African Dust in

Trade winds carry North African dust storms into the Caribbean and over North America, possibly affecting human health.

Joseph M. Prospero

The atmosphere is a daily host to a variety of particles. Many of us have seen particles, or aerosols, in thick hazes of pollution. Aerosols absorb and scatter radiation, affecting climate.

They can also affect our health. Many of them are smaller than 2.5 micrometers, making them easy to inhale. We breathe them into our respiratory systems, and they settle into our lungs. We know that certain types of fine particles, such as cigarette smoke, coal dust or asbestos, can affect our respiratory systems, but many other types can also cause problems. The U.S. Environmental Protection Agency recently introduced stricter standards to limit our exposure to aerosol concentrations.

Concern over the increasing levels of anthropogenic emissions has meant that aerosol research has emphasized pollutants. But not all aerosols are generated by human activity.

Trade winds can lift fine mineral particles from soils, and then carry those particles great distances around the planet. Over large areas of Earth, the concentration of soil dust far exceeds that of anthropogenic pollutants. Scientists are now investigating how this natural dust, or mineral dust, changes our environment and may affect our health. Humans have lived with pollution over the past several hundred years. But over their entire history, they have lived with mineral dust.

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Satellites give us an excellent picture of the transport of dust and other aerosols on a global scale. They show that dust storms can cover huge areas of the world and that dust can be carried great distances.

We also follow the path of the dust clouds by collecting aerosol samples at Earth's surface. Pumps draw air through filters, and we analyze that air for chemical and mineral species. In our program at the University of Miami's Rosensteil School of Marine and Atmospheric Sciences, we have carried out many studies on island stations and ships in all the oceans. We also sample dust clouds from aircraft, which allows us to characterize concentrations in the upper atmosphere and understand the role of meteorology in the transport process. In ocean regions where satellites show clear air, the concentration of dust we measure is usually negligible. But when a dust cloud advances into a region, concentrations can increase to hundreds of micrograms per cubic meter of air.

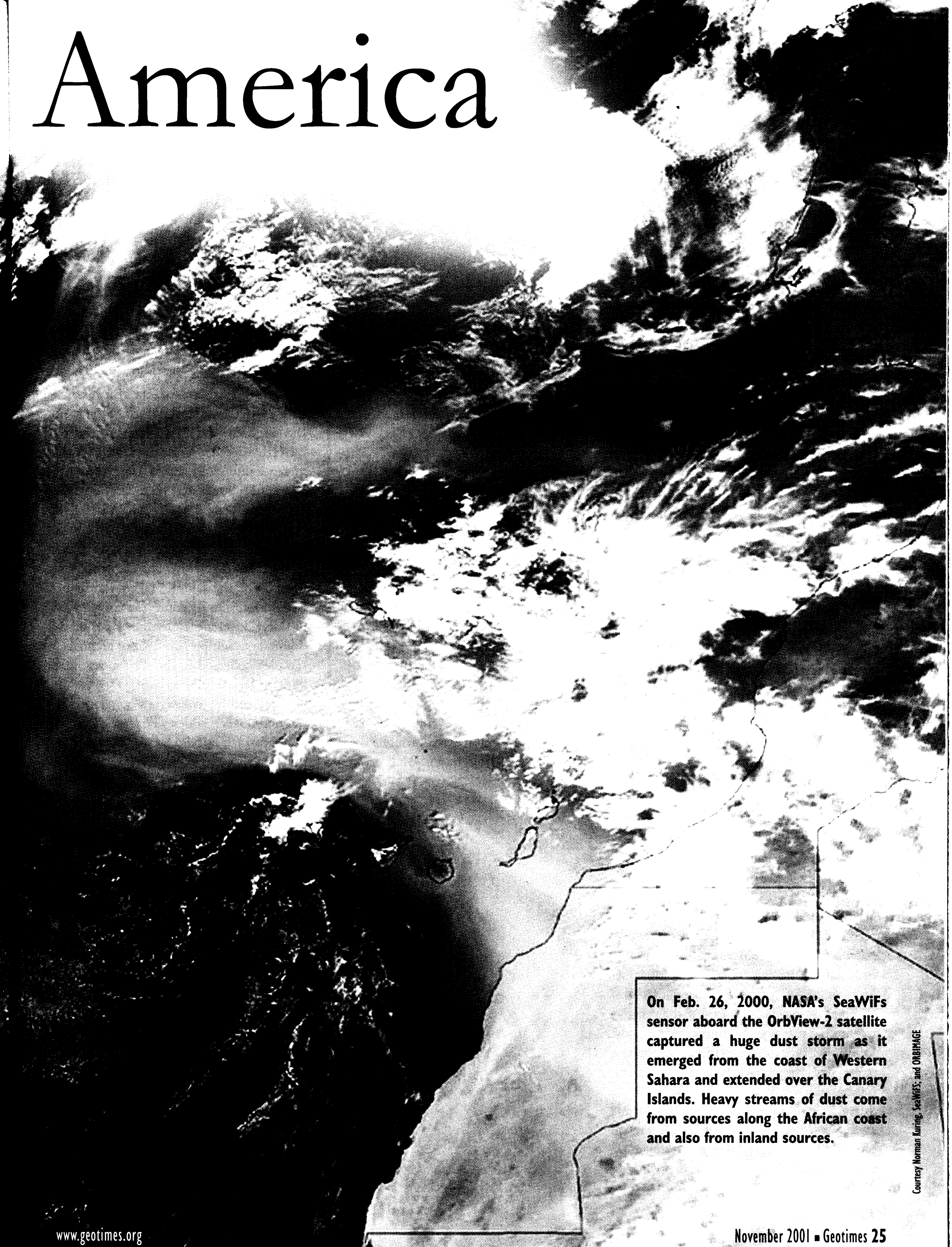
Dust: a North African export

Dust storms are a frequent occurrence in North Africa, making it the strongest dust source in the world. Africa exports dust much of the year, sending streams eastward across the Middle East and the Arabian Sea, north over the Mediterranean to Europe, and west across the tropical Atlantic to North and South America.

The intense dust activity is not a new phenomenon. Indeed, Charles Darwin, during his cruise on the *Beagle*, experienced heavy dust falls while the ship was sailing off the west coast of North Africa. He was moved to speculate on how such heavy dust deposits might affect the composition of ocean sediments. In fact, sediment samples from the tropical Atlantic show that the non-biogenic components of these deposits are primarily African dust. Furthermore, deep sediment cores taken in this region show large concentrations of African dust throughout, indicating that dust transport has been taking place for many thousands of years.

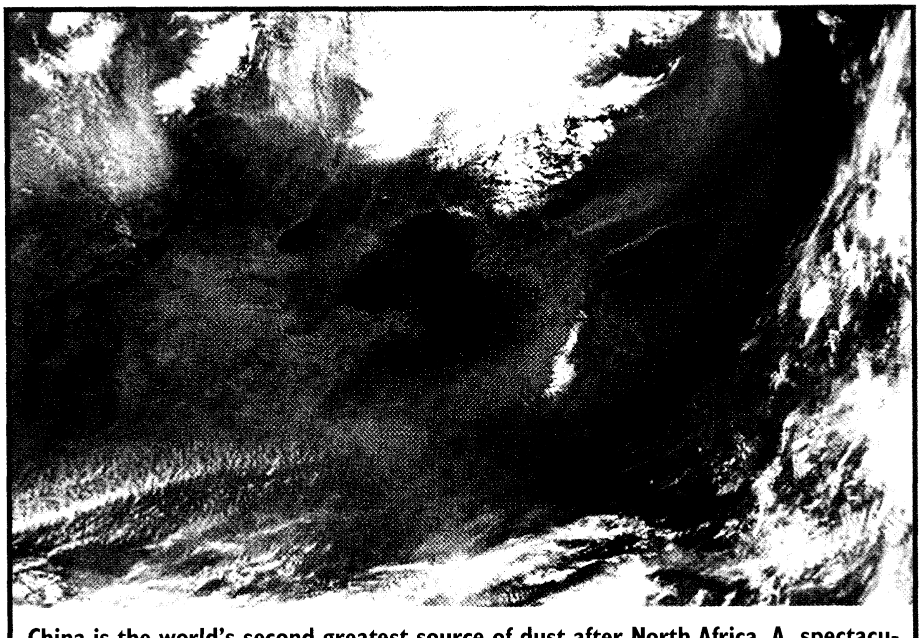
At the University of Miami, our interest in the origin of fine mineral particles in tropical Atlantic sediments lead us to study dust in the

America



On Feb. 26, 2000, NASA's SeaWiFs sensor aboard the OrbView-2 satellite captured a huge dust storm as it emerged from the coast of Western Sahara and extended over the Canary Islands. Heavy streams of dust come from sources along the African coast and also from inland sources.

Courtesy Norman Kuring, SeaWiFS, and ORBIMAGE



China is the world's second greatest source of dust after North Africa. A spectacular example is this April 2001 dust storm. The SeaWiFS sensor aboard the Orbview-2 satellite captured the entire life cycle of this storm beginning with its inception over northeast China. During the following days, SeaWiFS showed the dust cloud moving eastward over the North Pacific and across the northern United States and Canada, until it dissipated over the North Atlantic. Research shows that a similar, April 1998 dust storm caused sharp increases in aerosol concentrations and produced dense hazes in many areas of North America. These two examples are unusual because of the size of the storms and the distances they traveled. But many studies show that, every spring, frontal storms emerging from Siberia generate large quantities of dust in China. This process has been going on at least for hundreds of years. In Korea and Japan, Asian dust is such a historically persistent phenomenon that it has long been given a name, "kosa."

northeast trade winds. In 1964, a group of us at the university began making dust measurements in the trade winds on the island of Barbados, West Indies, at 13°15'N, 59°30'W.

At Barbados, dust concentrations go through a strong seasonal cycle with maximum values in summer. A longer-term variability is linked to North African rainfall. Africa has gone through cycles of pluvial and drought periods. After a period of abundant rain in the 1950s and early 1960s, North Africa entered a dry phase in the late 1960s. When we plotted Barbados dust concentrations against summer-mean rainfall deviations in the Sahel, the border region to the south of the Sahara, we found that dust concentrations clearly correlate with rainfall deficits in the Sahel. During the early 1970s and early 1980s, dust concentrations over Barbados increased again during periods of intense North African drought. The highest dust concentrations were obtained in 1983, the year following the onset of one of the most intense El Niño events in recent history. El Niño might have brought on the North African drought, but we don't know for certain.

Our work on Barbados started before the age of satellites. With satellites, we can now see that, during the summer months, the trade winds carry a steady stream of dust that covers much of the tropical Atlantic and the Caribbean.

Dusty summers east of the Mississippi

The summer trade winds carry African dust into the southeastern United States. We have made daily aerosol measurements at a coastal site in Miami, Fla., since 1974. The seasonal pattern of dust in Miami is similar to that at Barbados, except that dust concentrations are consistently higher at Barbados and that the dust transport season on Barbados is longer than that in Miami, where transport starts later in the year and ends earlier.

The same dust that we see in Barbados and Miami is often carried over much of the United States east of the Mississippi. During a study of air quality in national parks and wilderness areas, Kevin D. Perry of the Crocker Nuclear Laboratory of the University of California at Davis noticed a curious feature. His team expected to find that the arid Southwest would host the highest concentrations of fine soil particles during summer. Instead, they found the highest concentrations in the eastern United States.

Furthermore, Perry noticed a large-scale coherence in the temporal variability of dust in the East: When the dust concentrations increased in Atlanta, for example, they also increased in St. Louis, Birmingham and Nashville. As the dust moved north, concentrations would increase uniformly across a large area. This coherence suggested that the dust was associated with a large-scale process, not random local events that might be attributed to human activities, such as agriculture and construction. The elemental composition of the samples taken during these large-scale, summertime dust events was not only different from other types of soil-dominated samples, but also identical to samples collected in the Caribbean during known African dust events.

Perry and his colleagues concluded that the fine-dust episodes were associated with the advance of African dust clouds through the region. African dust over the United States is abundant in fine particles compared to locally generated dust, because the large particles settle out during the week-long journey over the Atlantic. Using their unique size and composition as a signature, Perry could follow the progress of some of these dust clouds as they moved from the Caribbean and Gulf of Mexico, into the southern states, across the northeast United States, and as far north as Maine.

African droughts and asthma

Concern is increasing about the health effects of particles that can be inhaled, including mineral dust. About half of the dust mass that travels from Africa to the eastern United States contains particles that are small enough to inhale.

We don't know much about the health effects of soil particles in general or of

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African dust in particular. But we do have evidence that aerosols coated with first-row transition metals, including iron, are particularly efficient in producing an inflammatory response in the lungs. The average iron content of all dust particles from Africa is 3 to 5 percent. The dust particles are heavily coated with iron and leave a red-brown coating on the filters we use for collecting them. A substantial fraction of the iron on dust could be quickly released into the lungs once the particles are deposited on lung tissue.

African dust also contains other substances that could stress the respiratory system: plant debris, microorganisms, and a wide range of organic materials derived from animal and plant materials.

Is there any evidence of health impacts from African dust? Perhaps. Anecdotal reports from Caribbean islands show that emergency room visits for asthma and other respiratory illnesses increase markedly during African dust events. The number of asthma cases in Caribbean populations has noticeably increased over the past couple of decades. Drought in Africa has also become more severe over that time, and the increase in asthma cases could be associated with more frequent dust events. In Barbados, the annual number of acute asthma attacks has risen from around 2,000 in the early 1970s to about 12,000 at present — a considerable fraction of the 1999 population of 265,000. The increase in asthma roughly parallels the increased dust concentrations we have measured on Barbados since the late 1960s. We are investigating whether a link does indeed exist between airborne dust and asthma.

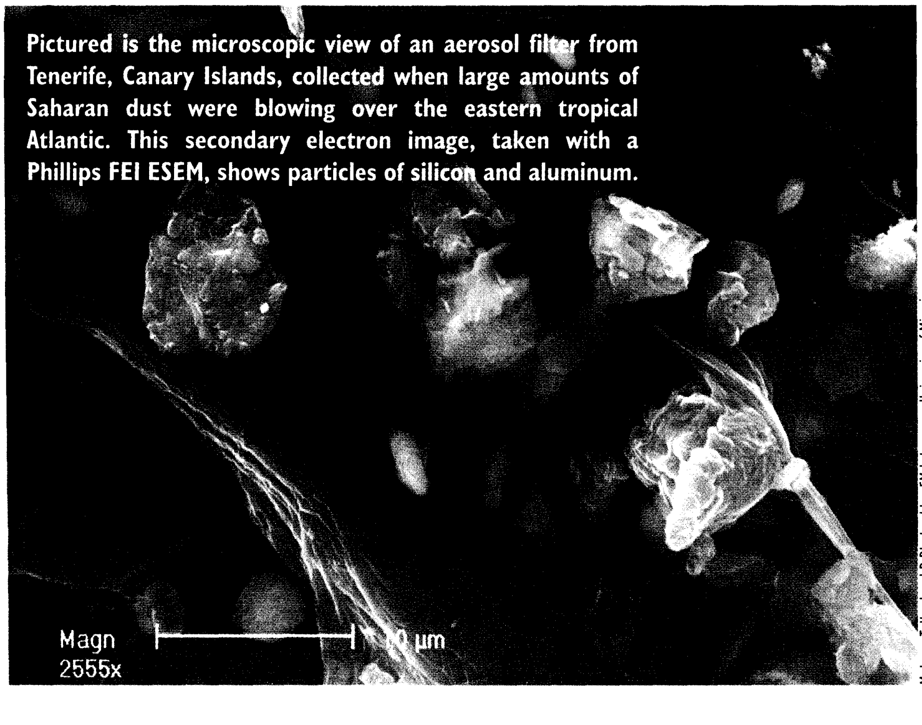
Pathogens across the Atlantic?

Soils contain microorganisms that could be pathogenic to humans or to plants. We would expect most organisms attached to airborne particles to die from desiccation or exposure to ultraviolet radiation. In the case of dust transport across the Atlantic, the long transport time would make survival difficult for all but the most hardy of species.

Nonetheless, research carried out by several of us at Rosensteil, in cooperation with colleagues in Barbados, shows that substantial concentrations of fungi and bacteria do survive the trans-Atlantic trip. Daily measurements made from 1996 to 1997 show that the concentrations of viable fungi and bacteria increase sharply with the concentration of dust. In contrast, air masses that arrive from the central North Atlantic, North America and Europe carry virtually no viable fungi and bacteria.

Some of the organisms in African dust are indeed pathogenic, according to Dale Griffin and colleagues at the U.S. Geological Survey Center for Coastal Geology in St. Petersburg, Fla. They carried out detailed studies of a number of aerosol samples collected during African dust events on St. John in the U.S. Virgin Islands during the summer of 2000 and found a large number of viable pathogenic fungi, bacteria and viruses. Some were known human pathogens and others were plant pathogens.

The long-range transport of organisms is a new field and it is not possible at this time to assess the importance of these wind-borne microorganisms. Clearly there is much work to be done.



Pictured is the microscopic view of an aerosol filter from Tenerife, Canary Islands, collected when large amounts of Saharan dust were blowing over the eastern tropical Atlantic. This secondary electron image, taken with a Phillips FEI ESEM, shows particles of silicon and aluminum.

M. Lynn, T. Hood and P. Blackwelder, EM Laboratory, University of Miami

Work ahead

The presence of high concentrations of mineral dust over such large areas of Earth has implications not only for human health, but also for meteorology, climate, geology and biogeochemical processes. These processes are all strongly linked. Indeed, the geological record shows that dust mobilization and concentrations have varied tremendously through time.

To properly assess the role of dust, we must have a better understanding of the physical, chemical and mineralogical properties of airborne soil particles. We also need to understand the processes that generate dust, which are highly nonlinear and extremely sensitive to climate change.

Understanding the role of dust in health will mean developing models that can characterize the global distribution of dust and its properties. Modeling dust sources and atmospheric transport of dust is perhaps the most difficult task facing modelers. In order to accomplish this goal, it will be necessary for geologists and mineralogists to work closely with atmospheric modelers. We need to study the processes that affect dust mobilization, and we need to relate the mineral properties of dust to the terrains from which it originates. And geologists and mineralogists must work with those in the medical sciences to understand how dust affects human health.

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