between spectral ratio and TiO_2 content in the mature lunar soils.

The data of Charette *et al.* (*2*) also show that immature soils with high Ti contents have spectral ratios that are too large for the mature soil curve. However, as a soil with a high Ti content matures, its spectral ratio decreases until it reaches the curve for mature soil. These relationships between TiO_2 content and spectral ratio can be accounted for by a mixture of glass with a high Ti content, with a band at 0.42 μm and thus a low spectral ratio, and ilmenite, with a band at 0.53 μm and thus a high spectral ratio (1.07). As a soil matures, some of the ilmenite is converted into glass and the spectral ratio diminishes, at constant TiO_2, until some sort of equilibrium between glass and crystalline phases is reached. Most highland soils have a separate curve because their TiO_2 contents are too low and their spectral ratios are determined mainly by the width of the 0.27-μm FeO band. In addition, the spectral ratios will also be influenced by other factors, especially the submicroscopic metallic Fe content of the soils.

Our glasses have no absorption bands in the range from 0.6 to 0.7 μm, where lunar rock powders also have low absorption but where lunar soils are strongly absorbing (*7*, *8*). None of our Fe or Ti glasses have strong absorption bands between 0.5 and 0.9 μm, unless they are partly oxidized. Since lunar soils are reduced and not oxidized, simple vitrification cannot be the primary mechanism for lunar soil darkening. The most viable hypothesis for lunar darkening remains submicroscopic metallic Fe formed in impact events and solar wind sputtering; evidence for such Fe, its probable origin, and its effect on the spectra of lunar soils has been presented elsewhere (*8*).

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Sulfate Aerosol: Its Geographical Extent in the Midwestern and Southern United States

Abstract. *Sulfate particles (sulfuric acid and its neutralization products with ammonia) dominate the submicrometer-sized, light-scattering component of the aerosol in more than 90 percent of 2850 pairs of humidographic measurements made over a 3-month period at three rural midwestern and southern sites. The nearly continuous optical dominance by sulfate in the aerosol at these spatially varied locations, particularly in the Ozark Mountains, suggests that sulfate is a component of the submicrometer-sized aerosol that is distributed over a large geographical region and is not due to local sources.*

The autumn hazes and high turbidity that occur over sparsely populated, vegetated areas of the Southeast (*1*) have been described as naturally occurring aerosols produced by photochemical transformation of terpenes during leaf decay in deciduous forest (*2*). We present here data showing that these hazes are dominated not by natural organic compounds but by sulfate aerosol particles, probably from the oxidation of SO_2 emitted by regionally distributed sources.

In earlier papers (*3*) we described the use of humidity-controlled nephelometry (humidograph) for in situ optical sensing of the deliquescence of $(NH_4)_2SO_4$ aerosol particles either directly or after the addition of NH_3 to the aerosol. This scheme thereby detects, as different species, acid sulfates (NH_4HSO_4 or H_2SO_4, or both), the neutralized salt [$(NH_4)_2SO_4$], and occasionally letovicite [$(NH_4)_3H(SO_4)_2$]. The particles in the optical size range from 0.1 to 1.0 μm in diameter are most sensitive to detection by this method (*4*). Direct comparison in rural Missouri of the humidographic technique with an infrared technique confirmed the utility of the humidograph for distinguishing periods in which acid or salt sulfate particles dominate the submicrometer-sized aerosol (*5*). In 1973, sulfate aerosol in the form of H_2SO_4 or its neutralization products with NH_3, or both, was shown to be the dominant submicrometer-sized aerosol species in all but one of 88 measurements in rural Missouri (*3*). We hypothesized (*3*) that the submicrometer-sized aerosol detected at this site resulted from regionally distributed sources and perhaps extended for distances comparable with SO_2 oxidation distances (about 1000 km). We report here results of experiments to test this hypothesis with respect to the geographical extent of the sulfate aerosol.

Humidographic measurements were made during the fall of 1975 at three spatially separated rural locations in the Midwest and South: an Ozark Mountain site in rural, northwestern Arkansas (*6*), a rural midwestern site in southeastern Michigan (*7*), and the same Missouri site (*8*) as used in 1973. Site locations were chosen for geographical representation of the hypothesized sulfate region and variable proximities to SO_2 sources (*6*–*8*). In this way effects of local source chemistry as well as the geographical extent of the sulfate haze might be observed. Systematic differences in the temporal variability of the molecular form of sulfate or in the percentage of time dominated by sulfate aerosol would be expected if local source chemistry were to dominate at any or all of the sites.

The experimental procedure duplicated that used in the 1973 measurements (*3*). Pairs of humidograms were used to detect the deliquescence of $(NH_4)_2SO_4$ automatically every half-hour with about 1 part per million of NH_3 add-

Table 1. Percentages of total humidogram responses.

Dominant optical scattering species	Location and date*			
	Tyson, Missouri, 11 to 26 September 1975 (750)	Milford, Michigan, 29 September to 14 October 1975 (656)	Hall Mountain, Arkansas, 4 November to 4 December 1975 (1444)	Tyson, Missouri, 21 to 27 September 1973 (88)
H_2SO_4 or NH_4HSO_4, or both	39	12	30	52
$(NH_4)_2SO_4$	60	73	57	47
$(NH_4)_3H(SO_4)_2$	0	8	5	0
Nonsulfate	1	7	8	1

*The number of humidogram pairs measured is shown in parentheses for each site.

ed to the second of each pair. Approximately 2850 pairs of measurements were made over a 3-month experiment period. The longer period of record by comparison with the case in 1973, the varied sites, and the large number of measurements increased our confidence in data interpretation.

Table 1 summarizes the humidographic responses for the Michigan, Arkansas, and Missouri sites and includes comparison data from the 1973 Missouri experiment. At each site sulfates dominated the submicrometer-sized, light-scattering component of the aerosol—essentially 100 percent of the time at the Missouri site and over 90 percent of the time at the Michigan and Arkansas sites. Furthermore, the nearly continuous dominance by sulfate particles was independent of wind or synoptic conditions. At each site virtually every wind direction and meteorological condition varying from strong frontal activity to high-pressure stability occurred, and there were no obvious systematic conditions associated with nonsulfate periods.

The particular form of sulfate aerosol listed in Table 1 characteristically persisted at each site on the order of a few hours to days. These duration times are comparable with those of local and synoptic weather features and suggest a relationship between the degree of sulfate neutralization with NH_3 and synoptic-scale air motions. In a spatially extensive aerosol system the sulfate form detected has been shown to correlate with the arrival trajectory of the air mass (*9, 10*). Therefore, aerosols that consist predominantly of H_2SO_4 or NH_4HSO_4 may be either younger aerosols or those aged in an NH_3-deficient environment [for example, air parcels with trajectories over southern laterite soils, low in NH_4^+ (*11*)]. Red-yellow laterite soils are characteristic of the southeastern United States and are low in *p*H. For example, the Missouri and Arkansas sites show significantly higher incidences of H_2SO_4 or NH_2HSO_4, or both (39 and 30 percent, respectively), than the Michigan site (12 percent). The production and modification processes involved in the generation of sulfate aerosols are not well understood, and it is likely that a variety of factors are involved.

Simultaneous measurements of the particle scattering extinction coefficients showed the same low-frequency variation of hours to days characteristic of the extensive aerosol systems. The coefficients at each site nominally varied between 10^{-5} and 10^{-4} m^{-1}. For the topography characteristic of these locations and in particular the Ozark Mountains (rolling hills with a horizontal separation of about 10 km), scattering coefficients of 10^{-4} m^{-1} result in a heavy haze when one is viewing neighboring hills. By comparison, clearer vistas have coefficients of 10^{-5} m^{-1}.

Several conclusions may be drawn from these data. (i) The haze-producing aerosol at the forested, Ozark location was not predominantly organic but was dominated by sulfate particles; the nature of the dominant sulfate species was similar to that observed in rural Missouri and Michigan. (ii) The similar aerosol light-scattering behavior and the nearly continuous dominance of the light-scattering hazes by sulfate particles at all three rural sites strongly suggest that this finely divided sulfate aerosol is regionally extensive, ranging from the northeast to the southwest for at least 1000 km. Abundant evidence regarding the lifetime of sulfate aerosols (largely from European studies of rain composition) indicates a half-life on the order of a few days and thus transport distances for the planetary boundary layer of a few to several thousand kilometers (*12*). Since the sources are separated on the average by much less than 1000 km, we expect a quasi-homogeneous aerosol field.

We believe that this sulfate aerosol may encompass much of the eastern United States. Similar sulfate hazes extending over large areas have been observed in western and northern Europe, particularly in Sweden (*10, 13*). Undoubtedly, sulfate will be of significant importance to the atmospheric optics of the entire region if the high concentrations of sulfate detected throughout the eastern third of the United States (*14*) are predominantly in the optically efficient size range (0.1 to 1.0 μm) as in St. Louis (*15*). One chief question remains: What fraction of sulfate aerosol is due to natural and what fraction to man-made sources in these varied locations?

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5. Concurrent with our measurements, samples were taken during September 1975 at the Missouri site with a Lundgren type impactor for infrared spectroscopic sulfate analysis [see P. T. Cunningham, S. A. Johnson, R. T. Yang, *Environ. Sci. Technol.* **8**, 131 (1974)]. Analysis of objectively selected periods show corroborating identification of acid or neutralized sulfate particles in the fine-particle size range.
6. The site was located in the forested hills of the Ozark Mountains, about 500 km southwest of the Missouri site. This region in northwestern Arkansas is sparsely populated and distinctly rural. The site was in a cleared area on private property near the summit of Hall Mountain, the second highest hill in the vicinity (elevation, about 800 m). The closest town of any size is Huntsville, Arkansas (population about 1000), about 30 km to the north. The nearest large urban center is Little Rock, Arkansas, about 200 km to the southeast. Area SO_2 emissions are negligible on a scale of at least 100 km in any direction. We estimate SO_2 emissions in a 100-km grid surrounding the site to be on the order of 10^{-9} to 10^{-8} g m^{-2} sec^{-1} [G. M. Hidy *et al.*, *Design of the Sulfate Regional Experiment (SURE)* (Environmental Research and Technology, Inc., Westlake Village, Calif., 1976), vol. 3, appendix C]. These emission rates are 10^{-2} to 10^{-3} of the area SO_2 emissions for regions surrounding the Missouri and Michigan sites.
7. Located in a rural, lightly wooded area of southeastern Michigan on the Milford General Motors Proving Grounds, the site is 5 km west of Milford, Michigan (population about 4500), about 50 km northwest of Detroit and approximately 750 km northeast of the Missouri site. Power plants that burn fossil fuels are distributed at intervals of 25 to 200 km throughout the region (in general, such a fossil fuel plant distribution pattern prevails over most of the north-central and northeastern states).
8. Located at the center of the Tyson Research Center grounds, a 1000-hectare, limited-access preserve operated by Washington University in St. Louis, the site was on a cleared area of a ridge at an elevation of about 200 m. The nearest town is Eureka, Missouri (population about 1400), about 5 km west-southwest. The nearest urban center is St. Louis, about 30 km north-northeast. Major SO_2 sources (primarily power plants that burn fossil fuel) are located at about 20-km intervals around the area. The nearest fossil fuel plant is approximately 20 km west of the site.

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A Cheetah-Like Cat in the North American Pleistocene

Abstract. *The discovery of abundant skeletal remains of* Felis trumani *from a late Pleistocene deposit in Wyoming shows that it was as highly modified for cursorial locomotion as the cheetah* (Acinonyx). *Several other Pleistocene felids that have been regarded as pumas seem to be related forms. The late Pleistocene fauna of the Big Horn Basin in Wyoming is dominated by cursorial taxa.*

Natural Trap Cave is a karst sinkhole feature of the Madison limestone (Mississippian, ~ 300 to 310 million years ago) located on the western slope of the Big Horn Mountains in north central Wyoming. The United States Geological Survey Natural Trap Quadrangle shows the site in the NW 1/4, SW 1/4, Sec. 28, R94W, T58N, Big Horn County, approximately 1510 m above sea level. The site is on a short grass and sagebrush plateau in the Juniper Breaks ecological zone. Excavations conducted jointly by the University of Missouri, Columbia, and the University of Kansas, Lawrence, in Natural Trap Cave have provided the first substantial evidence for a cheetah-like cat in the North American Pleistocene.

Until September 1973, when it was gated and closed off for protection by the Bureau of Land Management, the cave was an open natural trap for any unwary animal. The cave entrance is from 3.5 to 4.5 m in diameter and is hidden from view until the observer is virtually at its edge. There is a free fall of at least 20 m from the entrance to the floor. The cave is bell-shaped in cross section and has only one entrance, so there is no possibility of escape for any animal that might survive a fall into it.

The cave could not have been used as a den for large carnivores, nor was it suitable for human occupation. Besides the hazards of ingress and egress, a mean temperature of 5.56°C in the hottest month and a relative humidity of 98 percent militate against human comfort. Thus, there was no cultural filter to bias the species represented and no human or animal disturbance of the naturally deposited remains. However, the action of gravity and rainwater has resulted in the disarticulation of most of the skeletons. The extent of the deposit has not yet been determined. Our present excavations indicate fossiliferous deposits to a depth of approximately 3 m at which point large fragments of rockfall prevent further excavation. The bones are well preserved and lie intermingled with rockfall in 13 distinct strata.

Excavation of a small area (28 m^2) in 1974 resulted in a collection of over 2500 mammal bones, most of which were from horses. Radiocarbon dates on horse bone from these excavations indicate that the strata are of late Pleistocene age, and that they had been serially deposited. The deepest natural stratum tested in 1973 (about 1.5 m) was 12,770 ± 900 radiocarbon years ago. The next deepest stratum (1 m) was 10,920 ± 300 radiocarbon years ago. There are 1.5 m of fossiliferous strata below the older strata. Excavations during the summer of 1975 have added several thousand additional specimens, and the following large mammals are now known from the site: *Canis* sp. (wolf), *C. latrans* (coyote), *Vulpes vulpes* (fox), *Arctodus simus* (short-faced bear), *Mustela* sp. (weasel), *Gulo gulo* (wolverine), *Felis trumani* (extinct cheetah-like cat), *Panthera atrox* (American lion), *Equus* sp. (large form), *Equus* sp. (small stilt-legged form), *Camelops* (camel), a large cervid, an undetermined antilocaprid, *Bison* sp. (extinct bison), *Ovis catclawensis* (extinct mountain sheep), and *Mammuthus* sp. (mammoth). The sample of small mammals is not quite so rich but includes *Lepus* (jackrabbit), *Sylvilagus* (cottontail rabbit), *Marmota* (marmot), *Eutamias* (chipmunk), *Peromyscus* (field mouse), *Neotoma* (woodrat), and *Microtus* (vole). Our present information indicates that most of these animals lived contemporaneously. However, we intend to examine the faunal succession in detail at the conclusion of our excavations and would not be surprised to see changes in relative abundances or in actual faunal composition in the deeper strata. Almost all the taxa listed occur both in and below the strata that have been radiocarbon dated.

The structure of the late Pleistocene fauna in the Big Horn Basin appears to be unusual in that it is composed of highly specialized cursorial forms, suggestive of open country. The extinct bighorn sheep had much longer legs than the modern *Ovis canadensis*, and the dominant horse is the small stilt-legged form.

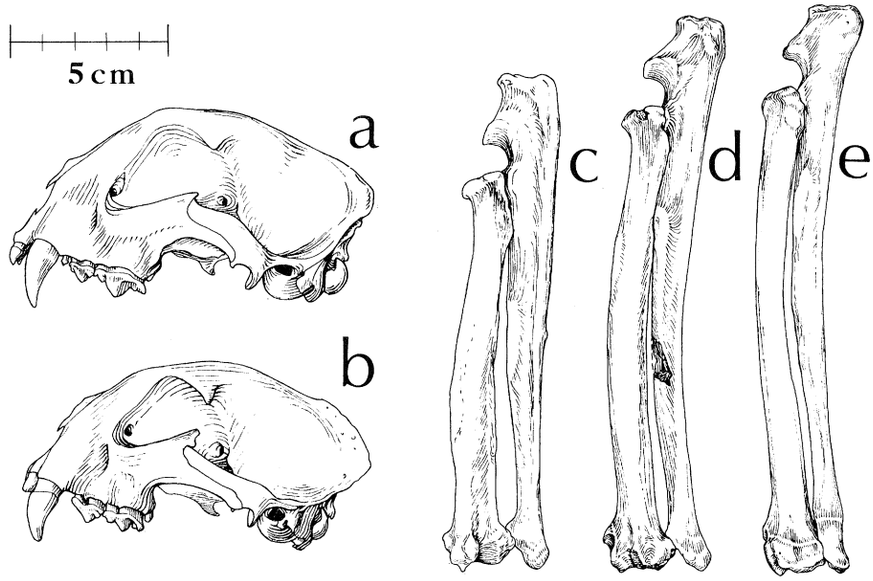

Fig. 1. Comparison of *Acinonyx jubatus* with *Felis* spp. (a and b) Lateral views of skulls: (a) A. *jubatus*, FMNH 34589, and (b) *Felis trumani*, WSI P3a/450, holotype. (c to e) Left radii and ulnae, lateral views: (c) *Felis concolor*, KUMNH 96904; (d) *F. trumani*, KUVP 26280; and (e) *A. jubatus*, FMNH 34589. See (5) for sources of specimens. [Drawn by D. A. Adams]