by a lengthy series of trial counting measurements (the authors can supply details).

As a test of our overall method and instrumentation, tree-ring samples of known age from sequoia (31 to 37 B.C. and A.D. 36 to 42) and oak (A.D. 1844 to 1850) were dated (*12*). Four counters designated C-4, C-5, C-6, and C-12 were used. The first three counters had volumes of 5 cm^3; the fourth, 7.5 cm^3. The proportional counter guard ring was used for background suppression.

The results of these dating measurements are given in Table 2. In all cases, the measured age agrees with the known age to within the limit of error at the level of 1 σ.

We have not as yet dated any samples of known age with the counters placed in the second (NaI well-crystal) anticoincidence shield. We have, however, measured dead CO_2 counter backgrounds in that shield and have found them to be one-half to one-third of those observed in the first shield (Table 2). The actual counting data for modern carbon and background are given in Table 1, where our pressurized counters in the two shields are compared with previously reported small ^{14}C counters.

The data in Table 2 were derived from counts of 45 days each for the oxalic acid and wood samples and 30 days for background in counters C-4, C-5, and C-6. We now feel that a reasonable counting time is 10^5 minutes for each, that is, about 70 days. Although 7 months are thus needed for an overall experiment, as noted above eight (or four) samples are measured simultaneously, and we may hope that with experience it may not prove necessary to redetermine modern carbon and background each time a date is measured.

It is perhaps premature to compare the use of small counters with Van de Graaff accelerators and cyclotrons in the dating of small samples—in the latter cases the state of the art is rapidly advancing, and the machines in use are not at all optimized as yet for dating studies. For very old or very small samples, or both, it would appear that the accelerator may have greater potential. The accelerator will certainly be the quicker, but also the more expensive, way to date samples of carbon in the 10-mg range. In addition, the accelerator consumes the carbon sample during the dating process.

Using a counter of 5 cm^3 containing CO_2 at 4 atm, counted for 69.4 days, we calculate that, for samples of age 0, 1, 2, and 3 times the ^{14}C half-life, the errors are ± 90, 150, 270, and 510 years if the ring shield is used and ± 80, 130, 200, and 350 years if the NaI crystal is used.

We estimate that a complete counting system set up for the simultaneous operation of eight proportional counters would cost on the order of $40,000. However, most conventional ^{14}C dating laboratories now functioning could probably adapt such small detectors to their existing equipment at much less expense.

GARMAN HARBOTTLE
E. V. SAYRE, R. W. STOENNER
Department of Chemistry,
Brookhaven National Laboratory,
Upton, New York 11973

References and Notes

1. D. E. Nelson, R. G. Korteling, W. R. Stott, *Science* **198**, 507 (1977); C. L. Bennett, R. P. Beukens, M. R. Clover, H. E. Gove, R. B. Liebert, A. E. Litherland, K. H. Purser, W. E. Sondheim, *ibid.*, p. 508.
2. C. L. Bennett, R. P. Beukens, M. R. Clover, D. Elmore, H. E. Gove, L. Kilius, A. E. Litherland, K. H. Purser, *ibid.* **201**, 345 (1978).
3. T. H. Maugh II, *ibid.* **200**, 635 (1978).
4. R. A. Muller, *Lawrence Berkeley Lab. Rep. LBL 5510* (1976); *Science* **196**, 489 (1977).
5. ———, E. J. Stephenson, T. S. Mast, *Science* **201**, 347 (1978).
6. T. P. Kohman and P. S. Goel, in *Radioactive Dating* (International Atomic Energy Agency, Vienna, 1963), p. 395.
7. M. A. Geyh, in *Radioactive Dating and Methods of Low-Level Counting* (International Atomic Energy Agency, Vienna, 1967), p. 575.
8. H. Oeschger, *ibid.*, p. 13.
9. Funded by the Conservation-Analytical Laboratory of the Smithsonian Institution under contract FC-5-53083 (Dr. R. M. Organ, laboratory director).
10. F. H. Kummer, R. W. Stoenner, R. Davis, Jr., *Brookhaven Natl. Lab. Rep. 16972* (1972).
11. R. Davis, Jr., *Brookhaven Natl. Lab. Rep. 24674* (1978).
12. Tree-ring samples were supplied by the Applied Science Center for Archaeology, University of Pennsylvania.
13. E. K. Ralph, H. N. Michaels, M. C. Han, *Mus. Appl. Sci. Center Archeol. (Univ. Pa.) Newsl.* **9** (No. 1), 1 (1973).
14. Research performed at Brookhaven National Laboratory under contract with the U.S. Department of Energy.

1 March 1979; revised 29 May 1979

Chrysotile Asbestos in a California Recreational Area

Abstract. *Dustfall along roads and trails being used recreationally in the Clear Creek area of San Benito County, California, located in the New Idria serpentinite, was found to be 90 percent or more chrysotile asbestos. Personal samplers worn by motorcyclists using one of the trails showed concentrations of airborne fibers ranging from 0.3 to 5.3 fibers per milliliter, according to methods prescribed for monitoring occupational exposures. The present workplace standard for brief exposures to asbestos is 10 fibers per milliliter; 5 fibers per milliliter is the proposed standard. The average total dust concentration estimated from personal samplers was approximately 20 milligrams per cubic meter of roughly 90 percent chrysotile. To our knowledge, this is the first demonstration of asbestos exposures of this magnitude, in size ranges known to be pathogenic, resulting from natural deposits not associated with mining, milling, or industrial use.*

Analysis of a sample of rock from the Clear Creek area in San Benito County, California, submitted by the Bureau of Land Management (BLM) of the U.S. Department of the Interior in mid-1977, showed a high concentration of chrysotile. The area is in a serpentine massif, part of the New Idria–San Benito body, known to contain this form of asbestos (*1*, *2*). A warning sign was posted, and additional studies were requested to determine whether chrysotile fibers were present in the air and water of the area. These studies were made during the spring and summer of 1978 and are the subject of this report.

The BLM supervises some 60,000 acres of federally owned land located in the southern Diablo Range, about 115 miles southeast of San Francisco. A portion of this land, comprising the Clear Creek watershed, has been designated a recreational area. Among its major attractions are sparsely vegetated and erosion-resistant slopes in one of the serpentine-rich areas. These attract adventurous cyclists. Of the 41,150 users of the area in 1975, about 85 percent were operators of off-the-road vehicles, principally motorcycles; the others were campers, hunters, or rock collectors. Most of the motorcyclists were weekend users and included many families with children.

The geology and mineralogy of the New Idria–San Benito serpentinite have been described by a number of observers (*2–4*). It is one of the larger of several major ultramafic complexes in California and appears as an outcropping more than 6 km wide and 20 km long at the southern end of the Diablo Range. In 1958, Rice and Matthews of the California Division of Mines (*5*) identified the white, fibrous, matted material that covers many hillsides in the area as chrysotile; its commercial development began in the early 1960's. Mumpton and Thompson (*2*) have reported on the mineralogy and possible origin of what has been called the Coalinga asbestos deposit. Their analyses of a large number of samples collected on the surface, in mine pits,

0036-8075/79/1109-0685$00.50/0

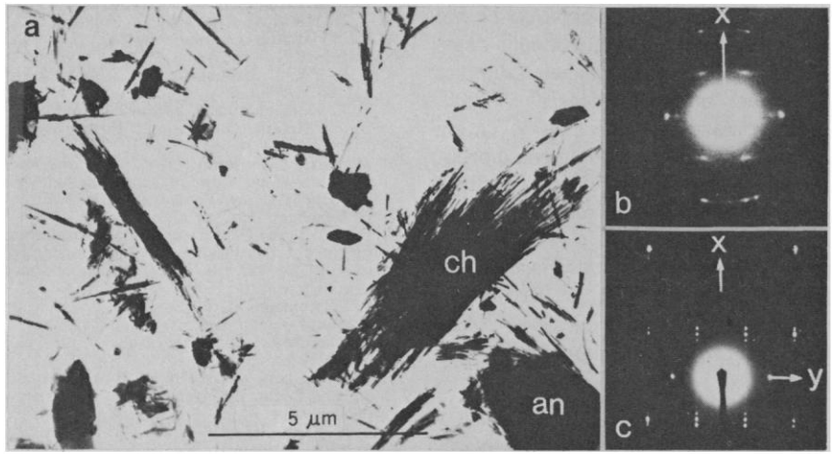

Fig. 1. (a) Electron micrograph of a typical dustfall sample collected along Clear Creek road, showing chrysotile fibers, including a chunk (*ch*) and an occasional flake of antigorite (*an*). (b) Diffraction pattern of chrysotile. (c) Diffraction pattern of antigorite.

and from drill cores have confirmed the extremely high chrysotile concentrations. Production from three mines is now about 100,000 tons annually. None of the producing mines, however, is near the Clear Creek recreational area, and mining operations have no effect on the quality of air or water in that area.

We report here (i) an analysis of dustfall along the main road and side trails and (ii) a determination of the concentrations and size characteristics of airborne dust collected from the personal samplers.

Dustfall collected at various sites during the period from 13 to 17 May 1978 provided samples large enough for analysis and permitted a quantitative estimate of the dust clouds generated by passing vehicles. A modification of the American Public Health Association standard method (*6*) was used. Ten cylindrical steel cans with a capacity of 3.8 liters and openings 15 cm in diameter were mounted about 1 m above ground level at distances from less than 1 to 150 m from the main road and side trails. After 2 weeks, during which more than 750 vehicles had passed along the main road, the cans were tightly covered and taken to the laboratory. The contents were weighed and the total dustfall expressed as grams per square meter per month of 30 days. The mineral composition was studied by x-ray powder diffraction (XRD) to determine the approximate proportion of serpentine. In five samples transmission electron microscopy (TEM) was used to determine morphological characteristics, diffraction patterns, and chemical composition.

The four containers near the road were the most heavily loaded with dust, the amounts ranging from 35 to 90 g/m² per month. Dustfall along two smaller motorcycle trails were 22 and 23 g/m² per month. Containers 15 to 150 m from the road collected 2 to 6 g/m² per month; these probably approach local background levels. The lower dustfall far from the road indicated that wind was a negligible factor in aerosol generation and dust dispersion.

XRD patterns were obtained with about 40 mg of material from each of the six most heavily loaded dustfall samples.

Table 1. Concentrations of airborne fibers longer than 5 μm detected by light microscopy and concentrations of total dust collected on personal samplers.

Location of sampler	Position of rider on line	Concentration	
		Fibers per milliliter	Total dust (mg/m³)
Motorcyclists	1	0.9	0.97
Run 1,	2	5.6	31
5.1 km	3	2.3	19
(15 minutes)	4	4.3	21
	5	2.8	59
	6	5.3	61
Run 2,	1	0.6	0.0
1.2 km	2	3.0	12
(5 minutes)	3	3.0	37
	4	4.9	20
	5	4.4	13
	6	3.1	22
Run 3,	1	0.3	1.0
10.3 km	(2)*	1.9	17
(41 minutes)	(3)	3.2	13
	(4)	2.9	11
	(5)	1.7	9
	(6)	2.9	22
Ranger, 5 km (47 minutes)		0.4	1.7
Fixed site (48 minutes)		0.2	0.4

*Positions not fixed after rider 1.

Examination by TEM of five samples revealed that more than 90 percent of the particles were fibrous, with the morphology and electron diffraction pattern of chrysotile (Fig. 1, a and b). Occasional flakes of antigorite (Fig. 1c) were also observed. In one sample, the number of chrysotile fibers per milligram of dust was estimated by TEM as being 10^7. Figure 2 is representative of most samples.

To obtain data on actual exposures of those using the area, three series of aerosol samples were collected in the breathing zones of six motorcycle riders on 18 June 1978. During the first two series the riders were asked to maintain their starting order. In the third and longest run, they were free to change their sequence in the group as they desired. Samples were collected and analyzed as recommended by the National Institute for Occupational Safety and Health and prescribed by the Occupational Safety and Health Administration (OSHA) for the monitoring of occupational asbestos exposures (*7*, *8*). At the sampling rate (1.8 liter/min), the capture or face velocity of an open-faced filter cassette 33 mm in diameter (holding a filter 37 mm in diameter) is only 43 mm/sec and is clearly not isokinetic with average vehicle velocities, which ranged from 4 to 6 m/sec (9 to 13 miles per hour). From a health perspective this is mitigated by the fact that inspiratory velocities through the mouth and nose are similarly anisokinetic. Because the nose and filter cassettes were similarly aligned, these determinations are believed to provide a good approximation of personal exposures for the riders.

Two other samples of airborne dust were collected on personal samplers. One was worn by a BLM ranger during a typical patrol in his pickup truck, along approximately 5 km of the main dirt road. The other was placed at a fixed site 12.9 km north of the main road. There were no strong winds to affect the latter samples.

Fiber counts of all aerosol samples were made in the prescribed manner, using phase-contrast light microscopy at 450× magnification. Samples were also examined by TEM, using a direct transfer method (*9*) that permitted observation and counting of fibrils, fiber bundles, chunks, and tangles of fibers. In addition, the mass of total dust was determined and expressed as milligrams per cubic meter of air sampled.

Table 1 shows concentrations of fibers longer than 5 μm ranged from 0.3 to 5.3 fibers per milliliter. Of these 65 to 80 per-

cent were less than 3 μm in diameter; 75 to 95 percent were less than 4 μm in diameter. The current OSHA standard for occupational exposures sets a limit of 2 fibers per milliliter as a time-weighted average (TWA) over a working day, and a ceiling of 10 fibers per milliliter for a 15-minute sampling period (*8*). The proposed OSHA standard (*10*) is 0.5 fiber per milliliter as a TWA, and 5 fibers per milliliter as a ceiling. The ceiling standards are appropriate for comparison with concentrations in the present study because of the short sampling periods. It can be seen that many of the values are not far below the current ceiling standard and that two are greater than the proposed ceiling standard.

The high mass to fiber ratio and the lack of a close correlation between mass and fiber concentrations largely reflect the deposition of numerous chunks of chrysotile, as depicted in Fig. 1a. Although many of these chunks appeared to be in a respirable size range (< 3 to 5 μm in diameter), they were not counted by light microscopy because they had length to diameter ratios less than 3 to 1 (*8, 10*). The potential dosage of fibers to the lungs would be much greater if the respirable chunks were broken down in vivo to individual fibers. In addition, the demonstration of large numbers of small fibers by electron microscopy (Table 2) would suggest total fiber exposures appreciably greater than indicated by the light microscope counts. The various categories cannot be added, however, because the pathogenicity of fibers shorter than 5 μm is not well established (*9*).

The concentrations of asbestos found at Clear Creek can be compared with those reported by Rohl *et al.* (*11*) related to the use of quarried serpentine rock in Montgomery County, Maryland, estimated as containing more "than a few tenths of a percent" of chrysotile, and possibly "several percent or more." Using a rubout technique, in which fibrils counted by TEM were converted to mass, they reported from 500 to 4700 ng/m^3 of chrysotile in aerosol samples. Corresponding fiber concentrations, determined by optical microscopy, ranged from 0.0 to 0.05 fiber per milliliter longer than 5 μm. On the other hand, mass concentrations found at Clear Creek were as high as 61 mg/m^3, that is 61 $\times 10^6$ ng/m^3, and fiber concentrations were as high as 5.3 fibers per milliliter. A sample collected 8 m from the Clear Creek road, outside the visible dust cloud, contained 0.4 mg/m^3, or 85 times the highest concentration at a similar distance from the source, as reported by Rohl *et al.* Since

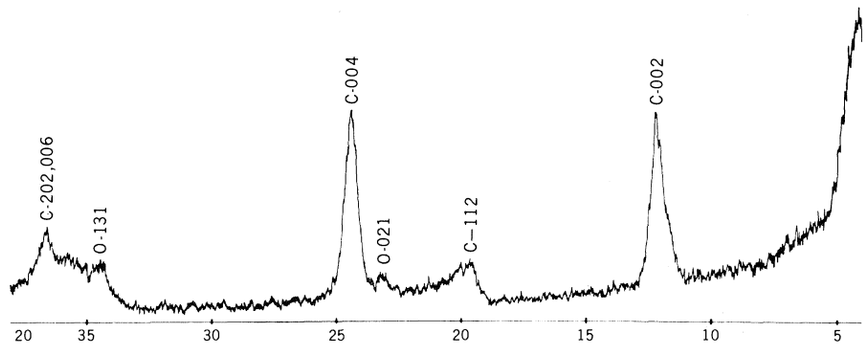

Fig. 2. X-ray diffractometer powder pattern of dust sample; this is a typical scan representative of most samples, consisting of almost pure chrysotile (*C*), as verified by TEM; with minor olivine (*O*).

the dust at Clear Creek was nearly 100 percent chrysotile, the total mass of dust provides a reasonable approximation of the mass of asbestos. Rohl *et al.* described the chrysotile concentrations found in Montgomery County as being about 10^3 times greater than those typically found in urban ambient air in the United States. The concentrations found in Clear Creek were therefore from 10^5 to 10^7 times greater than the urban air concentrations used by Rohl *et al.* for comparative purposes. Equally important, high concentrations of fibers longer than 5 μm were found, compared with very low concentrations of such fibers found in the Montgomery County air.

This is the first instance of which we are aware in which naturally occurring airborne asbestos, not the result of mining, milling, or other industrial activity, has been shown to occur at levels comparable to those in the workplace. It reflects, of course, the extremely high chrysotile content of the New Idria serpentinite. The airborne fibers in the Clear Creek recreational area have diameters, lengths, and concentrations that could be hazardous to health if inhaled over long periods of time. It is doubtful that the numbers of fibers that have been inhaled to date by intermittent users of the area will constitute a measurable risk, although admittedly this cannot be documented by epidemiological evidence. One can be encouraged in this view by the experience of Canadian chrysotile miners. As McDonald *et al.* (*12*) have reported, and this has been confirmed by Nicholson *et al.* (*13*), miners exposed to unmilled chrysotile do not appear to have as high an incidence of lung cancer as those who handle or use milled chrysotile, and the incidence of mesothelioma among the former group appears quite low. McDonald *et al.* reported that only those with the highest cumulative exposures were clearly at excessive risk. In spite of this, sustained or frequently repetitive exposures to concentrations such as reported at Clear Creek, especially by children, do not seem justifiable.

The reported airborne concentrations approach the maximum that might be expected from natural sources, in view of the unusually high concentrations of chrysotile in the rocks and soil, the dry terrain, and the dust-generating activities that were taking place. It is quite likely, however, that appreciable concentrations of airborne fibers may occur in other areas with serpentine outcrops.

The need for restrictions of use or other protective measures for the general public should be considered. Occupa-

Table 2. Comparison of light and electron microscopic counts of fibers collected on personal samplers worn by motorcyclist No. 4 and by the ranger.

Sample	Count			
	Light microscope	Electron microscope		Chunks (number per milliliter)
	Length > 5 μm (fibers per milliliter)	Length > 5 μm (fibers per milliliter)	Length < 5 μm (fibers per milliliter)	
Motorcyclist				
Run 1	4.3	1.0	13	3.3
Run 2	4.9	23	188	61
Run 3	2.9	6.5	42	24
Ranger	0.4	0.1	3.8	0.5

tional health standards provide guidelines, but they are not legally applicable or appropriate in view of the nature of the exposures and the population at risk. An industrial plant in which the observed concentrations prevailed even intermittently would be required to take action to meet OSHA regulations. Environmental Protection Agency standards that prohibit visible emissions containing asbestos presumably would be violated if an industrial site permitted such dust clouds. The federal government probably cannot ignore exposures in a recreational area under its control if its guiding principle is that there is no threshold level of carcinogenic effect for asbestos so that "exposures must be reduced as low as feasible" (*8*). This demonstration of high natural exposures further emphasizes the need for better understanding of dose-response relationships between asbestos and malignancies to guide those who must set levels of acceptable exposure.

W. C. COOPER
2150 Shattuck Avenue, Berkeley, California 94704
J. MURCHIO
W. POPENDORF
School of Public Health, University of California, Berkeley 94720
H. R. WENK
Department of Geology and Geophysics, University of California, Berkeley

References and Notes

1. S. J. Rice, *Calif. Div. Mines Geol. Miner. Inf. Serv.* **16-9**, 1 (1963).
2. F. A. Mumpton and C. S. Thompson, *Clays Clay Miner.* **23**, 131 (1975).
3. E. B. Eckel and W. B. Myers, *Calif. J. Mines Geol.* **42**, 81 (1946).
4. E. H. Bailey, W. P. Irwin, D. L. Jones, *Calif. Div. Mines Geol. Bull. 183* (1964).
5. S. J. Rice and R. A. Matthews, California Division of Mines and Geology, unpublished report.
6. Intersociety Committee, *Methods of Air Sampling and Analysis*, M. Katz, Ed. (American Public Health Association, Washington, D.C., 1977), pp. 585-587.
7. Occupational Safety and Health Administration, *Fed. Reg.* **37**, 11318 (1972).
8. ———, *ibid.* **40**, 47652 (1975).
9. J. S. Harington, *Ann. Anat. Pathol.* **21**, 155 (1976).
10. R. C. Cooper and J. C. Murchio, *Proceedings of the 5th Annual Conference on Environmental Toxicology* (Aerospace Medical Research Laboratory, Wright Patterson Air Force Base, Ohio, 1974; available from National Technical Information Service, Springfield, Va.), pp. 61-73.
11. A. N. Rohl, A. M. Langer, I. J. Selikoff, *Science* **196**, 1319 (1977).
12. J. C. McDonald, M. R. Becklake, G. W. Gibbs, A. D. McDonald, C. E. Rossiter, *Arch. Environ. Health* **28**, 61 (1974).
13. W. J. Nicholson, R. Lilis, I. J. Selikoff, paper presented at the International Conference on Health Hazards of Asbestos Exposure, New York Academy of Sciences, New York, 24 June 1978.
14. We appreciate the support of the Bureau of Land Management the Department of the Interior and especially thank T. Parker and D. Lehman for their assistance. Janet Teshima and Arturo DeLeon provided invaluable technical services. One of the authors (H.R.W.) is indebted to the National Science Foundation for a grant (EAR-00127) that made possible acquisition of the electron microscope used in the study.

12 January 1979; revised 9 March 1979

Fossil Counterparts of Giant Penguins from the North Pacific

Abstract. *New fossils of giant, flightless penguinlike birds have been found in late Oligocene and early Miocene rocks in Japan and in the state of Washington. These birds belong to the order Pelecaniformes, in the extinct family Plotopteridae, previously known by a single fragment of bone from California. Hindlimb and pelvic morphology is most similar to that of Recent anhingas, but the wing is paddlelike and remarkably convergent toward penguins and flightless auks. Both the Plotopteridae and the giant penguins became extinct by the middle Miocene, possibly because of competition from seals and porpoises.*

Fossils have recently revealed an unknown avian family which includes some of the largest swimming birds yet discovered. These marine birds were flightless, wing-propelled divers resembling penguins (Sphenisciformes) in their locomotory adaptations but belonging to the unrelated order Pelecaniformes (pelicans, cormorants, anhingas, and allies). They are known only from mid-Tertiary rocks bordering the North Pacific.

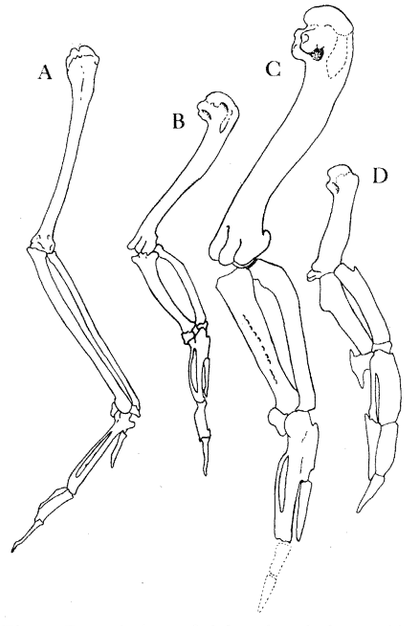

Fig. 1. Dorsal view of right wing skeleton. (A) Anhinga (Pelecaniformes); (B) great auk (Charadriiformes); (C) plotopterid (Pelecaniformes; largest Japanese species); and (D) penguin (Sphenisciformes). The similarities between the three wings on the right are due to convergence. The plotopterid (C) evolved from an ancestor with a wing like that of the anhinga (A). Drawn to scale.

Knowledge of these birds began with a single humeral end of a coracoid described from an early Miocene deposit in southern California as a new genus and species, *Plotopterum joaquinensis* (*1*). With exceptional insight, Howard (*1*) diagnosed this as a new family of Pelecaniformes, the Plotopteridae, having affinities with anhingas and cormorants (Anhingidae, Phalacrocoracidae) but showing adaptations for wing-propelled diving similar to those of auks (Charadriiformes, Alcidae) and penguins. However, because of its very fragmentary nature, *Plotopterum* drew little attention.

Newly discovered fossils fully confirm Howard's original conclusions. All are late Oligocene or early Miocene (*2*, *3*) and consist of single elements or associated partial skeletons from six localities in Japan and one partial skeleton from the state of Washington. Of the major skeletal elements, only the end of the bill remains unknown.

Coracoids associated with the specimen from Washington and with two from Japan clearly show that the new fossils are referable to the Plotopteridae. Counting *Plotopterum*, at least three genera can be recognized (*3*). Differences in size indicate a minimum of four species from Japan, and the Washington specimen could represent a fifth. Considerable taxonomic diversity within the family is indicated.

Plotopterum, by far the smallest known member of the family, was the

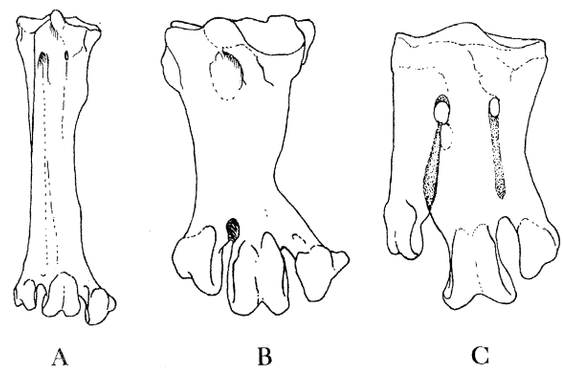

Fig. 2. Anterior view of right tarsometatarsus. (A) Anhinga (Pelecaniformes); (B) plotopterid (Pelecaniformes; largest Japanese species); and (C) penguin (Sphenisciformes). Not to scale.

0036-8075/79/1109-0688$00.50/0