Mae Sai Basin and Wiang Nong Lom: Radiocarbon Dating and Relation to the Active Strike-Slip Mae Chan Fault, Northern Thailand

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ABSTRACT

The Mai Sai basin and the Wiang Nong Lom swamp lie north of, and adjacent to, the northeast-trending Mae Chan fault, which is a left-lateral strike-slip fault in northernmost Thailand. The sediment in the Mae Sai basin is about 600 meters thick. The Mae Sai basin has an anticlinal fold below a 390-meter depth. This fold is buried by broadly downwarped sediment. In the Wiang Nong Lom swamp, sediment is about 170 meters thick.

Radiocarbon ages from a 2.7-meter auger hole at Ko Mae Mai in the Wiang Nong Lom swamp show that 0.5 meter of sediment accumulated in the past 218 years. This sediment rests on an older stiff clay. The stiff clay is Early Holocene in age. The age of this clay 1.05 meters below the sediment surface is 9,830 years. The stiff clay has hematite staining and a total organic carbon content of less than 0.6 per cent. This suggests that it has been sub-aerially exposed prior to inundation about 220 years ago.

Much of the sedimentary section at a site on the north edge of the swamp is older than Early Holocene and recent sediment there is no older than a few hundred years. A hiatus of deposition occurred when the site was dry. Time of inundation at this site does not agree with the legendary AD 460 earthquake and submergence of Yonok, but the age does allow that this site may have been dry and habitable in the interval from 1786 back to BC 9270. The sedimentation rate for clayey sediment at this site during the past 200 years is about 2.2 millimeters per year. This compares to similar high rates in the lake at Phayao in northern Thailand.

KEYWORDS: Mae Sai Basin, Wiang Nong Lom, Mae Chan Fault, Northern Thailand

INTRODUCTION

A cross-section in the Mae Sai basin and radiocarbon dating results from a 2.7-meter deep auger hole in the large swamp south of the basin, known as Wiang Nong Lom (Figure 1), provide preliminary information for the geological and geophysical exploration of the area. This exploration was focused on understanding the setting of the legendary 4th-century Yonok civilization reported in the Sinhanavati Chronicle (Notton, 1926), but for which little or no archaeological evidence has been found. The Sinhanavati Chronicle relates a detailed story of a great earthquake in 1003 BE, which is AD 460, in which the ancient city of Yonok sank into a swamp and all the inhabitants, except for one old widow, perished. Northern Thailand currently experiences a moderate level of crustal deformation and seismicity (Iwakuni and others, 2004). The possibility of such an earthquake is supported by recent paleoseismic studies of the Mae Chan strike-slip fault (Wood, 2001, Fenton and others, 2003; Rymer and others, 1996). Local legend tells of the site, Ko Mae Mai, where the surviving old widow resided and the approximate
location of the sunken city in the swamp of Wiang Nong Lom (Figure 1). The cross-section crosses the swamp, and the auger hole is at the Ko Mae Mai location.

![Map showing Fang and Mae Sai basins, and Mae Chan fault, the Wiang Nong Lom swamp, and location of the cross section of Figure 2.](image)

**Figure 1.** Map showing Fang and Mae Sai basins, and Mae Chan fault, the Wiang Nong Lom swamp, and location of the cross section of Figure 2.

**THE MAE SAI BASIN**

The Mae Sai and Fang basins are normal-fault half-graben structures along the active Mae Chan left-lateral strike-slip fault. The large Wiang Nong Lom swampy area appears to be a sag or downwarp along the fault (Figure 1). The tectonic model for the origin of similar rift basins in northern Thailand is debated. Some workers call such basins pull-apart basins associated with strike-slip faulting while others associate their origin with extension and changing stress systems related to the Tertiary-aged escape tectonics of Southeast Asia (Morley, 2002). A peculiarity of these Southeast Asia rift basins is fold structure attributed to a time interval in the Late Miocene when basins were subjected to an interval of compressional stress followed by continued subsidence. These events have been called basin inversion (Cooper and others, 1989).

The cross-section of the basin (Figure 2) shows the sediment in the southern Mae Sai basin to be about 590 meters thick. High relief of the mountains, such as Doi Tung, and peaks up to elevations of 1,500 meters that lay to the west indicate basin relief of about 2 kilometers. The range has an impressive steep east-facing escarpment that suggests considerable movement occurred in the Late Tertiary along the basin’s west boundary fault system (Figure 3). The deepest sediment in the basin is folded into a broad anticlinal structure, which is onlapped by sediments (Figure 2). The upper 390 meters is not folded, but shows broad basin downwarping. Lithology is not known in detail, but a well log (Figure 4) shows that metamorphic rock and limestone were drilled at a depth of about 620 meters.
The cross-section (Figures 1 and 2) extends southeast across the Wiang Nong Lom swamp. Meta-volcanic rock occurs in the outcrops and quarries in the hills between the Mae Chan basin and the swamp. This upland area is apparently an uplifted, or upwarped, bedrock area at an elevation of 460 meters relative to the swamp elevation of 370 meters. The cross-section indicates that bedrock is about 170 meters deep beneath the swamp (Figure 2).
SEDIMENTATION IN WIANG NONG LOM AND RADIOCARBON DATES

Wiang Nong Lom is a large swampy area about 7 kilometers wide and 15 kilometers long (Figure 5). This swampy area lies along the northwest side of the Mae Chan fault (Figure 1). It is probably a structural downwarp, or tectonic sag, associated with deformation along the Mae Chan fault. Sediment overlying the meta-volcanic Mesozoic bedrock is about 170 meters thick.

Satellite imagery indicates several leved channels flow through the swamp, but the drainage areas delivering water and sediment to these channels are not large according to what was outlined from 1:50,000 scale topographic maps. Sedimentation has built up the central area of the swamp as low floodplains beyond the leved channels; however the margins of the area are swampy wetlands with shallow lakes. The northeast end of the swamp drains along the Lua River (Figure 5). This river flows through a low,
northeast-trending bedrock ridge, called Doi Pa Lia, on the southeast side of the Mae Chan fault. From here, which is 1 kilometer northeast of Ban Thap Kuman Thong, the river flows across the fault and onto the flood plain of the Kok River.

Near Wat Pa Mak No (Figure 5), an attempt was made to drive a piston corer into the swamp sediments, but the sediment at the site below 0.5 meter is a stiff clay, through which the 5-centimeter diameter Lucite tube could not be pushed. A good pistoncore sample was obtained above 0.45 meter, but deeper samples could only be obtained by using an auger. Great care was taken to clean the hole to sampling depth by sucking out loose material with the piston corer before advancing into clean sediment with the auger. The samples selected for analysis were from the lower part of the auger head in order to minimize the possibility of contamination.

When the auger sample from a depth of 0.48 meter below the sediment surface was dissected, a thin, 3-millimeter thick, dark band was noticed. This band contained a 1-centimeter lump of charcoal that was cleaned of visible rootlets and submitted for AMS radiocarbon dating. Another sample of dark gray clay from a depth of 1.05 meters was selected for radiocarbon dating because it showed dark specks that were presumed to be charcoal and because it had fewer brick-red streaks than were observed deeper in the hole. Radiocarbon analysis was on the bulk sediment sample. Subsequent analysis showed the 1.05-meter sample to be 0.9 percent organic carbon (Figure 6b) and that even the deeper samples had enough carbon, about 0.5 per cent, for a radiocarbon-age determination.

Figure 5.
Map of Wiang Nong Lom, showing the location of Wat Pha Ma Ngaw (also transliterated to "Wat Pa Mak No"), which is build upon "Widow's Island" (Ko Mae Mai) area and also the location of the 2.7-m auger hole.
The radiocarbon age of the charcoal at 0.48 meter below the sediment surface is 160 ± 40 years BP. This calibrates to calendar year cal AD 1786 ± 94 years, which is year 2329 of the Buddhist Era, or about 218 years ago. (Appendix: Radiocarbon Dating). The radiocarbon age of the sample from 1.05 meters below the sediment surface is 9,830 ± 40 year BP, or cal BC 9,268 ± 20 years. The greater precision of the older age is because the calibration curve has less ambiguity at that age range.

The resulting radiocarbon dates were a surprise, since a core of continuously deposited sediment without hiatuses was anticipated. However, this great difference in radiocarbon age, as well as the abrupt stiffening of the clay at the 0.5-meter depth, indicates that only the upper 0.5 meter is a result of recent and continuous sedimentation. Apparently there was an interval of non-deposition or erosion at about 1.00 meter and the deeper clay is much older, yielding a radiocarbon age of 9,830 years BP (Figure 6a). The clay sediment below 1.05 meters has an increasing amount of red hematite color as streaks and spots (Figure 6a). There is also a diminishing amount of organic carbon downward.
in the core, with a pronounced break and reduction below 2.0 meters (Figure 6b). The red color and less than 6 percent of organic carbon suggest that this sediment had been dry and aerated in the past prior to its present inundation of about 0.5 meter of water and 0.5 meter of recent swamp sediment.

![Graph showing organic carbon content](image)

**Figure 6b.** Total organic carbon content of sediment from 2.7-m auger hole of Figure 6a (determined by Annette Lyle and Brandi Murphy at Boise State University).

The sedimentation rate for the upper part of the auger hole appears to be 0.48 meter per 218 years, or about 2.2 millimeters per year. This relatively high rate is compared to sedimentation in other lakes and swamps in the Southeast Asia region in Figure 7. It does compare to the sedimentation rate at the 20-square kilometer area lake, Khwan Phayao, between the radiocarbon years 780 to 1860 BP. Joyce and others (2004) interpreted the high sedimentation rates at Khwan Phayao to be associated with an intensification of land use since at least the 2nd century AD cal, presumed to be coincident with late iron-age settlement of the region. Details of the sediment of the Phayao core are not published, so the very high sediment rate of 13 centimeters per year for the years 640 to 780 BP may be rapid silt or sand deposition, and not typical of clay deposition. The lake is fed from the north by the upper Ing River and so sedimentation may be rapid at times. Sediments at Kara Lake in Cambodia are dark, fine-grained, with 15 to 17 percent organic carbon and 3 percent carbonate (Maxwell, 2001). Thus, they are unlike the predominantly clay sediment of Wiang Nong Lom, which has mostly less than 1 percent organic carbon.
CONCLUSIONS

The basin sediment in the Mae Sai basin is about 600-m thick. In the Wiang Nong Lom swamp, sediment is about 170-m thick. Mae Sai basin cross section show an anticlinal fold below 390 m depth, buried by broadly downwarped sediment.

Radiocarbon ages from a 2.7-m auger hole at Ko Mae Mai, in the Wiang Nong Lom swamp show 0.5 m of clay sediment was deposited in the past 218 years. That clay sediment rests upon an older stiff clay, with an age, 1.05 m deep in the sediment of 9830 years BP. The stiff clay has hematite staining and total organic carbon content of less than 0.6 per cent, suggesting it has been subaerially exposed (dry and above water), prior to inundation about 220 years ago.

It appears much of the sediment on this edge of the swamp is older than early Holocene, and recent sediment is no older than a few hundred years, with a hiatus of deposition when the site was dry. Time of inundation at this site does not agree with the legendary AD 460 (about 1500 years ago) earthquake and submergence of the ancient city of Yonok, but the age does allow that this site was dry and habitable 1500 years ago.

For further archaeological and geological exploration of the swamp, we recommend two-dimension imaging of the upper 10 meters, by lines directed northwest-southeast, across this area using shallow high-resolution seismic reflection with a high-frequency source, to search for signs of cultural features, and to better understand sedimentation in the swamp area. Deployment of instruments in the swamp area, however, will be difficult, as there is a floating grass mat, below which water is 0.5 or more meters deep, which is underlain by soft sediment. Full surface coverage, such as that obtained by three-dimension seismic surveys, or by a precision gradient magnetometer would be desirable, but access throughout the swamp is difficult, and complete coverage by boat or wading may not be possible.

We further recommend detailed mapping of the sedimentation system in this swamp from
aerial photographs and satellite imagery, to search for a site in the swamp in which water has been deeper (than the auger hole site, described above) in the past, and may have undergone continuous sedimentation over the past several thousand years. If such a site can be determined, it will be useful to obtain a core and radiocarbon ages and a detailed study of the sediment, pollen, and other features helpful in understanding the cultural history of the area. This will likely require coring from a floating platform, and a device that can core through both soft and stiff clay.

**APPENDIX: Radiocarbon Dating**

Reporting of radiocarbon ages can be confusing, because they are not exactly converted to calendar ages, and various corrections are applied to the laboratory results. By international convention, raw dates are reported as years before present, BP, which has been established as AD 1950. Thus, 0 BP equals AD 1950. Age calculation is based upon the radiocarbon half-life of 5568 years. A carbon-13 isotope measurement is also made on the sample to account for slight fractionation between different carbon materials that occur in nature and to correct for that effect. Ages reported here are $\delta^{13}C$ corrected. The uncertainty in the reported age is one standard deviation, 68 percent probability, that results from analytical procedures. The conversion of a radiocarbon age to a calendar age relies on calibration data sets derived mostly from detailed radiocarbon ages of tree-ring intervals of ancient bristlecone pine trees. Because there have been slight variations in the radiocarbon in the atmosphere, it is not a linear conversion. Furthermore, several calendar ages may have the same radiocarbon age. Thus, to rigorously evaluate a radiocarbon age, the probability distribution that it correlates to a range of calendar ages is reported. A radiocarbon age that has been calibrated in this manner to the calendar age is preceded by the word cal, whereas the raw radiocarbon determination is shown followed by BP.

Given the concern with matching sediment layers to known history in Thailand, the probability distribution for the 160 ± 40 year BP radiocarbon age on the charcoal at 0.5-meter depth below the sediment surface (Figure 8) is shown. The conversion using the calpal program (Stuiver and others, 1998), yields a most probable age of cal AD 1786 ± 90 years, as shown by the peak in Figure 8. Again, the ±, refers to one standard deviation. The spread in ages is mostly due to ambiguity in the calibration curve for this age range and not so much from analytical uncertainty.

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**REFERENCES**


Figure 8.
Conversion of radiocarbon age to calendar age for charcoal sample at 0.5 m below sediment surface. The curve shows the probability that the radiocarbon age is exactly any one calendar year, within the range shown. The strong peak is at about 1760, but the calculation yields AD 1786. Uncertainty arises because the calibration curve, based upon radiocarbon dating of tree-ring records is ambiguous, and several calendar ages have the same radiocarbon amount (see Stuiver and others, 1998)

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