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Scientists Investigate Recent Philippine Landslide

A massive landslide devastated the community of Barangay Guinsaugon, Municipality of St. Bernard, Southern Leyte Province, Philippines, at about 10:30 local time on 17 February. The landslide occurred along the steep fault scarp of the Philippine Fault Zone (PFZ) (Figure 1a), a large and active tectonic structure that traverses the entire length of the Philippines [*Allen*, 1962]. Barangay Guinsaugon is located at the foot of the scarp, directly in the path of the downward moving mass of earth. As of 24 February, the landslide caused 122 confirmed deaths; 1,328 people still are missing.

To assist in the search and rescue operations that followed the landside, a team of geologists and physicists from the University of Philippines (UP-Diliman, Quezon City) and Ateneo de Manila University conducted an investigation of this area on 21–25 February. The UP-Ateneo team provided technical advice on the geology, which included the identification of the type and characteristics of the landslide.

The Guinsaugon Rockslide-Debris Avalanche

Satellite imageries taken in 2003 and 2004 show traces of two prominent structures, the north-northwest trending PFZ and a northwest trending structure oblique to the PFZ (Figure 1a and 1b). The horseshoe-shaped feature found along the trace of the oblique structure, at an elevation of 675 meters, is the site of the recent landslide. Another horseshoe-shaped feature, 500 meters south-southeast of the present landslide head, is perhaps an old landslide scar (Figure 1b).

The landslide has a planform area of approximately three million square meters and a distance of 4.0 kilometers from the crown to toe. It has a thickness of 6–7 meters near the toe and 30 meters at the base of the fault scar (Figure 2a). The volume of the deposit is in the order of 15–20 million cubic meters. On the basis of accounts from residents of the area of the duration and the distance traveled by the landslide, the flow velocity was approximately 100–140 kilometers per hour.

The main sliding plane of the avalanche is a prominent north-northeast oriented plane at the head of the landslide intersected at an angle by a less planar feature (Figures 1c and 1d). The more planar surface exhibits slickensides (striations indicating movement) of a left-lateral fault. Below the crown are terraces composed of slope material that moved downward along sliding planes. The fan or foot portion of the slide has ridges, radial cracks (Figure 2b), and numerous hills known as hummocks (Figure 2c). The deposit is composed of volcanic rocks from the Leyte Central Highland Volcanics, sedimentary rocks of the Calian Formation, and breccias produced by the movement of the Philippine Fault (e.g., J. D. Azares et al. (Southern Leyte revisited: New geologic data and insights, unpublished report 2003; R. M. Saturay Jr. and R. A. Tamayo Jr. (Southern Leyte field and structural evidence for major Cenozoic tectonic events in the Philippines, unpublished report, 2003)). On the basis of these characteristics, the landslide was identified as a rockslide-debris avalanche.

The Guinsaugon rockslide-debris avalanche is the second major landslide of this kind to be described in the twenty-first century, and the volume of its deposit falls within the range generated by debris avalanches from the twentieth century that are examined here. Deaths, casualties, and other damages associated with each of these events are listed in Table 1.

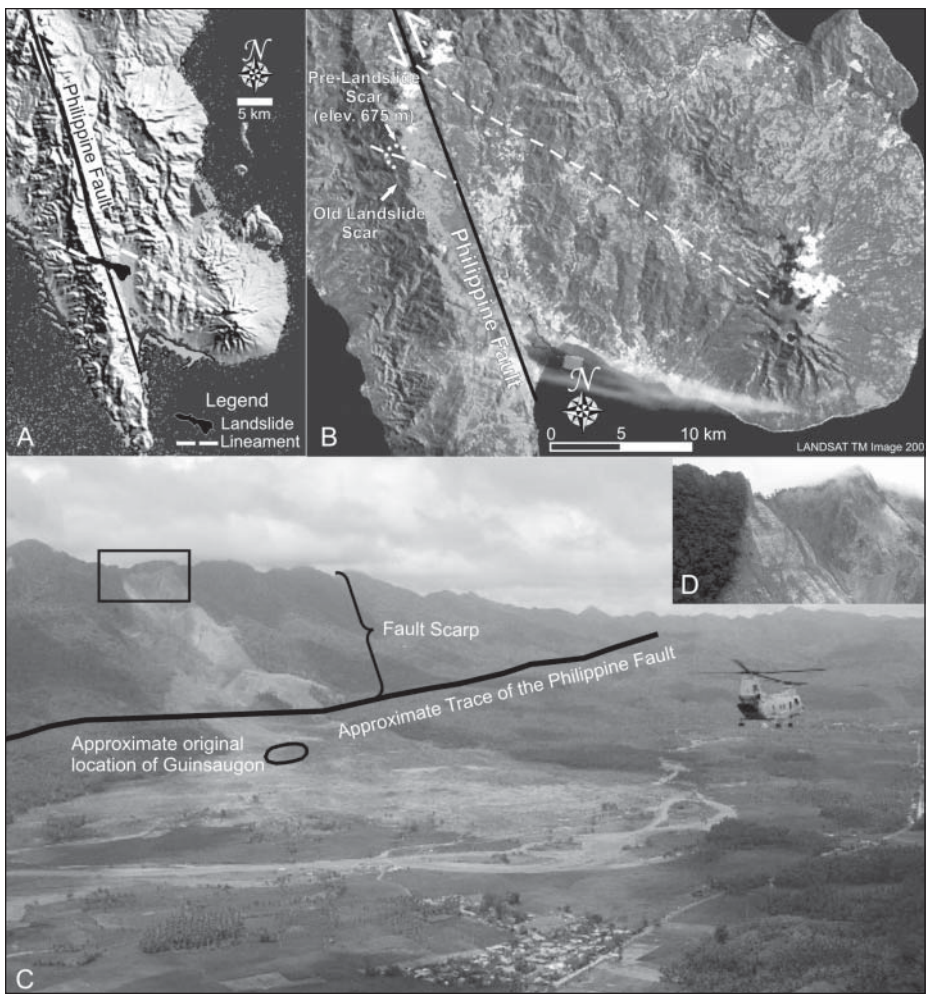

Fig. 1. (a) Shaded relief image generated from a Shuttle Radar Topography Mission (SRTM) digital elevation model with interpreted northwest lineaments (white dashed lines) intersecting the Philippine Fault (black solid line); (b) False-color Landsat image that delineates the pre-landslide scar where the Guinsaugon landslide originated. The pre-2006 landslide scar (white dotted line) is found northwest of an older landslide scar (indicated by arrow). Raw image data were taken from http://www.landcover.org; (c) Oblique aerial photo showing the relative positions of the Philippine Fault and the town of Guinsaugon with respect to the landslide. Raw image courtesy of Michael D. Kennedy (U.S. Navy). http://www.navy.mil/view_single.asp?id=32073; (d) Close-up view of the landslide head.

Causal Mechanisms

The factors suspected to have triggered the Guinsaugon rockslide-debris avalanche are rainfall and a 2.6 magnitude earthquake. Multi-satellite precipitation analysis from the NASA-Japan Aerospace Exploration Agency Tropical Rainfall Measuring Mission reported that 500 millimeters of rain fell in Southern Leyte between 4 and 7 February. The Philippine

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Decadal Drought Effects on Endangered Woodpecker Habitat

The critically endangered ivory-billed woodpecker (*Campephilus principalis*) apparently has been rediscovered in old-growth bald cypress (*Taxodium distichum,* Figure 1) and swamp tupelo (*Nyssa aquatica*) forests of Bayou DeView, located seven kilometers northwest of Brinkley, Ark. [*Fitzpatrick et al.,* 2005]. The evaluation of the impact of drought on forest history and wildlife population levels is critical to the conservation of the ivory-billed woodpecker and other similarly endangered species. Tree ring chronologies have been developed from old-growth forests at Bayou DeView to aid in this assessment.

This article also describes a conceptual model that has proven useful for the discovery of other noncommercial old-growth cypress-tupelo remnants in the Southeast. These relict cypress-tupelo stands may be candidates for conservation, restoration, and perhaps the eventual reintroduction of the ivory bill and other increasingly rare species native to this ecosystem.

By D. W. Stahle, M. K. Cleaveland, R. D. Griffin, M. D. Spond, F. K. Fye, R. B. Culpepper, and D. Patton

Tree Ring Chronologies and Drought

For this study, tree ring chronologies were developed at three sites in the Western Lowlands of northeast Arkansas (Figure 2a), the area that contains Bayou DeView. The chronologies are all at least 850 years long, and were based on core samples from centuries-old living bald cypress trees and fallen logs.

The simple mean ring-width chronologies exhibit the slow centuries-long decline in radial growth rates typical of trees that mature and senesce in a natural forest setting (Figure 2a). Bald cypress radial growth is driven primarily by precipitation during the growing season [*Stahle and Cleaveland,* 1992], and recent research indicates a similar response for tupelo. However, the mean and variance of the simple mean ring-width chronologies increase in the twentieth century, especially at Bayou DeView and at another Western Lowlands area, Mayberry Slough (Figure 2a), which may reflect both precipitation changes and human alterations of the drainage basin.

The three bald cypress tree-ring chronologies are significantly cross-correlated and have been used to develop a regional ring-width index chronology, where non-climatic growth trends have been removed with

Fig. 1. An ancient bald cypress tree in the 800-year age class at Bayou DeView, Ark., the rediscovery site of the ivory-billed woodpecker (diameter 2.6 meters at 2 meters above ground). David Stahle pictured for scale. Photo by Mark Spond.

detrending and standardization (Figure 2b). The three most severe episodes of low growth in the Western Lowlands occurred during the fourteenth, fifteenth, and sixteenth centuries (Figure 2b).

The severe sustained droughts of the fourteenth and fifteenth centuries were concentrated over the central United States (Figure 2c; *Cook et al.* [2004]) and appear to have shaped the age structure of the oldest bald cypress still surviving along Bayou DeView. Both droughts lasted for 10 consecutive years and must have caused the deaths of millions of forest trees in the lower Mississippi Valley. Though only a fraction of the living bald cypress exceed 600 years in age (Figure 2b), the oldest bald cypress germinated before 1380 A.D. and appear to be the last living members of a cohort that survived the extreme fourteenth- and fifteenth-century droughts.

The Effects of Decadal Drought

These decadal droughts may have created the ideal conditions for cypress regeneration. Bald cypress is "a tree of even-age groups within all-age stands" [*Mattoon,* 1915]. Cypress is exceptionally long lived, but cypress seeds will not germinate in water, and seedlings will not tolerate prolonged inundation. Consequently, old-growth cypress forests often included distinctive cohorts of even-age trees that regenerated infrequently when low water conditions persisted sufficiently long for both germination and seedling height growth. The inner ring and pith dates for many cypress in the Western Lowlands date soon after these droughts (Figure 2b). All cores were taken above the basal swell of the tree and

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NEWS

Fire-Made Minerals Found in Icy Comet

Minerals created under high temperature conditions have been found in particles collected from the comet Wild 2 and may have come from the formation of the Sun or another solar system, NASA mission scientists said at a 13 March press conference.

The Stardust spacecraft trapped the particles in an aerogel detector when it passed within 240 kilometers of the comet on 2 January 2004. Mission scientists have been processing the tiny grains, which range in size from 50 microns to less than one micron, since a few days after the Stardust return capsule landed in the Utah desert on 15 January 2006.

Stardust principal investigator Donald Brownlee, from the University of Washington, Seattle, said, "The interesting thing is we are finding these high-temperature minerals in materials from the coldest place in the solar system." The minerals, which include peridot, olivine, and titanium nitride, formed at temperatures above 1400 K, whereas the comet itself formed at about 30 K.

Michael Zolensky, Stardust curator and co-investigator at NASA's Johnson Space Center in Houston, Tex., suggested that if the high-temperature minerals originated from the Sun, they could have been ejected and carried out to the edge of the solar system on some sort of 'conveyor belt.'

Stardust scientists are still determining how best to handle these small samples, and so far only six of the 132 cells in the aerogel tray have been processed. Zolensky said that more than 150 samples—pieces of particles recovered from the aerogel—had been provided to scientists on five continents. After this processing phase concludes in the next several months, qualified scientists anywhere in the world will be able to request samples for analysis.

A second aerogel detector on Stardust collected samples of interstellar dust, particles much smaller than those collected from the comet. After a detailed scan of the tray and its samples, which should start in about a month, the images will be sent to participants in the Stardust at Home project. Using a 'virtual microscope,' project participants will search these images for evidence of interstellar dust impacts.

Information about Stardust is available at http://stardust.jpl.nasa.gov, and details about Stardust at Home is available at http://stardustathome.ssl.berkeley.edu/

—SARAH ZIELINSKI, Staff Writer

Research Aircraft Helps Scientists Study Troposphere

A newly developed advanced research aircraft will allow researchers to directly study the atmosphere for extended periods of time at altitudes that approach the troposphere-stratosphere boundary.

The plane, called the High-performance Instrumented Airborne Platform for Environmental Research (HIAPER), can carry nearly 3000 kilograms of scientific instrumentation, reach an altitude of more than 15,500 meters, and cruise without refueling for over 11,200 kilometers. Owned by the U.S. National Science Foundation (NSF) and operated by the National Center for Atmospheric Research (NCAR) in Boulder, Colo., HIAPER will be used to collect detailed information on the meteorology of the upper edges of hurricanes and thunderstorms, high-altitude chemical reactions that are believed to affect climate, and other research concerns.

HIAPER embarked on its first science mission on 2 March to study atmospheric whirlwinds called rotors, which form on the lee side of steep mountains and have contributed to several aircraft accidents. Through April, HIAPER is flying over rotors near California's Sierra Nevada range, as part of a project named the Terrain-Induced Rotor Experiment (T-REX).

The current science campaign "could not have been done without the long-range capabilities of such an aircraft," explained Margaret Leinen, assistant director for geosciences at NSF. HIAPER's ability to reach high altitudes will allow researchers to observe rotors from above and release surveying instruments into the most turbulent areas.

Leinen added that HIAPER's communications and data capabilities will allow the entire T-REX science team to participate in the experiment. Other researchers stationed on the ground are probing rotors though observing techniques including radar, lidar, and wind profilers.

"With our advanced instrument payload and our flight paths, the amount of data we will collect will be unprecedented for describing airflow over mountains," said T-REX scientist Jorgen Jensen of NCAR.

For more information, visit the Web site: http://www.haiper.ucar.edu

—MOHI KUMAR, Staff Writer

MEETING ANNOUNCEMENTS

■ 27–29 March 2006 **External Controls on Deep Water Depositional Systems**, Piccadilly, London, U.K. Sponsors: Geological Society of London; Society for Sedimentary Geology. (A. Johnson, The Geological Society, Burlington House, Piccadilly, London, U.K. W1J 0BG; Tel.: +011-44-020-7434-9944; Fax: +011-44-020-7434-0579; E-mail: alys.johnson@geolsoc.org.uk; Web Site: http://www.geolsoc.org.uk/deepwater)

Conference topics include links between climate and sea level, fluvial erosion and transport, paleoclimate modeling, ancient climate controls, and ancient shelf-edge systems.

■ 18–20 April 2006 **Guiding National Ocean Research Investment: Public Workshop on the Ocean Research Priorities Plan,** Denver, Colo., USA. Sponsor: National Science and Technology Council Joint Subcommittee on Ocean Science and Technology. (S. Walker, USGCRP/CCSP Office, 1717 Pennsylvania Avenue, Suite 250, Washington, D.C., USA 20006; Tel.: +1-202-419-3464; Fax: +1-202-223-3064; E-mail: swalker@usgcrp.gov; Web Site: http://ocean.ceq.gov/about/jsost_workshop/welcome.html)

The workshop will focus on key aspects of the Ocean Research Priorities Plan. Themes include the ocean's roles in climate variability and change, marine transportation and security, ocean education, and ocean observations and technology. The workshop will allow participants to address common research needs and provide input on the establishment of national ocean research priorities.

■ 26–27 April 2006 **National Commission on Science for Sustainable Forestry Forest Disturbance, Management and Biodiversity Symposium**, Denver, Colo., USA. Sponsors: National Forest Foundation; Surdna Foundation; The David and Lucile Packard Foundation; others. (A. Lien, National Council for Science and the Environment, 1707 H Street NW, Suite 200, Washington, D.C., USA 20006; Tel.: +1-202-530-5810; Fax: +1-202-628-4311; E-mail: aaron@ncssf.org; Web Site: http://www.ncseonline.org/NCSSF)

The symposium will bring together a diverse group of scientists, decision makers, and forest users to learn about current research and issues in the area of forest disturbance. Topics include the effects of invasive species, insect outbreaks, and fires on biodiversity.

■ 19–21 June 2006 **Academic Science and Its Role in the Development of the Productive Forces in the Northern Regions of Russia**, Arkhangelsk, Russia. Sponsors: Russian Academy of Science; Council for Research Productive Forces of the Administration of Arkhangelsk. (Y. Borovaya, Arkhangelsk Scientific Centre, Russian Academy of Science, ul. Sadovaya 3, Archangel, Russia 163000; Tel.: +011-007-8182-215765; E-mail: arhconf-2006@yandex.ru)

The conference is dedicated to the centennial anniversary of the opening of the first station of the Russian Academy of Science. Topics include the development of oil and gas fields, research on shelf seas and continental reservoirs, and problems in biodiversity and the conditions of ecosystems in the northern regions of Russia.

■ 2–7 July 2006 **XII International Symposium on Vulcanospeleology**, Tepoztlan, Morelos, Mexico. Sponsors: International Union of Speleology; Mexican Society for Underground Exploration; Association for Mexican Cave Studies; others. (R. Espinasa; E-mail: ramone@cablevision.net.mx; Web Site: http://www.saudicaves.com/symp06/index.html)

The symposium will include presentations on lava caves as well as three days of field trips to Iglesia Cave. There will be post-symposium field trips to the longest lava tube in the Americas and to the lava tubes of El Volcancillo Veracruz, which begin from a crater more than 100 meters deep. Abstract deadline is 31 March.

■ 16–21 July 2006 **7th International Conference on the Occurrence, Properties, and Utilization of Natural Zeolites**, Socorro, N.M., USA. Sponsors: International Natural Zeolite Association; Biolite, Inc.; GSA Resources, Inc.; others. (R. Bowman, New Mexico Tech, Department of Earth and Environmental Science, 801 Leroy Place, Socorro, N.M., USA 87801; Tel.: +1-505-835-5992; Fax: +1-505-835-6436; E-mail: bowman@nmt.edu; Web Site: http://www.ees.nmt.edu/Zeolite06)

Meeting topics will include zeolite formation and occurrence, mineralogy of natural zeolites, zeolites in radioactive waste control, and the environmental applications of zeolites. There will also be a mid-week excursion and a post-meeting field trip to zeolite localities in the southwestern U.S. Abstract deadline is 1 April.

Drought

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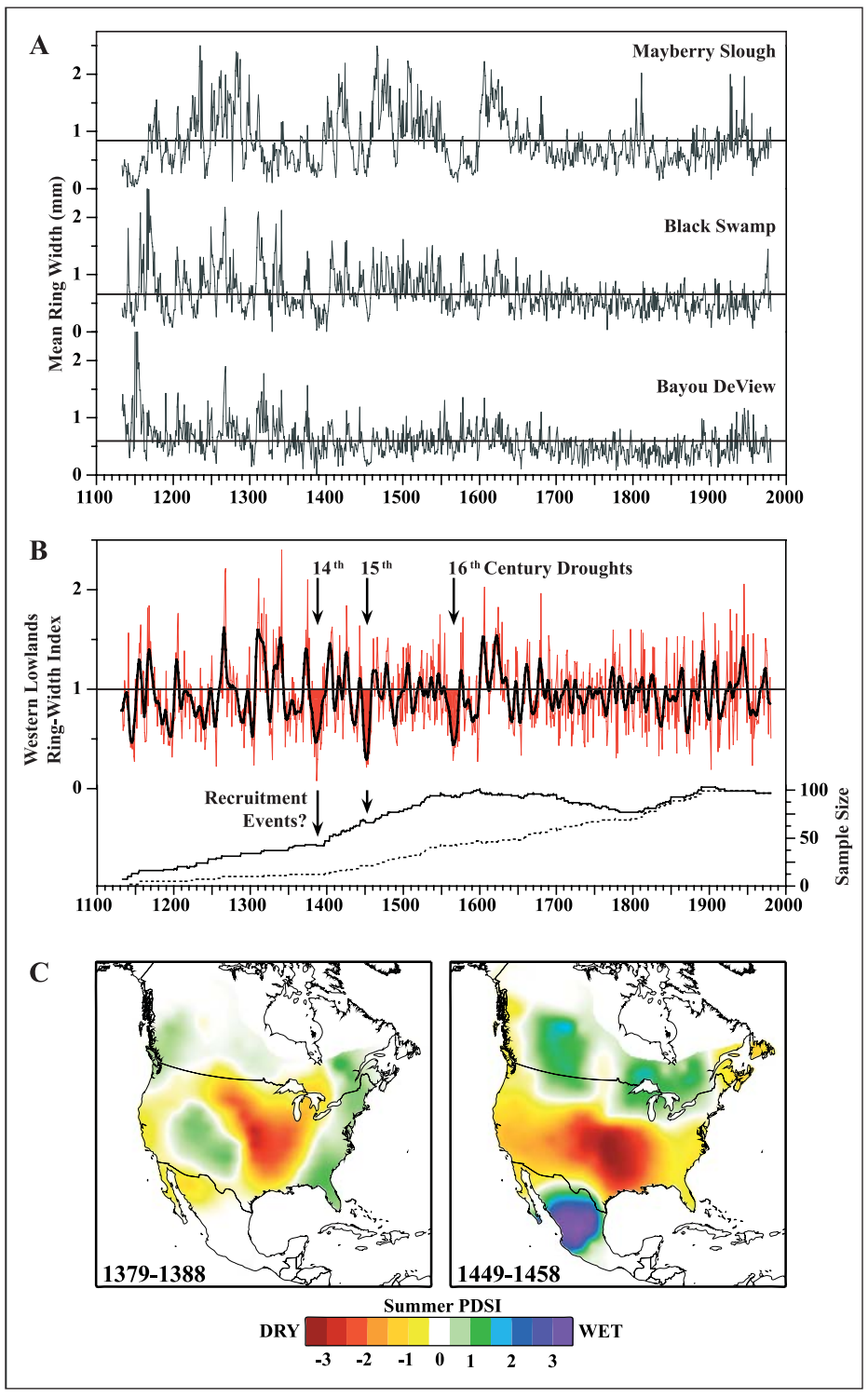

Fig. 2. (a) Mean ring-width chronologies for Bayou DeView, Black Swamp, and Mayberry Slough are plotted without detrending for the past 850 years. (b) The standardized ring-width chronology of bald cypress for the Western Lowlands is based on these three sites and documents severe sustained drought in the fourteenth, fifteenth, and sixteenth centuries (shaded red). The sample size profile (dashed curve indicates living trees, solid curve indicates trees and logs) suggests a survivorship effect and a subsequent recruitment event for cypress-tupelo forests in the Western Lowlands during the fourteenth- and fifteenth-century droughts (arrows). (c) The spatial pattern of tree-ring reconstructed Palmer Drought Severity Indices for North America during these epic droughts is based on Cook et al. *[2004].*

underestimate the true age of germination. Nevertheless, most of these trees, and no doubt millions of other cypress in the Western Lowlands, probably germinated during the prolonged drought and low water conditions of the fourteenth- and fifteenth-century droughts.

Ivory bill numbers also likely increased in the wake of the decadal droughts. Ivory-billed woodpeckers feed predominantly on wood-boring larvae in the *Cerambycidae*, *Buprestidae*, and *Elateridae* beetle families, especially in large old trees subject to decay and in recently dead trees [*Tanner,* 1942]. Early twentieth century observations indicate that the abundance of beetles and ivory bills both increased in areas with recently killed standing timber [*Tanner,* 1942]. Other species also respond to disasters, including Bachman's warbler (*Vermivora bachmanii*, now likely extinct), which seems to have increased in numbers following habitat changes caused by the New Madrid and Charleston earthquakes of 1811–1812 and 1886, respectively [*Shugart*, 2004].

Old-Growth Cypress-Tupelo Conservation

Bald cypress grew in a variety of wetland conditions and produced several grades of cypress lumber, some of which was more valuable for timber production than others (Figure 3). The commercially valuable virgin cypress forests with tall columnar trees were a preferred habitat for ivory-billed woodpeckers [*Tanner,* 1942] and were among the most heavily logged forest ecosystems in the world. Very few stands of virgin bald cypress with huge trees have been preserved. *Mattoon* [1915] estimated that the 'permanent swamp' ecosystem of the South covered nearly 17 million hectares, but it is estimated that no more than 5000 hectares of virgin cypress remain, perhaps only 0.0002% of the original uncut ecosystem. The best cypress growth was often observed in the large back swamps away from the main stream channels where cypress trees were obliged to grow under an unbroken canopy over 30 meters high, producing the remarkable forests of tall, 'clear' cypress stems (free of branching) so heavily exploited for lumber production.

Only three reasonably large tracts of virgin cypress with commercial grade timber are known to remain: a 1400-hectare tract on private property in southwestern Arkansas; and the National Audubon Society sanctuaries at Four Holes Swamp, S.C. (713 hectares), and at Corkscrew Swamp, Fla. (283 hectares).

Fortunately, a few small stands of old, 'overmature' bald cypress and tupelo in noncommercial settings survived the era of massive timber cutting and agricultural land clearing. The old-growth cypress-tupelo at Bayou DeView have suffered selective logging (primarily for tupelo), but thousands of decrepit, overmature cypress and tupelo still exist, including small parcels of uncut centuries-old forest in the Dagmar Wildlife Management Area and the Cache River National Wildlife Refuge, located near Brinkley. The Bayou DeView woodlands are representative of other selectively logged or uncut noncommercial cypress-tupelo stands still scattered sparingly across the southeastern United States.

Black River, N.C., is a premier example of noncommercial ancient cypress, dominated by smaller cypress trees too shaky, pecky, and heart-rotten to justify logging. The Black River site today contains the oldest-known living trees in the eastern United States, including one tree at least 1700 years old and several partly hollow trees likely over 2000 years old [*Stahle et al.,* 1988]. Noncommercial cypress timber was often found in acidic, nutrient-poor blackwater streams like the Black River, and in deeper water along bayous where smaller, heavily buttressed, and branching trees were common.

This environmental gradient in the form and size of cypress trees across virgin southern floodplains was discussed by *Dickeson and Brown* [1848] and illustrated by *Mattoon* [1915]. Mattoon's intricate drawings highlight the uneven distribution of both valuable and noncommercial cypress across the subtle topographic and hydrologic gradients of southern floodplains and swamps (Figure 3).

These two important historical sources provide a clear predictive model for where in the complex, highly altered southern floodplains old-growth bald cypress–tupelo remnants can still be found in noncommercial settings, proven in part by dendrochronological discoveries of centuries-old cypress at Bayou DeView, Black River, Choctawhatchee River (Fla.), Pascagoula (Miss.), and elsewhere (e.g., http://www.uark.edu/dendro/oldgrowth).

How much old-growth cypress-tupelo forest still remains in noncommercial timberlands of the southeastern United States and how they might be integrated into conservation and restoration efforts is not known. However, the discovery of at least one surviving population of ivory bills proves the habitat value of even the 'decrepit overmature' cypress-tupelo stands such as Bayou DeView and adds urgency to the identification and protection of other ancient swamp forests throughout the bottomlands of the South.

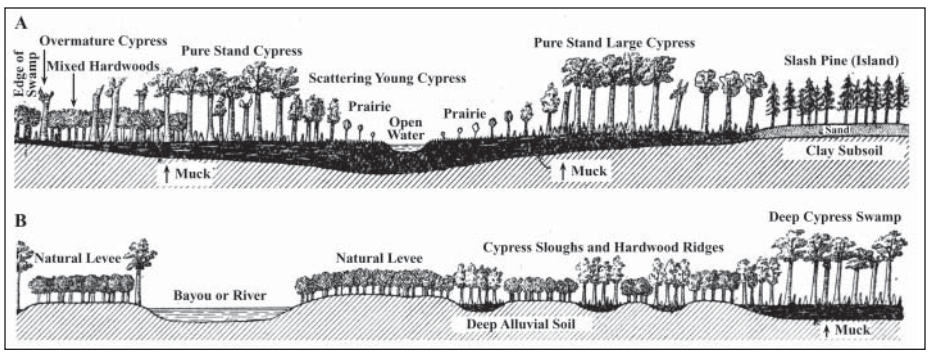

Fig. 3. These drawings illustrate the variable age structure and timber value typically found in virgin cypress swamps (redrawn from Mattoon *[1915]) and provide a conceptual model for where old-growth 'noncommercial' cypress-tupelo woodlands can still be found in the southeastern United States. (a) The transect across Okeefenokee Swamp, Ga., illustrates young cypress surrounding open water, moving outward to a pure stand of large cypress, and then to the oldest edges of the swamp where 'overmature cypress' and mixed hardwoods were typically encountered, a vegetation chronosequence reflecting the increasing age and infilling of the swamp. The pure stands of large cypress were heavily logged across the South, but the stands of decrepit overmature cypress were sometimes left uncut and a few survive today as core habitat for obligate old-growth species. (b) Mattoon's cross section of a typical southern floodplain also illustrates the 'deep cypress swamp' where large commercial timber was often found and was heavily cut. Stunted, poorly formed noncommercial timber was typical of deeper 'cypress sloughs,' where ancient trees can sometimes still be found lining these picturesque southern bayous.*

Acknowledgments

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