anomaly.

However, this is not our principal criticism. The flux rate, F, of a trace constituent to a region undergoing sedimentation is given by the simple expression $F = \rho c v$, where ρ is the bulk density of the rock, c the concentration of the constituent, and v the sedimentation rate. For a constant flux rate the concentration of the trace constituent will be enhanced for a geologic section that has a slow sedimentation rate, and the trace constituent concentration will be diluted in a section that has a more rapid sedimentation rate. Clearly it is essential to know the sedimentation rate if flux rate calculations are to be made from observed trace constituent concentrations. In this case it is necessary to have a knowledge of sedimentation rate ratios for materials above and below the K-T boundary as compared with the boundary sedimentation rate itself.

The Upper Cretaceous and Lower Tertiary sequence in Denmark has been well studied (*1–3*). Detailed descriptions of the sequence around the K-T boundary were given in a recent article by A. A. Ekdale and R. G. Bromley (*2*). The K-T boundary at two of the outcrop sections in eastern Denmark (Stevns Klint and Karlstrup) is marked by a laminated and in part carbonaceous clay layer, referred to as the Fish Clay because it contains skeletal fish remains. At these sections the Fish Clay varies in thickness from 0 to 35 centimeters over lateral distances of a few meters. A few hundred kilometers away in northwestern Denmark, at three other outcrop sections that have been studied in detail (Dania, Kjølby Gaard, and Nye Kløv), there is no Fish Clay, but rather an abrupt change from the underlying Maastrichtian sequence to the overlying Danian sequence. Similarly, in the type locality of the Maastrichtian in eastern Netherlands, more than a thousand kilometers to the south, no clay layer occurs at the K-T boundary (*4*).

The Fish Clay itself has a complex lithology (*2, 3*). Its upper and lower boundaries represent a transitional sequence marked by cyclical sedimentation characterized by finely alternating marl and carbonate seams that have been altered by solution compaction to form a microstylolitic fabric. In between the two transitional boundaries the Fish Clay can be subdivided into four obvious subunits, including, from bottom to top, (i) laminated gray-brown smectite clay containing tiny burrows that participate in the formation of the micronodular fabric in the basal part; (ii) laminated black carbonaceous shale containing common weathered pyrite concretions; (iii) laminated very dark gray smectite clay containing light gray horizontal streaks; and (iv) laminated gray-brown smectite clay grading upward through a burrow-rich, micronodular fabric into the overlying limestone.

The lithology of the Fish Clay clearly indicates that it is a condensed section and that there has been a pulse of calcium carbonate dissolution coincident with the K-T boundary events (*2*). There has been a substantial removal of the calcium carbonate fossiliferous remains that make up the bulk of the underlying Maastrichtian chalk and overlying Danian limestone. The observed iridium anomalies also indicate that the Fish Clay represents a condensed section. For the Dania section, which has no Fish Clay, the peak iridium value is 4 parts per billion compared with peak values of 29 to 87 parts per billion for the Fish Clay of the Stevns Klint section. It is difficult to estimate how great the reduction in sedimentation rate has been for the Fish Clay. If it is assumed that the flux of clay has been essentially the same throughout the K-T transition, a comparison of the clay content of the Fish Clay with that of the underlying and overlying chalk and limestone indicates a reduction in sedimentation rate of 1 to 7 (*2*). Multiplying the concentration anomaly, 3.6 to 1, by the sedimentation rate ratio, 1 to 7, leads to the conclusion that there is no positive anomaly in the flux of elemental carbon across the K-T boundary and perhaps even a negative anomaly.

Contrary to the known lithology of the Fish Clay, Wolbach *et al.* argue that it is the deposition product of a hypothesized asteroid impact and that the deposition time for the clay was 1 year. The Fish Clay is not a worldwide phenomenon and it is not even ubiquitous to all the Danish sections, occurring at two out of five of the outcrop localities. We conclude that the Fish Clay is not the deposition product of an asteroid impact, but rather a shallow-water clay whose complex lithology provides a record of the environmental conditions that prevailed at the time of its deposition.

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Response: Argyle is right in noting that living forests generally do not burn readily, and that a *prompt* global forest fire hence is unlikely. His idea—that the fires started only after the trees had died and "freeze-dried"—seems quite plausible. It had independently been suggested by a referee of our paper and by Paul J. Crutzen. However, soot and iridium appear simultaneously in the lowest 3 millimeters of the nearly undisturbed boundary clay at Woodside Creek, New Zealand (*1*), showing that soot accompanied even the earliest fallout.

We also accept Argyle's statement that an oceanic impact within 1000 kilometers of land has a probability of only 1 in 6. However, that is a virtue rather than a fault. Many taxa that became extinct at the end of the Cretaceous had survived several previous extinctions, and so there must have been something "special" about the Cretaceous extinction—perhaps a fire. As we concede, global fires would be hard to start, even if the impact was on land, as recent evidence suggests (*2*).

We need all the help we can get in finding a source for 10^{17} grams of soot at the Cretaceous-Tertiary (K-T) boundary, and therefore appreciate the suggestion by Cisowski and Fuller that spontaneous combustion of marine sediments may be responsible. However, there are some difficulties with this idea, especially if extended to account for the platinum metals at the K-T boundary.

Siderophile elements at the K-T boundary show a primitive, clearly meteoritic signature. Os, Ir, Au, Pt, Co, Pd, and Ru occur in chondritic proportions to $\pm 20\%$ (*3, 4*); Pt/Ir and Au/Ir ratios agree with meteoritic ratios to within 5% and 7% (*4*); and the Os^{187}/Os^{186} ratios of 1.0 to 1.6 (*5*) match the meteoritic range of 1.0 to 1.4, not the crustal ratio of 35. The Os^{187}/Os^{186} *isotopic* ratio is particularly decisive, as all crustal Os, having evolved in an environment of high Re/Os ratio, is strongly enriched in Os^{187} from the decay of Re^{187}. But even the *elemental* ratios in the crust strongly deviate from meteoritic ratios, and so black shales are not a plausible source of the siderophiles at the K-T boundary. A meteorite is still required.

Relieved of the burden of accounting for the siderophiles, the black shales become interesting potential sources of the K-T soot. As Cisowski and Fuller acknowledge, an enormous amount of shale must be ignited all at once at the precise time of the K-T impact, if the soot is to settle out with the Ir-bearing ejecta layer. It remains to be seen whether this mechanism can account for the large amount of soot, the synchrony of this event with the K-T boundary, and the absence of similar soot layers at other times.

Stripped to its essentials, the question raised by Officer and Ekdale is whether the Ir-rich boundary clay is terrestrial or "meteoritic" (that is, weathered impact glass). If terrestrial, then no one in his or her right mind could make a case for a global fire: 0.021 gram per square centimeter of soot, deposited over $\sim 10^3$ years, is pathetically little. But if meteoritic, then the deposition time must have been less than 1 year, as dust cannot stay aloft any longer (*6*), and 0.021 gram per square centimeter of soot formed all at once requires a fire involving all the world's forests or a comparable amount of fossil carbon.

Let us summarize some of the facts favoring an impact.

1) Ir, Os, and other noble metals are enriched up to 10^3-fold at the K-T boundary, at more than 70 sites worldwide (*7*).

2) There is no adequate terrestrial source.