Petrified Tree Trunks from a Gravel Deposit, Ban Tak Petrified Forest Park, Ban Tak–Sam Ngao Basin, Tak Province, Northern Thailand

Wickanet Songtham1*, Dallas C. Mildenhall2, Benjavun Ratanasthien3

Received : 25 January 2011 ; Accepted : 13 September 2011

Abstract

Eight fossil wood samples from seven excavation pits from Ban Tak Petrified Forest Park are identified as Koompassioxylon elegans Kramer and Pahudioxylon cf. sahnii Ghosh & Kazmi with botanical affinities to the extant species are Koompassia malaccensis and Afzelia xylocarpa respectively. The study area, Ban Tak-Sam Ngao basin, is a granite-based sedimentary basin containing fluvial sediments. The fossil tree stumps and trunks occur on the eastern flank of the Ping River in a channel gravel within fluvial and alluvial fan deposits formed from changes in flow direction of the Ping and Wang rivers and their tributaries. The sediments were deposited under a tropical moist climate during which time mix deciduous forests flourished. The age of sedimentation is tentatively assessed as Early Pleistocene.

Keywords: Koompassioxylon elegans, Pahudioxylon cf. sahnii, petrified woods, tropical moist forest, Tak province, Thailand.

Introduction

A large petrified tree trunk was first discovered in the study area in 2003. It was partly exposed along a creek in a gravel deposit as the basal stump of a trunk that was later excavated. The whole trunk is 72.22 meters in length and about 1.8 meters in diameter near the basal part (Figure 1). After this discovery an area covering about 5,000 acres was declared a Forest Park, named Ban Tak Petrified Forest Park by the Department of National Park Wildlife and Plant Conservation. The area is located about three kilometers east of Ban Tak district or about 21 kilometers north of Tak township.

Over forty fossil tree trunks were subsequently discovered by surface observation and detail geophysical prospecting by the Department of Mineral Resources but only seven sites were excavated to develop as tourist spots. Some government agencies allocated a budget to conserve, protect, and develop these spectacular fossil sites. Also, the Department of Mineral Resources conducted investigations and research to identify the fossils and study their geological setting in order to understand the processes that had occurred.

The study area is regarded as a sedimentary basin covering parts of Ban Tak and Sam Ngao districts in Tak province, about 450 kilometers from Bangkok via highway number 1. The area is more or less bounded by chains of low hills to high mountain ranges from about 200 to 1500 meters above mean sea level. The basin floor is characterized by a flat to undulating terrain ranging in elevation from 150 to 250 meters above mean sea level. Ping River is the...
main river, flowing from the north via Chiang Mai and its mountainous area southwards through the basin in Sam Ngao district and then south out of the basin. Wang River is a minor river flowing from the north via Muang Lampang, Ko Kha, Sop Prap, Thoen, and Mae Phrik, joining the Ping River at Ban Pak Wang in Ban Tak district as a tributary in the central part of the basin.

This paper reports the results on fossil wood identification and geological setting of the study area to provide new scientific information on Thai fossil plants. This will add to our understanding of the evolution and dispersal corridors for these plants in this region, provide evidence for conserving and developing the fossil sites for tourism and add to the geological education of the country.

**Geological setting**

The fossil site is located in the eastern portion of a sedimentary basin named herein “Ban Tak-Sam Ngao basin” (Figure 2). The basin covers an area of about 435 square kilometers being 16 kilometers wide along the east-west axis and about 27 kilometers long along the north-south axis. It covers part of Ban Tak and Sam Ngao districts of Tak province and is more or less surrounded by low hills to high mountain ranges. It is a granite pluton-based basin formed in Tak plutons. These plutons are represented as a single body, but in reality several phases of intrusion exist. There are two main components including a leucocratic granite (white granite) and an equigranular biotite granite (pink granite). The white granite is younger than the pink granite as can be seen by numerous off-shoots of the white granite cutting into the pink granite. Some small mafic xenoliths occur in the pink granite but not in the white. The white granite is dated as 208±4 Ma., whereas the pink granite is 212±4 Ma., Triassic¹. However, the plutons have composition varying from quartzdiorite, granodiorite, quartzmonzonite, to granite².

The western flank of the basin is bounded by inferred Precambrian mica-schist, gneiss, and calc-silicate rocks. It appears to be a large mountain range, about 40 kilometers wide, extending westwards reaching the eastern flank of Mae Sot basin in the far west. The mountain ranges are dominated by Precambrian metamorphic rocks with some Triassic granite sparsely exposed especially along valleys and cliffs and in some places have traces of past mining for feldspar ore³.

**Figure 1** The 72.22 meters long of petrified tree trunk, *Koompassioxylon elegans*, at excavation pit 1 in the Ban Tak Petrified Forest Park.
The basin is filled with inferred Quaternary sediments including alluvial fan and past and present fluvial sediments. The alluvial fan sediments occur along the piedmont zone of the western mountain ranges as debris flows at the proximal portions of the fans and as channel lag and channel bar alternations from the middle to the marginal zones of the fan deposits. These deposits occur as a series of overlapping fan deposits, bajada, parallel to the mountain foot. The nature of the modern river sediments are somewhat disturbed by two dams on the northern margin of the basin. The first dam is the country largest concrete dam, Bhumipol Dam, built in 1964 and the second dam, Lower Mae Ping Dam, is an earthfill dam about three kilometers downstream of the first dam built in 1995. The dams have blocked vast volumes of sediment from upstream disturbing the depositional styles downstream of the modern basin and changing the nature of the sediments deposited.

The middle part of the basin has been built and sculpted by the Ping River flowing from the north as the main fluvial system, together with the smaller Wang River, which flows from the north and joins the Ping River at Ban Pak Wang tributary in the middle of the basin. The Ping River has been blocked by two dams at the northern margin of the basin, disturbing the huge sedimentary supply downstream. Recent river sediments of the Ping River near the dam site are dominated by gravel deposits with sediment ranging in size from 7-12 centimeters in diameter to
less than one centimeter but normally sand size at Ban Tak, about 29 kilometers from the dam site and about three kilometers west of the petrified wood site.

The eastern margin of the basin is demarcated by a narrow chain of mountains, 1-2 kilometers wide, composed of intrusive leucocratic granite, feldspathic rock, granite, granodiorite, and probable diorite. This mountain chain is too narrow together with its rock material property to produce huge volumes of sediment to form a series of alluvial fans such as those found on the western margin of the basin. The piedmont zone of this part is characterized by a gentle undulating terrain underlain by an igneous batholith and covered by a very thin layer of poorly sorted angular sediment authochthonously produced by the underlying granitic rocks. The topsoil is mainly composed of fragments of quartz, feldspar, and some dark minerals, a saprolite.

On the eastern terrace of the modern Ping River, well rounded gravel deposits with numerous stumps of silicified woods overly a sand layer. These gravel, petrified woods, and sand deposits are regarded as a channel deposit from the ancient Ping and Wang rivers, not alluvial fans. The sand and wood are silicified forming a sandstone bed and silicified tree trunks; the gravel are also partially silicified into conglomerate, especially along the sand/gravel boundary. These characteristics are seen from Ban Mae Bon in the north to near Ban Tak hospital in the south. Silicification of the sand, gravel, and woods is postulated as taking place at the same time. There are some geomorphologic landforms that possibly relate to the tectonic movement of the basin and its vicinities. Areal photo images of the basin reveal some lineaments cutting across the gravel deposits from the western flank via Ping River to the eastern flank. An example of these lineaments is a trace from Ban Tung Kra Cho, Ban Dong Yang, and Ban Tak Tok on the western flank via the Ping River to Ban Tak on the eastern flank and along Huai Tafang Sung (a small stream) eastward on the eastern flank to the eastern margin of the basin. These lineaments were generated after gravel deposition. Tectonic uplift of the landmass generated these lineaments.

There is no reliable age evidence in the study area to date the gravel, sand, and fossil wood deposits. However, on the basis of regional geology of northern Thailand, the gravel deposits generally occur on river terraces more or less parallel to the modern rivers and are thus regarded as ancient river sediments. A gravel deposit in Ban Pong Pa Pao, Mae Tha, Lampang, is overlain by a basalt flow dated as 0.6±0.2 to 0.8±0.2 Ma. The age of the gravel deposit is older than the age of the basalt flows, more than 800,000 years old or Early Pleistocene, and this has been inferred as the age of the gravel deposits in this region.

Materials and methods

Materials used in this study include pieces of fossil wood taken from the seven petrified wood excavation pits in Ban Tak Petrified Forest Park. The fossil samples were taken from the outer portions avoiding damage to the fossil tree trunks. The samples were labeled with numbers prefixed by BT, arranged from BT-1 to BT-8 in accordance with the excavation pits 1 to pit 7 (the pit 7 contained two fossil tree stumps labeled as BT-7 and BT-8). The samples were taken back to the laboratory to cut into transversal sections each about two centimeters in thickness. Each slab was then marked by a color pen and cut into three thin sections as thin as 0.03 millimeters in transversal, tangential, and radial planes and mounted on microscopic glass slides in Canada balsam under cover slips.

A stereoscopic binocular microscope with top lighting, Nikon SMZ 1500, was used to investigate fossil wood cell structures on the transversal dissection slabs. The three thin sections of each sample were studied under another microscope, Carl Zeiss Axiolab, with 25, 50, 100, 400, and 1000 magnifications. Fossil wood cell structures of the vessels, rays, axial parenchyma, and fibers from the three thin sections were then described. All laboratory processes were carried out at the Department of Mineral Resources in Bangkok, Thailand and all the specimens and thin
sections have been housed at the Bureau of Fossil Protection in the Department.

**Systematics**

Genus: *Koompassioxylon* Kramer, 1974
Species: *Koompassioxylon elegans* Kramer, 1974 (Figure 3)

*Description*: Growth rings indistinct or absent, pore diffuse, exclusively solitary, diameter 162-265 μ, 5-6 pores per square millimeter, vessel element length 359-628 μ, simple perforation plate placed at right angle to tilt 45° to the vessel, intervessel pits rounded to polygonal, 4.0-6.2 μ in diameter, alternately arranged.

Parenchyma aliform to aliform-confluent, ray 1-3 cells wide (mostly 2 cells), 15-32 μ; height less than 1 mm (319-530 μ), 4-12 rays in one mm, mostly homogenous and procumbent.

*Botanical affinity*: This fossil wood is comparable to the extant genus *Koompassia* of the family Leguminosae-Caesalpinoideae. The genus *Koompassia* has 3 species of large and tall trees, *K. excelsa*, *K. malaccensis*, and *K. grandiflora*, inhabiting moist areas in Southeast Asia. This fossil wood closely resembles *K. malaccensis* inhabiting freshwater swamps in the Thai peninsula, Malaysia, Singapore, Brunei, and Indonesia. The species is endangered in Thailand.

*Fossil distribution*: The species *Koompassioxylon elegans* was first described by Kramer from a Neogene flora in the Malaysian archipelago. Bande and Prakash and Yadav found this Neogene species in West Bengal and the Lower Siwalik Formation in India. These discoveries suggest that *Koompassia malaccensis* was more widely distributed in Neogene forests than at the present day.

*Occurrence*: Site number 1, 3, 4, 6 and 7 in Ban Tak Petrified Forest Park.

Genus: *Pahudioxylon* Chowdhury, Ghosh & Kazmi, 1960
Species: *Pahudioxylon cf. sahnii* Ghosh & Kazmi, 1961 (Figure 4)

*Description*: Growth rings present, pore diffuse, exclusively solitary, diameter 190-218 μ, vessel element length 303-391 μ, simple perforation plates, intervessel pits rounded to polygonal, 4.6-5.4 μ in diameter, alternately arranged.

Parenchyma mostly aliform, ray 1-3 cells wide (mostly 2 cells), 25-35 μ, height less than 1 mm (285-341 μ), mostly homogenous and procumbent.

*Botanical affinity*: The fossil wood is comparable to the extant *Afzelia xylocarpa* (syn. *Pahudia xylocarpa*) of the family Leguminosae-Caesalpinoideae. It is widely distributed in Thailand, Laos, Vietnam, Cambodia, and Myanmar in the areas with 5-6 months rain and about 1,000-1,500 mm annual precipitation.

*Fossil distribution*: The generic names of the fossil wood have been widely used, *Pahudioxylon* and *Afzelioxylon*, but *Pahudioxylon* has priority under the International Code of Botanical Nomenclature. This species has been reported from many countries in Africa such as Algeria, Ethiopia, Chad, Tanzania, and Egypt and the age of the genus is as old as Paleogene. *Pahudioxylon* was first described from the Miocene of India by Chowdhury. *Pahudioxylon sahnii* was reported from a gravel deposit in northeastern Thailand.

*Occurrence*: Site number 2 and 5 in Ban Tak Petrified Forest Park.

**Discussions and conclusions**

Six of the eight silicified tree trunks (sample numbers BT-1, BT-3, BT-4, BT-6, BT-7 and BT-8) in the Ban Tak Petrified Forest Park are identified as *Koompassioxylon elegans* and are closely related to the modern *Koompassia malaccensis*. The fossils are characterized by large tall trunks. Their wood anatomies match with their exclusively solitary pores and aliform to confluent paratracheal parenchyma around the pores in the transversal section. Rays are relatively thin, slender, and tall as two-celled wide rays seen in tangential plane.

The fossil wood structures are distorted in many ways from trunk to trunk, even from place to
place in the same trunk. Specimens collected from each trunk varied greatly in the patterns and degrees of distortion. The well rounded or elliptical tubes of the vessel elements are flattened in some degrees. Rays on some specimens were distorted by compression and/or extension changing their original structures so much that they were difficult to describe and identify. Fortunately, a few specimens revealed cell structures closely resembling the original cell features even though distortions like shapes of the vessels, and twisting strips of rays on the transversal section still occurred, but they still retained some features allowing identification as *Koompassia*.

The other two fossil woods (sample numbers BT-2 and BT-5) are also highly distorted in their wood cell structure. Pores and the eye-shaped parenchyma cells around the pores together with strips of rays are mostly distorted and twisted shapes clearly observed in transverse section. However, all features can be reconstructed into their more or less original shape but the size measurements might be erroneous. Identification as *Pahudioxylon* is reliable and compares with the modern genus *Afzelia*, particularly *Afzelia xylocarpa*, in many characters. The heavy distortion of the fossil wood cell structures, only allows us to confidently identify these fossil materials to this generic level: the specific identification as *P. sahnii* is not confirmed until new samples are examined.

The actual mechanisms of these cell distortions are not clear and needs further research. Distortion prior to and/or during the silicification seems reasonable, since cell distortion should take place while the woods are still soft, without complete silica replacement. Distortion after silicification seems to be impossible as this would preserve and protect the wood from distortion by the pressure of overlying sediment.

The age of the fossil woods is also unknown. They occur in ancient river gravel and sand deposits overlying Triassic granite. These river gravel deposits occur near and parallel to the bank of the modern Ping and Wang rivers. There are many ancient gravel deposits occurring above recent rivers like the Thoen and Lampang indicating that the area has been uplifted and the rivers have changed their directions leaving the ancient river sediments on the river terraces. We assume that the age of the ancient river gravel deposits are uniform an Early Pleistocene age is given herein due to the known age of basalt flows overlying the ancient river gravel deposit in Lampang province. This age is tentative and needs further investigation to find a more reliable age determination.

The study area during Early Pleistocene was a sedimentary basin under a tropical moist climate with sedimentary influx into the basin by the Ping and Wang rivers from the north and some small tributaries from the west and east of the basin. Continuous sedimentation by the rivers since the Pleistocene combined with continuous uplift of the landmass raised some river sediments far above on river terraces. The small streams from the western mountains yielded much sediment to form a series of alluvial fans along the piedmont zone. The *Koompassioxylon elegans* and *Pahudioxylon cf. sahnii* inhabited swamp forest and mixed dipterocarp forest on sandy ridges in the basin. *Koompassioxylon elegans* was the tallest tree in the swamp and tropical moist forests comparable to modern forests with *Koompassia malaccensis*.

**Acknowledgments**

We sincerely thank Parinya Somwong-In and all his colleagues at Ban Tak Petrified Forest Park, the Department of National Park Wildlife and Plant Conservation, who kindly welcomed us and provided important information about the study area as well as many comments. We thank the Department of Mineral Resources in providing financial and logistical support throughout the research. We thank GNS Science, New Zealand, in providing support on references for the research.
References

Figure 3  Photomicrographs of fossil wood *Koompassioxylon elegans* from Ban Tak Petrified Forest Park: A) transversal section showing pores and aliform to aliform-confluent parenchyma cells; B) tangential section showing mostly biseriate rays.

Figure 4  Photomicrographs of fossil wood *Pahudioxylon* cf. *sahnii* from Ban Tak Petrified Forest Park: A) transversal section showing pores and aliform parenchyma cells; B) tangential section showing mostly biseriate rays; C) alternately arranged intervessel pits.