Table 2. A comparison of nitrogen dioxide and sulfur dioxide as sensitizers for photooxidation of organic compounds (see Leighton and Perkins, *1*).

Active wavelengths in sunlight	NO_2 (2900 to 3900 A)	SO_2 (2900 to 3300 A)
Active species	O atoms	SO_2* (triplet)
Quantum yield for producing active species	1	10^{-2}
Absorption rate at 10 pphm (pphm/hr)	260	8
Principal product	Ozone and partially oxidized organic vapors and aerosols	Nonvolatile, highly oxidized organic strong acid as aerosol
Action on neutral KI	Oxidation to I_2	No reaction
Secondary light absorption	Products absorb sunlight less strongly than do reactants	Products absorb sunlight much more strongly than do reactants

chloride, ethyl ether, or concentrated aqueous hydrochloric acid. The liquid formed a colloidal suspension in water with *p*H less than 2. The liquid was soluble in aqueous sodium bicarbonate solution, with strong evolution of gas. The mixed liquid products did not oxidize neutral potassium iodide solution to iodine, but it did reduce permanganate with an apparent equivalent weight of 1500 to 3000 (probably due to dissolved sulfur dioxide). The acid equivalent weight of the sample formed in the presence of air (wet or dry) was between 100 and 120. Elemental analysis of the mixed liquid product gave an average empirical formula of $C_2H_5SO_5$. Spot tests for organic peroxide were negative. These superficial chemical tests indicate that the mixed products are highly oxidized, sulfur-containing, organic strong acids.

These studies were made with a view toward determining the role of sulfur dioxide in air pollution. It is well established that the dominant chemical system in photochemical air pollution is that of nitrogen dioxide, sunlight, and hydrocarbons with intermediates and products including oxygen atoms, ozone, and partially oxidized hydrocarbons (*4*). There are many strong differences between the nitrogen dioxide sensitized photooxidation of organic materials and the sulfur dioxide sensitized photochemical system, as pointed out in Table 2. Nitrogen dioxide responds much more rapidly, and its photochemical products include easily monitored oxidants. As a corollary, nitrogen dioxide in the atmosphere is rapidly depleted by photochemical reaction, and its steady-state partial pressure is far less than 10 parts per hundred million (pphm). Sulfur dioxide responds relatively slowly to sunlight, and the principal product is a slowly settling aerosol with no easily monitored, specific chemical property. The slow photochemical reaction continues, however, throughout the day, and the concentration of sulfur dioxide may greatly exceed that of nitrogen dioxide. It is proposed that the slow, cumulative photoreactions of sulfur dioxide with organic material and air may add up to a significant contribution to air pollution, although its nature differs substantially from that produced by nitrogen dioxide (*5*).

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Connection between Archaeopteris and Callixylon

Abstract. Characters of two Upper Devonian genera, *Archaeopteris*, often considered to be a fern, and *Callixylon*, classified with the gymnosperms, have been recognized in a single specimen.

Archaeopteris Dawson (*1*) and *Callixylon* Zalessky (*2*) were among the most prominent genera of late Devonian times, similarly distributed over a wide area of the Northern Hemisphere. *Archaeopteris*, which commonly occurs as fragments of large, fernlike fronds, is known, primarily, from studies of compressions. Extensive information about the external morphology of its leaves and details of its fructifications has been accumulated. Except for the occasional observation of tracheid fragments isolated by maceration, its anatomical structure has remained, until now, a complete blank in paleobotanical knowledge. *Callixylon*, on the other hand, is characterized, mainly, by the gymnospermous internal structure of petrified roots, stumps, logs, and branch fragments, but no knowledge of its foliage or fructifications has been previously acquired.

In North America, *Archaeopteris* is a common fossil of the continental beds of the East, having been collected in several localities from Gaspé Peninsula, Quebec, to southwestern Pennsylvania. Because of its great abundance, it is considered to have been one of the predominent elements in the vegetation during late Devonian times. It is usually thought of as a low, shrubby plant, and is so illustrated in restorations.

Petrifactions of *Callixylon* are usually found in marine beds, well-known localities occurring in western New York, Kentucky, Indiana, Oklahoma, and southwestern Texas. A stump of *Callixylon* with a diameter of 5 feet has been discovered in the Woodford chert of Oklahoma, and logs 20 and 28 feet long have been uncovered in the New Albany shale of Kentucky and the Caballos chert of southwestern Texas, respectively. *Callixylon* was, therefore, a large tree, and the Oklahoma specimen has been estimated by Arnold (*3*) to be at least 60 feet tall.

Remains of *Callixylon* preserved in marine sediments are fragments of drift wood. The source of the western New York specimens was, undoubtedly, a land mass to the east, represented today, in part, by the continental beds of the Catskill region and adjacent areas of New Jersey and Pennsylvania. The discovery of foliage and fructifications of *Callixylon* in the richly fossiliferous beds of these areas has long been a recognized possibility, and a goal of several paleobotanists. Since the horizontal banding of groups of round-bordered pits on the radial walls of the secondary tracheids is a unique character of this genus, the recognition of this feature in even a small axis fragment of an identifiable foliage compression would be sufficient evidence for proof of common identity. Until now the searches of several paleobotanists have been fruitless, although *Callixylon* has been found occurring with *Archaeopteris* in the Oswayo sandstone in Pennsylvania by Arnold (*4*). However, while recently collecting (*5*) in beds of late Devonian age in the western part of the Catskill region, I had the good fortune to discover a large specimen (about 80 cm long) which consists of a partially compressed, pyritized stem with the internal primary and secondary structure of *Callixylon*, to which is attached fragments of several fronds of *Archaeop-*

teris, one of which bears both fertile and vegetative pinnae (*6*).

The great significance of this specimen becomes apparent when one realizes that the two organ genera, now known to represent one plant, have been widely accepted as having close affinity with members of different classes of the plant kingdom, *Archaeopteris* frequently being classified with the ferns and *Callixylon* conceded by most to be a gymnosperm. This plant, which according to the rule of priority must be called *Archaeopteris*, is unique among known vascular plants. It was a tall, straight, forest tree, with branches bearing large, pinnately-compound leaves. In size, excurrent habit, and wood anatomy it had the appearance of a conifer. Its pycnoxylic secondary xylem, containing tracheids with alternate, round-bordered pits restricted to radial walls, and narrow rays containing ray tracheids, is of a relatively advanced type, and appears to have been more highly specialized than that of some modern conifers. Its leaves, however, were unlike those of any known coniferophyte (that is, cordaite, ginkgo, taxad, or conifer), and although, in gross form, they were fernlike, they were no more similar to those of the ferns than to those of another gymnosperm group, the pteridosperms. All positive evidence indicates that this extraordinary plant reproduced pteridophytically. Significantly, at least one species of *Archaeopteris* had evolved to the level of heterospory (*7*), and it is very probable that the genus is one of a group of Devonian and Lower Carboniferous plants which was directly ancestral to some of the late Paleozoic seed-bearing plants.

Archaeopteris, which 300 million years ago formed extensive forests of tall, graceful, trees over large parts of the earth, now becomes one of the best known Devonian plants.

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Numerical Comparison of Geomorphic Samples

Abstract. The distribution of elevations representing a region can be shown as a cumulative frequency curve plotted on probability paper. Many elevation distributions are "zig-zag" curves which can be represented conveniently by measures of skewness and kurtosis. A plot of skewness versus kurtosis permits the recognition of six major, non-Gaussian forms, with countless gradations.

Skewness and kurtosis, computed from elevation or relief data, can be used to characterize various geomorphic regions (*1*). This is true because, for most areas, the distribution of elevation data is not Gaussian, nor can it be made to appear Gaussian by any standard transformation. The departure from the normal (or log-normal) curve commonly depends on the fact that most such relief distributions contain three major components: uplands, slopes, and lowlands. These three components can be combined in various distinctive ways. Seven examples, six of which are non-Gaussian, are given as insets in Fig. 1. The upper right inset, showing much upland, little slope, and no lowland, can be taken as representative of Davisian youth. The upper left inset, showing a little slope and much lowland, can be taken as Davisian old age. The concept of maturity (all slope; a Guassian distribution) is shown by the middle inset. The other four insets show departures from the ideal Davis cycle.

The insets are not only illustrative. They are also plotted, individually, to scale. For each inset, the vertical ordinate is percent of relief (from 0, at the bottom, to 100 percent, at the top). The horizontal ordinate is the common probability scale, ranging from 1 percent at the right end, to 99 percent at the left end. The curve that is shown in each inset is a cumulated frequency curve.

It is obvious that the departures of the outer six insets from the central inset can be represented by moment measures, specifically, skewness and kurtosis. The "maturity" inset, having a true Gaussian distribution, has a skewness value of 0 and a kurtosis of 3.

The small circles represent actual areas studied. For each area, a sample of elevations (generally some multiple of 100 measurements) has been taken, and converted to percent relief. From the classified cumulated data, skewness and kurtosis were obtained. Actual areas fall in many parts of the chart except in the vicinity of "youth." Absolute relief, or absolute elevation, does not show in any way.

Two points need to be made clear about this diagram. First, the chart, as a whole, cannot be taken to indicate the relative number of areas which are in youth, maturity, old age, or off the Davis sequence. The choice of study areas has been influenced by the availability of detailed maps. Furthermore, no effort has been made to randomize the choice of study localities (although actual sample points have been randomized). On the other hand, a wide variety of areas is shown. Oklahoma and Alabama are represented by eight areas each; Arizona and Arkansas, by six each; and Kentucky, Tennessee, Pennsylvania, North Dakota, South Dakota, California, Minnesota and Maine, by one or two each. Ten areas are from Asia and Africa. The lack of true randomization of study areas does not detract from the basic purpose.

The second problem, a more serious matter, involves the definition of a sample or study area. It has been suggested by some that the river basin (outlined by divides) is the only natural unit of study. This notion ignores large portions of the earth's surface, where no good, continuous divides exist. In sand hills, karst plains, swamps, deserts, tundra, and glaciated regions one may find that he must choose his study area arbitrarily. His decision may be forced by the realities of map availability. And if he chooses limits other than the edges of the map, he may find that his work is not closely reproducible.

Computation of skewness and kurtosis measures, for a given area, allows an investigator to make a reasonably objective analysis. Furthermore, examination of the probability plot itself (such as the insets in Fig. 1), permits an esti-

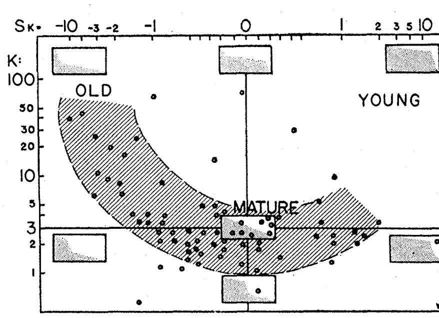

Fig. 1. Plot of skewness (horizontal ordinate; modified tangent scale) versus kurtosis (vertical ordinate; log scale), for geomorphic relief data for 75 selected areas (small circles). Stippled insets are representative cumulative relief plots, made on a horizontal probability scale. The labels "young," "mature," and "old" refer to Davisian concepts. The shaded area shows that most samples (about 85 percent) represent mature or old regions, some samples (about 15 percent) are non-Davisian, and few or none represent regions in youth.