

JAN 21 1959

GRAY HERBARIUM

arnoldia

The Magazine of the Arnold Arboretum

METASEQUOIA AFTER FIFTY YEARS





U.S.
A-418

JUN 28 1999

GRAY HERBARIUM

arnoldia

METASEQUOIA AFTER FIFTY YEARS

VOLUME/NUMBER 58/4 • 59/1 1998–1999

Arnoldia (ISBN 004-2633; USPS 866-100) is published quarterly by the Arnold Arboretum of Harvard University. Second-class postage paid at Boston, Massachusetts.

Subscriptions are \$20.00 per calendar year domestic, \$25.00 foreign, payable in advance. Single copies of this issue are \$10.00; copies of most earlier issues are \$5.00. Remittances may be made in U.S. dollars, by check drawn on a U.S. bank; by international money order; or by Visa or Mastercard. Send orders, remittances, change-of-address notices, and all other subscription-related communications to: Circulation Manager, *Arnoldia*, The Arnold Arboretum, 125 Arborway, Jamaica Plain, Massachusetts 02130-3500. Telephone 617/524-1718; facsimile 617/524-1418; e-mail arnoldia@arnarb.harvard.edu.

Postmaster: Send address changes to
Arnoldia Circulation Manager
The Arnold Arboretum
125 Arborway
Jamaica Plain, MA 02130-3500

Karen Madsen, *Editor*
Andy Winther, *Designer*

Editorial Committee

Phyllis Andersen
Ellen S. Bennett
Robert E. Cook
Peter Del Tredici
Gary Koller
Stephen A. Spongberg
Kim E. Tripp

Copyright © 1999. The President and Fellows of Harvard College

Cover: Metasequoia Valley, Xiaohe Commune, Hubei Province, China, photographed in 1980 by Stephen A. Spongberg.

Inside front cover: The foliage of *Metasequoia glyptostroboides* photographed by Rác & Debreczy.

Inside back cover: The fluted trunk of the *Metasequoia* on Meadow Road near the Hunnewell Building. It was grown from seed received from China in 1948.

Back cover: A grove of *Metasequoia* at Swarthmore College, Philadelphia, Pennsylvania. Photographed both winter and summer by Peter Del Tredici.

A BRIEF HISTORY

Page

- 4 How *Metasequoia*, the "Living Fossil," Was Discovered in China
H. H. Hu
- 8 Reminiscences of Collecting the Type Specimens of *Metasequoia glyptostroboides*
Hseuh Chi-ju
- 12 Notes on Chinese-American Botanical Collaboration
Karen Madsen
- 17 Another "Living Fossil" Comes to the Arnold Arboretum
E. D. Merrill
- 20 How to Fund Botanical Expeditions
- 23 "As remarkable as discovering a living dinosaur": Redwoods in China
Ralph W. Chaney
- 28 The Tree as Celebrity
- 33 *Metasequoia* and the Living Fossils
Henry N. Andrews
- 35 The California Academy–Lingnan Dawn-Redwood Expedition
J. Linsley Gressitt
- 40 An Ecological Reconnaissance in the Native Home of *Metasequoia glyptostroboides*
Kwei-ling Chu and William S. Cooper
- 47 *Metasequoia glyptostroboides*—Its Status in Central China in 1980
Bruce Bartholomew, David E. Boufford, and Stephen A. Spongberg

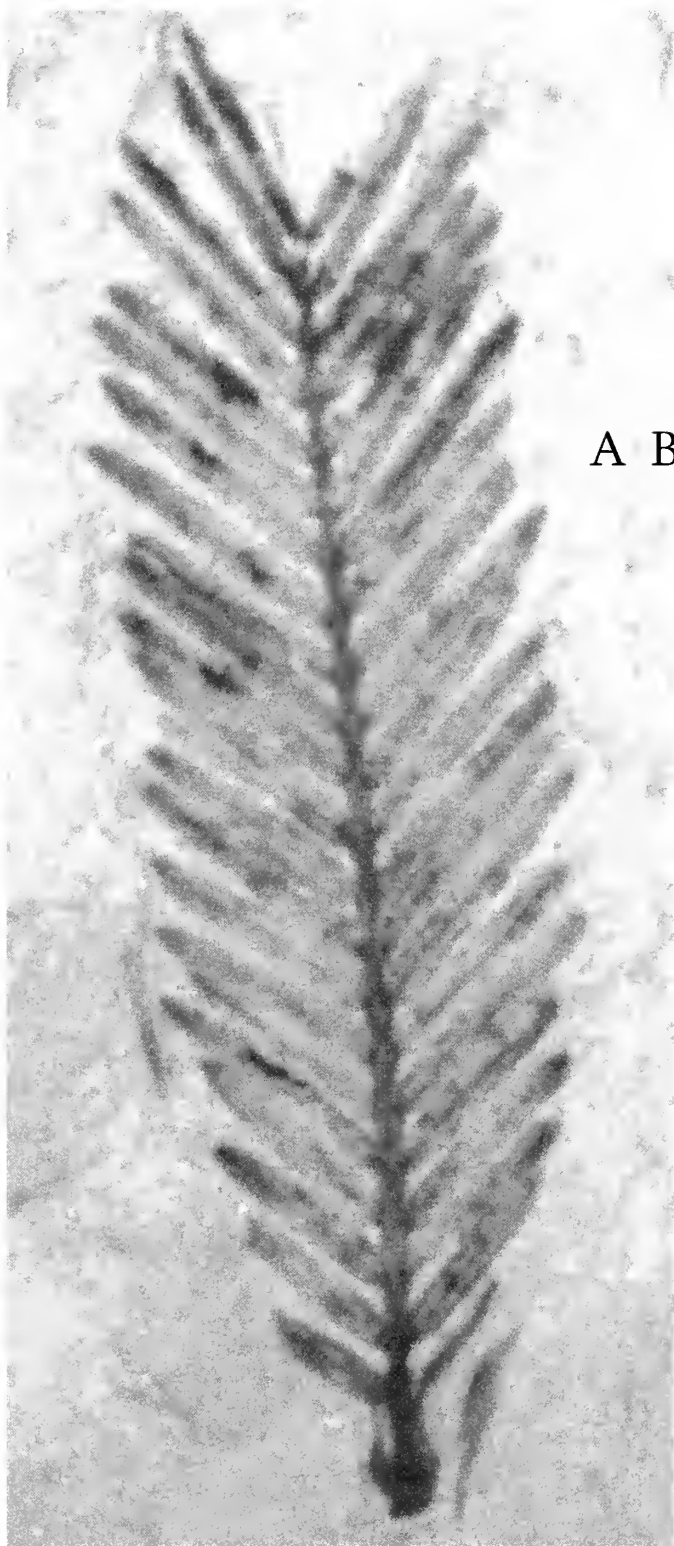
AN UPDATE

- 54 *Metasequoia*: An Overview of Its Phylogeny, Reproductive Biology, and Ecotypic Variation
Jianhua Li
- 60 From Fossils to Molecules: The *Metasequoia* Tale Continues
Hong Yang
- 72 *Metasequoia* Travels the Globe
Keiko Satoh
- 76 *Metasequoia glyptostroboides*: Fifty Years of Growth in North America
John E. Kuser
- 80 A Guide to *Metasequoia* at the Arnold Arboretum
Karen Madsen
- 84 Chinese Names in Transliteration: A Conversion Table

M*etasequoia glyptostroboides*, dawn redwood, living fossil, dinosaur-age tree: by any name, it's *Arnoldia's* pick for tree-of-the-century. The story has unusual crossover appeal. For botanists, the living fossil betokened a missing link in evolutionary relationships; paleobotanists looked to it for a picture of life in Mesozoic times. For historians of science, it illuminates Chinese-American botanical collaborations in war-torn China. Horticulturists were challenged to save it from extinction; foresters anticipated a new source of wood. Adventure abounded, and most certainly journalists recognized the story's potential: the tree's "common" name was invented early in 1948 in the offices of the *San Francisco Chronicle*, preceding the scientific name by several months.

In the first part of this issue, a brief history of *Metasequoia*, 1941–1980, is constructed from the writings of those most directly involved. As a plant collector remarked, "It is only natural that people, when admiring this species of primeval tree, should wonder about its original habitat and should wish to know how it was discovered." How true, and next is the wish to know how it fares today and what's been learned about it. The second part of the issue comprises botanical, paleobotanical, and horticultural updates.

Firsthand accounts from 1948 communicate the awesome presence of the trees and the uniqueness of the valley where they are concentrated, both in its unusual flora and its state of preservation. To the scientists, it seemed entirely natural that the valley's settlers should have recognized in the large, old trees something worthy of a special respect, even veneration. Some part of that recognition also comes to those who discover the tree today. We at the Arnold Arboretum are very pleased that our institution played a part in distributing *Metasequoia glyptostroboides* around the globe. An early explorer predicted that it would someday be judged one of the most beautiful of existing trees. He was right, and this issue, as well as the Arboretum's logo, is our homage to this special tree and all who have promoted its well-being.



A BRIEF HISTORY

How *Metasequoia*, the "Living Fossil," Was Discovered in China

H. H. Hu

Professor Hsen Hsu Hu (1894–1968) was director of the Fan Memorial Institute of Biology in Beijing when he collaborated with Wan-Chun Cheng (1904–1983), professor of forestry at National Central University in Zhongjing, in naming and describing *Metasequoia glyptostroboides*. He had been among the first from his country to study botany in the West, and was the first Chinese botanist to receive a doctorate from Harvard University. Primary credit for the discovery of *Metasequoia glyptostroboides* belongs to Professor Hu and his Chinese colleagues.

In the winter of 1941 Professor T. Kan of the Department of Forestry of the National Central University journeyed from Hupeh to Szechuan, and saw on the roadside at Mou-tao-chi in Wan Hsien a large deciduous tree that was called by the natives *shui-sa*, or water fir. This attracted the attention of Professor Kan. Unfortunately no specimens were collected at that time as all the leaves had fallen off. Next year Professor Kan requested Mr. Lung-hsin Yang, the principal of the Agricultural High School, to collect herbarium specimens for him. But these were not identified. In the summer of 1944 Mr. T. Wang, a staff member of the Central Bureau of Forest Research, went to western Hupeh to explore the forests at Shen-lung-chia, and was asked by Mr. Lung-hsin Yang to go to western Hupeh by way of Wan Hsien and Enshi in order to investigate the *shui-sa* at Mou-tao-chi.

At Mou-tao-chi Mr. Wang collected herbarium specimens of leafy branches and fruits of this tree and thought it to be *Glyptostrobus pensilis* Koch, or *shui-sung*, the water pine, which is a common deciduous coniferous tree in Kwangtung province found also in Kiangsi. Mr. Chung-lung Wu, an assistant in the department of forestry of the National Central University,

met Mr. Wang, who gave him a branchlet of the water fir with two cones. Mr. Wu presented these to Professor W. C. Cheng of the same department, who considered this tree not a *Glyptostrobus* but a new genus, on account of the opposite character of the peltate fruiting scales, which differ from those of *Glyptostrobus* although the deciduous linear leaves are somewhat similar.

Professor Cheng then sent his assistant, Mr. C. Y. Hsieh, to go twice to Mou-tao-chi in February and May 1946, and these trips resulted in the collection of specimens of flowers and young fruits of this water fir, from which Professor Cheng understood the morphology of this tree more clearly. In the autumn of the same year Professor Cheng sent to me fragments of herbarium specimens Mr. Hsieh collected and asked my opinion about this new genus, which he thought to be closely allied to the American genera *Sequoia* and *Sequoiadendron*, the California coastal redwood and the famous big tree.

It happened that I had a reprint of a paper by a Japanese paleobotanist, Mr. S. Miki, instructor in Kyoto University, entitled "On the Change of Flora in Eastern Asia since Tertiary Period," in which he proposed the new generic name *Metasequoia*, based on two fossil species that

were formerly known as *Sequoia disticha* Heer and *Sequoia japonica* Endo, both found in the Pliocene beds near Tokyo. He found his new genus *Metasequoia* differing from the true *Sequoia* in the long stalk and in the opposite scales of the fruits. I had on hand also a paper by another Japanese paleobotanist, Professor S. Endo, entitled "A New Palaeogene Species of *Sequoia*," in which he published a new species, *Sequoia chinensis* Endo, from Eocene beds in Fushun coal mines in southern Manchuria and Kawakami coal mines in southern Saghalien. This I found to be also a species of *Metasequoia*. Thus I published a paper in the *Bulletin of the Geological Society of China*, Vol. 26, 1946, entitled "Notes on a Palaeogene Species of *Metasequoia* in China," in which I transferred *Sequoia chinensis* Endo to the genus *Metasequoia* and announced the discovery of a living species of this remarkable tree in Wan Hsien of Szechuan province.

I then communicated with Professor Ralph W. Chaney of the Department of Paleontology of the University of California, who had not seen either Miki's or Endo's paper. On the basis of the descriptions I supplied to him, Professor Chaney found that *Sequoia macrolepis* Heer, *S. fastigiata* Sternberg, *S. concinna* Heer, *S. Langsdorfii* Heer, *S. Nordenskioldi* Heer, *S. Reichenbachii* Heer, and *S. Heerii* Lesquereux all belonged to this new genus *Metasequoia*. He considered the discovery of this living *Metasequoia* the most interesting in botany in a century.

After Mr. Hsieh made the collection of herbarium specimens [1946] Professor Cheng sent a



The tree from which the type specimen of *Metasequoia glyptostroboides* was collected, in Modaoqi village in west central China. The drawing came to the Archives of the Arnold Arboretum through the courtesy of Dr. H. H. Hu.

specimen to Dr. E. D. Merrill for examination. I wrote to Dr. Merrill telling him my identification of this new tree to the fossil genus *Metasequoia* and requested him to send \$250 to enable Mr. Hsieh to go to Szechuan to collect seeds. Dr. Merrill sent the money and Mr. Hsieh flew to Chunking in the autumn of 1947 and then went to Mou-tao-chi where he collected large quanti-

tics of seeds,¹ which Professor Cheng sent to Dr. Merrill, who distributed them to 76 institutions and persons interested in trees for propagation purposes. I also distributed these seeds to a few institutions and persons abroad, and many important institutions of botany and forestry in China have been given seeds also for propagation purposes.

Last winter Professor Chaney wrote to me expressing his wish to visit the *Metasequoia* region to make personal investigations. Early in February this year Professor Chaney flew to Nanking and with Mr. Hsieh both flew to Chunking, from where they journeyed to Mou-tao-chi and Shui-sa-pa in Lichuan Hsien of Hupeh province. In these bandit-infested regions they explored for three weeks and took photographs and wood-borings and collected herbarium specimens of plants associated with this tree.² I met Professor Chaney in Nanking in the latter part of March. We discussed the phylogeny of *Metasequoia* and *Sequoia*, and the relationship between the families of Metasequoiaceae, Taxodiaceae, and Cupressaceae.³

At the same time we started the movement to establish a committee in the Chinese government for the conservation of *Metasequoia*, which is on the verge of extinction as there are found no more than 1,000 large and small trees of this living fossil in existence, and the peasants are still cutting the trees for interior finishing purposes. Now such a committee has been established, the ministries of interior, education, and agriculture, the Academia Sinica, the National Central Museum, and the Fan Memorial Institute of Biology all have representatives



W. C. Cheng, professor of forestry at National Central University in Nanjing and co-author of the botanical determination of *Metasequoia glyptostroboides*, journeyed to Sichuan and Hubei to see the tree for himself in August 1948. Here he stands on the buttressed trunk of the type tree in Modaoqi.

to participate in this work, looking forward to the establishment of a *Metasequoia* National Park in the type region: Professor Chaney was appointed a foreign member of this committee. Professors Merrill and Chaney have jointly made an appeal to subscribe money for this purpose.

Mr. Hwa has journeyed extensively in Szechuan and Hupeh to search for all the trees of *Metasequoia* growing in these regions. *Metasequoia* was first discovered at Mou-tao-chi of Wan Hsien in Szechuan province.⁴ There are found three trees, the largest of which is 33 meters (108 feet) in height and 3.3 meters (10 feet) in diameter at the swelling buttress and 2 meters (6.6 feet) in diameter at breast height; the other two are small trees. These are all the *Metasequoia* trees found within the boundary of Szechuan province.⁵ In Chien-nan county of Lichuan Hsien of Hupeh province Mr. Hwa discovered another tree measuring 30 meters (98

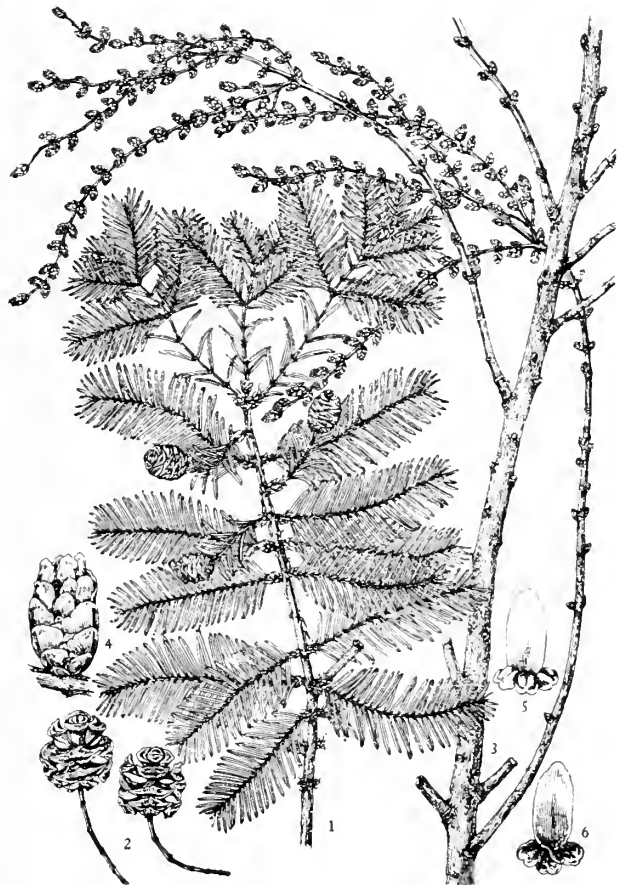
¹ It was C. T. Hwa, not Mr. Hsieh (Hsueh), who collected seeds in 1947.

² Chaney and most other sources give the date as early March; and once again, it was C. T. Hwa who accompanied Chaney. He and his party explored the region for three days, rather than three weeks.

³ In their 1948 paper, "On the New Family Metasequoiaceae and on *Metasequoia glyptostroboides*, a Living Species of the Genus *Metasequoia* Found in Szechuan and Hupeh," H. H. Hu and W. C. Cheng proposed a new family, Metasequoiaceae, for the genus *Metasequoia*.

⁴ The borders of Sichuan and Hubei have since been shifted, placing Mo-tao-chi in Hubei province.

⁵ Since then, the part of Sichuan in which *Metasequoia* grew wild has become the administrative unit Chongqing Shi.



This drawing of the botanical characters of the *Metasequoia glyptostroboides* accompanied the publication of Hu and W. C. Cheng's formal description in the *Bulletin of the Fan Memorial Institute of Biology* (1948) *New Series* 1(2): 153-161.

feet) in height, 1 meter (3.3 feet) in diameter at breast height; another in Wang-cha-ying measuring 35 meters (115 feet) in height and 2.1 meters (7 feet) in diameter breast high. From Ta-pan-ying through Shui-sa-pa to Shio-ho, along valleys about 40 li long,⁶ there are large and small trees, altogether about 1,000 individuals, among which the large ones there number about 100, the tallest measuring 30 meters (98 feet) in height. The natives frequently dig the wild young trees or make cuttings and plant them along the rice fields or streams or before their doors. North from Wan Hsien and south down to Shui-sa-pa, the *Metasequoia* region extends to an area about 800 square kilometers, with Shui-sa-pa as the distribution center. Altitudinally *Metasequoia* is distributed from 800 to 1,350 meters (2,600 to 4,400 feet). Within this region there is plenty of rainfall and a large amount of humidity, cool in summer and with heavy snow in winter. Its ideal site for propagation is the highlands in central and eastern and southwestern China at an altitude of about 1,000 meters (3,300 feet).

As Professor Chaney returned to Nanking, Mr. Hwa was left behind to make further exploration. He traveled extensively in western Hupeh. Though no further discovery of *Metasequoia* trees has been made, he discovered several large tracts of forests that have not been discovered before. He made extensive collections of herbarium specimens. Surely there will be new species of plants discovered.

⁶ *Li* is a traditional Chinese measure of distance; it has been standardized at 500 meters, or 547 yards.

Reminiscences of Collecting the Type Specimens of *Metasequoia glyptostroboides*

Hsueh Chi-ju

On a visit to Kunming in 1984, Dr. Peter S. Ashton, then director of the Arboretum, happened to meet Professor Hsueh of the Southwestern Forestry College and suggested that he write a short memoir of his early involvement with *Metasequoia glyptostroboides*. The article, originally published in *Arnoldia* in 1985, is included here for its sharp, very fresh sense of excitement about the discovery; no anthology devoted to *Metasequoia glyptostroboides* would be complete without it.

Forty years ago [1945], I happened to see the specimen of *Metasequoia glyptostroboides* that Mr. Wang Zhang had collected at Modaoqi village in Wanxian county, China. The next year, following the route Mr. Wang had taken, I made two trips there to collect perfect specimens and to conduct further investigations. Although I am old now, the two trips are still fresh in my memory.

I graduated from the Forestry Department of the former National Central University at Zhongjing (Chungking) in 1945 and then worked on the gymnosperms, studying for a master's degree under the guidance of Professor Cheng Wanjun. One day in 1945, Wang Zhang, who worked at the Central Forestry Experimental Institution, sent a cone-bearing specimen collected at Modaoqi to Professor Cheng for identification. Its vernacular name was *shui-shan* (water fir), and it was somewhat similar to *Glyptostrobus pensilis* (*G. lineatus*). After making a preliminary identification, Professor Cheng considered that it might belong to a new taxon of the Gymnospermae, since the opposite arrangement of the leaves and cone scales differed from that of *G. pensilis* and other members of the Taxodiaceae.

Since the specimen Mr. Wang collected had no male inflorescences and since the cones had

been picked up from the ground, we didn't know how the cones grew on the branches. In addition, we had no information on whether it was deciduous or evergreen, on its flowering season, or on its ecological characteristics and distribution.

Further research being necessary, Professor Cheng naturally advised me to collect some perfect specimens and to make an investigation. Since we had no funds and everybody was quite hard up, I could only go to the place on my own, carrying a few pieces of simple baggage and specimen-clips. I left Chungking city by steamboat and, after two days, arrived at Wanxian county, on the northern bank of the Changjiang (Yangtze) River. After crossing the river, I had to walk 120 kilometers [72 miles] to my destination. In 1946 I made two trips from Chungking to Modaoqi, in February and May, respectively, both times singlehandedly.

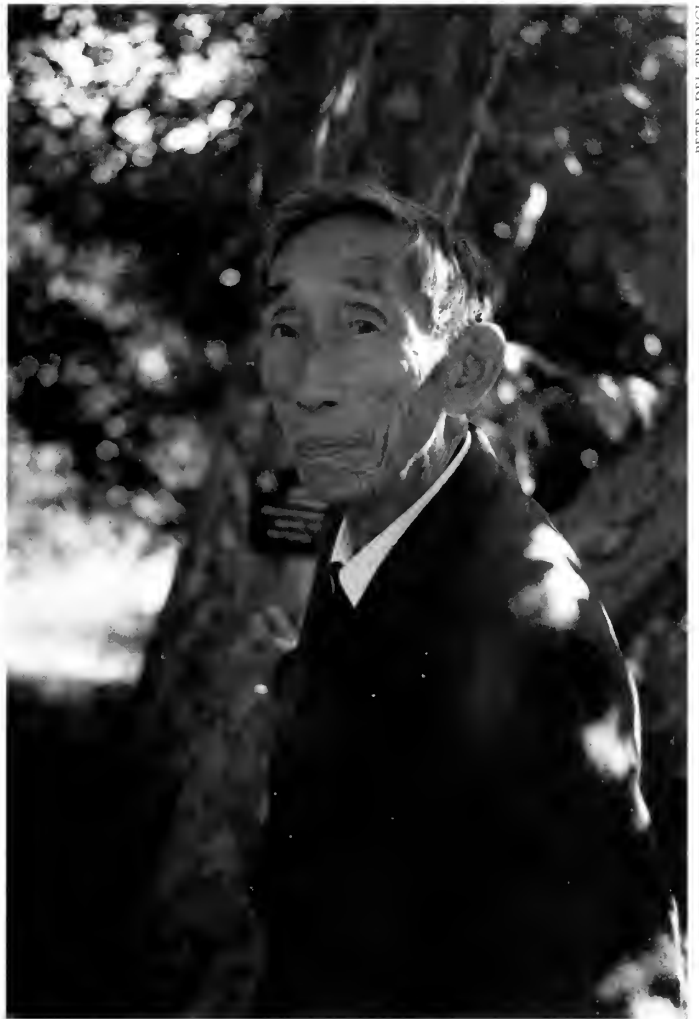
The First Trip to Modaoqi

I remember that on my first trip the boat was moored in Fengdu county for the first night. On a hill behind the county town was a temple regarded in the Old China as an inferno where the "Lord of Hell" reigned. Dead souls were supposed to go there to register. So I made use of this rare opportunity to take a solitary night

walk in this weird and dreadful place—evidence that I was full of vigor and curiosity in my youth.

At that time there was no highway from Wanxian county to Modaoqi village. My trip was very difficult, the trails threading through the mountains being less than one foot wide. The region was inhabited by the Tu minority and had been isolated from the outside world for ages. During the war of resistance against Japan, the Hubei provincial government moved to Enshi county in its neighborhood; thenceforward its intercourse with the outside world had somewhat increased. Since this region was located on the border between Sichuan and Hubei provinces, an area characterized by difficult and hazardous roads, murder and robbery occurred frequently. It was regarded as a forbidding place and was seldom visited by travelers.

On my trip, I set out from Wanxian and stayed at Changtanjing for the night. My fellow travelers were several peddlers. While we chatted around a fire at night, the innkeeper came to give us a warning: "If you go any farther you will travel along a narrow valley cut by the Modaoqi River. Travel will become more dangerous and threatened with robbery, which often occurs at dangerous turns of the river. Travelers from both directions are robbed by being jammed together, or 'rounded up.' Therefore, if you see no travelers coming your way for a long time, it is very likely that a robbery has occurred ahead, and you had better take care. Only a few days ago we witnessed such an incident in this vicinity." The innkeeper then gave a vivid and horrible description of a murder. The poor peddlers, my fellow travelers, were very frightened. They dared not go any farther and returned to Wanxian the next morning. As for me, I was bent on finding that colossal tree and collecting more specimens, so I resolutely continued my trip along the route marked out by Mr. Wang, without any fear or hesitation.



PETER DEL TREDICI

Professor Hsueh was photographed in October of 1996 when, accompanied by his daughter and granddaughter, he visited the Arnold Arboretum. His chief area of botanical interest is the bamboo family.

Finally, at dusk on the third day, I reached my destination safely. I set out immediately to search for that colossal tree despite hunger, thirst, and fatigue, and without considering where I would take my lodging. It was February 19th and cold. The tree was located at the edge of the southern end of a small street. In the twilight nothing was discernible except the withered and yellowed appearance of the whole tree. My excitement cooled.

"Am I to bring back just some dried branches?" I asked myself.

The tree was gigantic; no one could have climbed it. As I had no specific tools, I could



One of the many specimens of *Metasequoia glyptostroboides* that Professor Hsueh collected during his trip to Modaoqi. This specimen is in the herbarium of the Arnold Arboretum.

only throw stones at it. When the branches fell from the tree, I found, to my great surprise, that there were many yellow male cones and some female cones on the leafless branches. I jumped with joy and excitement. The weather being cold, many plants were not yet in flower. Since I was short of money, I returned to Chungking city three days later.

The Second Trip to Modaoqi

The second trip was in May of the same year, its purpose being to collect the cone-bearing specimens in addition to ascertaining the natural distribution of *Metasequoia* and the flora of the region. On my way to Modaoqi, about half a

day's walk from my destination, I came across a peasant carrying a fagot mixed with some *Podocarpus nagi*. The wood was said to have been cut from a nearby mountain. I took two twigs and pressed them as specimens. This indicated that *P. nagi*, another primeval gymnosperm, occurred in the vicinity.

This time I took measurements of the *Metasequoia* tree. It was 37 meters (about 122 feet) high and 7 meters (about 23 feet) in girth, and still grew vigorously.

To ascertain the distribution of *Metasequoia*, I interviewed many local people, but none of them knew. The innkeeper did tell me that a whole stretch of *shui-shan* trees might be found at Xiahoe, in Lichuan county, Hubei province, about 50 kilometers (30 miles) away. As I had almost exhausted my traveling allowance, and as communication was extremely inconvenient, I had to give up my attempt to extend my trip to that place. Nevertheless, the innkeeper had provided an important clue for a more thoroughgoing exploration later. All I could do was—taking the original spot as a center—to make a reconnaissance within the area I could cover in one day. In a few days I had collected more than one hundred specimens.

Two things impressed me deeply. One was that I came across whole stretches of *Geastrum* sp. (an earthstar fungus) mixed with small stones of a similar shape, forming a peculiar landscape. The other thing that impressed me was an incident. Not even by the day before my departure had I given up on the possibility of making a reconnaissance. At four in the afternoon of the last day, I met a traveler coming from the southeast and asked him where the *shui-shan* tree could be found. He told me that it could be got near a small village about 5 kilometers (3 miles) from where we were. Upon hearing this I almost broke into a run, intending to return to the inn before dark so that I might leave for Wanxian the next day. After trotting for a while, I met another peasant and asked him how far it was to the village. (I can't be sure now, but it may have been Nanpin village in Lichuan county.) "Five kilometers," he replied. Mountain people sometimes differ considerably in their gauge of distance.

I was wavering as to whether to go or not. If I should go, it was certain that I could not have returned to the inn before dark and that the innkeeper would worry. Then, too, I had already hired a man to carry the specimens for me; we had agreed on the next morning as the time for departure. I could not break my word! But finally I made up my mind to make another reconnaissance for *shui-shan*.

It was getting dark when I arrived at the small village. The villagers in their isolation seldom met outsiders, especially "intellectuals" such as I was. My arrival aroused their curiosity. They surrounded me, making all sorts of inquiries. But I was anxious to see the *Metasequoia* trees. When I was told that there were no such trees, I was very disappointed. However, I did not give up hope, and asked the villagers to accompany me to make one last reconnaissance. There was, indeed, no *Metasequoia*. I did collect some specimens of *Tsuga chinensis*, however.

I intended to return to the inn in spite of the dark night. However, the friendly villagers had already made arrangements for my food and lodging, and had warned me repeatedly of the frequent robberies on the way, insisting on my leaving the next day, escorted by some local people. Yet I could hardly fall asleep, thinking that I could not cause them so much trouble or break my word to the hired carrier. And then I thought that in the depth of the night there would be no "bandits," since there would be no travelers to rob. So at two in the morning I awoke my roommates, explaining to them the reason for my prompt departure, and left the villagers a letter of acknowledgment. Since the door was locked, I could only jump over the wall so as not to disturb others. In the moonlight I passed through stretches of dark pines, returning to the inn before dawn. That very day I left for Wanxian.

Geomancy Spared the Type Tree

Modaoqi was a very small village, to the southeast of which stood the Chiyue Mountains. Its altitude was 1,744 meters [about 5,755 feet]. At the time it was in Wanxian county, Sichuan province. It was so called because of its situation at the source of the river. As *modao* in Chinese means "knife-grinding" and suggests sinisterness, the name was changed to Moudao, which means "truth-seeking" in Chinese. At present it is under the jurisdiction of Lichuan county.

As the local people looked upon the *Metasequoia* as a sort of divine tree, they built a shrine beside it. Among the villagers there were quite a few traditions about the *Metasequoia*. As a result, the villagers considered its fruit-bearing condition to be an indication of the yield of crops, and the withering of its twigs or branches a forecast of someone's death. It was also rumored that, some time after the founding the Kuomin Tang government, some foreign missionaries who were passing through the village were willing to buy the tree for a big sum of money. The villagers refused to sell, however, because of the geomantic nature of the place. Thus, it was because of feudalistic superstition that the tree had survived. Its age is estimated at four hundred years.

With the advent of well-regulated highway communication, the poor village of the former days changed its aspect long ago. The *Metasequoia* tree, which had survived the ravages of time and is reputed to be a "living fossil," has not only persisted, but is being disseminated. Now *Metasequoia* trees are "settled" in many countries of the world. It is only natural that people, when admiring this species of primeval tree, should wonder about its original habitat and should wish to know how it was discovered.

Notes on Chinese-American Botanical Collaboration

Karen Madsen

Collaborations between Chinese botanists and their colleagues in the West began in the early part of this century. In many cases, the bonds that fostered those collaborations were forged at Western institutions, including the Arnold Arboretum and Harvard University Herbaria.

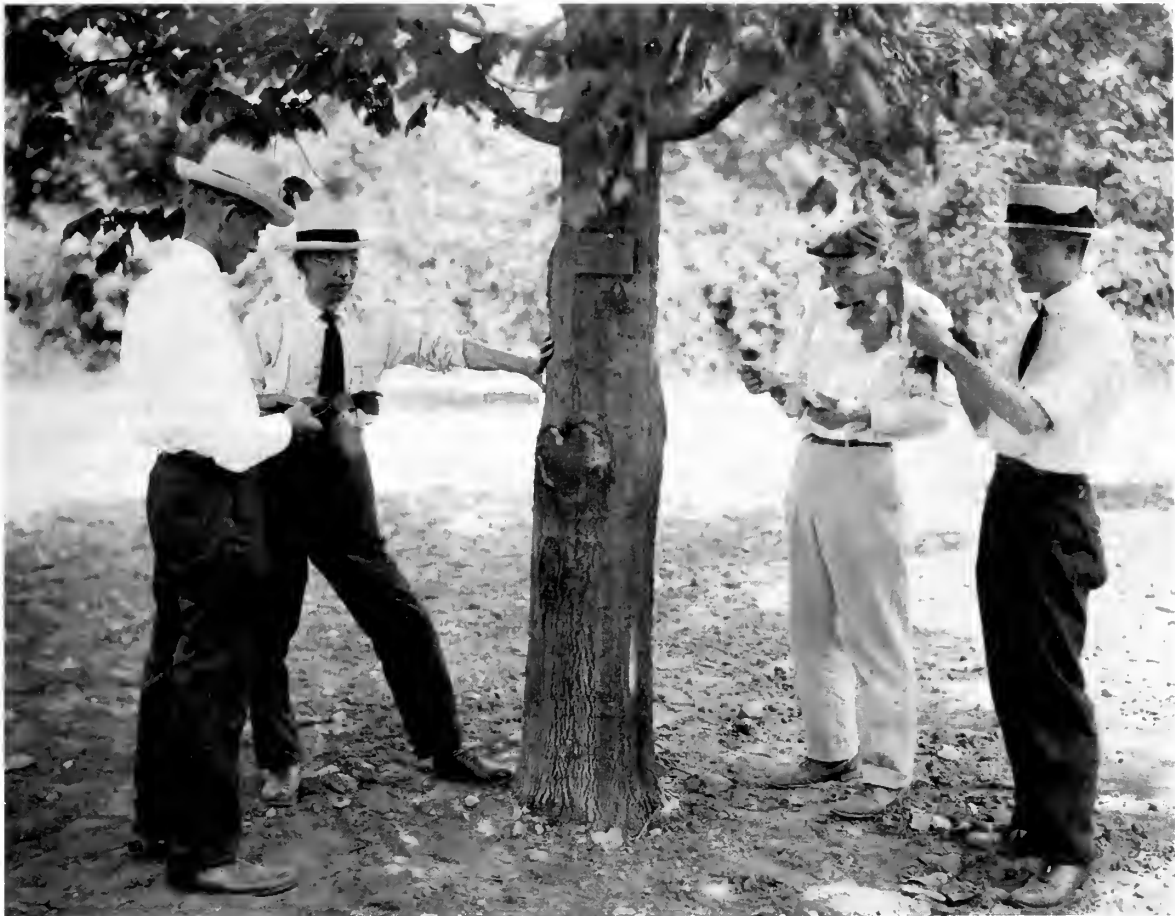
Modern science first gained a foothold in China with the overthrow of the Qing Dynasty in 1912 and the cultural revolution that followed in 1915. Botany began there as it had in the West, with systematics: the names and relationships of plants had to be established before other research could proceed.

Work in systematic botany was partly inspired by the many Western collectors who developed a fascination for the rich Chinese flora. One of these was Charles Sprague Sargent, first director of the Arnold Arboretum, who made the study of East Asian plants a major focus of the Arboretum early in this century. Sargent's interest had been aroused by Asa Gray's observation (1859) that at least forty genera of plants occur only in eastern Asia and northeastern North America, an indication that the two flora are closely related. For Sargent, this suggested eastern Asia as a source of new plants for New England, since the species of one region might grow well in the other. The Arboretum's success in growing seeds sent from Beijing by Emil Bretschneider, a Russian physician living there, confirmed Sargent's theory, and he began to acquire Chinese specimens actively, at first chiefly through European institutions. In 1907 he hired Ernest H. Wilson to collect in western China; later he employed the collector and ethnologist Joseph F. C. Rock. As the Arboretum's collection of Chinese plants grew, so did knowledge of China's flora, thanks largely to Alfred Rehder, curator of the Arboretum's herbarium.

But Rehder was only one of several Western botanists who extended the the world's scien-

tific knowledge of the Chinese flora. Others included the Regius Keeper of the Róyal Botanic Gardens at Edinburgh, William Wright Smith; Heinrich Handel-Mazzetti, an Austrian who collected extensively in China and published the seven-volume *Symbolae Sinicae* (1929–1937); and the American Elmer D. Merrill, who worked throughout his career to advance the study of botany in China. On his first visit there, in 1916, Merrill helped establish the herbaria at Lingnan University in Canton and at the University of Nanjing. He also collected plants in the vicinity of Canton with botanists from Lingnan and returned a year later for more extensive fieldwork. He identified plants for the herbaria of many institutions, including those at Lingnan, Nanjing, and the Fan Memorial Institute of Biology (Beijing). In his various directorships, beginning in 1916 at the Bureau of Science in Manila and continuing at the University of California's College of Agriculture, the New York Botanical Garden, and the Arnold Arboretum, he supported botanical exploration by Chinese institutions through cooperative arrangements.

Just as Americans had earlier been obliged to travel to European herbaria to study American plants, Chinese in the early part of this century were obliged to travel to American and European institutions to study Chinese plants. The China Foundation for the Promotion of Education and Culture sent students to the Royal Botanic Gardens at Kew and Edinburgh, Jardin des Plantes, the Berlin Botanic Garden, the New York Botanical Garden, and the Arnold Arboretum. Had the early Chinese botanists not been able to use the research collections at these



A. A. GRIFFIN ARCHIVES OF THE ARNOLD ARBORETUM

*Professor John G. Jack (left) and three of his Chinese students examining a black maple (*Acer saccharum* var. *nigrum*) photographed in the Arnold Arboretum during the summer of 1917.*

institutions, they would have had to begin their study of the flora of their country from the very beginning. Woon-Young Chun came to Harvard in 1915 specifically to use the rich collections at the Arboretum, because "it would take me a lifetime of travel to study what I can find out here about Chinese trees in a few years" (Haas 1988).

The Arboretum did not officially offer graduate instruction, but did admit special students who could pursue botanical research with the use of the Arboretum's herbarium, library, and living collections. Assistance was also available from the staff, usually in the person of John G. Jack. Chinese students often registered at the Arboretum's neighbor and fellow Harvard institution, the Bussey Institution for Research in Applied Biology, which offered graduate studies in subjects related to agriculture, such as genet-

ics, entomology, plant anatomy, and economic botany. In addition to Jack's work at the Arboretum—checking plant identifications, lecturing to field classes, and supervising the plantings—he was associated with both the Bussey and the Harvard Forest as assistant professor of dendrology and of forestry. He shared Sargent's interest in east Asian flora and in 1905 traveled to Japan, Korea, and China at his own expense to collect specimens for the Arboretum.

An enthusiastic and effective teacher, Jack went out of his way to help his Chinese students, often paying their wages for work at the Arboretum out of his own pocket or arranging Harvard loans for them. He helped them classify their plant specimens and prepare their manuscripts for publication. One of those students, Hsen Hsu Hu, maintained a warm correspondence with his teacher after his return to China



Undated photograph of H. H. Hu.

and honored him (and his relationship to Chinese botany) in the name of a new genus, *Sinojackia*. (Hu named another new genus in *Styracaceae*, *Rehderodendron*, for the Arboretum's taxonomist.)

Chinese students had been coming to America since shortly before the turn of the century; by the teens, 1,600 Chinese were studying in the United States. H. H. Hu was among the first generation of botanists to come to Harvard for graduate training. He had acquired an undergraduate degree at the University of California at Berkeley in 1916 and then returned to China for seven years, teaching at the Nanjing Higher Normal School (the predecessor of the National Southeastern University, Nanjing) and pursuing fieldwork in Zhejiang and Jiangxi provinces (Haas 1988, Li 1944).

Hu first made contact with the Arnold Arboretum by sending specimens, a standard method

used by Chinese botanists to establish relationships with eminent botanists in the West. In 1920 he sent Sargent a collection of woody specimens from Jiangxi Province, asking Sargent to identify them in return. Over the years, he built up the research collections at Southeastern University by attaching Sargent's identifications to an identically numbered duplicate set retained in Nanjing.

Hu was enrolled at the Bussey Institution from September 1923 to June 1925, during which time he took four forestry courses with John Jack. He left Harvard with a doctor of science degree and a thesis on the genera of Chinese flowering plants that was to be published in multiple volumes. Expectations for this pioneering generation were high. In his 1924–1925 annual report, Dean Wheeler of the Bussey Institution wrote:

[Hu's thesis] will be the foundation for all manuals on the flora of China and a necessary and valuable aid to students of the plant life of that extensive country. Professor Hu proposes to conduct vigorous explorations and studies of the complex and comparatively little known plant life of his native country, and in this work he will continue to have such assistance and cooperation as Professor Jack can give.

Hu's letters to Jack in the 1930s portray botanists full of energy and zest for the opportunities before them. The war with Japan began in 1931 and caused many upheavals, but none so great as to stop progress in science. In 1933 Hu wrote,

I believe if we can resist Japanese aggression, there will be a very important scientific renaissance in China. . . . The time for dallying about philosophy and political science and economic theories and revolutionary jargon is passed. We are setting heart to learn real things" (7/15/33).

Plant-collecting expeditions were mounted. Taking the advice of C. S. Sargent, Woon-Young Chun used his 1919 Sheldon Travelling Fellowship from Harvard to begin collecting plants on southern China's unexplored Hainan Island. He amassed a collection that by 1934 Hu described as "enormously large"; like many collections, it was shared with the Arnold Arboretum. Hu's collector, Mr. Wang, explored southwestern Sichuan and "penetrated southeast Tibet where Handel-Mazzetti and George Forrest and indeed

any white man have not penetrated." The yield was ten specimens of each of 10,000 numbers, or kinds of plants. Hu also directed a five-year investigation of Yunnan Province that began in 1933 and by 1936 had harvested 3,000 numbers and 30,000 specimens. The Royal Horticultural Society and Arnold Arboretum cooperated with the Fan Memorial Institute of Biology on a seed-collecting trip to the Burma-Yunnan border; many herbarium specimens and rare seeds were collected.

"The rare rhododendron, *R. sinonuttallii* [now *R. nuttallii*] of which only 3 mature fruits have been collected by Kingdon Ward, we found in great abundance and 60 mature fruits have been collected last year" (2/3/39).

New plants were discovered, named, and studied. In Yunnan new species of tropical genera were too numerous to detail. In southwestern Yunnan alone two dozen new species of *Castanopsis*, *Pasania*, and *Quercus* were collected. Sometimes plants were renamed: Chun placed two species in genus *Rehderodendron* that Hu revised and placed in separate genera; Merrill informed Hu that his *Sinomerrillii* was *Neuropeltis racemosum* Wall (3/7/38). *Huodendron* was discovered almost simultaneously by Hu, Chun, and Rehder, on which Hu commented, "Such things as these are quite heartening" (8/6/35).

New institutions were founded. H. H. Hu joined the new Fan Memorial Institute of Biology in Beijing as head of botany in the late 1920s, later to become its director. In 1934 he established a 1,700-acre arboretum and botanical garden at Guling (Lushan Arboretum and Botanical Garden). After only a year a seed list had been issued and they had procured 3,800 kinds of seeds. In 1938 it was in Kunming, the capital of Yunnan Province, that a new botanical institute was organized, and Hu was asked to initiate yet another in eastern Tibet, "which E. H. Wilson explored

30 years ago—the type locality for many botanical treasures, Muping, will be next door" (11/18/38). When the staff of Lushan Botanical Garden was obliged to evacuate owing to the war in 1939, Hu sent them to Kunming to help with the new institute.

Publications abounded. In 1921 W. Y. Chun published *Chinese Economic Trees*, a work he had begun at Harvard. *Icones Plantarum Sinicarum*, a collaborative effort by Hu and Chun, was published in five large-format volumes, 1927 to 1938. (The first volume was dedicated to Charles S. Sargent, the fourth to E. D. Merrill, and the fifth to Alfred Rehder.) Hu's very long list of publications included enumerations of plants, descriptions of new species and genera, analytical keys, geographic distribution studies. He collaborated with R. W. Chaney on a study of Miocene flora in North Shantung, China. For years he ambitiously planned a "Silva of China, after the fashion of Prof. Sargent's *Silva of North America*" (6/17/31). In 1948 the sole volume of *Silva of China, A Description of Trees Growing Naturally in China*, volume 2, Betulaceae to Corylaceae, was published.

Throughout the afflictions and dislocations of war, Hu retained his confidence. In 1939 he wrote, "You may be sure that epoch-making



Woon-Yung Chun, founder and director of the South China Botanical Institute, Canton, and collaborator with H. H. Hu on *Icones Plantarum Sinicarum*.

developments of Chinese horticulture is about to be initiated" (2/3/39). In 1948 he briefly summed up the accomplishments of his generation of Chinese botanists:

Since Chinese botanists have taken active part in the botanical exploration and systematic studies of Chinese flora, numerous new discoveries have been made, such as the genera *Pseudotaxus*, *Nothotsuga*, *Smithiodendron*, *Sinojackia*, *Rehderodendron*, *Huodendron*, and *Zenia*, all interesting trees, both botanically and horticulturally. Crowning all is the *Metasequoia*. . . . the "living fossil" discovered in Central China, the most remarkable botanical discovery in the century (Hu 1948).

Very soon thereafter, following the successful revolution led by the Chinese Communist Party, science in China was completely reorganized. On 1 November 1949, the Chinese Academy of Sciences was established as the umbrella organization for scientific research institutes in the Beijing area. Work was suspended at the Fan Memorial Institute while control was transferred to the new Academy. In a 1949 letter to Elmer Merrill, Hu voiced a hope that the Institute would return to normal operations when the new arrangements were complete, but that was not to happen in his lifetime (11/24). When China's Great Proletarian Cultural Revolution began in 1966, most scientific work came to a halt; Hu died in 1968.

In the mid-1970s scientific work resumed, and communication between Chinese and American botanists was slowly re-established. Botanical collaboration between the two countries officially resumed in 1978 with an invitation to a delegation of American botanists—among them Richard A. Howard, then director of the Arnold Arboretum—to tour botanical gardens and institutions in the People's Republic of China.

Bibliography

- Gray, Asa. [1859] 1889. *The Flora of Japan*. In *Scientific Papers of Asa Gray*, II, ed. C. S. Sargent. Boston: Houghton Mifflin.
- Haas, W. J. 1988. Transplanting Botany to China: The Cross-Cultural Experience of Chen Huanyong. *Arnoldia* 48(4): 9–25.
- Hay, Ida. 1995. *Science in the Pleasure Ground: A History of the Arnold Arboretum*. Boston: Northeastern University Press.
- Howard, R. A. 1978. Botanical Impressions of the People's Republic of China. *Arnoldia* 38(6): 218–237.
- Hu, H. H. 1931–1949. Letters of H. H. Hu to J. G. Jack and to E. D. Merrill. Chinese Correspondence, Archives of the Arnold Arboretum, Harvard University.
- . 1948. How *Metasequoia*, the "Living Fossil" Was Discovered in China. *Journal of the New York Botanical Garden* 49(585): 201–207.
- Hu, Shui-ying. 1980. The *Metasequoia* Flora and Its Phytogeographic Significance. *Journal of the Arnold Arboretum* 61: 41–94.
- Li, Hui-lin. 1944. Botanical Exploration in China During the Last Twenty-Five Years. *Proceedings of the Linnean Society of London* 156: 25–44.
- Merrill, E. D. 1946. *Merrilleana: A Selection from the General Writings of Elmer Dana Merrill*. *Chronica Botanica* 10(3/4).
- Sargent, C. S. 1920–1927. *Reports of the Arnold Arboretum, Reports of the President and the Treasurer of Harvard College, 1918–1926*. Cambridge: Harvard University.
- Sax, K. 1949. John George Jack. 1861–1949. *Journal of the Arnold Arboretum* 30(4): 345–347.
- Sutton, S. B. 1970. *Charles Sprague Sargent and the Arnold Arboretum*. Cambridge: Harvard University Press.
- Wheeler, W. M. 1925. *Report of the Bussey Institution, Reports of the President and the Treasurer of Harvard College, 1923–1924*. Cambridge: Harvard University.

Karen Madsen is editor of *Arnoldia*.

Another "Living Fossil" Comes to the Arnold Arboretum

E. D. Merrill

Elmer D. Merrill was director of the Arnold Arboretum from 1935 to 1946 and Arnold Professor thereafter until his death in 1956. A botanist and administrator of many accomplishments, he is nonetheless best remembered for having distributed several bushels, or at least a kilogram, of *Metasequoia* seeds. Early in February 1948, Merrill announced the discovery of the living *Metasequoia* to the scientific community with a brief note in the journal *Science*, calling it "an event of extraordinary interest to both botanists and paleobotanists."

The following account of how the seeds were acquired and subsequently dispersed is from the article Merrill published in *Arnoldia* one month later.



Edwin Dana Merrill, photographed at age 68, appropriately enough with herbarium specimen in hand. His successor as director of the Arnold Arboretum, Richard A. Howard, estimated that over Merrill's career as collector, systematist, and director, he was instrumental in "amassing botanical resources totaling over one million sheets of herbarium specimens and untold numbers of duplicates distributed for the benefit of the botanists to follow him."

When botanical specimens [of *Metasequoia glyptostroboides*] were received at the Arnold Arboretum in the latter part of 1946, I immediately became interested in the possibility of securing seeds of this extraordinary species, and accordingly communicated with Dr. H. H. Hu, Director of the Fan Memorial Institute of Biology in Peiping, one of the joint authors concerned with the actual description of the species. Incidentally, Dr. H. H. Hu was trained at the Arnold Arboretum, receiving his Sc.D. degree from Harvard University in 1925. Dr. Hu responded favorably and accordingly a modest grant was made from the Arnold Arboretum's restricted Chinese exploration fund provided by the late Harrison W. Smith of Tahiti, himself a graduate of Harvard in 1895 and long interested in matters Chinese. On the basis of this grant Professor Cheng organized a third expedition to the type locality, this also led by his assistant Mr. Hsueh.*

. . . While 1947 was reported as not being a good seed year, an ample supply of seeds was secured during the time that Mr. Hsueh was in

Excerpted from "Metasequoia, Another 'Living Fossil,'" *Arnoldia* (5 March 1948) 8(1): 1-8.

* The third expedition was led by C. T. Hwa.

the field. These were delivered in Nanking early in December; the first small sending reached Boston January 5, 1948, and a second and larger shipment is now in transit. Seeds were planted in our propagating house early in January, and many of these germinated before the end of the month. Thus it is that in due time the Arnold Arboretum will have a certain number of living plants for distribution.

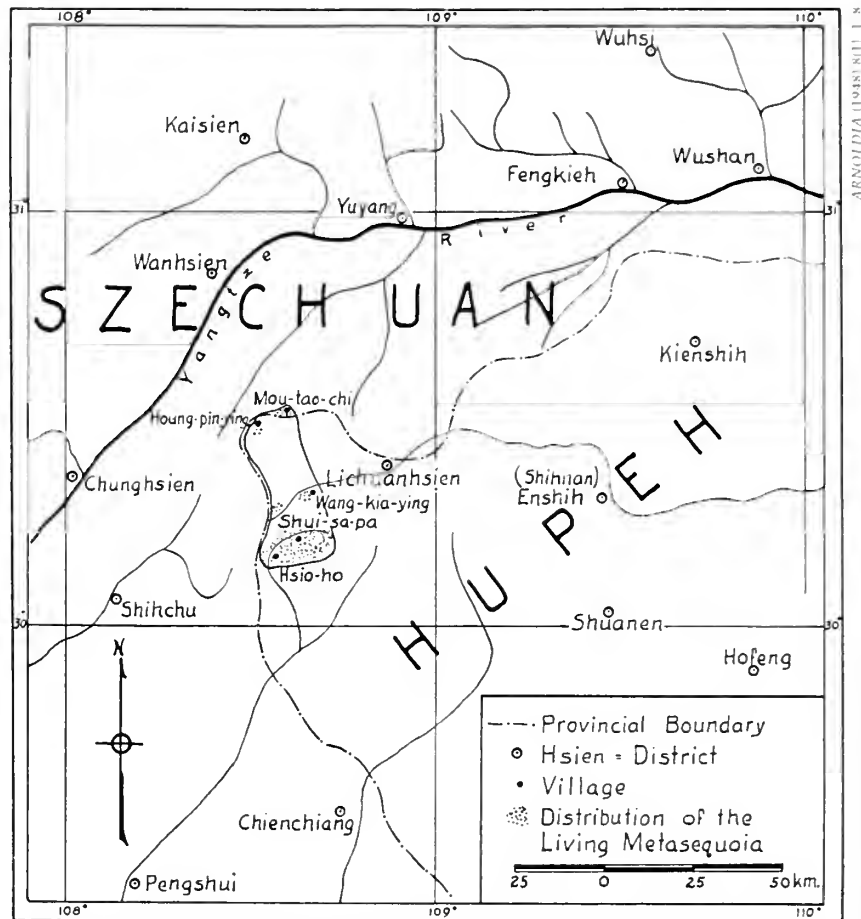
Following long established Arnold Arboretum practice, packets of seeds have been widely distributed to institutions in the United States and Europe. It is, of course, not known whether this remarkable species will prove to be hardy under the rather difficult climatic conditions characteristic of the Boston area. With excellent germination records

it is now certain that we shall be able to establish this ancient but now nearly extinct type in various parts of the United States and elsewhere, for somewhere, with us, favorable climatic conditions will be found—if not in the Northeast, then in the South or on the West Coast.

The point is emphasized that in spite of the present unfavorable economic conditions, in spite of adversities in China rendering travel difficult, and in spite of unfavorable exchange conditions, this cooperative project did succeed; that as a result an ample supply of seeds is available; that the seeds are viable; and, this being the case, the Arnold Arboretum has made an important contribution, working through its Chinese associates, in thus being involved in an

attempt to preserve a remarkable conifer, and a species that in its native habitat is apparently not far from the verge of extinction. Incidentally, Professor Cheng who, with Dr. Hu, cooperated with us, writes that without the modest grant made by the Arnold Arboretum, it would have been impossible for his representative to make the trip to Szechuan and Hupeh in 1947, and comments on the fact that trees are being rapidly destroyed by cutting in this region as well as in various other parts of China. . . .

It has been argued in some quarters that we approach the condition of diminishing returns in the botanical exploration of China, a field that has long been one in which the Arnold Arboretum has specialized. This statement is doubtless true to a certain degree, but from what



This map of the limited geographic area of Metasequoia was drawn from data provided Dr. Merrill by Professor Wan-Chun Cheng.

has appeared in extensive collections made within the past three decades, I am of the opinion that a vast amount of fieldwork is still called for and is still justified. This remarkable *Metasequoia* find bears out this belief. In spite of all that has been published on the enormously rich flora of China in the past century, and particularly within the past four or five decades, there are vast areas still remaining to

be explored, and the already known flora will be very greatly increased, as to the number of actually known species, when the more recently assembled collections are studied in detail.

For an account of Merrill's early years and of his time in the Philippines, see "E. D. Merrill, From Maine to Manila" by Ida Hay in *Arnoldia* (Spring 1998) 58(1): 11–19.



CHRONICA BOTANICA [1950] 12(1)/21. ARCHIVES OF THE ARNOLD ARBORETUM

The delegates to a UNESCO-financed symposium on botanical nomenclature and taxonomy held in Utrecht, the Netherlands, June 1948, included botanists from Europe, the United States, India, Australia, and Indonesia. E. D. Merrill is standing, fifth from the right. It is said that he made a lasting impression by appearing on the speakers' platform, pockets bulging with *Metasequoia* seeds.

How to Fund Botanical Expeditions

E. D. Merrill had become an expert on Chinese plants during his years as director of the Bureau of Science in the Philippines; his ability to identify prodigious quantities of specimens with phenomenal speed became legendary. Also extraordinarily effective as an administrator, he developed his own methods of supporting fieldwork in distant countries, as the letters below illustrate.

In the first letter that follows, Merrill—recently retired as director of the Arnold Arboretum—responds to a request for the names and addresses of responsible, trained, and experienced plant collectors in China, “all very efficient and very trustworthy.” Merrill continued this mode of funding with the *Metasequoia* expeditions, acting through Professors W. C. Cheng and H. H. Hu, his friend and colleague of thirty years. The \$250.00 Merrill sent to Hu in 1947 financed C. T. Hwa’s trip to Sichuan and Hubei for herbarium specimens and seeds, and in 1948 two grants of \$100.00 enabled Hwa to spend the summer and early fall with Cheng and K. L. Chu investigating the plant species associated with *Metasequoia*. The second letter, which accompanied the first of the \$100.00 grants indicates some of the difficulties faced by Chinese botanists and their collaborators.

January 27, 1947

Mr. Henry Hicks
Hicks Nursery
Westbury
Long Island, N.Y.

Dear Mr. Hicks:-

I haven't forgotten our conversation regarding “raids” on China from a horticultural-botanical standpoint, for in pre-war years I had strongly developed this field. In earlier days the only way of securing plants, seeds, etc. was to send an expedition, as Sargent financed the Wilson trips, the Purdom explorations, the Rock expeditions for the Arnold Arboretum, etc. These were super-expensive as high salaries and high travel expenses were, of course, involved.

Beginning about 1915 the situation changed with the return to China of certain Chinese students who had been sent abroad to

secure special training. . . . The result: that there is now in China a body of trained men who know their way around in field work appertaining to both horticulture and botany.

Beginning about 1918 I started in to take advantage of this situation while I was in Manila, making two vacation trips to China (Canton and Nanking) to help train Chinese botanists in field methods. After my return to the United States in 1923 I continued this exploitation at the University of California, New York Botanical Garden, and the Arnold Arboretum. The system is a very simple one. I make a modest grant to this or that individual or institution in China (these grants have varied from \$50.00 to \$100.00 up to \$500.00) giving the individual carte blanche on the actual expenditure of the funds to cover costs of field work, the resulting collections of plants and seeds to be divided equitably between the cooperating institutions. There has not been a single failure. The results have been most astonishing. In general, for what it would cost to send one man from here and cover his salary and travel expense I could maintain a dozen expeditions in China, and from each one of the dozen would receive as our share on a 50-50 split about as much material as the one man sent from here! This sounds rather absurd, but it is actually the truth. It means that no "salaries" were supplied, for the cooperating institution in China covered the modest cost of the services of the trained collectors, and funds that I supplied were used only for expedition expenses in the field. . . .

I'm personally tremendously intrigued with a recent discovery in Szechuan. A giant tree like Sequoia and Taiwania, representing a new genus to be described as Metasequoia or some such name. Only three living trees in the stand! Later another grove with perhaps 20 trees located. We got a botanical specimen recently & Dr. Hu has promised to send seeds as soon as he can get them. Here is a forest giant just on the edge of extinction! If C.S.S[argent] were alive and learned of such an extraordinary thing he would probably send out a special expedition to bring home the bacon. I can do it at practically no cost.

Now I do not know what the policies of my successor here may be and whether or not our "Field" will continue to be eastern Asia. I've done my bit and I am rather proud of it. Let us hope that this eastern Asiatic work will continue.

Very sincerely yours

E.D.Merrill

March 26, 1948

Professor Wan-Chun Cheng
National Central University
Nanking, China

Dear Professor Cheng:

Referring to our previous correspondence, I enclose herewith check No. 22690 in amount of \$100.00 payable to you. . . . I am sure that you will be able to negotiate this check, which is drawn to your personal order, to advantage. . . .

This grant of \$100.00 is to be used at your discretion, but primarily for the purposes of keeping your assistant in the field during the collecting season in the *Metasequoia* area. I judge from the last letter that I received from you that the Rector of the University approved your plan and that Mr. Hsueh* will remain in the field after Dr. Chaney shall have returned to Nanking. It is, of course, understood that if necessary or desirable you can utilize some of these funds for actually shipping specimens to this institution. This, to me, has been a very discouraging phase of the situation in China, in that we could have large collections made but for the difficulties in arranging for shipment of specimens to the United States, which have proved to be insuperable. Maybe, here, you could enlist the cooperation of proper representatives in the American Legation in Nanking; some years ago, when the situation in Peking became very acute after the "incident" that set off the war between Japan and China, the American officials in Peking sent an enormous lot of botanical material to the Arnold Arboretum in the diplomatic pouches. . . .

I now have, thanks to you, all of the *Metasequoia* seeds that we need. You sent a package, I believe, through diplomatic agencies; a few days ago this large package was delivered to me here and contains some scores of thousands of seeds. It is the package in which was also included some *Metasequoia* cones and a number of seeds of ligneous species. I have sent all of the latter over to our propagating house and will find out what we can do with the species under our climatic conditions.

With best wishes.

Very sincerely yours,

E. D. Merrill
Arnold Professor of Botany

EDM: AG

* In W. C. Cheng's response on May 12, he corrected Merrill's mistake. It was C. T. Hwa, not Mr. Hsueh, who accompanied Chaney and stayed on to continue exploring through the summer and into the fall.

“As remarkable as discovering a living dinosaur”: Redwoods in China

Ralph W. Chaney

By 1948, Ralph Chaney—professor of paleontology at the University of California, Berkeley, and passionate advocate for the North American redwoods—had been hearing for a year and a half from his colleague Professor H. H. Hu about the discovery in China of trees that had been thought extinct for millions of years. Chaney wrote that when he received seeds of *Metasequoia* from China, “the reality of this new tree so impressed me that I decided to visit it in its native home. I wanted to see how it lived and with what other trees it was associated.” That was on January 9, 1948; less than two months later, Chaney was in Modaoqi, marveling at the newly found tree, shooting roll after roll of photographs, and absorbing information on the climate and topography of the tree’s native region and on the plants that grew around it.*

The details of the trip have been told elsewhere—how Dr. Milton Silverman, Science Writer for the San Francisco *Chronicle*, and I flew across the Pacific and up the Yangtze valley to Chungking how we took a river boat down to Wan-Hsien and then walked over the steep and slippery trails for three days to Mo-tao-chi and for two days more to Shui-sapa [the so-called *Metasequoia* Valley]. In March, at the time of our visit, the trees were bare of leaves, having shed them last November. Hanging from their branches were long catkins bearing the male cones, and the shorter female cones were also developing on the trees. We collected some of these cones for later study in America, but our immediate interest was in the environment of these close relatives of the California Redwoods and in the other trees that were growing with them.

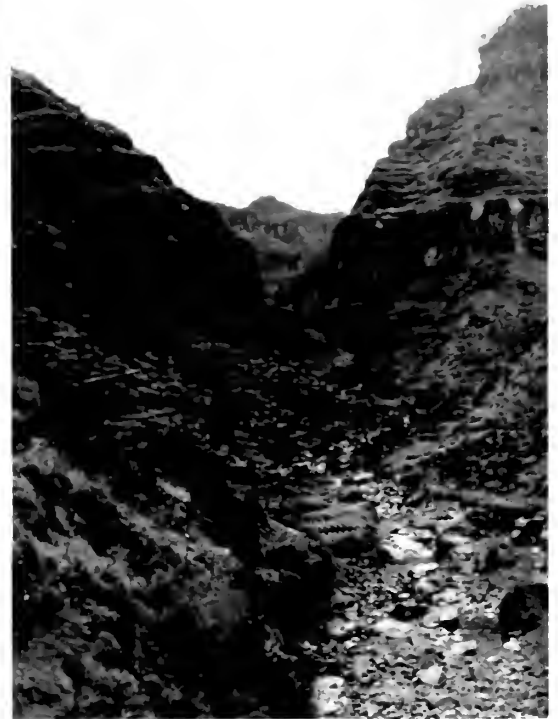
The idea was gradually developing in my mind that it was fossils not of *Sequoia* but of *Metasequoia* that I had collected in Manchuria

in 1925, at the end of a season with the Central Asiatic Expedition in Mongolia. If that were the case, perhaps other fossil redwoods I had found in many other parts of the world were likewise related to the newly discovered trees of central China. The key to our understanding of the ancient forests of the northern hemisphere might be found not only in the living Coast Redwood (*Sequoia sempervirens*) of California but in the groves of Dawn Redwoods (*Metasequoia glyptostroboides*) in Szechuan. If so, it was important to learn as much as we could about the climate and topography of the region in which these “living fossils” had survived and to determine whether the trees now associated with them were the same sorts of trees as those living with them in the forests of the remote past. . . .

Summarizing the evidence of *Metasequoia* distribution, we find that it appeared at high latitudes in the Cretaceous period, was widely distributed there in the Eocene, had moved

Excerpted from “Redwoods in China,” *Natural History Magazine* (December 1948) 47: 440–444

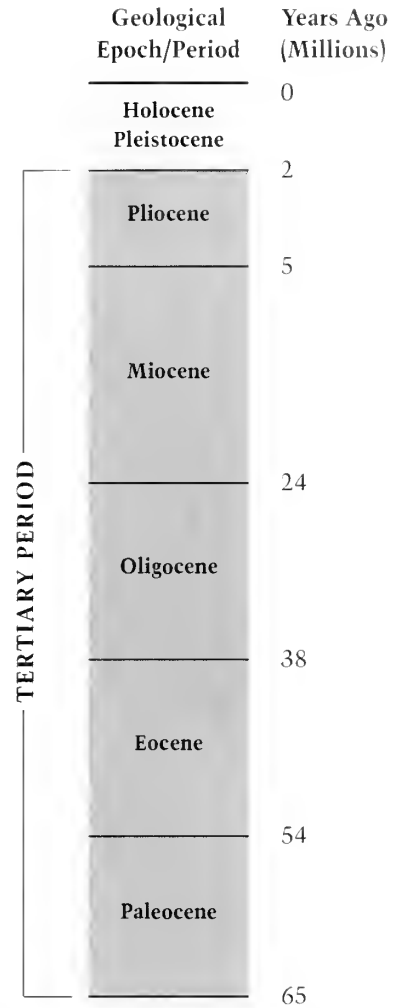
* Milton Silverman, *The Search for the Dawn Redwoods*, 1990.



south and was abundant in the United States and northern China in the Oligocene, was more scattered in distribution during the Miocene, and disappeared from the fossil record on both sides of the Pacific before or during the Pliocene period. Why has it survived only in central China after living so widely around the world in earlier ages?

This brings us back to the valley at Shui-sa-pa, where Dawn Redwoods are living under what appear to be natural conditions. When I was there last March, all of the hardwoods as well as the Dawn Redwoods were without leaves, but I was able to recognize most of the common trees. Birch (*Betula*), chestnut (*Castanea*), oak (*Quercus*), sweet gum (*Liquidambar*), beech (*Fagus*), and katsura (*Cercidiphyllum*) were among those living in immediate association, all typical members of the Arcto-Tertiary Flora [an assemblage of trees that originated in the Arctic during the Tertiary]. Their presence here with *Metasequoia* makes these groves more similar to the ancient forests of North America and Eurasia than any I have ever seen. So it is important to learn as much as we can about environmental conditions in these valleys of central China. It will tell us what Manchuria and Oregon looked like 40 million years ago and will restore for us the terrain in Greenland and Alaska as far back as 100 million years ago. Observations on the existing climate in the area now occupied by Dawn Redwoods will enable us to make some long-range weather predictions in reverse regarding the rains and winds of Manchuria and Oregon in the days when *Metasequoia* lived there and left behind its leaves and cones to be preserved as fossils.

Our stay last March was too short to permit other than preliminary studies. Furthermore, there are no climatic



LATE CRETACEOUS PERIOD

RALPH W. CHANEY, BY COURTESY OF HONG WANG



Ralph W. Chaney, Milton Silverman, and the buttressed trunk of the large *Metasequoia* at Modaoqi.



The three *Metasequoia* trees in Modaoqi. The smaller two are growing at the edge of a rice field. The largest is the "type tree," from which botanical specimens were taken for determination of the species. It was, as Chaney wrote, "sacred to the local inhabitants, as indicated by the shrine at its base, and venerated by science because it represents a holdover from the age of the dinosaurs." The figure on the path is his travel companion, Milton Silverman.

records from any region nearer than Chungking, which is lower in altitude by about 3000 feet. However, we learned enough about the climate at Shui-sa-pa, at an altitude of about 4000 feet, to make some suggestions. Winters are cool and rainy, with temperatures rarely falling below freezing but with conditions not well suited to plant growth. Rainfall is abundant, much of it falling in the summer. The climatic regime of summer rainfall and of unfavorable winters is now to be found widely in north temperate regions, where trees bear their leaves during the summer and shed them in the winter. The deciduous habit of the Dawn Redwood and of its hardwood associates seems to have been developed in past ages in regions with summer-wet and winter-cool climate. Why, then, is the

Dawn Redwood no longer widely distributed as it was in the past?

No final answer can be given until further studies are made by Chinese botanists. . . . I can now make only a few suggestions to help explain the wide differences between its past and present distribution. There is probably no other place in the world outside of the tropics where a mild, uniform climate is combined with a summer rainy season. In the southern United States we do have wet summers in the region occupied by a close relative of *Metasequoia*, the swamp cypress (*Taxodium distichum*), but the winters are cold, with temperatures regularly falling below freezing. In California we have mild winters in the region occupied by another close relative of *Metasequoia*, the Coast Redwood (*Sequoia sempervirens*), but the summers are dry. The



Three specimens of the newly discovered conifer in Shuisapa, Hubei province. The evergreen conifers farther to the left are *Cunninghamia*; at right are chestnuts and bamboos. Three small figures can be seen just to the left of the dawn redwoods.



RALPH W. CHANEY ARCHIVES OF THE ARNOLD ARBORETUM

The landlord of the property on which the second group of dawn redwoods was found stands with his children near one of the largest trees.

same may be said of all parts of temperate Asia I have visited; mild winters characterize regions with dry summers, while in places where the summers are wet, the winters are cold. If it were not for the ranges of mountains that surround Mo-tao-chi and Shui-sa-pa, the winds from North China would come down during the winter and make these valleys too cold for the Dawn Redwood. And the hot summer winds from the north and wet would make them too dry. These mountains were built during the Pliocene epoch, when *Metasequoia* was disappearing from other parts of the world. They have preserved in this limited area the climate on which the existence of the Dawn Redwood depends. If for any reason the climate here were to change, they would probably become extinct in these valleys, as they have in all other known parts of the world.

The climates congenial to *Metasequoia* have proven far less narrow in range than Chaney and others feared. His greatest hope was to preserve the species in its native area, preferably by instituting a national park, and the trees have indeed come to be protected by the government; not even small trees can be cut down.

Chaney himself brought back seeds and four seedlings from China. Concerned that his prizes might be taken from him at customs in Hawaii, he tucked the seeds and twigs into an inner pocket and requested intercession for the seedlings from a former student at the Department of Agriculture in Washington. Word did not reach the inspector at Plant and Economic Quarantine in Honolulu, however, and he demanded that the four seedlings be handed over for incineration. Chaney's protestations that the trees were priceless, more than a million years old, were of no avail. According to Milton Silverman, the ensuing argument grew louder and louder until Chaney, close to hysteria, was shouting defiantly and citing "millions of years, tens of millions of years, a hundred million years." Suddenly the agitated inspector asked a question, "Are they more than a hundred and fifty years old?" And so, officially declared antiques, the seedlings continued their journey to California.

Other articles on *Metasequoia* by Ralph W. Chaney

- 1948. The bearing of the living *Metasequoia* on problems of Tertiary paleobotany. *Proceedings of the National Academy, U.S.A.* 34: 503-515
- 1948. Redwoods around the Pacific basin. *Pacific Discovery* 1(5): 4-14
- 1950. A revision of fossil *Sequoia* and *Taxodium* in western North America based on the recent discovery of *Metasequoia*. *Transactions of the American Philosophical Society, New Series* 40(3): 171-263, plates 1-12.

An account of Chaney's trip to China by his traveling companion, Milton Silverman

- 1990. *Search for the Dawn Redwoods*. San Francisco, CA: The author.

in the *Pittsburgh Press* from a Harvard news release, is quietly conservative; in marked contrast are the clippings from the *San Francisco Chronicle*. Milton Silverman, science writer for the *Chronicle*, was with Ralph Chaney in January 1948 when he received seeds of *Metasequoia*. Almost immediately, Chaney began to plan a trip to see the tree, and so did Silverman. In three lavishly illustrated stories relayed from central China, Silverman recounted their adventures in high style. The first was published in the *Chronicle* on March 25, the last on April 5, after Chaney had returned.

OLD RACE OF REDWOODS

... a Spectacular Discovery

... WHOSE FAMILY LIVED WITH THE DINOSAURS

Today. An elephant is related to the long-dead mammoth. Callor's famous red woods are related to the ancient redwood trees. Fossils of these "long-dead" trees have been found in many parts of the earth.

Now, for the first time in the history of science, it is learned that these ancient trees did not die out. Some of the species are still alive—looking exactly as they looked 100,000,000 years ago; same bark, same size, same

seeds. More than a month ago, Professor Ralph Chaney of the University of California left here by plane to see the trees, reportedly growing in the interior of China. The editor of *The Chronicle* assigned Dr. Milton Silverman, the newspaper's science writer, to accompany the expedition. Its results, the editor felt, might help us all to understand better the world in which we live.

Quite apart from its scientific implications, the expedition pro-

duced an absorbing adventure story—the account of a 20th century journey into a part of the world occidentals have seldom visited; a journey made by air, river boat and on foot.

Today *The Chronicle* is publishing the first dispatch from the expedition. On succeeding days further dispatches will appear until *The Chronicle* has furnished a complete, documented account of one of the most spectacular scientific discoveries of our day.

historic plants. He is the first modern scientist to see them.

"To me," he said, "finding a living dawn-redwood is at least as remarkable as discovering a living dinosaur."

He confirmed the fact of their existence—an unparalleled epic of survival—after traveling more than 10,000 miles by airplane from San Francisco to Chungking and then by river boat down the Yangtze Kiang.

The last stage of his journey, from the little town of Wan-hsien, took three days over muddy, slippery trails which zigzagged over a succession of mile-high mountain ranges.

Although groups of bandits were reported operating around these mountain trails and robbing travel-

Continued on Page 2, Col. 1

...ces of their distinctive needles and cones.

Three of these "living fossils,"

however, were seen alive here today by Dr. Ralph Chaney of the University of California and the Car-

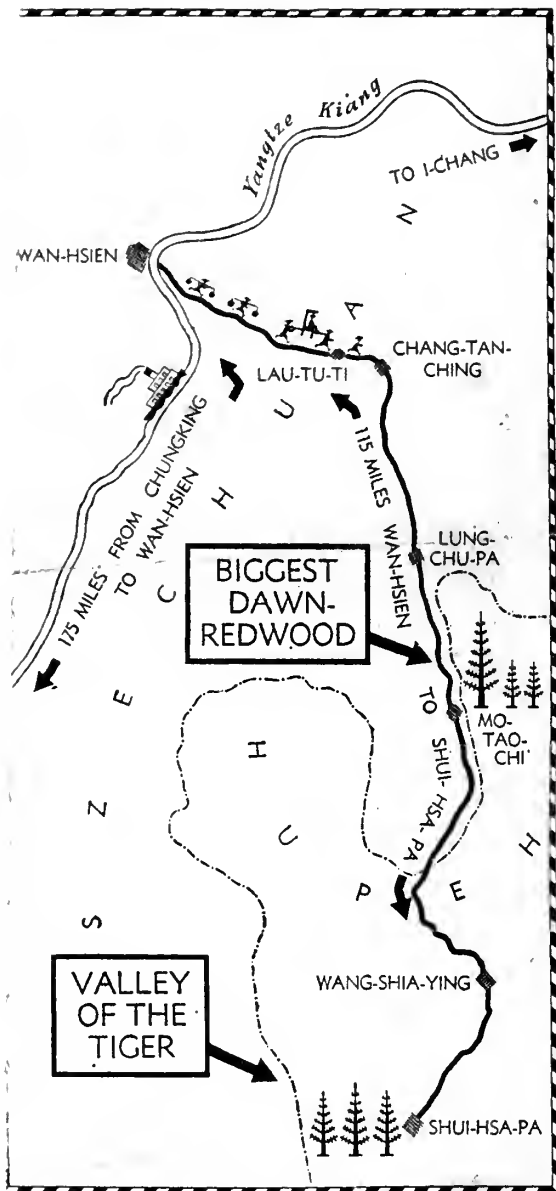
negie Institution of Washington.

Dr. Chaney is one of the world's most eminent authorities on pre-

San Francisco Chronicle

ONLY HOME-OWNED NEWSPAPER





TRAIL TO THE DAWN-REDWOODS—This is the route followed by U. C. Fossil-Hunter Ralph W. Chaney and Chronicle Science Writer Milton Silverman to the dawn-redwood groves in the interior of China. Told by "authorities" the trees were only a few miles from Wan-Hsien, the two Americans struggled for 10 days to make 230 miles over mountains lubricated by mud, slime and sleet.

PAGE 3 THURSDAY, MARCH 25, 1948 CCCCA SAN FRANCISCO CHRONICLE

U. S. Scientists Reach Home of Dawn-Redwoods

The historic expedition to the dawn-redwoods in a remote mountain fastness of China is shown in these pictures dispatched from the scene by Chronicle Science Writer Dr. Milton Silverman. The negatives were sent out of the wilds by runner to Wanh sien, thence by boat along the Yangtze to Chungking, thence by air to San Francisco. The party is seen below on the sampan journey to Mo-Tao-Chi, village off the Grindstone river, near the site of the redwoods. Dr. Silverman stands in stern of sampan. In center photo the

biggest of the three dawn-redwoods discovered near Mo-Tao-Chi rises 95 feet out of a temple on the bank of a rice paddy. The altar itself is built right at the base of the tree trunk. It is 11 feet in diameter at the base. Natives of this rugged region of interior China—a land seldom trod by white men—worship the "palo alto" as a god. Picture at far right presents the "Mei-kuo" (American) discoverers—Dr. Silverman (left) and Dr. Ralph Chaney of the University of California.



The living god

Copyright 1948 The Chronicle Publishing Co.



This is the Valley of the Tiger near Shui-Hsa-Pa in Hupeh province, the finest stand of dawn-redwoods found by Chaney and Silverman. Here scores of the trees, sur-

vivors of an ancient race, grow surrounded by axless rhododendrons, iris and hydrangeas. The pools at the bottom are typical Chinese rice paddies.

The discovery of *Metasequoia* precipitated a bicoastal controversy that hasn't entirely faded. On the East Coast, credit for distributing the seeds went to the Arnold Arboretum and E. D. Merrill; on the West Coast, R. W. Chaney took the honors. As the story of Chaney's three-day trip to *Metasequoia* Valley was told and retold, the more flourishes and fewer facts it contained. Some reporters even wrote that Chaney himself had discovered the tree.

In his scientific publications Chaney very carefully set forth the circumstances accurately, offering due credit to Merrill when he wrote, "For the first time in nearly a score of million years, *Metasequoia* lived again in the western hemisphere as a result of Merrill's distribution of these seeds." Still, Merrill could not be convinced that Chaney had done enough to set the story straight.



CHANNEY

THE HARVARD CRIMSON

THURSDAY, OCTOBER 9, 1952

Professors Squabble Over Seeds From China's Living Fossil Trees

by David C. D. Rogers

There is a big fight in the tree-world. Two professors are waging a bitter war over a fast-growing tree, believed extinct for many millions of years.

In 1941 a Chinese University employee stumbled across a giant coniferous tree—the *Metasequoia*—in remote central China. Ever since scientific journalists have squabbled as to whether Elmer D. Merrill, Arnold Professor of Botany, emeritus, or Ralph W. Chaney, professor of Paleontology at the University of California, is responsible for sending expeditions to bring back and distribute seeds from this "living fossil."

"Credit is credit in any man's language . . .," Merrill grumbled yesterday. "Chaney had nothing to do with it; the Arnold Arboretum of Harvard University deserved all the credit."

Claims have been made that Chaney, and not Merrill, imported the seeds. No denials of such claims, appearing in the press, seem to have been made. According to Merrill, even some foresters and botanists do not know the facts.



MERRILL

Metasequoia and the Living Fossils

Henry N. Andrews

Dr. Andrews, professor of botany at the University of Washington and paleobotanist at the Missouri Botanical Garden, turned a cool eye on the furor over "the living fossil" and with a hint of mockery introduced a bit of perspective to the dialogue.

Shortly after last Christmas [1947] the Garden received a small packet of seeds from Professor Wan-Chun Cheng of the Arboretum of the National Central University in Nanking. These are the seeds of a new conifer recently discovered growing in eastern Szechuan and southwestern Hupeh provinces of central China. Its discovery was rather noisily announced a few months ago in the daily press as a "living fossil," and while it is an appropriate term it seems to be somewhat less deserving of that title than many other modern plants . . .

It is fascinating indeed to find that a group of plants supposed to be extinct still lives on, in a part of the earth remote from the searching eyes of botanical explorers. There is something of the "Lost World" motif about it that is attractive to all naturalists, and irresistible to the popular science writers who may find it profitable to mix the facts with their fancies. And one may wonder whether the *Metasequoia* stir would have had as much appeal if the sequence of discovery had been reversed. The answer is almost certainly in the negative . . .

Metasequoia glyptostroboides has been hailed as a "living fossil"—a phrase that makes good headlines but one which is notably lacking in precision as far as the time element is concerned. The fossil specimens described by Miki were found in clay beds of early Pliocene Age in Japan. The Pliocene period is generally accepted as having begun some 7 or 8 million years ago. Thus it may be appreciated that accounts of this new conifer which appeared in the daily press, hailing it as "a tree believed extinct for

100,000,000 years," may be commended for their enthusiasm but not their accuracy! One is tempted to believe that news writers keep in stock a special supply of type bearing the inscriptions "dinosaurs" and "100,000,000" with which liberally to season all of their copy dealing with life of past geologic ages. We do know a good deal about the more ancient history of the conifers; we know that as a group they were abundant and well developed in the dinosaur age, but we do not know that *Metasequoia glyptostroboides* itself dates back that far. It is possible that such may be the case, but a careful review of the many fossil *Sequoias* described in botanical literature will be necessary before significant conclusions can be drawn.

As a brief passing commentary on geologic times and the origin of various forms of living things, it may be of interest to note that large forest trees (not *Metasequoia*!) are known to have existed on the earth more than 300 million years ago; more primitive plants were established on the land some 375 million years ago; highly developed invertebrate animals existed in the seas in excess of 500 million years ago; and still simpler forms of life such as the algae go back much farther. *Metasequoia* is a real living antique but it cannot be ranked among the most ancient by a long shot.

While *Metasequoia* will undoubtedly prove to be a significant link in our knowledge of the evolution of the conifers and very possibly a valuable horticultural acquisition, it is overshadowed as a living fossil by the ancient and honorable genealogies of plants growing



Three-month-old dawn redwood seedlings at the Missouri Botanical Garden, 1948.

in our own backyards. A few of these may be of interest—to dispel the illusion of the far-away and justly to recognize the plants we live with every day.

There are very few plants that have served man to greater advantage than the pines. . . . yet the pines, not their distant relatives but pines as we know them today, may be traced well back into the Cretaceous period—at least 90 million years ago—and into still earlier periods their ancestral derivatives trail back for at least another 130 million years. There is no reason to believe that it is still an actively evolving group of plants but its retention of great virility through the ages is equalled by very few other living things and, like the modern forests, their fossil remains are widely scattered. Here is one of the greatest of all living fossils.

Numerous other existing members of the conifer order are known to have originated far back in the past, and among those of particular interest to the present discussion are the Sequoias—the California Redwood (*Sequoia sempervirens*) and the Big Tree (*Sequoiadendron giganteum*). Although these giants are at present confined to a small area in California and Oregon, their fossil remains are found widely scattered through Tertiary and late Cretaceous rocks of the northern hemisphere—from England, Greenland, Alaska, Italy, Spitzbergen, and numerous other localities come the records of their past distribution.

In the petrified forests of Yellowstone Park are great stumps indicating trees in excess of 14 feet in diameter that grew there in Miocene times. These were closely related to the modern Redwood as well as *Metasequoia*. . . .

The highly prized forest tree *Taxodium distichum* (Bald Cypress) of our southern swamps presents a fossil record that is not unlike that of the Redwood. In fact, our understanding of the past distribution of these two is not always perfectly clear since they are closely related and the foliage of the two is so similar that they are not always readily distinguished in the fossil forms. . . .

[The cycads,] palm-like in appearance, are found today from Florida and Mexico through the Indies into northern South America, in South Africa, and in the tropical Pacific isles from Japan to Australia. Our only native American species, *Zamia floridana*, is common in the sandy open pine woods of Florida. It is not a showy plant, with its underground stem and smallish palm-like leaves, but it is a lingering remnant of a once large and diversified group that apparently attained the zenith of its evolutionary powers in the Jurassic period some 140 million years ago, and there is reason to believe that its more remote ancestors originated from the Coal Age Seedferns still farther back in the past. From a clay bed exposed along a wave-swept beach in northeast England the leaves, as well as the seed-and-pollen-bearing cones, of a plant seemingly closely related to *Zamia* have been excavated. And from the Black Hills of South Dakota and the sun-scorched Ferris Mountains of Wyoming come beautifully petrified plants belonging to the great cycad complex—bearing evidence of diversity and former distribution of the cycadophytes and of changing climates and topographies. . . .

Many other instances of exceptional racial longevity might be cited. Perhaps such well-known plants as the ginkgo and the clubmosses should at least be mentioned in passing, but since these have been considered in detail by many previous writers we have chosen to consider some of those plants whose ancestry has been somewhat less publicized.

The California Academy–Lingnan Dawn-Redwood Expedition

J. Linsley Gressitt

After Dr. Chaney's hurried trip to central China, an expedition was arranged jointly by the California Academy of Sciences and Lingnan University, Canton. It was led by Gressitt, an American with a great deal of field experience who was then working at Lingnan. His major goal was to collect zoological materials, but in the years from 1933 to 1936, he had also made extensive botanical collections in Hainan, Guandong, Fujian, and southern Jiangxi.

From mid-July to mid-August of 1948 Gressitt and the five Chinese students who accompanied him explored all the ravines, valleys, and hills in the vicinity of Modaoqi and Shuisapa, raising the count of known dawn redwoods from about 100 to 1,219. Gressitt was very much taken by the beauty of the trees, but they were not his primary interest; he hoped to find insects and other animals that might, like *Metasequoia*, be related to ancient North American species.

The dawn redwood] was apparently unknown outside its range before its recent scientific discovery by Chinese plant collectors. Probably its range in recent historic times has not been much more extensive than at the present time. This is suggested by the fact that the wood is not considered valuable, and is not carried out of the mountains as is the wood of *Cunninghamia*, or "Chinese fir." Nevertheless, the species has probably been suffering reduction of numbers over a long period. The fact that it requires a damp habitat and grows along streams makes its survival precarious with the increase of population and the rice fields spreading up into the higher valleys. Possibly the massacre 300 years ago of most of the people in eastern Szechuan by the Imperial forces for failure to pay taxes may have been an important factor in saving the tree from extinction in recent years. Another factor may be the apparent state of semicultivation under which the tree exists. The fact seems to be that a con-

siderable percentage of the existing trees have been transplanted to their present situations. For example, many of the large trees are in straight rows up ravines, paralleling the small streams. Others are around the farmhouses. Many young and medium-sized trees are in straight rows along the edges of rice fields bordering streams.

The reason for transplanting volunteer seedlings from the shaded ravines to particular situations, often in rows, is apparently based on local superstition. The mountain people have the habit of predicting their crops on the basis of cone development on the trees. A heavy crop of cones on the upper portions of the trees is said to indicate a good rice harvest, and an abundance of cones on the lower branches signifies good results from the hill crops (corn, drugs, herbs, lacquer, etc.). Thus it may actually be that the dawn redwood has been preserved from final extinction more or less by chance. It is interesting to note that the water pine,

ALL PHOTOS: LINSLEY GRESSITT ARCHIVIS OF THE ARNOLD ARBORIUM



Gressitt's count of 1,219 *Metasequoia* trees did not include all the young trees and, he suspected, not quite all the large trees. This one, located in lower Shuisapa valley near Hsiao-ho, at 115 feet in height and 8 feet in diameter is the largest he found, although he encountered several of about 100 feet high and 5 feet in diameter (at 6 feet above the ground).

Glyptostrobus pensilis, of southernmost China, is also planted for geomantic purposes, generally along old paths in the delta country.

After observing the soft and flexible nature of the foliage and branches, it is easy to understand how the tree has come to be semi-sacred and used for divination purposes. Particularly when observed in a breeze, the tree has a feathery and somewhat fairy-like appearance, and this seems to suggest its uniqueness.

The principal purpose of our trip was to collect insects and other animals in the hope of finding some ancient faunal elements of possible North American affinity

that might have survived with *Metasequoia* and the other ancient trees associated with it. . . . A number of the other genera of trees found in the same fossil deposits are still growing with the living dawn redwoods. What is still more striking is that the present dawn-redwood area is the only known place in the world where all of these particular trees, exclusive of *Metasequoia*, are now growing together. Thus we hoped to find some animals which might be descended from species that we find preserved in ancient fossil deposits, contemporaneous with the old deposits of *Metasequoia* that have been found in many places in Europe, North Asia, and North America. We even hoped to find some insects related to those in the present redwood association of California and Oregon. Since fossil birds are extremely few and the chance of wild animals having survived very slight, hope and emphasis were placed upon the insects. . . .

It is [Shuisapa] valley that contains the unusual assemblage of plants of ancient northern affinity, many of them being among the most familiar and conspicuous types of trees in Europe and North America. Among them are beeches, birches, poplars, willows, oaks, chestnut, maples, hornbeam, hop hornbeam, linden, sassafras, pine, and yew. If it were not for the rice paddies, farmhouses, and people, a European or American might believe himself near home. Forests of the extent found in this valley



Members of the California Academy-Lingnan dawn-redwood expedition. The author is at left.



The middle portion of Shuisapa valley as Gressitt photographed it in 1948. "The valley extends northeast and southwest and curves eastward at its upper end. The lower end is more or less closed by an east-west range of hills, the stream passing through a break in them, and continuing beyond to the southeast for a few miles, partly underground. On each side of the valley extends a fairly sharp ridge, the east ridge reaching 5,500 feet and the west ridge 5,100 feet in altitude."

are rarely seen in China except on the steeper slopes of high mountains, and in precipitous canyons or temple preserves. Immediately on entering the valley one cannot but sense its uniqueness, both from the standpoint of the unusual nature of the flora and from the extent of its preservation. Probably one reason for the slower rate at which the trees are being cut is that the nearest large commercial center is Wan Hsien, 120 miles walk to the north and in another province, whereas the stream in the valley flows in the opposite direction for a short distance underground just outside the valley, and then a very long distance, round about, with dangerous rapids and narrow gorges up which boats may not be towed, before meeting the Yangtze River between Chungking and Wan Hsien. Foresters who might dare to float rafts of logs downstream would have to dispose of their poles and ropes and walk back. Though trees are being cut locally at a seemingly alarming rate,

they are used mostly for local purposes, particularly for houses, fuel, and coffins. . . .

We made our headquarters in one of the two large farmhouses on the east side of the stream at Shuisapa. Part of this house was occupied by a former mayor, with the present mayor living in the other house. Since Dr. Chaney's visit four months earlier, the mayor's wife and one child had died and the mayor was now sick. We therefore could not live in his house, and had to be somewhat careful until we had made friends with the people, as they tended to ascribe this bad luck as caused by the foreigners coming and cutting down a dawn redwood for specimens. However, the local people themselves cut the trees not infrequently. There is a prevalent local custom of cutting the branches off the *Metasequoia* and *Cunninghamia* trees periodically, often almost to the very top, at least for the trees close to their houses. Thus most of the trees outside the shady ravines are apt to have an

extremely slender appearance as new branches are growing out. Sometimes the trees are thus killed, as had recently happened to two large metasequoias next to our farmhouse. For those not killed the practice reduces the potential self-seeding of the trees. . . .

Our principal emphasis was on insects, particularly those in association with the *Metasequoia* and other interesting plants of the valley. The plants we collected principally for the purpose of identifying the host-plants of the insects, and the serial numbers of the plant specimens were assigned to the insects col-



Side valley connecting with the eastern portion of Shuisapa valley. "Dawn redwoods are found scattered throughout the valley, and in some neighboring valleys to the immediate south. They are most abundant in the shady ravines branching from the central portion of the valley, though there are some large groups in certain spots near the southern end. Many young ones are also planted along the main stream, bordering rice fields. There can hardly be said to be any Metasequoia forests or even moderate natural stands."



Two Metasequoia trees, pruned for firewood, in Shuisapa valley.

lected on them. To all the local people we met we advertised our miscellaneous needs, offering to buy all kinds of animals. The returns from this method of acquiring specimens were less fruitful than I had experienced in some other parts of China, perhaps because these people seemed to have less use for money. . . .

Gradually, as a result of making rather high payments for specimens brought in, we acquired a certain number of snakes, lizards, frogs, and birds, but almost no mammals. The people stated that the summer was not the season for hunting, and they adhered to their custom. One of the reasons given, in addition to the fact that the animals are harder to find in summer, was that the summer was the breeding season. This, of course, was a commendable viewpoint.

From questioning the inhabitants, we gathered that tigers, leopards, wildcats, bears, deer, mountain goats (serow or ghoral), muntjacs,

foxes, civets, wild pigs, rabbits, squirrels, and others occurred here. Someone told us there was a family of leopards with small young at a certain point in the valley, but that was all we heard of them. . . .

In our daily collecting we generally divided into two groups, at least after lunch, as there were as many as nine of us collecting at one time. We attempted to collect along each ravine and ridge, to investigate all types of floral situations. . . . Much of our collecting consisted of sweeping the vegetation, one species at a time, when possible, to collect the insects from each kind of plant. At other times we worked on dead branches, fences, logs, stones, streams, and rotting materials. When there were no trails up to the passes or peaks, we had rough going through very dense vegetation, or had to detour. . . .



In south-central Shuisapa valley, members of the expedition and local boys hired to help with the collecting. In addition to butterfly nets, they carry a large cyanide jar, a plant press and other equipment, and lunch.



The largest of the three originally discovered Metasequoia trees, located at Modaoqi, Sichuan. Gressitt measured it at 90 feet in height and 5 feet in diameter. "My first view of the foliage reminded me vividly of the coast redwood, except for the softer and more fragile nature. These characteristics seem to set it off rather conspicuously from many other conifers. In fact, after the species has grown longer in cultivation, it may be judged one of the most beautiful of existing trees."

Our collecting resulted in the bringing back of tens of thousands of insects in addition to the plants and miscellaneous animals. . . . As to the scientific results, it will be some time before any conclusions can be drawn as to possible relationships of the insect fauna of the dawn-redwood flora with that of western North America. It may prove more closely related to that of southeastern North America, as is the case with most of the plant genera in common between eastern Asia and North America.

An Ecological Reconnaissance in the Native Home of *Metasequoia glyptostroboides*

Kwei-ling Chu and William S. Cooper

In August 1948, Professor Wan-chun Cheng of the National Central University, Nanjing, who with H. H. Hu named and described *Metasequoia glyptostroboides*, traveled to central China to see the trees for himself. He led an expedition that included Professor Chu, plant ecologist at the National Nanjing University, and C. T. Hwa, whom Cheng had sent to gather the seeds that he sent late in 1947 to Boston, St. Louis, Copenhagen, and Amsterdam, as well as to several institutions in China and elsewhere. The expedition was supported in the main by a grant from the American Philosophical Society under the joint sponsorship of E. D. Merrill and R. W. Chaney.

Chu's role in the enterprise was "to gather as much information as possible bearing upon the ecology of *Metasequoia*—its physical environment, its ecological life history, and its community relations." Cooper, professor of botany at the University of Minnesota, did not accompany the expedition, but provided literature not available in China and helped with the formulation of some of the conclusions as well as with the final preparation of the manuscript. The authors noted that within the short space of three years (1947–1949) fifty publications on *Metasequoia* had already appeared—almost all of them in China and the United States—about equally divided between scientific contributions and popular articles.

History of Shui-hsa Valley
[Over the course of the expedition] the senior author was fortunately able to glean something concerning the cultural history of Shui-hsa valley through conversations with Mr. Wu, more than sixty years old, who with his two brothers, prosperous and intelligent men, are the descendants of the earliest permanent settlers in the valley. The region was originally controlled by primitive nomadic tribes, some of whom still live in adjacent mountains. Mr. Wu's ancestors migrated from Szechuan to the Shui-hsa-pa region about two hundred years ago. From the Ching tribe in Chung-lu they bought

an area of mountain land in the vicinity of Shui-hsa-pa more than eight kilometers [five miles] long. At that time, according to Mr. Wu, the mountain slopes bore a forest cover so dense that one could not see the blue sky through the canopy, and the level valley floor had never been disturbed by man. Fires were set to destroy the forest, and rice paddies were established. Rice culture since then has extended over practically the whole of the level valley floor, and the forests on the mountain slopes have been largely destroyed because of timber use and charcoal making. The era of agricultural economy, with the destruction of native vegetation that it has

entailed, thus goes back about two centuries. It is significant that Shui-hsa valley has suffered less than any other part of the region, and one reason for this is doubtless the fact that it is a closed basin with no easy river route into it.

The Natural Habitat of *Metasequoia*

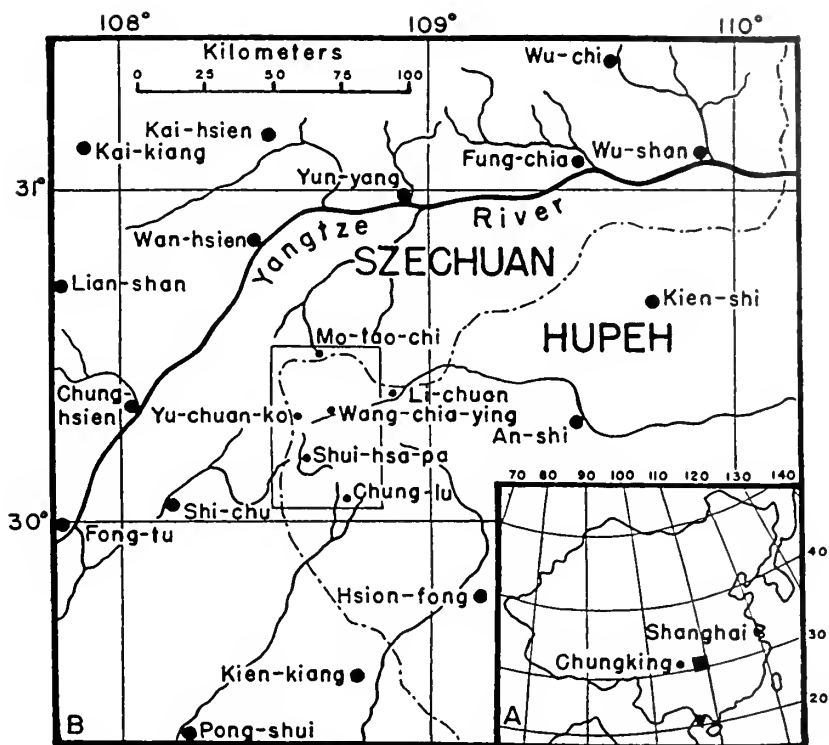
The region within which trees of *Metasequoia* have been found is estimated to have an area of about 800 square kilometers [312 square miles], with altitudes ranging from 700 to 1350 meters [2,300 to 4,400 feet]. However, only in a much smaller area does the tree appear to be an actively reproducing constituent of a natural forest community. It is situated in Shui-hsa valley and forms a strip along the main river 25 kilometers [15.5 miles] long and less than 1.5 kilometers [one mile] wide. The altitude here ranges from 1000 to 1100 meters [3,280 to 3,600 feet]. Outward from this center in all directions *Metasequoia* decreases in frequency. For a considerable distance—5 kilometers [3 miles] south of Shui-hsa-pa and 35 kilometers [22 miles] north to Mo-tao-chi, with altitudinal range of 900 to 1250 meters [3,000 to 4,100 feet]—many good trees occur and some fine large ones, for example the type tree at Mo-tao-chi and a very large one at Wang-chia-ying. This area, which is marked by the occurrence of fairly good or large trees, may be regarded as the region of optimum growth. The trees themselves may be relics from a time when the natural community including *Metasequoia* was more widespread than now. The trees most remote from the center, at the lowest and highest altitudes, are in poor condition.

In Shui-hsa valley *Metasequoia* finds its natural habitat in side ravines descending to the valley floor. Following a ravine or side valley down the mountain slope from either side one is sure to find *Metasequoia* trees at the lower end. They

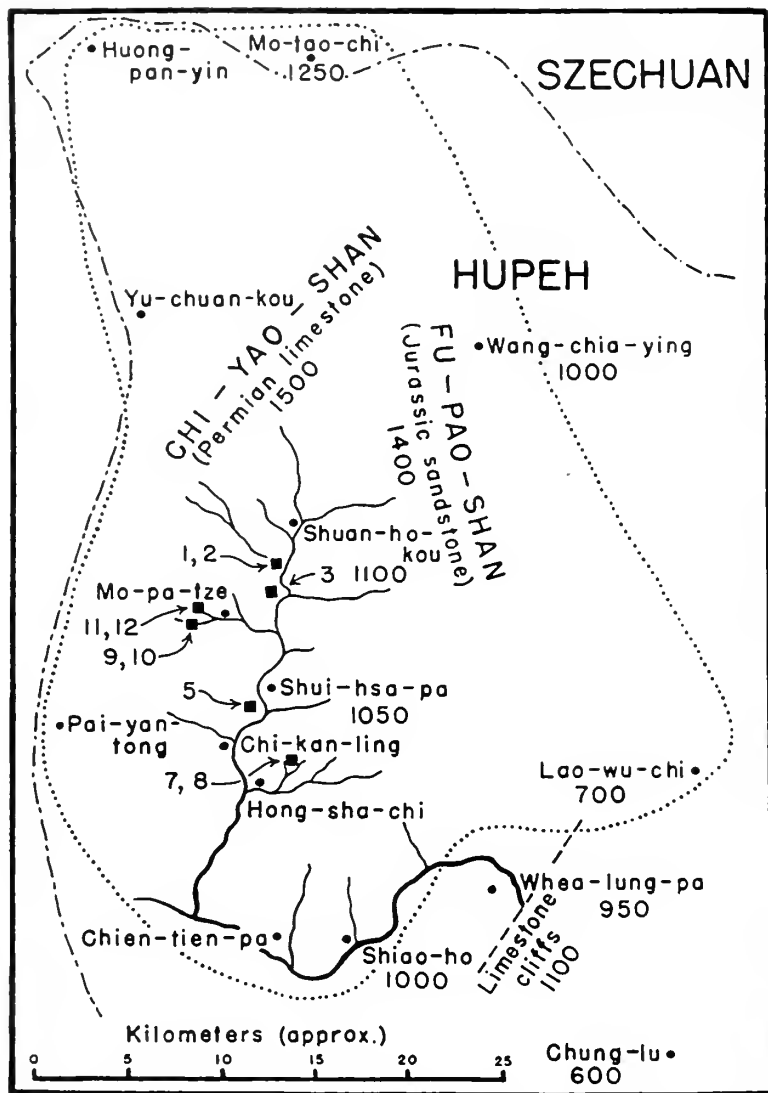
thrive particularly along the banks of small streams, among rocks and boulders covered thickly by liverworts and mosses, occurring usually in small groups or short lines. With them grows a variety of other trees, and in many places there is a dense thicket-like growth of shrubs and woody lianas. These growths are often very difficult to penetrate; inside them it is much cooler, darker, and wetter than without. In such places *Metasequoia* reproduces naturally. The habitat as described above is strongly reminiscent of that of blue spruce (*Picea pungens*) in the Rocky Mountains of Colorado, U.S.A. *Metasequoia* grows also in seepage areas at the foot of the slopes where there is abundant shade and moisture. The tree is found upon the valley floor itself, but here it has obviously been planted.

Quadrat Studies

To obtain more accurate knowledge concerning *Metasequoia* in its home a quadrat study was undertaken. The main purpose was to discover



A) Map of China. The black square indicates the location of B, the region surrounding the native home of *Metasequoia*. The rectangle indicates Shui-hsa valley and its immediate surroundings.



A sketch map of Shui-hsa valley and its immediate surroundings. Numbered black squares indicate the location of quadrats; the dotted line follows the approximate limits of *Metasequoia*. Large numbers give altitudes in meters. Shan means mountain range.

what species of trees, shrubs, and herbs are associated with *Metasequoia* in its natural habitat, and the relative proportions of these. No attempt was made to identify and distinguish plant communities; a comprehensive survey of the whole region would be essential for this. Another important aim was to gain information as to the reproducing ability of *Metasequoia* in its natural habitat.

Ten 10 x 10-meter [33 x 33-foot] quadrats were laid out in areas in which *Metasequoia*

was important. Selection of sites was determined by apparent approximation to natural conditions, and the area over which the quadrats were distributed coincided roughly with the region in which such conditions were found. The quadrats were placed along the foot of the mountain slopes on both sides of the river. A secondary quadrat (2 x 8 meters [6.6 x 26 feet]) was laid inside each major one for the counting of shrubs and seedling trees, and a still smaller one (0.25 x 4 meters [10 inches x 13 feet]) for herbs; but the density values of the shrubs and herbs were very variable and apparently of little significance and are therefore not given here.

For the tree species five size classes were distinguished: I, seedlings less than one foot tall; II, seedlings more than one foot tall; III, trees one to three inches in diameter; IV, trees four to nine inches in diameter; V, trees ten inches or more in diameter. Density (number of individuals in the 1000 square meters [a quarter of an acre] of the ten quadrats combined) has been computed for each species and each size class of a given species, and also presence (number of quadrats in total of ten in which a species occurs).

The following trees, not occurring in quadrats but close to them, are close associates of *Metasequoia*: *Cephalotaxus Fortunei*, *Fagus longipetiolata*, *Quercus acutissima*, *Sassafras tsumu*, *Tapiscia sinensis concolor*, *Ulmus multinervis*.

The large number of tree species making up the assemblage of which *Metasequoia* is a constituent—27 species occurring in 1000 square meters [a quarter of an acre] and 6 others nearby—is a striking point. Of the 33 species, only 4 are gymnosperms. As to average spacing of individuals, one [with diameter greater than ten inches] occurs each 33 square meters [40 square yards]. Those of one to nine inches diam-

Density and Presence of Tree Species on Ten 10 x 10-Meter Quadrats

	DENSITY					ALL CLASSES	PRESENCE
	SIZE CLASSES						
	I	II	III	IV	V		
<i>Metasequoia glyptostroboides</i>	16	17	4	7	18	62	10
<i>Cunninghamia lanceolata</i>	18	7	1	7	7	40	8
<i>Castanea Seguinii</i>	5	11	3	6		25	7
<i>Liquidambar formosana</i>	8	7		7		22	6
<i>Rhus</i> (3 spp.)	1	12	1	3		17	6
<i>Cornus controversa</i>	1	5		3	2	11	4
<i>Lindera glauca</i>	1	7				8	6
<i>Meliosma Oldhami</i> ¹	1	5		1		7	4
<i>Acer Davidii</i>	3	3	1			7	4
<i>Styrax japonica</i>		5		1		6	3
<i>Idesia polycarpa</i>		3		1		4	2
<i>Populus adenopoda</i>	1	1			2	4	3
<i>Nyssa sinensis</i>	1	2				3	2
<i>Prunus</i> sp.	1	2				3	2
<i>Kalopanax pictus</i> ²		2		1		3	2
<i>Clerodendron mandarinorum</i>		1		2		3	1
<i>Taxus chinensis</i>	3					3	1
<i>Pterocarya paliurus</i> ³	1				1	2	1
<i>Morus</i> sp.		2				2	2
<i>Quercus variabilis</i>		2				2	2
<i>Toricellia angulata intermedia</i>		2				2	1
<i>Salix</i> (2 spp.)		2				2	1
<i>Cercidiphyllum japonicum sinicum</i>				1		1	1
<i>Betula luminifera</i>			1			1	1
<i>Carpinus Fargesii</i> ⁴		1				1	1
<i>Ficus heteromorpha</i>		1				1	1
<i>Litsea elongata</i>		1				1	1
Total	61	101	11	40	30	243	
Ratio of <i>Metasequoia</i> to Total	.20		.36	.18	.60	.26	

¹ = *Meliosma pinnata*² = *Kalopanax septemlobum*³ = *Cyclocarya paliurus*⁴ = *Carpinus laxiflora* var. *macrostachya*



Members of the ecological expedition, from left, C. T. Hwa, W. C. Cheng, the expedition's leader, and K. L. Chu, standing in front of the trunk of the largest *Metasequoia glyptostroboides* found in 1948, near Wang-chia-ying.

eter are spaced one to each 20 square meters [24 square yards]. Seedlings occur one to each 6 square meters [7 square yards]. The picture is of a forest of moderate density as to mature trees and rather poor in reproduction. Five species are represented by individuals greater than ten inches in diameter—*Metasequoia*, *Cunninghamia*, *Cornus*, *Populus*, and *Pterocarya*. Fourteen are represented by individuals greater than four inches—in addition to the above, *Castanea*, *Liquidambar*, *Rhus*, *Meliosma*, *Styrax*, *Idesia*, *Kalopanax*, *Clerodendron*, and *Cercidiphyllum*. Eleven species are represented by seedlings only.

The species of outstanding importance, so far as the quadrats show, are obviously *Metasequoia*, *Cunninghamia*, *Castanea*, and *Liquidambar*—two gymnosperms and two angiosperms. They comprise 74 percent of the three upper size classes and 54 percent of the seedling classes. Moreover, they are for the most part well represented in all size classes, indicating that their present preeminence will be maintained. In presence they rank as high or higher than any in the list. . . .

Turning to *Metasequoia* in particular, it is plain that this species is the most important one in the assemblage. Of the total trees greater than 10 inches in diameter it makes 60 percent, and most of these individuals are 24 to 36 inches

in diameter. In the combined seedling classes it makes only 20 percent, but it surpasses every other single species. It is represented in every size class. All the evidence indicates that it will continue to maintain itself as an important member of the forest assemblage. . . .

Notes on Ecological Life History

. . . Seedlings are found in crevices between rocks and boulders and in moist sandy places. In the thicket-like growth beneath the forest trees are seedlings and young saplings up to 3 meters [10 feet] tall. As they grow larger, they encounter

serious interference from the lianas that are so thickly interlaced among the trees and shrubs. Other tree species are usually rigid enough to penetrate the mass without much difficulty. The stems and branches of *Metasequoia*, however, are flexible, and are bent over and deformed by the load of liana stems. The struggle to get through is a keen one. Such conditions are certainly not ideal for successful reproduction. *Metasequoia*, however, is evidently very shade-tolerant, and the dense thicket growth gives it a certain amount of protection from biotic dangers. . . .

Having finally penetrated the shrub-liana layer, *Metasequoia*, which probably has a faster growth rate than its companion species, develops rapidly, finally standing out conspicuously above them and recognizable at a great distance by its bright green color. . . .

Influence of Man

The present local distribution of *Metasequoia* has been much influenced by man, through destruction and also by planting. Its occurrence as an important forest constituent was once far more widespread than now, as is indicated by isolated big trees at considerable distances from Shui-hsa-pa. The type tree at Mo-tao-chi is 35 kilometers [22 miles] distant and the big tree near Wang-chia-ying more than 20 [12 miles].



The "big tree" noted by the authors, the largest found, photographed in 1948 by W. C. Cheng. Chu measured it at 50 meters [165 feet] tall and 2.22 meters—over 7 feet—in diameter at breast height. It grew in isolation on an open slope near Wang-chia-ying; in 1951 it was struck by lightning, split in three parts, and killed.

Such trees, three centuries old at least, must antedate the initiation of agricultural activity in the valley. After the natural vegetation had been displaced or profoundly modified because of agricultural use, effective reproduction was no longer possible. The natives apparently venerated the biggest trees and therefore protected them. It seems quite natural that the first permanent settlers in the region should recognize in the tree something different, unusual, and worthy of special respect. A small temple stands

beside the type tree at Mo-tao-chi. In neighboring valleys the natural communities of which *Metasequoia* was a constituent have been completely destroyed in the last two centuries. In Shui-hsa valley destruction has been only partial—but it still goes on. It seems certain that even before the period of destruction the stands of *Metasequoia* were discontinuous, occupying mainly ravines and stream banks as they do today.

In Shui-hsa valley there has been considerable planting of *Metasequoia*. Natives are constantly removing good-sized seedlings and saplings from their native sites. Small trees are growing along the banks of the main stream in straight rows. They are also seen on the margins of the rice paddies, along roadsides, and in home yards.

In view of the common practice of transplantation it is not surprising that stands of uncertain origin occur which may be hardly distinguishable from natural stands. Some of these consist of groups of ten to thirty mature trees that appear as if they had had a natural origin. The site, however, is not the normal one for *Metasequoia*. It is drier, the floor is clearer, and conditions are not favorable for reproduction. On the other hand, there are many natural stands so altered by man that they appear as planted.

It is not clear why the natives plant so extensively a tree that is of little economic importance to them. There is no systematic tree culture in Shui-hsa valley. A few trees of economic value are planted: *Magnolia officinalis*, the bark of which is used as a medicine, *Juglans cathayana* for the nuts, *Rhus verniciflua* for lacquer. *Cunninghamia lanceolata* is regarded as the best timber tree of the region, but it is not planted. *Metasequoia* is sometimes used for fuel and in construction, but its wood is not considered to be of good quality. Aside from these rather incidental uses,



Metasequoia glyptostroboides is most often found in the wild on unarable terrain. Professor Cheng photographed these trees in a ravine at the side of Shui-sha valley, August 1948. Members of the expedition found that *Metasequoia* trees in Shui-sha valley were generally 6–9 decimeters [2 to 3 feet] in diameter; medium-sized trees were uncommon.

the reason for planting *Metasequoia* must be mainly an aesthetic one.

The fate of *Metasequoia* rests with man. If destruction continues, all the native stands will be eliminated. The massive veterans will ultimately die, leaving only the planted trees surviving—the same fate that has already overtaken *Ginkgo*.

Conclusion

... [*Metasequoia*] is partial to slightly acid or circumneutral soils derived from sandstone; it avoids soils of limestone origin in areas that appear to be otherwise suitable. Moist soil and humid atmosphere seem to be essential for successful reproduction. These various conditions are fulfilled in narrow ravines and seepage grounds; the tree is essentially a member of a streambank community. The evidence for these conclusions comes from Shui-hsa valley, a very small part of the whole range of the species.

The scattered individuals of considerable or large size growing beyond the confines of the valley need to be accounted for. It seems necessary to conclude that conditions like those in

Shui-hsa valley existed elsewhere nearby in the none too distant past; that in favorable spots reproduction of *Metasequoia* was possible recently enough to have given rise to the existing mature trees. Increase of human population, with consequent exploitation of the natural resources of the area, has resulted in general destruction of the conditions essential for reproduction of *Metasequoia*; a certain number of mature individuals survive.

Only in Shui-hsa valley does *Metasequoia* exist under an approximation to natural conditions. This may be due in part to certain environmental advantages. The valley lies at a somewhat higher elevation than others in the sandstone region, it is narrower, and certain features of its local climate seem to be in its favor. More important, probably, is

the fact that this valley was the last to be occupied by permanent settlers, the period of occupation extending back only two centuries. Late settlement is doubtless due to its higher altitude, the comparatively small area favorable for rice culture, possibly poorer soil, and particularly its unique character as a basin completely enclosed by mountains, with no easy river route into it. Increase of population pressure outside finally became the incentive leading to its occupation. Shorter period of occupation and sparser population have permitted *Metasequoia* to remain here in an approximately natural state.

It is gratifying to know that a "*Metasequoia* Conservation Committee" has been formed in China. Its honorary chairman is Dr. Hu Shih, former ambassador to the United States; its chairman is Mr. Wong Wen Ho, former Premier of China and a noted geologist. It is to be hoped that the efforts of these Chinese scientists to preserve the natural stands of *Metasequoia* through the establishment of a national park or some other form of nature reservation will, in spite of formidable difficulties, be crowned with success before it is too late.

Metasequoia glyptostroboides—Its Status in Central China in 1980

Bruce Bartholomew, David E. Boufford, and Stephen A. Spongberg

After the success of the Communist revolution in 1949, China closed its boundaries to Westerners, ending collaboration between Chinese and American botanists until the 1970s. With the invitation in 1978 to a delegation of American botanists to visit the People's Republic of China, ties broken three decades earlier were renewed. After the month-long visit, the Americans in turn invited their Chinese colleagues to visit the United States the next year. During that visit plans were made for a collaborative expedition to western Hubei Province—the 1980 Sino-American Botanical Expedition—conducted under the auspices of Academia Sinica and the Botanical Society of America.*

As members of that expedition, the authors of this report did fieldwork in western Hubei Province in the late summer and early fall of 1980. Most of their time was spent in the Shennongjia Forest District, but they also made a brief visit, October 5 to 10, to the region where *Metasequoia* still grows wild, the first foreigners to visit since 1948.

After a visit to Modaoqi to see the tree that was the source of the type specimen of *Metasequoia glyptostroboides*, they continued on to Lichuan. For the next three days, they traveled to Metasequoia Valley, three hours each way. They sought out noteworthy trees of *M. glyptostroboides* and interviewed local officials about their work in inventorying and conserving the naturally occurring trees and about their program of seed collection and propagation. This excerpt relates their observations of the condition of wild-growing *Metasequoia* and of the vegetation associated with it.

Almost all of the naturally occurring trees of *Metasequoia* grow in the central valley of Xiaohe Commune. Since 1974 the Bureau of Forestry of Lichuan Xian [county] has maintained a staff of five people in the Commune, with one of their objectives being to measure each tree every four years. The Forest Bureau has counted and numbered 5,420 trees with a diameter (at breast height) of at least

20 centimeters [8 inches]. We were told that approximately 1,700 to 1,800 of these are mature, seed-producing trees. The tallest recorded trees in the valley are on the east side in the vicinity of Hongshaxi: several reach a height of about 50 meters [165 feet]. . . .

In its natural habitat *Metasequoia* is now protected by the government, and not even small trees may be cut. The trees that we saw (includ-

Excerpted from "*Metasequoia glyptostroboides*—Its Present Status in Central China," *Journal of the Arnold Arboretum* (1983) 64: 105–128.

* Richard Howard's account of his 1978 visit to China was published in *Arnoldia* (Nov./Dec. 1978) 38(6): 218–237. See also Stephen A. Spongberg, *A Reunion of Trees* (Cambridge: Harvard University Press, 1990), 238–239.



ing the two ancient ones at Modaoqi and Xiaohe) all appeared to be in good health. However, we did not see any small seedlings. This differs from the situation in 1948, when Chu and Cooper found seedlings in thickets surrounding older *Metasequoia* trees. In 1980 vegetation was either absent around the trees of *Metasequoia*, or very closely cropped, presumably by the local people and not by animals. The lack of governmental protection of the habitat (and thus the lack of associated vegetation) probably accounts for the lack of seedling establishment.

The "Metasequoia Flora"

The habitat of *Metasequoia* is reminiscent of that of *Taxodium distichum* in the southeastern United States, a parallel previously drawn by Chaney. *Metasequoia* is a riparian species, and before habitation the valley floor may well have been a *Metasequoia* forest. *Metasequoia* trees that occur away from the valley floor are restricted to the moist bottoms of ravines and draws that drain into the main valley. *Taxodium* commonly occurs in flat,



Above, participants of the 1980 expedition to western Hubei Province. Bruce Bartholomew, David Boufford, Stephen Spongberg, and James Luteyn, with two residents who remembered the 1948 visit of J. L. Gressitt to Metasequoia Valley.

Below, the type tree, near Modaoqi, looked essentially the same in 1980 as it does in photographs taken in 1948. The shrine seen at the base of the tree in photographs from 1948 had been removed, and the tree was surrounded by rice fields and a small, ditched stream. It appeared healthy and bore seed-filled cones, but it had grown only very slightly in the previous thirty years.



The oldest *Metasequoia* tree in Xiaohe Commune stands near the town of Xiaohe. A partial coring in 1977 yielded an age estimate of 420 years.

virginica, *Cornus* spp., and *Lindera benzoin*. . . . While each of the species of this group has specific microhabitat requirements, all are usually found growing in close proximity to *Taxodium*.

In their list of plants growing with *Metasequoia*, Chu and Cooper included species of many of the same genera. We noted several large trees of *Liquidambar acalycina* and species of *Salix*, *Acer*, *Pterocarya*, and *Quercus* in habitats similar to those occupied by *Metasequoia*, but not on the adjacent slopes. Moreover, it seems likely that at one time the floor of the *Metasequoia* Valley was occupied by trees that were



The group was disappointed to find that the ecological conditions in *Metasequoia* Valley had changed drastically since the 1948 expeditions. The thickets in which Chu and Cooper had found seedlings and young plants had been cleared from the base of each *Metasequoia* tree. This grove of *Metasequoia glyptostroboides* is growing at the bottom of a small ravine above the main valley floor near the village of Xiaohe.

poorly drained depressions behind natural levees along slow-moving rivers. Based on this similarity of habitats, on reports of the species associated with *Metasequoia* (Chaney, Chu & Cooper, Gressitt), on [Shuiying] Hu's enumeration of the "*Metasequoia* Flora," and on our own observations, both in the southeastern United States and in the *Metasequoia* Valley in 1980, it is possible to hypothesize a past *Metasequoia* forest analogous to present-day *Taxodium distichum* forests.

Among the dominant tree species usually found with *Taxodium distichum* are *Nyssa aquatica*, *N. sylvatica* var. *biflora*, *Populus heterophylla*, *Quercus* spp., *Liquidambar styraciflua*, *Carpinus caroliniana*, *Betula nigra*, *Acer rubrum*, *Ulmus americana*, *Carya* spp., *Fraxinus* spp., and *Salix* spp. The associated shrubs include *Ilex* spp., *Viburnum* spp., *Itea*



Two views of *Metasequoia* Valley. At the top is J. L. Gressitt's 1948 photograph. The slopes in the background are covered in forest, and only on the level valley floor are there fields.

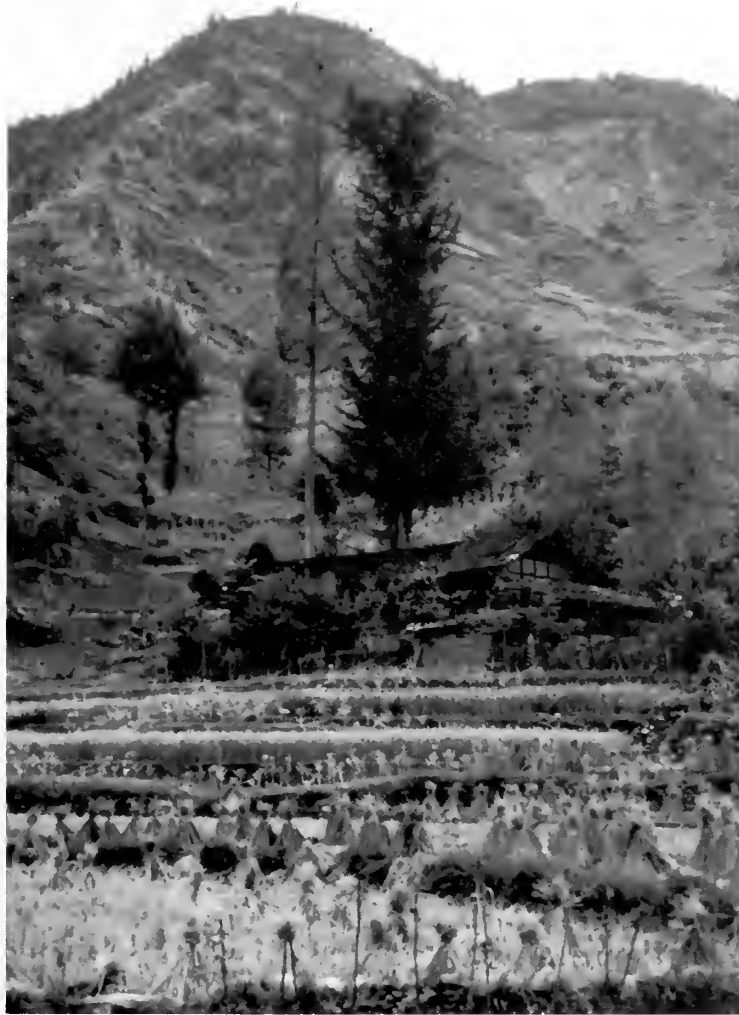
Below, in a photograph taken in 1980, rice is cultivated extensively on the lower slopes as well as on the valley floor. The columnar trees along the edges of the paddies are a mixture of *Metasequoia glyptostroboides* and *Cunninghamia lanceolata*; the columnar habit has resulted from pruning the lateral branches for firewood. (This photo can be seen in color on the cover.)

luminifera; *Carpinus fargesii*; *Quercus* spp.; *Morus* sp.; *Cocculus orbiculatus*; *Ulmus multinervis*; *Lindera glauca*; *Liquidambar acalycina* (*L. formosana* in Chu and Cooper); *Ilex* spp.; *Berchemia* spp.; *Nyssa sinensis*; *Cornus controversa* and *C. macrophylla*; *Clethra fargesii*; *Styrax bodinieri* and *S. suberifolius*; *Viburnum* spp.; and *Smilax* spp. . . .

Chu and Cooper stated that *Metasequoia* appears to grow naturally only in sandy soil derived from Jurassic sandstone, and that only cultivated trees grow over limestone. They also mentioned that the valley floor is derived mainly from sandstone, providing rather strong suggestive evidence that the floor could have been occupied—and perhaps dominated—by much more extensive stands of *Metasequoia*. Additional evidence of a once more widespread *Metasequoia* forest on the valley floor is provided by several large trunks of *Metasequoia* that we saw that had recently been unearthed in the center of paddy fields far from the nearest slopes and ravines where the trees now grow. Altogether more than 200 of these trunks, many over two meters [6 1/2 feet] in diameter, have been found in the paddies along the level floodplain of the main river and side streams (T. S. Ying, pers. comm.). Also (according to Liu et al.), some of the houses in the valley were constructed of boards cut from *Metasequoia*. These houses are believed to be 200 to 300 years old

and date roughly from the time of the original settlers. . . .

The high population density [of the valley containing the main *Metasequoia* population] has resulted in considerable damage to the local vegetation. Both Chu and Cooper and Gressitt reported that the forests had largely been destroyed by the time of their visits, and even the *Metasequoia* communities showed signs of alteration due to man's activities. We found that conditions had deteriorated even more since these reports. Our observations indicate that



The results of human habitation can be seen on the highly disturbed slopes of a side valley photographed in 1980. The upper slopes are largely denuded of native vegetation, and the lower slopes have been given over to rice paddies and cornfields. (The tree behind the building is *Ginkgo biloba*.)

tolerant of periodic flooding, could grow in poorly drained soils, and occupied more or less specific microhabitats. Among the species listed as being associated with *Metasequoia glyptostroboides* by Chu and Cooper, Gressitt, and Hu, the following grow in habitats similar to those of their American counterparts associated with *Taxodium*: *Houttuynia cordata* (in place of *Saururus cernuus* in the southeastern United States); *Populus adenopoda*; *Salix* spp.; *Pterocarya hupehensis*; *P. paliurus* and *P. stenoptera* (all in place of *Carya* spp.); *Betula*

there has been so much human and domestic animal disturbance that there are very few plants now associated with *Metasequoia*. However, there are areas in Xiaohe Commune, particularly in side ravines and on slopes on the east side of the main valley, where secondary forests are developing. Although these areas are close to the *Metasequoia* groves, they are separated by cut-over slopes and cultivated fields from the riparian areas occupied by *Metasequoia*. Comparison of the present condition of the forests with photographs taken in 1948 shows considerable destruction during the past 32 years. We were told that many large trees, particularly *Castanea henryi* and *C. mollissima* were cut in the mid to late 1950s during the Great Leap Forward to make charcoal for smelting iron. However, no significant amount of iron was ever produced.

The protected status currently given by the government to the remaining naturally occurring trees of *Metasequoia* will probably insure their survival for the immediate future, but the lack of protection for the surrounding habitat will likely result in little, if any, natural reproduction. The thickets that Chu and Cooper mentioned as being around many of the trees are no longer there, and it was in those habitats that they reported finding seedlings and small trees of *Metasequoia*. The efforts to monitor the natural populations of *Metasequoia* may have

resulted in disturbance and clearing of other vegetation, thereby contributing to the destruction of suitable germination sites.

References

- Chaney, R. W. 1948. The bearing of the living *Metasequoia* on problems of Tertiary paleobotany. *Proceedings of the National Academy U.S.A.* 34: 503-515.
- Chu, K. L., and W. C. Cooper. 1950. An ecological reconnaissance in the native home of *Metasequoia glyptostroboides*. *Ecology* 31: 260-278.
- Gressitt, J. L. 1953. The California Academy-Lingnan dawn-redwood expedition. *Proceedings of the California Academy of Science* 28: 25-58.
- Hu, S. Y. 1980. The *Metasequoia* flora and its phytogeographic significance. *Journal of the Arnold Arboretum* 61: 41-94 [also, <http://www.herbaria.harvard.edu/china/HarvardPapers/hu-shui-ying1980.htm>].
- Liu, Y. C., X. T. Zhou, and P. L. Su. 1978. Shuisha. Hubei: Hubei People's Press [in Chinese].

Bruce Bartholomew, leader of the expedition in 1980, was then at the University of California Botanical Garden in Berkeley. Presently he is at the California Academy of Sciences. David Boufford was at the Carnegie Museum of Natural History in 1980, but soon thereafter moved to the Harvard University Herbaria. Stephen A. Spongberg, then at the Arnold Arboretum, has recently moved to Martha's Vineyard, Massachusetts, where he is director of the Polly Hill Arboretum.



AN UPDATE

Metasequoia: An Overview of Its Phylogeny, Reproductive Biology, and Ecotypic Variation

Jianhua Li

The discovery of the dawn redwood sparked renewed interest in the relationship between two important families, Cupressaceae (well-known genera include *Chamaecyparis*, *Cupressus*, *Juniperus*, *Thuja*, *Calocedrus*) and what used to be called Taxodiaceae (*Cryptomeria*, *Cunninghamia*, *Glyptostrobus*, *Metasequoia*, *Sciadopitys*, *Sequoia*, *Sequoiadendron*, *Taiwania*, *Taxodium*). *M. glyptostroboides* is similar to Cupressaceae in the opposite arrangement of the vegetative and floral organs, whereas the pollen and wood anatomy of *M. glyptostroboides* are most similar to members of Taxodiaceae. It was on the basis of these morphological peculiarities that *Metasequoia* was placed in its own family—*Metasequoiaceae* (Hu and Cheng 1948). However, this placement was never widely accepted; taxonomists have traditionally classified it within Taxodiaceae. Based on recent phylogenetic studies, many now combine Taxodiaceae with Cupressaceae under the latter name.

Initially, many botanists believed *Metasequoia* to be closely allied with four genera, three of which consist of a single species: *Sequoia sempervirens* (California redwood, endemic to the California coast), *Sequoiadendron giganteum* (giant sequoia, endemic to the Sierra Nevada mountains of California), *Glyptostrobus pensilis* (the water pine, endemic to the south coast of China), and *Taxodium* (the bald cypress), which has two species, *T. distichum*, of the southeastern United States,



Dawn redwood *Metasequoia glyptostroboides*



Coast redwood *Sequoia sempervirens*

and *T. mucronatum*, which is scattered throughout Mexico.

In a study of the chromosomal and morphological characteristics of these five genera, G. L. Stebbins (1948) concluded that *Glyptostrobus* and *Taxodium* resemble each other more than either resembles *Sequoia*, *Sequoiadendron*, or

Metasequoia. Among the last three genera, he concluded that if only vegetative characteristics (notably, leaf arrangement and nondeciduousness) are considered, the two North American genera are more closely allied, but that on the basis of number of chromosomes, the giant

sequoia is more similar to the dawn redwood than to the coast redwood.

In more recent research—an examination of DNA sequences in the chloroplast *rbcl* gene conducted in 1994 by Brunsfeld and co-authors—all three genera were found to be closely related, but the authors concluded that the closest relationship is between *Sequoia* and *Sequoiadendron*. Their conclusions are supported by other lines of evidence, including the karyotypic similarities found by Schlarbaum and Tsuchiya in 1984; the 1989 immunological analysis of Price and Lowenstein; and cladistic analyses of morphological, anatomical, and chemical traits conducted by Yu in 1996.



Giant redwood *Sequoiadendron giganteum*

Reproductive Biology

Metasequoia is monoecious (with both female and male cones on the same plant). The male cones appear in mid-June, the female in early July.

Table 1. Comparison of Some Morphological Characters

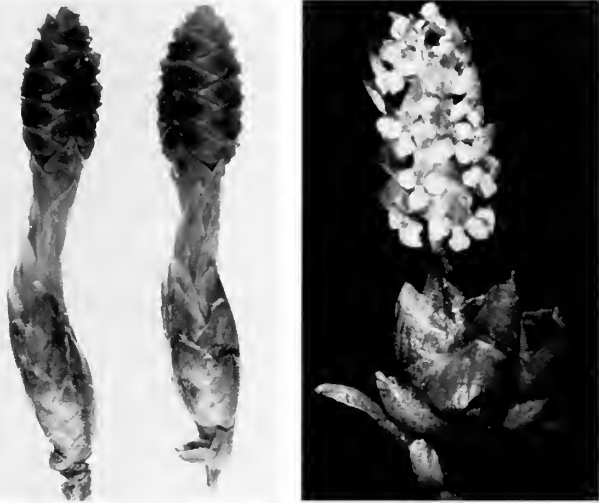
	<i>Metasequoia</i>	<i>Sequoia</i>	<i>Sequoiadendron</i>
Deciduousness	yes	no	no
Leaf arrangement	opposite or decussate	alternate or spiral	alternate or spiral
Leaf shape	linear	needle and scale	scale
Number of microsporangia	3	3	3
Ovule orientation	anatropous	anatropous	anatropous
Seed wing	lateral	lateral	lateral
Seed scale	wide	wide	wide
Cotyledon number	2	2	6
Chromosome number (2n)	22	66	22

Pollen forms in November and is carried to the female cone by the wind in early spring of the following year. Fertilization occurs in June; the embryo matures in October or November.

Seed production is low, for several reasons. In the wild, a dawn redwood tree does not produce



A branch of *Metasequoia* with young female cones.



Developing cones of *Metasequoia glyptostroboides*. Left, female cones; male cone at right.



Female *Metasequoia* cones.

This cladogram, or phylogenetic tree, is taken from Brunfeld and co-authors (1994); it represents their interpretation of the phylogenetic relationships within a plant family. "T" denotes genera traditionally placed in Taxodiaceae and "C," Cupressaceae; "O" stands for outgroup, genera outside the family that are close relatives of the ingroup and which are included in order to "root" the tree.

The numbers above the branches on the tree indicate the numbers of changes in nucleotide—the building blocks of DNA—composition in the gene that Brunfeld and his co-workers studied. These changes occurred during the evolution of the now-extinct ancestors that are represented by the branch; the lower the number, the closer the relationship.

However, quantity does not always convert to quality, and the percentages given below the branches indicate the results of a test applied to the data to see just how strongly the evidence supports each branch of the tree. The closer the figure is to 100 percent, the better supported a branch is; figures much below 70 percent suggest at most only moderate support.

Branches in phylogenetic trees are usually paired. Sometimes, however, as with *Taiwania*, *Taxodium*, and *Athrotaxis*, several branches arise together, and that probably means that the particular gene studied did not provide enough data to convert this part of the cladogram into its normal bifurcating condition.

If we read the tree from the "root" up, within Cupressaceae (defined as including Taxodiaceae), *Cunninghamia* is the "basal offshoot"; the other genera (excepting *Sciadopitys*, which many taxonomists place in its own family) are all part of a "clade," or lineage, that comprises the rest of the family. Within this large clade, *Metasequoia* and the even more closely related *Sequoia* and *Sequoiadendron* form a small clade (the *Metasequoia* clade), as do *Glyptostrobus* and *Cryptomeria* (the *Glyptostrobus* clade). The *Glyptostrobus* clade and the clade of traditional Cupressaceae (C) share a common ancestor (the node connecting the two clades); thus, they are more closely related to each other than either is to the *Metasequoia* clade. The phylogenetic tree, therefore, suggests that traditional Cupressaceae originated within Taxodiaceae.

The authors also point out that because *Metasequoia* is closely allied to the nondeciduous *Sequoia* and *Sequoiadendron* and because the three deciduous genera—*Metasequoia*, *Glyptostrobus*, and *Taxodium*—lack close affinities, the deciduous habit may have evolved as many as three separate times in the Taxodiaceae.

fertile male cones—nor, therefore, viable seeds—for twenty-five or thirty years. The extreme humidity and high rainfall in the habitat of the native *Metasequoia* during the pollination period may affect pollen transport and/or prevent the female cones from opening to accept the pollen. As a consequence, on plantations artificial pollination is often used to increase seed production.

Ecotypic Variation

The largest natural populations of the dawn redwood are limited to small valleys within an area of about 600 square kilometers (235 square miles) in western Hubei Province. Albeit small, these valleys include a variety of microhabitats, in which dawn redwoods of different types have developed. Local researchers, after years of intensive observation, have recognized three

Table 2. Traits of the Three Ecotypic Variations of Dawn Redwood

<i>Ecological type</i>	<i>Large cone</i>	<i>Medium cone</i>	<i>Small cone</i>
Cone size (cm)	2.2 x 2.0	2.0 x 1.8	1.5 x 1.4
Number of seeds per 500 grams	128	161	280
Number of seeds per cone	106	85	62
Seed size (cm)	0.6 x 0.5	0.53 x 0.48	0.48 x 0.42
Weight per 1,000 seeds (grams)	2.96	2.84	2.4
Seed germination rate (%)	15	21	18
Branch angle	>90	medium	<50
Branch distribution	sparse	medium	dense
Branch canopy	wide	medium	narrow
Leaf density	low	medium	high
Leaf color	yellowish green	green	dark green
Stem furrows	distinct	very distinct	indistinct
Bark color	gray	brownish gray	brown
Bark thickness	thick	medium	thin
Ecological preference	mountain slope drought-tolerant	wide; medium drought-tolerant	ditch or creek drought-intolerant
Growth rate	fast	medium	slow

variations based on the size of their cones, large, medium, and small. The large-cone type tends to grow on mountain slopes. Compared to the other types, it resists drought better and develops a broader canopy, making it the preferred choice for use as a street tree. It also surpasses the others in seed production, a quality useful for plantations. At the other end of the spectrum, the small-cone type grows along streambanks. It tolerates drought less well, but develops a more uniform trunk and is therefore the type of choice for construction timber.

The delineation of these variations is based solely on morphological observations; further study is needed to determine whether they are genetically different. Assessment of the correlation between genetic and ecotypic variations should provide a basis for horticultural and economic selections. Allozyme research has revealed genetic variation in wild dawn redwoods, but studies have not addressed genetic structure associated with ecotypic variations.

References

- Brunsfeld, S. J., P. S. Soltis, D. E. Soltis, P. A. Gadek, C. J. Quinn, D. D. Strenge, T. A. Ranker. 1994. Phylogenetic Relationships among the Genera of Taxodiaceae and Cupressaceae: Evidence from *rbcL* Sequences. *Systematic Botany* 19(2): 253–262.
- Committee of Science and Technology of Lichuan, Hubei. 1980. *Metasequoia*. *Lichuan Science and Technology* 2.
- Hu, H. H. 1948. On the new family Metasequoiaceae and on *Metasequoia glyptostroboides*, a living species of the genus *Metasequoia* found in Szechuan and Hupeh. *The Bulletin of the Fan Memorial Institute of Biology*: New Series 1(2): 153–161.
- Kuser, J. E., D. L. Sheely, and D. R. Hendricks. 1997. Genetic variation in two *ex situ* collections of the rare *Metasequoia glyptostroboides* (Cupressaceae). *Silvae Genetica* 46: 258–264.
- Price, R. A., and J. M. Lowenstein. 1989. An immunological comparison of the Sciadopityaceae, Taxodiaceae, and Cupressaceae. *Systematic Botany* 14: 141–149.
- Schlarbaum, S. E., and T. Tsuchiya. 1984. Cytotaxonomy and phylogeny in certain species of Taxodiaceae. *Plant Systematics and Evolution* 147: 29–54.
- Stebbins, G. L. 1948. The chromosomes and relationships of *Metasequoia* and *Sequoia*. *Science* 108: 95–98.
- Yu, Y., and L. Fu. 1996. Phylogenetic analysis of the family Taxodiaceae. *Acta Phytotaxonomica Sinica* 34: 124–141.

Acknowledgments

The author is grateful to Karen Madsen for her great efforts in making the article more readable and to Dr. Peter Del Tredici for constructive suggestions.

Jianhua Li is currently the botanical/horticultural taxonomist at the Arnold Arboretum. His research interests include phylogenetic relationships and the biogeography of the disjunct plant groups of eastern Asia and eastern North America.

From Fossils to Molecules: The *Metasequoia* Tale Continues

Hong Yang

Recent studies of the wild population in China using the techniques of cuticle micromorphology and population genetics have introduced new ideas about the evolutionary history of *Metasequoia glyptostroboides*, previously limited to hypotheses drawn from the fossil record. The new information suggests that the living *Metasequoia* trees may be recent immigrants to their remote valley in central China, rather than Tertiary relics dating back as far as 15 million years ago.

My first encounter with the genus *Metasequoia* occurred more than fifteen years ago when I was a college student in Wuhan, a city along the Yangtze River in the Hubei Province of central China. In a paleobotany lab session, I was shown a fossil of *Metasequoia* foliage collected from a Tertiary deposit in northeastern China; minutes later I was led outside to inspect the city tree of Wuhan—living dawn redwoods planted along roadsides. Seeing the close resemblance between a fossil imprint preserved in a rock for over 50 million years and the green leaves shining in front of my eyes was a breathtaking experience. Equally astounding to me was the story of *Metasequoia glyptostroboides*, the dramatic discovery of a living tree previously known to science only as a fossil, a story that had unfolded in that same province in the early 1940s (Hu 1948, Merrill 1948). What I could not foresee was that this college exercise had planted a seed in my mind that later grew into a strong professional attachment to this species. The dawn redwood legend has led me twice to “*Metasequoia* Valley” in central China and engendered a tremendous interest in pursuing its evolutionary history through both fossil records and DNA molecules.

I came to the United States in 1988 for graduate training under Professor Charles J. Smiley at the Tertiary Research Center of the University of Idaho, and it was there, in Smiley’s personal library, that I read intensively in the literature on both modern and fossil *Metasequoia*.¹ Smiley had been a graduate student of Professor Ralph W. Chaney, the first Western scientist to travel to *Metasequoia* Valley, in 1948, and in Smiley’s files were copies of remarkable photographs that Chaney and his traveling companion had taken during their trip there shortly after the discovery of the living trees.

In 1988, Smiley was conducting research on the *Clarkia* Miocene fossil site, an exceptionally well-preserved fossil deposit in northern Idaho that contained abundant *Metasequoia* fossils as well as other warm-temperate plant genera that Chaney had observed during his trip to *Metasequoia* Valley. I was interested in the theory of “Arcto-Tertiary flora” that Chaney had put forward to explain the origin and distribution of plants around the Pacific basin. He argued that *Metasequoia* and the plants associated with it originated in the high northern latitudes during the Cretaceous period, over 65 million years ago; then the whole assemblage was gradually pushed southward into the modern *Metase-*

¹ After Dr. Smiley’s sudden passing on January 1, 1996, his personal library was donated to the Nanjing Institute of Geology and Palaeontology, the Chinese Academy of Sciences.



The oldest Metasequoia tree in Xiaohe Commune, estimated at 440 years of age, photographed in 1997. Photographs taken in 1948 and 1980 can be seen on pages 36 and 49, respectively.

quoia Valley during the Tertiary, beginning around 40 million years ago when the global climate started to cool. A trip to Metasequoia Valley to trace Chaney's steps among the "living Tertiary flora" appealed to both Smiley and me.

Historical Biogeography Revealed by Its Fossil Record

In June 1990 Professor Smiley, his wife Peg, Professor Fred Johnson, a forest ecologist from the University of Idaho, and I took only four hours

to complete the journey from Wanxian (known as Wan Hsien in the old spelling) to Moudao (also known as Mo-tao-chi) that Chaney completed in three days in 1948. Still, the narrow road and steep slopes reminded me of a poem by Li Bai, the great poet of the Tang Dynasty, who described traveling in the mountains of Sichuan as being as difficult as climbing to the sky. Although the hardwood forest that Chaney had seen growing alongside the dawn redwoods had been cut down over the previous forty years, the enormous, centuries-old dawn redwood that Chaney had admired in Moudao still stood proudly in the middle of farmland, and I could not help but be amazed by its power to endure time and environmental change. Touching the tree's reddish bark and looking up at its top branches, I had to wonder when and how it got there, and why the species survives only in this remote valley. The answers to my questions, it seemed, were to be found only in the fossil record.

For Chaney, the discovery of living *Metasequoia* provided a critical piece of evidence in support of his theory, but since his time, more fossil *Metasequoia* have been reported. I

wanted to find out if Chaney's theory was still valid in light of new findings from China, Japan, and Russia. Shortly after our trip to Metasequoia Valley, I started to compile the *Metasequoia* fossil record from the Cretaceous onward, and a more detailed picture of *Metasequoia* history started to emerge (Yang and Smiley 1991). It is apparent that the story of this remarkable tree encompasses the entire history of the Northern Hemisphere over the past 100 million years, including the changes in land connec-

tions and climates and the evolution of living organisms.

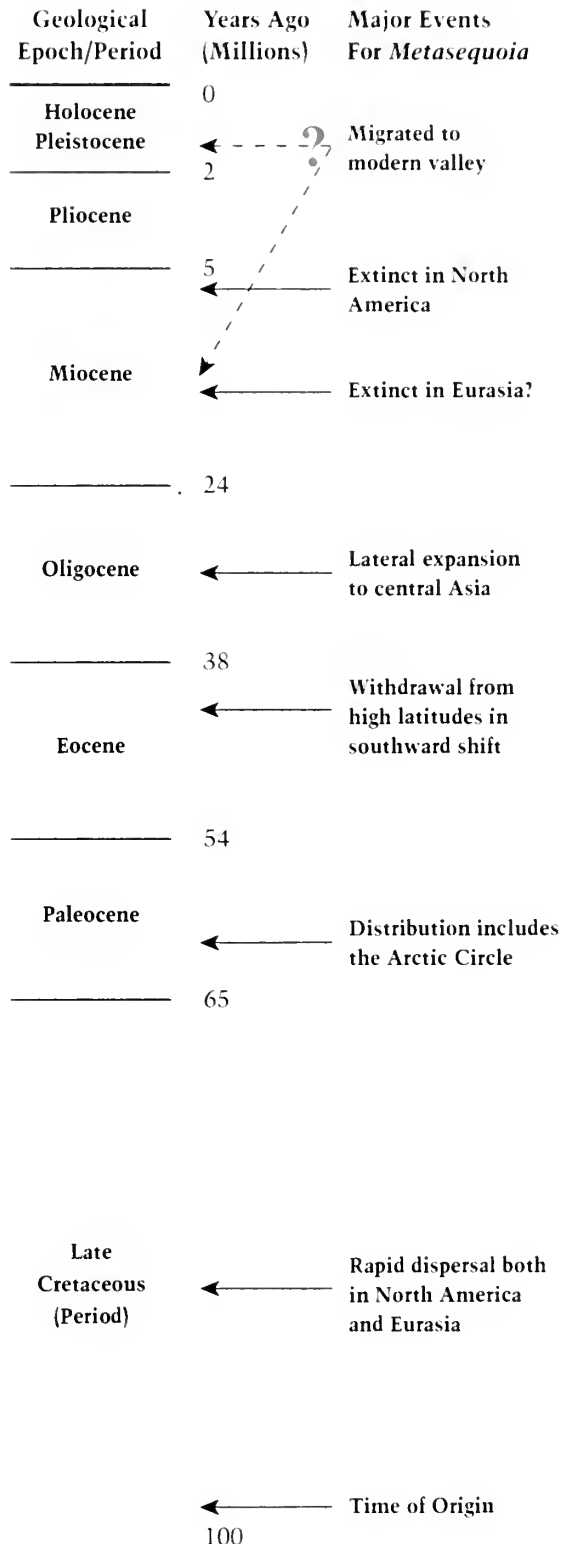
The up-to-date fossil record reveals the following four major phylogeographic events in the history of this genus:

First, it is likely that *Metasequoia* first evolved in eastern Russia (about 60 degrees North) during the early Late Cretaceous period, around 100 million years before the present, as the earliest dawn redwood fossils were reported from this region. Thanks in part to the low temperature gradient across the Northern Hemisphere and the Bering land connection between North America and eastern Eurasia, *Metasequoia* spread very rapidly in two opposite directions shortly after its origin: southward to lower latitudes in eastern Russia, northern Japan, and northeastern China; and northward across the Bering land connection to North America. By the end of the Cretaceous, when dinosaurs became extinct, *Metasequoia* had traveled as far south as New Mexico (about 35 degrees North) in North America and had become a dominant tree in ancient forests of southern Japan (about 36 degrees North) in Asia.

Second, during the Paleocene, about 60 million years ago, *Metasequoia* moved to the high latitudes of North America and invaded northern Europe to become a prominent member in ancient floras circumscribing the North Pole. At the same time, *Metasequoia* maintained the distribution pattern at lower latitudes around the Pacific basin that it had established during the Late Cretaceous.

Third, when major global cooling occurred during the Late Eocene, 40 million years ago, and the cooler climate persisted, the distribution pattern changed dramatically: *Metasequoia* disappeared from high latitudes. By the Early Oligocene, 35 million years before present, *Metasequoia* had moved to lower latitudes and undertaken a longitudinal expansion to arrive in central Eurasia along the foothills of the Ural Mountains. During the Middle Miocene, when the climate again warmed up, *Metasequoia* re-entered the Arctic Circle. It had vanished from Eurasian fossil floras by the Middle Miocene and from North America by the end of the Miocene.

(continued on page 65)



Fossil Remains of *Metasequoia*

The discovery of living *Metasequoia* in China more than fifty years ago shed light on the study of fossil Taxodiaceae, the family of redwoods and bald cypresses. After his trip to China, Chaney (1951) reassigned to the genus *Metasequoia* many fossils that had been misidentified as *Taxodium* or *Sequoia*. Since then, new *Metasequoia* fossils have been reported from the Northern Hemisphere, the oldest dating back to the Late Cretaceous. *Metasequoia* foliage and cones are among the most common fossils in Paleocene and Eocene floras around the Pacific Ocean. From small branchlets to single shoots, the leaves of *Metasequoia* show morphological characteristics that differ from those of other members of Taxodiaceae.

The graceful, opposite arrangement of leaves allows quick, sure identification in the field (figure a). However, reliable identification is difficult in pollen and wood fossils of *Metasequoia*: separated from the male cone, *Metasequoia* fossil pollen grains are almost indistinguishable from those of members of Cupressaceae, Taxaceae, or other Taxodiaceae; likewise, its wood anatomy is very similar to that of other members of the same family.

Metasequoia fossils have been reported from exceptionally well preserved deposits, revealing morphological and anatomical details of dawn redwoods that lived millions of years ago. For example, three-dimensional *Metasequoia* fossil cones from the Clarkia Miocene lake deposit in Idaho yielded seeds that give an accurate

description of *Metasequoia* seeds in Miocene time (figure b). Mummified *Metasequoia* leaves found in an Eocene deposit on Axel Heiberg Island in Canada's Arctic archipelago have permitted detailed anatomical studies of its soft tissue, and leaves trapped in amber for more than 50 million years at Fushun, a Paleocene-to-Eocene coalfield in northern China, offer a remarkably detailed snapshot of an ancient *Metasequoia*.

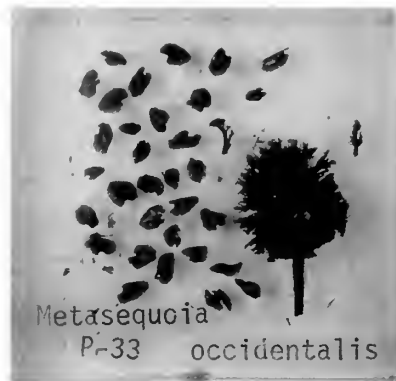


HONG YANG

Metasequoia leaves trapped in amber found in a Paleocene coal mine in Fushun, China.



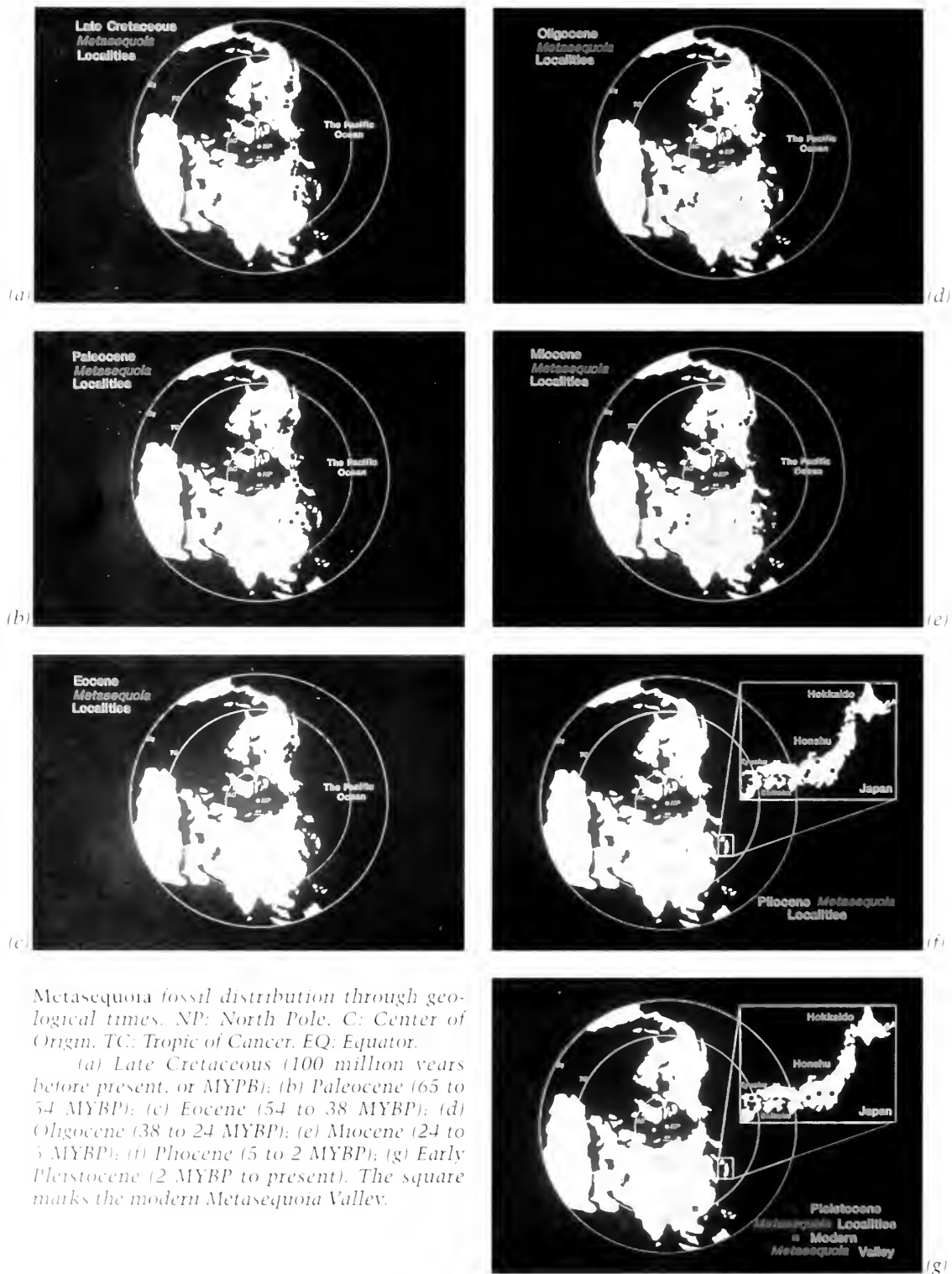
(a)



COURTESY OF C. J. SMILEY

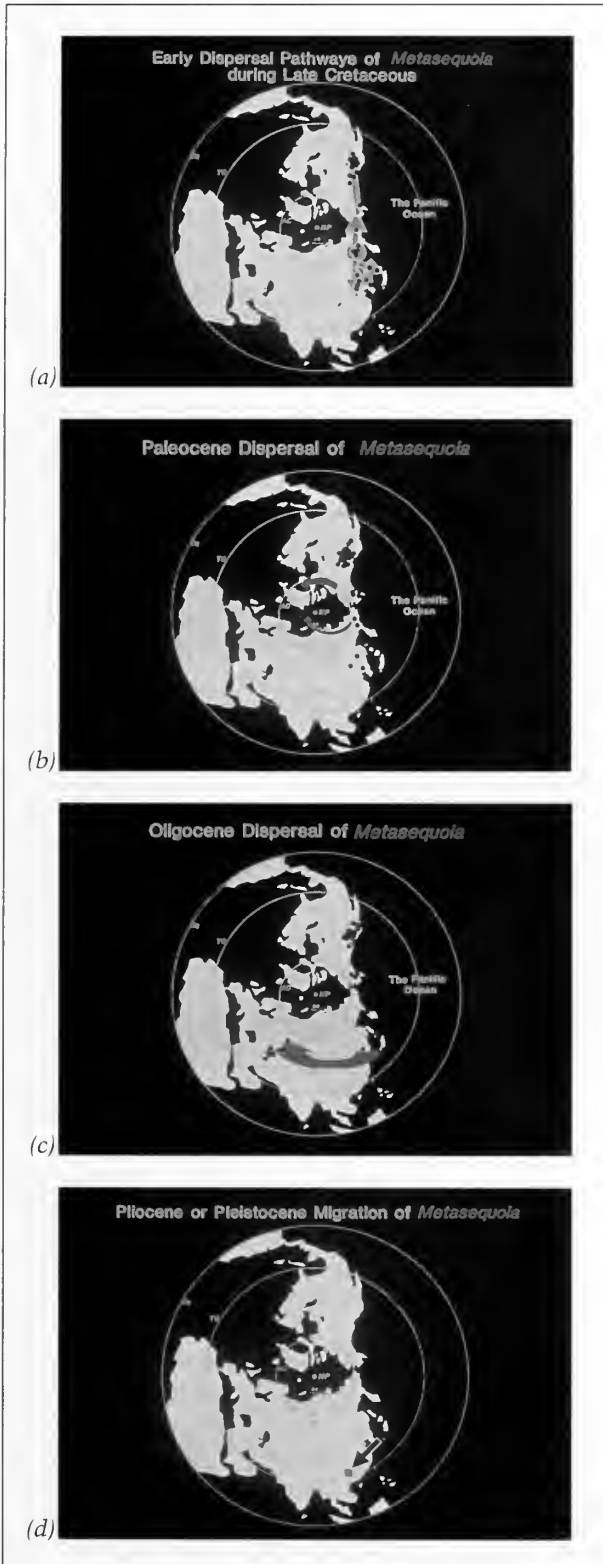
(b)

Metasequoia fossil remains: shoots (a) and female cone with seeds (b) from the Clarkia Miocene deposit in northern Idaho.



Metasequoia fossil distribution through geological times. NP: North Pole, C: Center of Origin, TC: Tropic of Cancer, EQ: Equator.

(a) Late Cretaceous (100 million years before present, or MYBP); (b) Paleocene (65 to 54 MYBP); (c) Eocene (54 to 38 MYBP); (d) Oligocene (38 to 24 MYBP); (e) Miocene (24 to 5 MYBP); (f) Pliocene (5 to 2 MYBP); (g) Early Pleistocene (2 MYBP to present). The square marks the modern *Metasequoia* Valley.



The fossil record shown on the preceding page was compiled from published paleobotanical literature, using only clearly illustrated fossil leaves and cones. These records give a feeling for the extensive distribution of *Metasequoia*. The oldest was found in Late Cretaceous rocks (about 100 million years old) in northeastern Russia. At the other extreme, the youngest *Metasequoia* fossil was collected from Pleistocene deposits in southwestern Japan: the lower part of the Osaka Group—about 1.6 million years old—marks the extinction of *Metasequoia* from Japan.

The highest latitude at which a *Metasequoia* fossil has been reported is 82 degrees North in northeastern Greenland, where abundant Paleocene fossils have been found. The prize for southernmost distribution goes to the Shihti Formation, a Miocene deposit in Taiwan at a latitude of 25 degrees North. To the west, *Metasequoia* fossils have been reported from Oligocene deposits in central Asia as far as 60 degrees East.

Possible *Metasequoia* dispersal and migration routes: (a) center of origin; (b) Paleocene dispersal paths showing invasion of higher latitudes; (c) lateral Oligocene dispersal paths; (d) Late Pliocene or Early Pleistocene migration direction.

(continued from page 62)

Fourth, the post-Miocene history of *Metasequoia* has been less studied, yet it is critical to the explanation for its survival in central China. *Metasequoia* fossils from the Pliocene and Pleistocene epochs—roughly from 5 to 1.7 million years ago—have been found only in central and southern Japan. Non-marine Pliocene and Pleistocene deposits have been commonly reported in eastern China, but no *Metasequoia* fossil has been found. If we read the fossil record literally, it suggests that the living *Metasequoia* is geologically a newcomer to its valley at the juncture of Sichuan, Hubei, and Hunan Provinces in central China, most likely having immigrated from Japan during the Late Pliocene or



These isolated trees are located in a field inside an iron fence in the remote Longshan area of Hunan Province, about 70 miles southeast of Metasequoia Valley.

Early Pleistocene, only 2 million years or less before the present.

It is interesting to note that the morphology of *Metasequoia* has changed little during the 100 million years since its origin. A recent taxonomic revision of *Metasequoia* fossils by Liu et al. (1999) has reassigned twenty of what were formerly twenty-one species (excluding only *M. milleri*) to a single species: *M. occidentalis*. This merger suggests a considerable degree of morphological stasis and implies a slow rate of morphological evolution. This would explain the striking similarity in morphology between

the Tertiary fossil and the modern *Metasequoia* twig that I compared fifteen years ago in Wuhan.

Morphological Variation at the Population Level

In 1997, seven years after my first trip, I revisited Metasequoia Valley with colleagues from the Nanjing Institute of Geology and Paleontology, the Chinese Academy of Sciences. The aim of the second trip was to collect modern *Metasequoia* leaf samples from trees in the wild for study of both cuticle and genetic variations at the population level. In the past few years, China's market economy has reshaped the country, and I was eager to see how these trees had weathered the environmental changes that accompanied economic reform. To my surprise, the rapid economic growth that has taken place elsewhere in China had not penetrated the remote Metasequoia Valley. And thanks to the *Metasequoia* conservation program, most of the wild trees are still healthy, although I was sad to learn that eight huge trees under which we picnicked in 1990 had died a couple of years ago.

On this trip, we made a special effort to travel to the remote Longshan area of Hunan Province, about 110 kilometers (70 miles) southeast of Metasequoia Valley, to visit and sample leaves from several large, wild trees that have rarely been seen by outsiders. We also sampled leaves from large *Metasequoia* trees in eight natural dawn redwood groves in the provinces of Sichuan and Hubei. Each sample was divided into two sets: one for study of cuticle micromorphology and another for DNA analysis. Cuticle from each tree was prepared and examined under a scanning electron microscope by Qin

Leng, a paleobotanist at the Nanjing Institute of Geology and Paleontology. We were not surprised to find that the cuticular characteristics among living trees within *Metasequoia* Valley display little variation, but Leng did make an exciting discovery: the sample collected from an isolated wild tree in Paomu, Longshan, showed some variation. Among other noticeable differences, the internal surface of the lower cuticle in the Longshan leaves possesses a uniquely even cuticular membrane between the stomatal zone and the non-stomatal zone—a characteristic that is not observed in any of the groves.²

Moreover, compared with all other samples, the Paomu sample also showed variation in the micromorphology of its guard cells. The differences in these features are great enough to warrant designation of two separate cuticle types, and the data imply that the isolated tree in Hunan Province may have preserved some characteristics that do not exist in the trees in *Metasequoia* Valley. Is this an indication that this isolated dawn redwood possesses a slightly different gene pool? If so, it is exciting news for the endangered *Metasequoia* population, whose genetic variability is expected to be very low. New morphological features found in the wild population may signal an increase of genetic diversity, which would help to alleviate its endangered state.

Clues from DNA Molecules

The past fifty years have witnessed the rapid development of molecular biology, and the impact of DNA-based biotechnology is felt in almost all subdisciplines of biological science. Earlier genetic work on *Metasequoia* has examined chromosome characteristics and, more recently, electrophoretic patterns of enzyme polymorphism (Kuser et al. 1997), but population structure at the DNA level for wild *Metasequoia* remained unexplored. Accordingly, a set of leaf samples collected during our 1997 trip was used to assess genetic diversity; the project is still in progress, but some preliminary data are intriguing.

As a small population with a very limited number of individuals living in a restricted geo-



In 1992, the post office of the People's Republic of China issued stamps celebrating dawn redwood as well as other prominent Chinese conifers.

graphic area, we would expect the modern *Metasequoia* population to display a very low level of genetic diversity, especially since the morphology of several of its features has shown considerable homogeneity at the population level. However, preliminary DNA analysis, using a RAPD (random amplified polymorphic DNA) technique, by Dr. Qun Yang and his student Chunxiang Li at the Nanjing Institute of Geology and Paleontology indicates that the species possesses a moderate genetic diversity that exceeds that of other endangered Chinese conifers, such as *Cathaya argyrophylla*. Further, the RAPD analysis also reveals that the genetic differences among sampled *Metasequoia* trees is primarily related to the geographic distance between them (Li et al. 1999). This interesting revelation suggests several possibilities: First, the genetic constitution of isolated trees in Hunan Province may have helped to increase the overall genetic diversity of the population. If this is true, the data from molecular analysis could fit with the findings in the comparison of cuticle morphology, which also imply a slightly different gene pool for the grove in Hunan Province from that of the groves in *Metasequoia* Valley.

Second, the unexpected level of genetic diversity may reflect a relatively recent establish-

(continued on page 69)

² Q. Leng, H. Yang, Q. Yang, and J-p. Zhou. 1999. Variation of cuticle micromorphology in native population of *Metasequoia glyptostroboides* Hu et Cheng (Taxodiaceae) (in progress).

A Glimpse of the Living Population

Cuticle is a waxy layer covering the outer cell walls of the plant leaf that serves as an effective barrier against water loss. Both botanists and paleobotanists are interested in plant cuticle because their faithful impressions of epidermal cells provide valuable physiological and sometimes taxonomic information. The cuticle's stable chemistry allows it to be preserved in sedimentary rocks for millions of years; therefore, it is particularly valuable for paleobotanists, who use it to classify fossil plants and infer their paleoenvironment. However, for both botanist and paleobotanist, studies of fossil cuticle are greatly improved when preceded by analysis of the cuticle micromorphology of living plants, and the limited distribution of existing *Metasequoia* will simplify this task of examining the variability of cuticle micromorphology within the species. Thus, the results of these studies will be very useful for interpreting cuticular features in the fossil material.

In the laboratory, cuticle from both sides of *Metasequoia* leaves can be prepared, and both internal and external surfaces of each piece can be examined. Cuticle is separated from the leaf by means of an acid solution. After the material is washed in distilled water and dried in the air, it can be coated with platinum and then amplified hundreds of times under a scanning electron microscope. In addition to the cuticle's thickness, micromorphological features of taxonomic or physiological value include the shape of epidermal cells, size and shape of stomata, shape of guard cells around stomata, and patterns on various cell walls.

Two types of cuticle micromorphology were observed by Qin Leng in the wild *Metasequoia* population. The isolated tree growing in the Longshan area of Hunan Province exhibits slightly different cuticle characteristics from those of trees in the Sichuan and Hubei groves, some 110 kilometers (70 miles) away. For example, epidermal walls in the Paomu sample from Longshan are more regular, with a defined boundary, and the shape of the guard cells around stomata differs from those of the Sichuan and Hubei samples. These differences point to a possible source of morphological variation in the wild population.



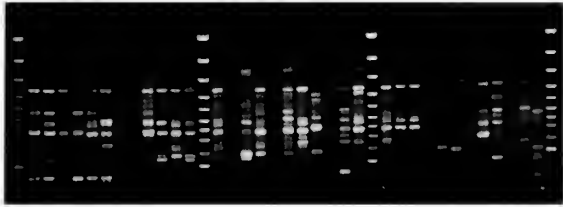
COURTESY OF Q. LENG

Cuticle micromorphology of living Metasequoia magnified 200 times; both show the internal surface of the cuticle on the underside of the leaf, comparing the two cuticle types: (a) from an isolated tree in Longshan, Hunan Province, (b) from Metasequoia Valley in Lichuan, Hubei Province.

DNA from *Metasequoia*

Only recently have molecular approaches been applied to the field of paleobiology, providing evolutionary biologists with an independent data set that helps compensate for the incomplete fossil record. In higher plants, DNA molecules reside in the nucleus and in two organelles, chloroplast and mitochondria. A biochemical procedure permits a mixture of the three types of DNA to be extracted and purified from plant cells. Then, using a new molecular technique called polymerase chain reaction (PCR)—a kind of molecular copy machine—selected portions of the DNA can be amplified into millions of identical copies. Depending on the goals of the research, amplified DNA fragments can be sequenced to reveal nucleotide base pairs or can be cut by various enzymes to detect variations. It is the variation in DNA molecules that is the genetic basis

COURTESY OF Q. YANG AND C.-X. LI



Agrose gel electrophoresis pattern showing RAPD amplifications derived from 27 different wild *Metasequoia* trees.

for morphological variability and population diversity.

RAPD (random amplified polymorphic DNA) analysis, a PCR-based technique, is a new molecular tool that has proved powerful in detecting genetic diversity at the population level. Primers—small synthetic pieces of DNA—will locate any regions of the chromosome (“priming sites”) that exhibit sequences complementary to the primers’ sequences. PCR will amplify all complementary fragments of DNA; if, due to a mutation, a priming site is absent from an individual, then PCR will skip over it. Thus, by counting the number of fragments shared by two individuals we get a crude measure of their genetic difference.

When fragments from each *Metasequoia* sample are separated and stained according to their size, a series of bands is created. Variations in amplification patterning among the samples mirror the underlying DNA variation of the *Metasequoia* population. Therefore, the amount of genetic variation within the population can be measured by the pattern of banding after amplification. By comparing amplified bands, computer-based statistical programs are able to calculate the genetic divergence among examined *Metasequoia* samples. For DNA collected from any two individual trees, the more differences among the bands, the larger the genetic distance.

Only in the past few years has ancient DNA from amber been extracted and sequenced. I have cracked open an amber from Fushan containing a *Metasequoia* shoot similar to that shown on page 63, hoping to find ancient genes that had survived for over 50 million years. Despite repeated efforts, I have been unable to find DNA; perhaps this goal will be achieved in the future.

(continued from page 67)

ment of the living population. In theory, the longer a population exists in a confined area, the more homogeneous its genetic diversity would become as inbreeding increases.

Third, the unexpected level of genetic diversity may also indicate divergent evolution of small, isolated populations due to habitat fragmentation from a once genetically homogeneous, large population. Unfortunately, our current data are insufficient to prove or disprove these possibilities. The RAPD technique used in this study is a rough, molecular-level survey and, moreover, the sample size is not large enough for a meaningful statistical test. DNA sequences of appropriate genes derived from individual *Metasequoia* may yield more quantitative information. Nonetheless, the available DNA data reveal an interesting level of genetic variation in the wild *Metasequoia* population.

When Did *Metasequoia* Arrive There?

Traveling through *Metasequoia* Valley in 1948, Chaney thought that he had seen a Tertiary fossil flora come to life. Based on the close resemblance between fossil remains that he had studied in Tertiary deposits around the Pacific basin and living plants that he encountered in *Metasequoia* Valley, Chaney believed that *Metasequoia* and its Tertiary associates had taken refuge in central China since Tertiary time. He asserted that *Metasequoia* “participated in wide migrations” from north to south and “continued down to the present *Metasequoia* valley” (Chaney 1948). In other words, he viewed the living *Metasequoia* as a Tertiary relic. However, the detailed fossil record seems to tell a slightly different story.

The absence of post-Miocene *Metasequoia* fossils in China suggests that the dawn redwood is a relatively recent arrival in central China. The youngest *Metasequoia* fossils found in China are from Middle Miocene deposits (about 15 million years before present) in Jilin Province, more than 2,000 kilometers (1,240 miles) northeast of *Metasequoia* Valley, and in Taiwan, an island more than a thousand kilometers (620 miles) east of

the present native population. Despite fifty years of intensive searching (Li 1995), no post-Miocene *Metasequoia* has ever been found in China. It is possible, of course, that younger *Metasequoia* fossils are waiting to be discovered in central China, but it is also conceivable that the chronological and geographical gap in the fossil record reflects the tree's absence during the period of more than 15 million years between the Middle Miocene and Early Pleistocene.

Pliocene and Pleistocene *Metasequoia* fossils have been found only in central and southern Japan. Geological evidence shows that the land link between southern Japan and eastern China (at about 34 to 36 degrees North) was available most recently during the late Pliocene to early Pleistocene interval, during the same period that *Metasequoia* trees are known to have lived in southern Japan. This land connection could have provided a migration route for its westward relocation (Wang 1985).

There is also evidence that, while the climate in Japan during the Pliocene appears to have been suitable for *Metasequoia*, the aridity of central China in that period would not have allowed it to survive. Conversely, during the Pleistocene "Ice Age," southern Japan may have become too cold for *Metasequoia* (Momohara

1992), while central China, which was not significantly influenced by continental glaciation, thanks to the intervening mountains, could have been a protected haven for the species. One possible interpretation of the fossil distribution and climate data is that *Metasequoia* migrated southward during the Late Pliocene or Early Pleistocene from Japan to the modern *Metasequoia* Valley.

Finally, the preliminary RAPD data seem to be compatible with the fossil record, suggesting the recent establishment of *Metasequoia* in its present range. Unfortunately, it offers no precise information regarding the antiquity of the living population, but further molecular study may yield better data.

Conservation Efforts

During my second visit to *Metasequoia* Valley, I was happy to see promising results from local conservation efforts, including preservation of large trees in the wild, a plantation of grafted trees, and reintroduction of seedlings to other parts of China and throughout the world. Despite a very limited budget, a *Metasequoia* conservation station in Xiaohe, with Mr. Shenhou Fan as the director and only employee, has maintained a large *Metasequoia* seedling farm and a plantation grown from grafts of wild

PETER DEL TREDDICI



Long He, Hubei. 1994. In China. *Metasequoia* has been planted in groves and along roads in great numbers, and many nurseries have been established to produce seedlings for cuttings. The rooting efficiency of cuttings decreases with the age of the source tree; the best source of cuttings is from seedlings aged one to three years.

trees. Local people still worship the giant trees, believing they bring the family good luck (nowdays translated into prosperity) and bless their children with healthy bodies and bright minds. Educational programs are increasing, as is local awareness of the significance of these trees. Many articles in the Chinese press have featured *Metasequoia*, describing its discovery, scientific value, and current conservation programs.

Over the next fifteen years or so, the *Metasequoia* trees will witness the construction of the controversial Three Gorges Dam on the Yangtze River, not far from their native land. The huge manmade lake behind the dam is bound to affect the local climate and related ecosystems. It is my hope that the remarkable resilience of this species will again enable it to cope with dramatic environmental changes, as it has so successfully done throughout its history.

Fifty years may be short for the dawn redwoods, whose lifespans easily exceed hundreds of years, but it is long enough for political, economic, and technological changes to occur around their native valley. Our knowledge of these magnificent trees has grown substantially over the past fifty years, thanks to new technologies and to several generations of industrious scientists. As studies of the species continue to provide scientists with new inputs for new ideas and hypotheses, the fascinating *Metasequoia* tale will continue to evolve.

Literature Cited

- Chaney, R. W. 1948. The bearing of the living *Metasequoia* on problems of Tertiary paleobotany. *Proceedings of the National Academy of Sciences, USA* 34(11): 503-515.
- . 1951. A revision of fossil *Sequoia* and *Taxodium* in western North America based on the recent discovery of *Metasequoia*. *Transactions of the American Philosophical Society, New Series*, 40(3): 171-262.
- Hu, H. H. 1948. How *Metasequoia*, the "living fossil," was discovered in China. *Journal of the New York Botanical Garden* 49: 201-207.
- Kuser, J. E., D. L. Sheely, and D. R. Hendricks. 1997. Genetic variation in two *ex situ* collections of the rare *Metasequoia glyptostroboides* (Cupressaceae). *Silvae Genetica* 46(5): 258-264.
- Li, X-x (ed.). 1995. Fossil floras of China through the Geological Ages. Guangzhou: Guangdong Science and Technology Press, 695.
- Li, C-x., Q. Yang, J-p. Zhou, S-h. Fan, and H. Yang. 1999. RAPD analysis of genetic diversity in the natural population of *Metasequoia glyptostroboides*, central China. *Acta Scientiarum Naturalium Universitatis Sunyatseni* 38(1): 64-69.
- Liu, Y-j., C-s. Li, and Y-f Wang. Studies on fossil *Metasequoia* from northeast China and their taxonomic implications. *Journal of the Linnean Society* (in press).
- Merrill, E. D. 1948. Another "living fossil." *Arnoldia* 8(1):1-8.
- Momohara, A. 1992. Late Pliocene plant biostratigraphy of the lowermost part of the Osaka Group, Southwest Japan, with reference to extinction of plants. *The Quaternary Research* (Tokyo) 31(2): 77-89.
- Wang, H-z (ed.). 1985. *Atlas of the Palaeogeography of China*. Beijing: Cartographic Publishing House, 143.
- Yang, H., and C. J. Smiley. 1991. The history of *Metasequoia*—Its origin, early dispersal and migration. *Proceedings of the First Canadian Paleontology Conference, Program with Abstracts*. Vancouver, B.C., Canada, 26.

Acknowledgments

This article is dedicated to two scientists of previous generations whose work brought me to *Metasequoia*: Dr. Ralph W. Chaney, whom I never met, but whose thinking on *Metasequoia* and other fossil plants has always intrigued me, and Dr. Charles J. Smiley, with whom I shared the joys of both the *Clarkia* fossil site in Idaho and *Metasequoia* Valley in China. I would like to thank my colleagues at the Nanjing Institute of Geology and Paleontology and the Zhongshan University for their collaboration. The research is supported by a Bryant College course release and by summer stipends. My trips to China have been supported by grants from the Chinese National Science Foundation, China Bridge International, and the K. C. Wong Educational Foundation.

Dr. Hong Yang is on the faculty of Bryant College where he teaches biology and earth science. He is also an adjunct research professor at the Nanjing Institute of Geology and Paleontology, the Chinese Academy of Sciences. His research interests lie at the interface between paleobiology and molecular biology. The author can be reached at the Department of Science and Technology, Faculty Suite C, Bryant College, 1150 Douglas Pike, Smithfield, Rhode Island 02917 or, via e-mail, hyang@bryant.edu.

Metasequoia Travels the Globe

Keiko Satoh

Fifty years after *Metasequoia* seemed threatened by extinction, the tree has taken firm root in soils both alien and familiar. Not only has it been re-introduced to its ancestral domains in the American Northwest, in Russia, and in Japan, but it has established itself in new homes all over the globe, thanks in part to Professor E. D. Merrill's determination to find sanctuary for the species. Dr. Merrill was perhaps not the first Westerner to receive *Metasequoia* seeds from China—records show that some had already arrived at the University of Copenhagen in Denmark and perhaps also at the Hortus Botanicus in Amsterdam by late 1947—but it was from the 1948 shipments to the Arnold Arboretum that a network of individuals and institutions was formed that ensured the tree's wide distribution. The enthusiastic reception accorded the seeds is exemplified by the comment of Lord Aberconway, president of the Royal Horticultural Society in 1948, to his colleagues at their annual general meeting: "We hope that in due course our English gardens may bristle with that very interesting plant, in spite of its forbidding name."

Indeed, one can admire some very fine specimens of *Metasequoia* in England as well as in the rest of the British Isles. Seeds were shared from the lots sent from the Arnold Arboretum to the Royal Botanic Gardens of Kew and Edinburgh, as well as to several universities. Seeds were also given to individuals, including the above-mentioned Lord Aberconway, whose head gardener, Mr. Puddle, received a packet of seeds directly from Dr. Merrill at the Chelsea Flower Show in 1948. The seeds germinated immediately in his garden at Bodnant, in north-



ARCHIVES OF THE ARNOLD ARBORETUM



MAINAU GMBH

At the Arboretum on the island of Mainau in Lake Constance, Germany. Said to be the oldest allée of *Metasequoia* in Europe, the trees were five feet tall when planted in 1959. Above, they appear in a 1970 photograph; below, they are seen twenty-some years later.

west Wales, and from the spring of the following year and continuing into the 1970s, the plants were shared with institutions with a special interest in rare plants.

Ireland's first *Metasequoia* seeds came from Seattle via London. The curator of the Univer-



Metasequoia glyptostroboides at the University of Copenhagen Arboretum, Denmark. The seed germinated February 1948 and was planted on the grounds in June of the same year.



At National Botanic Gardens at Glasnevin near Dublin. The seed was sown on 3 April 1948; the tree is now about 40 feet tall.



At Jardin des Plantes, Orleans, part of the Arboretum National des Barres. One of the oldest and largest specimens in France, photographed both in summer and winter.



At the Dumedin Botanic Garden, New Zealand. This tree is one of many propagated at the Timaru Botanic Garden and distributed to New Zealand gardens. It's said that when the director of the Timaru garden read about *Metasequoia* in 1948, he immediately wrote away for seeds.



At the Royal Tasmanian Botanical Gardens, Hobart, Tasmania. This 46-foot tall tree was two years old when it was planted in 1958. It produced seeds in 1992.



At Mount Royale Cemetery, Montreal, Canada, next to a monument to E. H. Wilson (1876–1930). Both monument and tree—said to be the first planted out of doors in Canada—were installed in May 1949. When photographed in 1995, the tree was less than two meters tall (just over six feet). The cause of the leaderless growth is unknown, but the habit is often found in specimens growing in very cold climates, where the average minimum winter temperatures fall below -15 degrees Fahrenheit.

sity of Washington Arboretum sent a batch to the Londonderry arboretum of Commander Frank Gilliland, a plantsman with a taste for conifers, who in turn forwarded some to the director of the National Botanic Gardens, Glasnevin. From Glasnevin, which later received two shipments of seeds directly from the Arnold Arboretum, plants were distributed to other counties in Ireland.

The International Botanical Congress held in June of 1948 at the University of Utrecht in the Netherlands presented Dr. Merrill with a splendid opportunity to disseminate seed. Nineteen delegates representing ten countries were present, from as far away as India, Indonesia, and

Australia, and each no doubt returned home with future trees in their pockets. The hosts of the Congress sowed their seeds the same evening that Dr. Merrill handed them out; subsequently they distributed to other Dutch universities, gardens, and nurseries both seeds and seedlings that eventually made their way into the commercial trade.

Inquiries to botanic gardens worldwide revealed that trees are growing in most of the European countries from Ireland in the west to Czechoslovakia in the east, from Scandinavian countries in the north to the gardens of the Mediterranean. They grow high in Katmandu, the capital of Nepal, and dot the hills of Hawaii. The garden of Kirstenbosch in South Africa sports a fairly large specimen, as do various cities on the coast of mainland Australia and in Tasmania and New Zealand.

Metasequoia trees survive winter diebacks and the weight of heavy snows in the botanic gardens of Hamilton and Montreal in Canada. At the other extreme, *Metasequoia* tolerates the sizzling summer rays in the city of Adelaide, Australia, which lies within hardiness zone ten. The specimens in Europe's oldest allée of *Metasequoia*—on the island of Mainau in Lake Constance, which borders Germany, Austria, and Switzerland—were planted in 1959 as five-year-olds; it is hoped that those recently planted in northern Tasmania, along the driveway leading to a new arboretum, will prove equally prosperous.

And in Japan, in Miki-Town, Kagawa Prefecture on the island of Shikoku, an "Ancient Wood Park" honoring Dr. Shigeru Miki was opened in 1993, complete with a grove of dawn redwoods and life-size models of dinosaurs. A hilltop monument in the park commemorates the paleobotanist who, studying what he assumed to be the fossil of a long-extinct species, gave the name to the ancient, but very much alive, genus *Metasequoia*.

Bibliography

- Belder, J., and D. O. Wijnlands. 1979. *Metasequoia glyptostroboides*. *Dendroflora* 15/16: 24, 25.
- McLaren, H. D. [Lord Aberconway]. 1948. Extracts from *The Proceedings of the Royal Horticultural Society*. *Journal of the Royal Horticultural Society* 73: xxxv.
- Nelson, E. C. 1998. *Metasequoia glyptostroboides*, the dawn redwood: Some Irish glosses on its discovery and introduction into cultivation. *Curtis's Botanical Magazine* 15(1): 77–80.
1950. *Botanica Chronica* 11 (1/2): 7.

Acknowledgments

I am grateful to all those people who have provided me with valuable information and images and especially to Victoria Schilling of the Tree Register of the British Isles; Jan Tolsma of the Botanic Garden of Utrecht University; Rebecca Govier and Debbie White of the Royal Botanic Garden, Edinburgh; Martin Puddle of Bodnant; Jette Dahl Møller of the University of Copenhagen Arboretum; Thierry Lamant of the Arboretum National des Barres; Tom Myers of Dunedin Botanic Garden; William Steans, Parks Manager, Timaru District Council; Milan Velička of Arboretum Nový Dvůr; Christy Crosby of the National Botanic Gardens, Glasnevin.

Metasequoia glyptostroboides: Fifty Years of Growth in North America

John E. Kuser

Now, half a century after *Metasequoia glyptostroboides* was introduced into the West from China, the dawn redwoods produced from these seeds rank among the temperate zone's finest trees. Some of them

have grown to remarkable size in the relatively short time of fifty years. Perhaps the largest overall is a tree at Bailey Arboretum, in Locust Valley, New York, which in late August 1998 measured 104 feet in height, 17 feet 8 inches in breast-high girth, and 60 feet in crownsread. Several trees in a grove alongside a small stream in Broadmeade Park, Princeton, New Jersey, are now over 125 feet tall, although not as large in circumference or crown as the Bailey tree. In favorable areas, many others are over 100 feet in height and 12 feet in girth.

In 1952 a visiting scholar from China, Dr. Hui-Lin Li, planted dawn redwoods from a later seed shipment along Wissahickon Creek in the University of Pennsylvania's Morris Arboretum in Philadelphia. Li knew the conditions under which *Metasequoia* did best in its native range: in full sunshine on stream-side sites, preferably sloping south, with water available all summer and seasonal variations in temperature like those found on our East Coast—warm summers and cold winters. Today, Li's grove beside the Wissahickon inspires awe; its trees reach as high as 113 feet and measure up to 12 feet 6 inches in girth.

Large dawn redwoods now occur as far north as Boston, Massachusetts, and Syracuse, New York, and as far south as Atlanta, Georgia, and Huntsville, Alabama, and are found in all the states between. Many of the best specimens grow along the fall line between the Piedmont and the Coastal Plain, usually close enough to a constant supply of water to justify the Chinese name *shui-sha* (water fir). Smaller specimens grow as far north as Maine, across temperate sites in the



Two beautifully buttressed trunks. Above, the Sarah P. Duke Gardens' dawn redwood has been growing in this wet spot since 1949. Below, a specimen that stands with its feet in Lake Auburn in Mount Auburn Cemetery, Cambridge, Massachusetts. Both trees derive from the original distribution.

ED. ALBRECHT FOR THE SARAH P. DUKE GARDENS

DAVID BARNETT, MOUNT AUBURN CEMETERY

JOHN E. KUSER



JOHN E. KUSER



Metasequoia glyptostroboides at Bailey Arboretum, Locust Grove, New York, photographed in September 1998. At 104 feet high and 17.8 feet around, it may be the largest individual outside China.

Midwest, and along the West Coast from Los Angeles to Vancouver. In the West, they must be watered during the growing season; a tree at Los Angeles' Huntington Gardens that had remained small for years began to grow rapidly when moved next to a stream and is now a large tree.

Warm summer temperatures as well as moisture appear to be needed for the species' best growth. When planted where summers are cool, as at Strybing Arboretum in San Francisco, Pacific Lumber in Scotia, California, and Butchart Gardens in Victoria, British Columbia, trees remain small and twiggy compared to those growing in areas with warmer summers. Even within its favored climate range, however, *Metasequoia* is somewhat site-selective: it does not thrive in dry or windswept locations and, like yew and hemlock, needs good drainage in addition to moisture. At present, *Metasequoia* in the United States remains free of serious disease and insect pests. It is sometimes disfigured by heavy populations of Japanese beetles, but refoliates quickly because it is an "indeterminate grower," that is, it continues to grow all summer as long as sufficient warmth, moisture, and daylight are available.

Metasequoia is usually propagated by cuttings, either hardwood or softwood; the latter works well between mid-August and mid-September if the cuttings are treated with hormone and rooted under mist. In general, juvenile trees root more easily than large ones although there are exceptions. Like many other species from eastern Asia, however, *Metasequoia* is also capable of reproducing naturally in eastern North America; self-reproducing trees have been reported in Tennessee and New Jersey. Seedlings come up regularly in my lawn and garden, but since they cannot compete with grass and weeds, there is little danger the species will become another *Ailanthus* or *Paulownia*.

Shortly after the introduction of *Metasequoia*, hopes were high that it would serve as a new source of commercial softwood. Danish forestry professor Syrach Larsen made "timber" selections from trees he had grown near Copenhagen from Arnold Arboretum seeds; these lacked the basal fluting usually present in



A dawn redwood at home in a sheepfold on Naushan Island, Massachusetts.

the species and thus produced better logs. (The fluting of the lower trunk can be reduced, if desired, by pruning the tree up to eight or ten feet or by growing trees closely spaced to cause natural pruning.) We now know that by Western standards *Metasequoia* is too intolerant of shade to be grown commercially: it cannot be as closely spaced in plantations as its cousin *Sequoia*, and because so much light passes through its crown, plantations require constant, expensive weeding. Moreover, its wood is rather brittle, although the light, purplish, aromatic heartwood is highly resistant to decay. Houses built of *Metasequoia* wood have been known to survive as many as seven generations of Chinese farmers.

When used as a street tree, *Metasequoia* should be planted at least ten feet from sidewalks to allow room for its wide, shallow, aggressive root system. As a park or lawn tree, dawn redwood grows to majestic proportions when soil, sun, and moisture are to its liking; and when used in an allée, it could well rival in effect the splendid *Taxodium* allée at Longwood Gardens in Pennsylvania. No one knows how tall it will finally grow outside its native range, but one 450-year-old tree in China's Hubei Province is 154 feet high.

Genetic Diversity

For a species whose native range is now very restricted, *Metasequoia* possesses a surprising amount of genetic variation. In 1991 a group of researchers at Rutgers University compared the allozyme diversity and growth rates of seedlings grown from seeds of fifty-two parent trees in Hubei, Hunan, and Sichuan Provinces with those of forty trees derived from the Arnold Arboretum's 1948 seedlot. The 1991 Chinese seedlings had more allozyme variation and produced a few unusually fast-growing individuals, several dwarfs, corkscrews, and a "featherleaf." A



Dawn redwoods planted at the Secret Arboretum in Wooster, Ohio, in 1948 or shortly thereafter.

JOHN E. KUSER



The roots of a dawn redwood planted too close to a sidewalk thirty-five years ago in Paramus, New Jersey.

JOHN E. KUSER



Clone 27A dwarfs its fellow clones grown from seeds from Hubei, China, at Rutgers Test Plantation.

JOHN E. KUSER



This dwarf weeping form also derives from one of the 1991 seeds from Hubei.

comparison made of the genetic variations within the *Metasequoia* seedlings and those of other conifer species showed *Metasequoia* to be about average in this respect—neither as diverse as lodgepole pine (*Pinus contorta*) nor as monomorphic as red pine (*P. resinosa*).

Professor Li Minghe of Huazhong University in Wuhan, who was responsible for the 1991 seed shipment, reported that the species' range had been much more extensive until quite recently; indeed, 11,000-year-old *Metasequoia* logs have been found buried under the city of Wuhan, about five-hundred kilometers (three hundred miles) from Modaoqi, the center of the species' present range. This may help to explain the amount of genetic variation that still exists.

Fifty years after its introduction to North America, *Metasequoia* continues to grow. The 125-foot-tall trees in Broadmeade Park continue to add two feet of height each year. Fast-growing, essentially disease-free, both beautiful and interesting, *Metasequoia* also continues to grow in popularity.

References

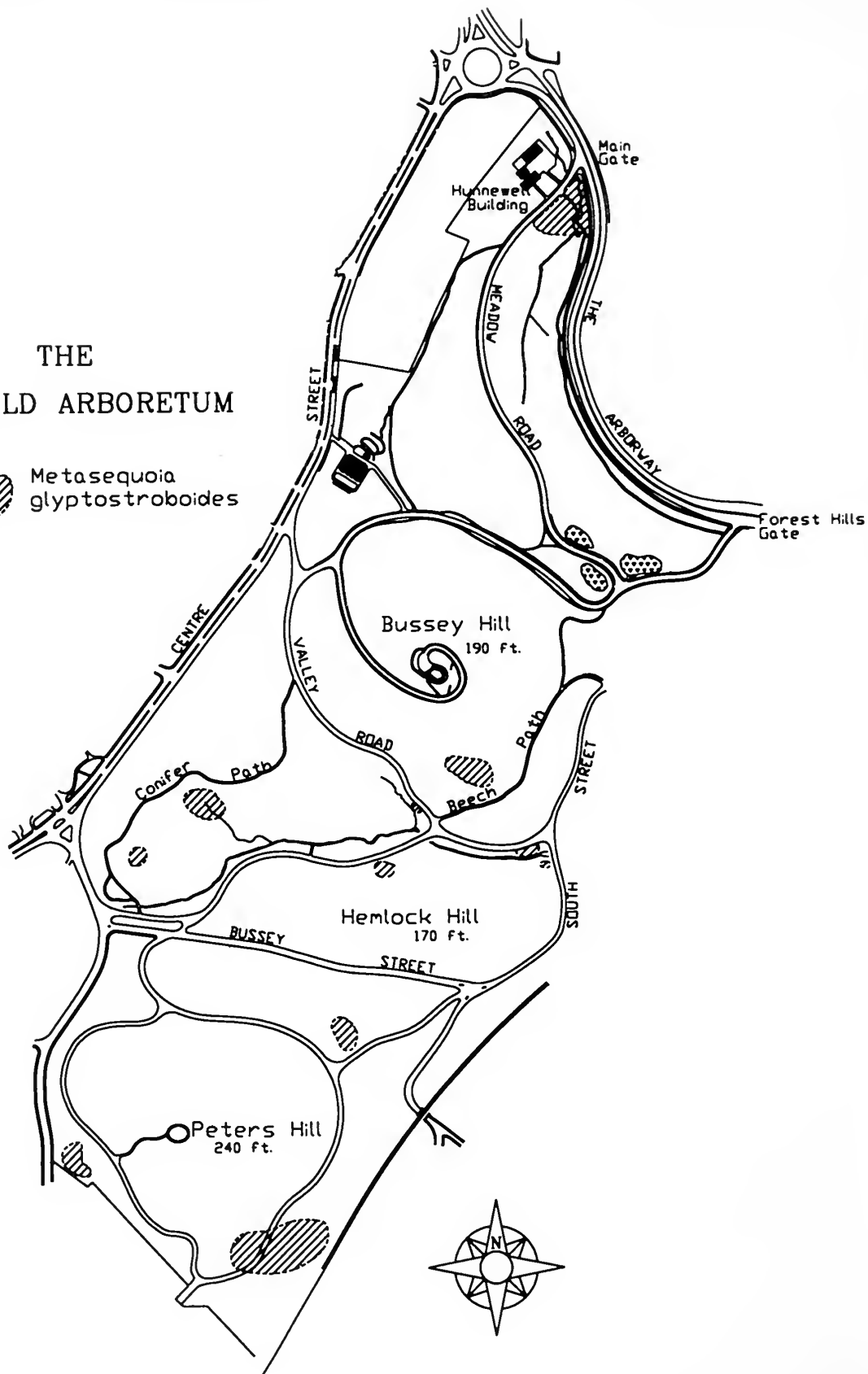
- Kuser, John. 1982. *Metasequoia* Keeps on Growing. *Arnoldia* 42(3): 130–138.
- . 1987. Clonal and Age Differences in the Rooting of *Metasequoia glyptostroboides* Cuttings. *Arnoldia* 47(1): 14–19.
- . 1998. Genetic Variation in Two *ex situ* Collections of the Rare *Metasequoia glyptostroboides* (Cupressaceae). *Silvae Genetica* 46: 258–264.
- Kuser, John E., D. L. Sheely, and D. R. Hendricks. 1983. Inbreeding Depression in *Metasequoia*. *Journal of the Arnold Arboretum* 64: 475–481.

John Kuser teaches dendrology, forest ecology and silvics, urban forestry, and forest genetics at Cook College, Rutgers University. He has written extensively on *Metasequoia* and several other conifers as well as *Paulownia tomentosa*. A textbook, *Urban and Community Forestry in the Northeast*, will be published by Plenum Press later this year. During next year's sabbatical he will work on a rangewide study of the genetic architecture of *Chamaecyparis thyoides* and will expand and update the 1992 leaflet, *Exotic Trees in New Jersey*.

THE ARNOLD ARBORETUM



*Metasequoia
glyptostroboides*



A Guide to *Metasequoia* at the Arnold Arboretum

Karen Madsen

M*etasequoia* was not introduced into the West for its potential as an ornamental, nor primarily for its botanical interest. The remnant populations in central China appeared to be on the verge of extinction, and the great concern was to expand its range. Once seeds had germinated and there was confidence that somewhere outside central China favorable growing conditions would be found, interest at the Arboretum turned to finding favorable conditions within its own walls. Early speculation suggested that the species might not be hardy north of Georgia, where the climate of the coastal plain is similar to the tree's native habitat. To determine their cultural requirements, Donald Wyman, then managing horticulturist, planted specimens and groves at a variety of sites. Today our *Metasequoia* population is concentrated in four areas: the wet meadow near the Arborway; the southern slope of Bussey Hill; in the conifer collection; and on Peters Hill.

Of the Arboretum's 13,187 plants, 106 are *Metasequoia glyptostroboides*, .8% of the total. Before the advent of computerized record-keeping in the 1980s, the Arboretum's plant data were recorded in an accessions book and a card catalog. On the card for accession 3-48 is typed,

Metasequoia glyptostroboides. Seeds, received by Dr. E. D. Merrill, Arn.Arb. from Szechuan, China, Jan. 14, 1948. (This is the oldest plant in the U.S.)

Certainly it is the oldest individual in the Arboretum, and the only one derived from the first seedlot. The newcomer wasted no time establishing itself; seedlings were up in two weeks.



PETER DEL TREDUCI

The Arboretum's oldest and most unusual specimen of *Metasequoia*, located in the conifer collection, where soil drainage is good and surrounding trees block strong winds. An early trauma must have caused it to regenerate from basal suckers. It lost some large branches in the April Fool's Day blizzard of 1997, but by the end of the year it was in good condition again. Because of its historical interest and "collections quality," clones of 3-48 have been propagated, and in 1992 three scions were added to the collections.



When conditions suit them, dawn redwoods grow with astonishing speed. When this specimen was transplanted at age three from poor, dry soil to good soil, it was at the height pointed to by the girl. In the following season it grew 4'4", doubling its height.

Metasequoia proved easy to propagate by cutting, but for many years the Arboretum trees produced no viable seed. Female cones were formed, but male cones were lacking. In 1980 Alan Longman of the Institute of Terrestrial Ecology, Edinburgh, Scotland, in collaboration with Peter Del Tredici, then assistant propagator, undertook an experiment in flower induction. Both male and female cones formed by September, but the success of the gibberellic-acid-induced male cones was overshadowed by coincidence: 1980 turned out to be the year that they were also produced naturally.

The second, much larger shipment of seeds arrived in Jamaica Plain on March 19, 1948. For this 500-gram lot, library and herbarium staff supplemented the greenhouse staff in sorting the very small seeds into hundreds of packets for distribution around the world. Twelve of the plants from these seeds remain on the grounds. When assessed during the past three years, all of the trees dating from 1948 were in "good" condition excepting only one "poor," one "fair," and one "excellent." Happily, the "excellent" tree is the most visible one: It stands on Meadow Road near the Hunnewell Building. At 84 feet it is not notably tall, but few of its



The "excellent" dawn redwood on Meadow Road, in 1964. Donald Wyman noted, "This is the best of several forms now growing in the Arnold Arboretum." Wyman was a close observer of the species, but not a great fan. In 1970 he wrote, "Although very fast growing, it is not a distinguished ornamental and is definitely too large for the small garden."



The grove of dawn redwoods that terminates Chinese Path on Bussey Hill photographed shortly after they were planted in spring of 1995. They were grown in the Dana Greenhouses from seed sent from China in 1991.

cohorts rival it in diameter. Its 130 centimeters (50.7 inches) at breast height is second only to the 134 centimeters (52.3 inches) of the tree on Valley Road near Bussey Brook.

Six dawn redwoods were grown from seeds brought to the Arboretum by the delegation of Chinese botanists who visited in 1979, three located in the wet meadow, the others in the conifer collection. With the exception of one cultivar, 'National', which came from the U.S. National Arboretum in 1962, all other dawn redwoods were planted in 1995. To broaden the genetic base of the *Metasequoia* collection, the Arboretum joined a small consortium organized by John Kuser of Rutgers University to sponsor the collection of seeds from all known wild populations in China. From these seeds came 69 plants from 43 different parent trees. Nineteen form a grove that terminates Chinese Path on Bussey Hill. Three other groves are sited on Peters Hill, one in a low, sunny spot; another, dry and sunny; the third, dry and shady.

Certainly the Rutgers seedlings have greatly expanded the parentage of the Arboretum's collection of *Metasequoia*, but interestingly, investigations of both the two 1948 seedlots and the forty-six 1991 seedlots indicate that the 1948 lots contain fully 80 percent of the genetic variation found in the species overall (Kuser et al.



The grove in spring 1999.

1997). Half a century after Elmer Merrill received the first seed shipment from China, concerns about genetic variation have been put to rest; hardiness has been established across a broad geographical range; propagation has been ensured; the threat of extinction is past: We are free to concentrate on the dawn redwood's very ornamental features.

Bibliography

- Kuser, J. E., D. L. Sheely, and D. R. Hendricks. 1997. Genetic Variation in Two *ex situ* Collections of the Rare *Metasequoia glyptostroboides* (Cupressaceae). *Silvae Genetica* 46(5): 258-264.
- Wyman, Donald. 1951. *Metasequoia* Brought Up-to-Date. *Arnoldia* 11(3): 25-28.
- . 1968. *Metasequoia* After Twenty Years in Cultivation. *Arnoldia* 28(10-11): 113-123.

Acknowledgments

Many thanks to Carol David, Susan Kelley, and Kyle Port for indispensable help.



Silhouetted by falling snow in the wet meadow, the rightmost Metasequoia is the tallest of the Arboretum's dawn redwoods; in December 1997 it was 102.2 feet in height and 80 centimeters (31 inches) in diameter at breast height; to its left is a bald cypress (Taxodium distichum), planted in 1933. The other dawn redwoods seen here were propagated in 1962. In 1997, all fell within 64 to 75 feet in height.

Chinese Names in Transliteration: A Conversion Table

In 1979, the People's Republic of China officially adopted the Pinyin system for transliterating Chinese ideograms into the Roman alphabet. Prior to that time, most spellings accorded with the Wade-Giles system (although variations are common). In the historical articles in this issue, the original spellings of names and places have been retained; some of them reappear in Part 2 in changed form and it is those that are included below. The older spelling is given in the first column; the newer, Pinyin spelling is on the right.

Canton	Guangzhou	Kuling	Guling
Cheng, Wan-Chun	Chen Wanjun	Kuo, P. Q.	Guo Bingwen
Chun, Woon-Young	Chen Huanyong	Kwantung	Guangdong
Chung, H. H.	Zhong Xinxuan	Mou-tao-chi	Modaoqi/ Moudao
Chungking	Zhongjing	Nanking	Nanjing
Chung-lu	Zhonglu	Peiping, Peking	Beijing
Hsiao-ho	Xiaoho	Shen-lung-chia	Shennongjia
Hsien	Xian	Szechuan	Sichuan
Hsuch, Chi-ju/ C. Y.	Xue Ji Ru	Wan Hsien	Wanxian
Hu, Hsen Hsu	Hu Xiansu	Wang-chia-ying	Wang Zhang
Hupoh	Hubei	Yangtze	Changjiang
Kiangsi	Jiangxi		

Another group of synonyms may be helpful:

Shuisapa Shui-hsa Valley Valley of the Tiger *Metasequoia* Valley





