phyllaceae, and *Rumex,* major constituents of the laminated clay and sand, are rare in the massive sandy silt, except near the base of the unit. *Potamogeton filiformis* seeds are abundant in the massive sediments but decrease upward. The fact that there are no foraminifera in either the laminated or massive sediments suggests that shorelines on eastern Graham Island 15,000 to 16,000 years ago probably were no higher than at present.

A woody terrestrial peat bed overlies the drift complex and the organic-rich mineral sediments described above. At the study site, the base of this peat is 11,100 ± 90 years old (GSC-3337), but radiocarbon dates as old as 12,400 ± 100 years B.P. (GSC-3112) have been obtained from the peat at other localities on eastern Graham Island (*8, 11*). Logs, tree stumps in life position, and *Picea sitchensis* cones indicate forested conditions at Cape Ball during the later phase of peat deposition. The peat bed locally extends across the present intertidal platform below sea level, an indication that the level of the sea relative to the land was lower at the close of the Pleistocene than at present. In contrast, at the same time, shorelines on the British Columbia mainland coast east of the Queen Charlotte Islands were as much as 200 m above present sea level (*12*). This difference is the result of variable isostatic depression of the crust by late Wisconsin glaciers. On the mainland coast, glacier ice was sufficiently thick (up to about 2000 m) that isostatic depression more than compensated for lower eustatic water levels, and consequently lowland areas were inundated. In contrast, in the vicinity of Graham Island, eustatic lowering dominated over glacio-isostatic depression, indicating a thin localized ice cover. A large part of western Hecate Strait probably was subaerially exposed during latest Pleistocene time, as shown by the presence of what are thought to be submerged sea cliffs and drowned stream valleys to about 42 m below sea level east of Graham Island (Fig. 1).

The peat bed at the study site is overlain by marine and estuarine sediments deposited during a transgression which culminated about 7500 to 8000 years ago when the sea was about 15 m higher relative to the land than at present (*12*). Subsequent marine regression during middle and late Holocene time permitted recolonization of formerly submerged lowland areas and led to the accumulation of the surface peat at Cape Ball.

Several important implications emerge from these studies. The Cape Ball area was ice-free 15,000 to 16,000 years ago at the time of maximum late Wisconsin glaciation in southern British Columbia (*9, 13*) and the area remained unglaciated continuously thereafter. The variety and abundance of plant macrofossils in the laminated clay and sand unit at Cape Ball argue that there was a well-established flora there at 16,000 years B.P. Because present land areas bordering the Queen Charlotte Islands probably were covered by glaciers at this time, the flora recorded at Cape Ball most likely persisted somewhere on the islands throughout the last glaciation, perhaps on a presently submerged platform in western Hecate Strait or on mountain nunataks. The low sea levels necessary to form such a subaerial surface imply only minor glacio-isostatic depression of the crust, which supports our contention that late Wisconsin ice on the Queen Charlotte Islands was thin and localized.

The climatic regime on the Queen Charlotte Islands during late Pleistocene time probably was moderately oceanic and cooler than the present but was not so severe as to preclude the survival of biota. The former coexistence near sea level of *Salix reticulata*, which is now restricted to high elevations on the Queen Charlotte Islands, and *Callitriche*, a low-elevation aquatic taxon (*1*), supports this conclusion and raises the possibility that late glacial landscapes at the edges of the Cordilleran ice sheets were able to accommodate a more diverse biota than modern environments.

The presence of a refugium on northeastern Graham Island indicates that land areas on the islands were available for possible occupation by early man. Only after more studies of this kind have been carried out in other parts of the Pacific coast of northwestern North America can we assess the importance of past ice margin positions in shaping both modern biotic and cultural patterns.

BARRY G. WARNER
ROLF W. MATHEWES
Department of Biological Sciences,
Simon Fraser University, Burnaby,
British Columbia V5A 1S6, Canada
JOHN J. CLAGUE
Geological Survey of Canada,
100 West Pender Street, Vancouver,
British Columbia V6B 1R8, Canada

References and Notes

1. J. A. Calder and R. L. Taylor, *Can. Dep. Agric. Res. Branch Monogr. 4* (1968).
2. J. B. Foster, *B.C. Prov. Mus. Occas. Pap. 14* (1965); W. B. Schofield, *Madrono* **20**, 155 (1969).
3. E. L. Bousfield, *Can. Field Nat.* **72**, 55 (1958); A. S. Randhawa and K. I. Beamish, *Can. J. Bot.* **50**, 79 (1972); G. G. E. Scudder, *Entomol. Soc. Can. Mem.* **108**, 87 (1979); D. H. Kavanaugh, *Can. Entomol.* **112**, 1129 (1980).
4. V. K. Prest, *Geol. Surv. Can. Map 1257A* (1969).
5. C. J. Heusser, *Spec. Publ. Am. Geog. Soc. 35* (1960).
6. K. R. Fladmark, *Archaeol. Surv. Can. Pap. 43* (1975); *Am. Antiq.* **44**, 55 (1979).
7. A. Sutherland Brown and H. Nasmith, *Can. Field Nat.* **76**, 209 (1962); A. Sutherland Brown, *B.C. Dep. Mines Pet. Resour. Bull.* **54**, 1 (1968).
8. J. J. Clague, R. W. Mathewes, B. G. Warner, *Can. J. Earth Sci.*, in press.
9. J. J. Clague, *Geol. Surv. Can. Pap. 80-35* (1981).
10. The radiocarbon dates are on macroscopic plant detritus (coarser than 250 μm), washed from noncalcareous sediments comprising volcanic and granitic detritus. Dates were corrected for isotopic fractionation.
11. R. W. Mathewes and J. J. Clague, *Can. J. Earth Sci.* **19**, 1185 (1982).
12. J. Clague, J. R. Harper, R. J. Hebda, D. E. Howes, *ibid.*, p. 597.
13. J. J. Clague, J. E. Armstrong, W. H. Mathews, *Quat. Res. (N.Y.)* **13**, 322 (1980).
14. Sources of data: Canadian Hydrographic Service charts 3714, 3802, 3894, and 3902; Canada Surveys and Mapping Branch Topographic Map NN-8/9.
15. Radiocarbon dates were provided by W. Blake, Jr. (Geological Survey of Canada). R. G. Long assisted in the field. We thank the Province of British Columbia, Ministry of Parks and Housing, for giving us permission to collect samples in Naikoon Provincial Park, and in particular we appreciate the cooperation of R. Roos. We thank W. B. Schofield and J. M. White who read a draft of the manuscript. This study was supported in part by grant A3835 from the Natural Sciences and Engineering Research Council of Canada.

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Chemical Composition of Acid Fog

Abstract. *Fog water collected at three sites in Los Angeles and Bakersfield, California, was found to have higher acidity and higher concentrations of sulfate, nitrate, and ammonium than previously observed in atmospheric water droplets. The pH of the fog water was in the range of 2.2 to 4.0. The dominant processes controlling the fog water chemistry appear to be the condensation and evaporation of water vapor on preexisting aerosol and the scavenging of gas-phase nitric acid.*

In the fall of 1981, a field study was initiated to determine the chemical composition of fog water in the Los Angeles basin. Results show that the fog water is significantly more acidic and concentrated with respect to chemical composition than cloud and rain water collected in southern California. Liljestrand and Morgan (*1*) determined the chemical composition of rain in Los Angeles and reported that light, misting rainfalls had the highest acidity (*2*). Earlier fog water studies (*3–5*) in nonurban environments have reported concentrations of major

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Table 1. Ranges in concentrations observed during six fog events in the Los Angeles area during 1981 and 1982 (*11*). Representative concentrations for other fog, cloud, and rain samples are presented for comparison. The ranges shown in the values for this study are from

Location	*N*	Date	*p*H	Concentration (μeq/liter)					
				H^+	Na^+	K^+	NH_4^+	Ca^{2+}	Mg^{2+}
Pasadena	4	11/15/81	5.25–4.74	5.6–55	12–496	4–39	370	19–360	7–153
Pasadena	4	11/23/81	4.85–2.92	14–1,200	320–500	33–53	1,290–2,380	140–530	89–360
Lennox	8	12/7/81	5.78–2.55	2–2,820	28–480	6–160	1,120–4,060	44–4,350	17–1,380
Lennox	3	12/17/81	2.81–2.52	1,550–3,020	80–166	19–40	950–1,570	73–190	43–99
Bakersfield*	3	1/14/82	3.07–2.90	850–1,260	151–1,220	39–224	5,370–10,520	165–1,326	20–151
Pasadena*	1	1/17/82	2.25	5,625	2,180	500	7,870	2,050	1,190
Los Angeles rain (volume-weighted means at nine sites)		1978–1979	5.4–4.4	4–39	4–37	0.24–4.9	1–36	3.9–17	1.7–11
Coastal California fogs		9–10/76			78–944	8–26	1–578	9–102	17–175
Whiteface Mountain		7–8/80	4.2–3.2	63–630	1–55	1–6	4–310		
Fog and clouds, U.S.S.R.		1961–1964	5.3–4.7	5–20	30–104	15–44	33–100	20–50	17–83

*[Na^+], [K^+], [Ca^{2+}], [Mg^{2+}], and [NH_4^+] for filtered aliquots.

ions comparable to those reported for cloud (*6, 7*) and rain (*8*) water. However, urban fogs tend to form under more polluted conditions than clouds. Our research program expands upon these earlier studies in an attempt to focus on the chemical and physical processes that occur in the atmospheric aqueous phase before a precipitation event. In the Los Angeles basin, fog and cloud water processes may represent a significant pathway for SO_2 and NO_x oxidation and for the concomitant production of acidity. Furthermore, morning fog and low clouds along the coast have been strongly correlated with high SO_4^{2-} aerosol concentrations during the afternoon in the Los Angeles basin (*9*).

In this study, fog water was collected with a rotating arm collector (*10*). Droplets impact in slots along the ends of the arm and are driven outward by centrifugal force into sample collection bottles which serve effectively to isolate the collected liquid. In cloud chamber tests, the lower particle size cutoff for this collector was estimated to be 8 μm. Two of the collection sites were in the Los Angeles basin (Pasadena and Lennox), and the third was located in the San Joaquin Valley near Bakersfield. The Pasadena site was located in a residential neighborhood 25 km from downtown Los Angeles; the Lennox site, 2 km from the Los Angeles International Airport, was adjacent to a freeway and near two power plants and one oil refinery; and the site in the San Joaquin Valley was located in Oildale, which is surrounded by secondary oil recovery operations.

The concentration ranges of major chemical components observed during six separate fog events are listed in Table 1. These ranges represent the low and high values measured in time-sequenced samples over the duration of the particular fog events (*11*).

The first fog event in Pasadena followed a day with good air quality; the second fog event in Pasadena was preceded by a hazy day. Concentrations of most ions in the second fog event were much higher than in the first. The third and fourth fog events were sampled in Lennox on nights of dense coastal fog. Smog and dense haze had persisted throughout the day preceding the third fog event, accompanied by high ambient NO_x concentrations along the coast. These samples had even higher concentrations than the Pasadena fog samples. In addition, the fog water contained a significant amount of solid material, especially the final sample taken as the fog dissipated. Most of the particles remained suspended in the samples after standing for several days, which suggests that they were too small to have been collected unless incorporated in larger droplets.

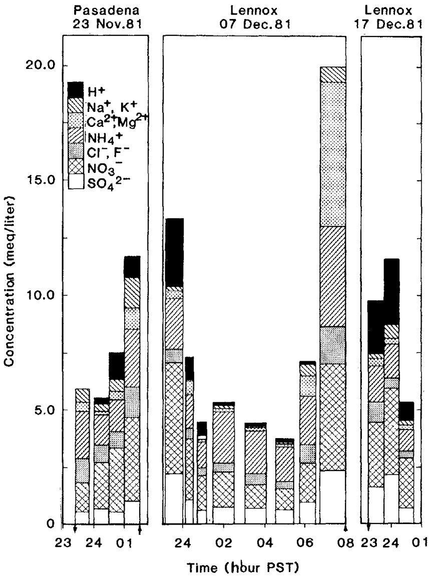

Fig. 1. Ionic composition in serial samples collected during three Los Angeles fog events; *PST*, Pacific standard time. The width of each bar represents the sampling interval. Fog formation and dissipation (that is, the beginning and end of individual fog events) are indicated by arrows. Fog had formed at least 1 hour prior to the taking of the first sample on 7 December 1981; sampling on 17 December 1981 ended before the fog dissipated. The effect of dilution and concentration can be seen in terms of the proportional changes in ionic concentration.

A single fog event at Bakersfield was monitored during a period of extended fog throughout the entire San Joaquin Valley. The southern portion of the valley has a number of oil fields in which steam-injection oil recovery methods are used. Consequently, the sulfur emissions are high for a nonurban, agricultural area. The fog water analyses, which were characterized by low *p*H values (2.9) and high [SO_4^{2-}] (5.0 meq/liter), [NO_3^-] (5.1 meq/liter), and [NH_4^+] (10.5 meq/liter), reflect the dichotomous land use in the San Joaquin Valley.

The last sample, a single fog water sample, was collected on the night of 17 January 1982 in Pasadena. The *p*H of this sample (2.25) was unusually low with corresponding high [NO_3^-] (12 meq/liter), [SO_4^{2-}] (5 meq/liter), and [NH_4^+] (8 meq/liter); however, the duration of this fog event was relatively short (~ 1 hour).

The concentrations of the major components in the California fog samples were significantly higher than in previously reported samples of fog, cloud, and rain water (Table 1). The observed values of [SO_4^{2-}], [NO_3^-], [NH_4^+], and [H^+] were 10 to 100 times higher than the earlier values. Values of [Na^+], [K^+], [Ca^{2+}], [Mg^{2+}], and [Cl^-] were high but more in line with values reported for fog sequential samples during individual events with the exception of the sixth event. For the comparison data, the ranges represent many events.

Concentration (μeq/liter)				Concentration (mg/liter)		Reference
F^-	Cl^-	NO_3^-	SO_4^{2-}	Fe	CH_2O	
120	56–280	130–930	62–380	0.094–2.1		
180–410	480–730	1,220–3,520	481–944	0.92–1.77	3.1–3.5	
115–395	111–1,110	820–4,560	540–2,090	0.34–24	4.6–12.8	
180–500	90–197	2,070–3,690	610–1,970	1.02–2.08		
126–242	203–592	3,140–5,140	2,250–5,000		6.1–14.4	
637	676	12,000	5,060			
	5–52	11–44	7–56	0.004–0.17		(*1*)
	96–1,230	23–234	52–490			(*5*)
11–54	1–15	7–190	40–800			(*7*)
	59–177	2–13	13–185			(*4*)

and cloud water in other areas. High values of [CH_2O], [Fe], [Mn], and [SO_3^{2-}] (30 to 260 μeq/liter) were also found. The observed concentrations of S(IV) appear to be in excess of those predicted by Henry's law considerations, although formation of sulfonic acid derivatives and iron sulfito complexes can account for this apparent discrepancy (*12*).

Figure 1 illustrates the changes in total ionic concentration with respect to time for three fog events. A concave trend in the profile of concentration versus time (decreasing at the beginning and rising toward the end) was observed. Changes in the absolute concentration of individual ions that are proportional to the changes in total concentration indicate that water vapor condensation and the evaporation of fog droplets are the dominant processes. Sharp decreases in concentration during the first few hours of the fogs in Lennox were due primarily to initial droplet deliquescence on preexisting aerosol. Similarly, most of the increase in concentration that was observed as the fogs dissipated was due to evaporation and the regeneration of fine aerosol. These physical effects apparently play a dominant role in determining fog chemistry in the Los Angeles basin.

The dominant ions in the fog water were NH_4^+, H^+, NO_3^-, and SO_4^{2-}, and their highest concentrations were observed after days of dense haze. During the early phases of the Lennox fogs, these ions make up ≥ 90 percent of the total ionic concentration. This result suggests that preexisting aerosol is a major determinant of the chemical composition of fog water, since these four species are the major components of the daytime aerosol haze (*13*).

In Los Angeles, the equivalent concentration ratio of NO_3^- to SO_4^{2-} in fog water was about 2.5, which is comparable to the reported emission ratio (*9*). The corresponding ratio in Los Angeles precipitation was close to 1.0 (*1*). In the Bakersfield fog, the same ratio was ~ 1.

The observed changes in fog water composition may have resulted either from chemical changes in the droplets or from the advection of different air masses over the sites. In Pasadena, [H^+] and [NO_3^-] increased simultaneously as a function of time; this result suggests the transport of HNO_3 or N_2O_5 into the droplets (*14*). On 7 December 1981 in Lennox, [NH_4^+] doubled from the third to the fourth sampling period while there was a corresponding decrease in [H^+]. Transfer of gaseous NH_3 into the droplets could account for this neutralization. However, the delay in the [NH_4^+] increase after the onset of fog suggests that the advection of fog formed on condensation nuclei with different characteristics was responsible. During the last few hours of that event, an increase in [Ca^{2+}], [Mg^{2+}], and [Fe] was observed. This increase coincides with the morning rush hour traffic on the adjacent freeway and can be attributed to the incorporation of road and soil dust into the fog. The fogs in Lennox initially exhibited a high acidity that was progressively neutralized, whereas the fogs in Pasadena became more acidic during a fog event. This result suggests differences in the composition of the aerosol preceding the fog at each site and differences in the transfer characteristics from gas or solid to liquid.

The results of this study show that the concentrations of major chemical species in fog water collected at three sites in Los Angeles and Bakersfield are significantly higher than previously reported in atmospheric water droplets. The chemistry of fog water in Los Angeles appears to be dominated by the composition of the haze-forming aerosol that precedes it. Subsequent effects of condensation and evaporation control the observed concentrations. Secondary aerosol, which has high [NH_4^+], [H^+], [NO_3^-], and [SO_4^{2-}], deliquesces initially to give a concentrated fog water. Further condensation of water results in dilution. After initial formation, the fog water appears to incorporate additional NH_3, HNO_3, and calcareous dust. As the fog dissipates by evaporation, higher concentrations are again observed.

In light of the inordinately high concentrations of acidic components found in Los Angeles fog, further research is needed to determine the role of aqueous atmospheric droplets in SO_2 and NO_x conversion and acidity transport processes. High [H^+], [NO_3^-], and [SO_4^{2-}] found in fog water may have a significant effect on health and on materials and plants in urban areas such as Los Angeles and in nonurban areas such as Bakersfield.

JED M. WALDMAN
J. WILLIAM MUNGER
DANIEL J. JACOB
RICHARD C. FLAGAN
JAMES J. MORGAN
MICHAEL R. HOFFMANN*
Environmental Engineering Science,
W. M. Keck Laboratories,
California Institute of Technology,
Pasadena 91125

References and Notes

1. H. M. Liljestrand and J. J. Morgan, *Environ. Sci. Technol.* **12**, 1271 (1978); *ibid.* **15**, 333 (1981); H. M. Liljestrand, thesis, California Institute of Technology, Pasadena (1980).
2. J. J. Morgan and H. M. Liljestrand, *Report Ac-2-80* (California Air Resources Board, W. M. Keck Laboratory, California Institute of Technology, Pasadena, 1980).
3. H. Houghton, *J. Meteorol.* **12**, 355 (1955).
4. O. M. Petrenchuk and V. M. Drozdova, *Tellus* **18**, 280 (1966).
5. E. Mack and U. Katz, *Report CJ-6017-M-1* (Calspan Corporation, Buffalo, N.Y., 1977).
6. H. Mrose, *Tellus* **18**, 266 (1966); T. Okita, *J. Meteorol. Soc. Jpn.* **46**, 120 (1968); C. S. Martens and R. C. Harriss, *J. Geophys. Res.* **78**, 949 (1973); R. E. Falconer and P. D. Falconer, *ibid.* **85**, 7465 (1980); R. Castillo, personal communication.
7. P. D. Falconer, Ed., *Publication 806* (Atmospheric Sciences Research Center, State University of New York, Albany, 1981).
8. V. M. Drozdova and E. P. Makhon'ko, *J. Geophys. Res.* **75**, 3610 (1970); L. Granat, *Tellus* **24**, 550 (1972); C. V. Cogbill and G. E. Likens, *Water Res.* **10**, 1133 (1974).
9. G. R. Cass, thesis, California Institute of Technology, Pasadena (1977); *Environ. Qual. Lab. Mem. 5* (California Institute of Technology, Pasadena, 1975).
10. The Caltech rotating arm collector was modified from an original design by E. J. Mack and R. Pilie [U.S. Patent 3885532 (1975)]. The impaction surfaces move at a velocity of approximately 50 m/sec. A sampling velocity that is much greater than the ambient wind speed serves to minimize the bias due to anisokinetic sampling [K. R. May, in *Airborne Microbes*, P. H. Gregory and J. L. Monteith, Eds. (Society for Gener-

al Microbiology, Cambridge, England, 1967), p. 60]. Thermodynamic and mass transfer calculations suggest that evaporation of the fog water is insignificant during the time of collection.

11. Immediately after collection, the *p*H of the sample was measured and aliquots were separated for later analyses. Major metal cations were determined by atomic absoption spectrophotometry and major anions by ion chromatography. Both NH_4^+ and CH_2O were determined by standard colorimetric methods. Ultrex grade HNO_3 was added to preserve the trace metals; SO_3^{2-} was stabilized by reaction with CH_2O at *p*H 4.
12. L. D. Hansen, L. Whiting, D. J. Eatough, T. E. Jensen, R. M. Izatt, *Anal. Chem.* **48**, 634 (1976).
13. B. R. Appel, E. L. Kothny, E. M. Hoffer, J. J. Wesolowski, *Adv. Environ. Sci. Technol.* **9**, 315 (1980).
14. J. H. Seinfeld, *Air Pollution* (McGraw-Hill, New York, 1975).

15. Financial support was provided by the California Air Resources Board (grant AO-141-132), and logistical support was provided by the South Coast Air Quality Management District. We thank G. Cass, D. Lawson, and J. H. Seinfeld for assistance.

* To whom correspondence should be addressed.

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Longevity of Guard Cell Chloroplasts in Falling Leaves: Implication for Stomatal Function and Cellular Aging

Abstract. *Guard cell chloroplasts in senescing leaves from 12 species of perennial trees and three species of annual plants survived considerably longer than their mesophyll counterparts. In* Ginkgo biloba, *stomata from yellow leaves opened during the day and closed at night; guard cell chloroplasts from these leaves showed fluorescence transients associated with electron transport and photophosphorylation. These findings indicate that guard cell chloroplasts are highly conserved throughout the life-span of the leaf and that leaves retain stomatal control during senescence.*

Deciduous trees shed their leaves in autumn as an adaptive strategy for survival at low temperatures. Before leaf abscission, many compounds are catabolized and transported into perennial branches for further reutilization in the next growing season (*1*). Having a high nitrogen content, mesophyll chlorophyll is degraded and recycled; loss of chloroplast integrity is one of the earliest events in leaf senescence (*1*, *2*). Because of chlorophyll degradation, leaves turn yellow and photosynthetic capacity declines as senescence progresses, with abscission occurring over a period of several days or even a few weeks, depending on the species and environmental conditions.

The fate of guard cell chloroplasts during leaf senescence is unknown (*1*). Chloroplasts are a highly conserved feature of guard cells, and guard cell chloroplasts are the only green plastids in the epidermis of the leaves of most higher plants (*3*, *4*). Using fluorescence microscopy, we monitored chlorophyll degradation in senescing leaves of *Ginkgo biloba* and found that guard cell chloroplasts were brightly fluorescent in leaves where mesophyll fluorescence was no longer detectable (*5*).

We quantified the degradation of mesophyll and guard cell chloroplasts at different stages of senescence by measuring the chlorophyll fluorescence intensity at 685 nm. We found that chloroplast fluorescence in single guard cells remained stable throughout the senescing process, whereas mesophyll fluorescence declined steadily (Fig. 1). Furthermore, yellow leaves collected at the time of abscission (*6*) and kept in the laboratory in a humidified Plexiglas chamber under ambient light and at room temperature retained fluorescing guard cell chloroplasts for 10 days.

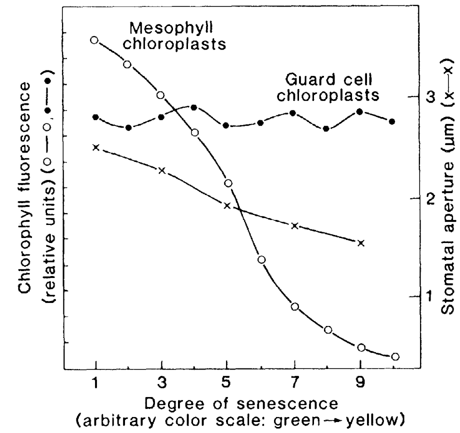

Fig. 1. Chlorophyll fluorescence and stomatal apertures in senescing leaves of *Ginkgo biloba*. Yellow leaves from trees growing near the laboratory were ranked visually by color, and mesophyll and guard cell chlorophyll fluorescence was measured in a Nonospec 10 microfluorospectrophotometer mounted on an American Optical optical microscope. Actinic light was supplied by a 50-W mercury lamp filtered with a BG12 exciting filter, a OG515 barrier filter, and a 500 nm dichroic beam splitter. Relative fluorescence intensity at 685 nm was recorded from the digital readout of the microspectrophotometer within seconds after the opening of an electronic shutter blocking the light path. Mesophyll fluorescence was measured in the adaxial side of the leaf with a ×20 objective. Fluorescence from guard cell chloroplasts was measured in single guard cells from epidermal peels, at ×400 magnification. Each point is the average of 18 readings in three different leaves. Stomatal apertures were measured microscopically with an ocular micrometer in peels made a few minutes after gathering the leaves at midmorning (light intensity, 1.2 to 1.4 mmole m^{-2} sec^{-1}). Each point is the average of 90 measurements; standard errors were less than 20 percent of the means.

A survey of yellowing leaves of trees from several perennial species growing in the vicinity of the laboratory showed that prolonged survival of guard cell chloroplasts was common. Yellow leaves from *Citrus limonia* (lemon), *Diospyrus virginiana* (persimmon), *Populus* sp. (poplar), *Prunus armeniaca* (apricot), *P. cerasifera* (cherry plum), *P. domestica* (plum), *P. glandulosa* (almond), *P. persica* (peach), *P. persica nucipersica* (nectarine), *Punica granatum* (pomegranate), and *Quercus* sp. (oak) exhibited fluorescing guard cell chloroplasts whereas the chloroplasts of mesophyll cells had lost all or most of their fluorescence. Furthermore, observations of old, senescing leaves in growing plants from *Commelina communis* (dayflower), *Vicia faba* (faba bean), and *Phaseolus vulgaris* (bean) showed that guard cell chloroplasts in these annuals also retained their fluorescence much longer than their mesophyll counterparts. Thus, the extended longevity of guard cell chloroplasts appears to be a widespread phenomenon in senescing leaves from both annual and perennial plants.

In isolated mesophyll chloroplasts, chlorophyll fluorescence intensity and electron transport rates decline steadily with age (*7*). The stability of fluorescence levels in guard cell chloroplasts from yellow leaves thus constitutes evidence of their integrity. Their functional competence was further ascertained by measurements of chlorophyll *a* slow fluorescence transients, which are correlated with electron transport and photophosphorylation (*8*, *9*).

Segments from green or yellow leaves from *G. biloba* were viewed on a microscope slide under low magnification and dark-adapted for several minutes. At time zero, the segments were illuminated with blue light from a mercury lamp of an epifluorescence illuminator, interfaced with an electronic shutter. Fluorescence emission at 685 nm was measured with a microspectrophotometer (*10*). The voltage output from the microspectrophotometer was fed into a microcomputer, sampling every 100 msec. Sampling and opening and closing of the shutter were under software control. The amount of actinic light provided by a ×4 objective