

# THE GEOARCHAEOLOGY OF THE PREHISTORIC DITCHED SITES OF THE UPPER MAE NAM MUN VALLEY N.E. THAILAND, II: STRATIGRAPHY AND MORPHOLOGICAL SECTIONS OF THE ENCIRCLING EARTHWORKS

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## ABSTRACT

*Iron Age occupation of a large number of sites in the Mun River Valley, northeast Thailand are characterised by distinctive encircling earthworks, these sites being commonly known as "moated sites". The previous focus on the "moat" as an essential structure has tended to obscure the relationship between site and landscape. This paper reports the preliminary results of the first excavations of any significance within the moats themselves at six sites – Noen U-Loke, Non Muang Khao, Ban Non Khrua Chut, Ban Non Ngiu, Ban Makham Thae and Ban Non Wat – where the structure of the moats has been examined in section. Lithology, stratigraphy and cross-sectional morphology have been recorded and from these observations several broad conclusions may be reached and are reported here. Typically, subsurface features comprise infilled river channels and an undulating bedrock and alluvial surface. Significantly, the surficial morphology of the moats, and notable the regularity of shape and patterning of the moats in plan, usually does not reflect buried channel morphology. The surficial patterning of the moats may, indeed, be a relatively recent phenomenon, and the buried channel features probably reflect more accurately the landscape of the period of Iron Age occupation of the region.*

This paper emerges from the "Origins of the Civilisation of Angkor" archaeological project, northeast Thailand. The project focus is the Iron Age occupation of a large number of sites characterised by distinctive encircling earthworks. Importantly, these sites appear to provide evidence for the development of increasingly centralised social and political organisation in the region, possibly as the precursor to the emergence of the polities of Zhenla and Angkor. Much of this interpretation is dependent on a correct interpretation of the structure and function of the earthworks. While there has been much speculation in the literature, no firm interpretation has hitherto been forthcoming.

In the late 1940s and early 1950s, Williams-Hunt published work using aerial photography to identify archaeological sites in this little known region, identifying the abundant "irregular earthwork" sites of the Mun valley in northeast Thailand as an important group of prehistoric archaeological sites (Williams-Hunt 1948, 1949, 1950). He cautiously expressed the view that these sites had significant structural regularity and locational patterning worthy of investigation. Significant though these contributions were, perhaps his most important contribution lay in what may have been a subconscious comment. Having carefully described the sites – settlement sites or mounds surrounded by irregular ditches and banks – as "earthworks" sites, towards the end of one paper (Williams-Hunt, 1950) he refers to "ramparts" and, importantly, "moats". This latter label was taken up by all subsequent investigators, and the sites became known as "moated sites", with all the implications that such a term brings with it (Quaritch-Wales 1957; Supajanya and Vanasin 1982; Villabhotama 1982, 1984; Welch 1983, 1984, 1985, 1989; Moore 1988; Higham 1989, 1996; McNeill and Welch 1991; Welch and McNeill 1991). In particular, the focus on the "moat" as an essential structure has tended to obscure the relationships between site and landscape.

More recently, revised aerial photograph interpretation of the region by the authors has questioned traditional views regarding the existence of moats. Photographic interpretation and field mapping indicates that the sites are intimately associated with now-extinct rivers, rivers characterising environmental and climatic conditions very different from those at present. In this context, many of the "moats" may be adequately explained as river channels and meanders (Boyd *et al.* n.d.). This paper reports the preliminary results of excavations across the "moat" complexes at six of these "moated sites" so their structure could be examined in section. Detailed sedimentological analysis remains to be completed, although lithology, stratigraphy and cross sectional morphology have been

recorded, and at selected localities pollen analyses of "moat" infill is now available (Boyd unpublished data).

## METHODS

During 1997-1998 the moat structures at six sites – Noen U-Loke, Non Muang Khao, Ban Non Khrua Chut, Ban Non Ngiu, Ban Makham Thae and Ban Non Wat – were examined in section by excavating trenches across the moat complexes with a mechanical backhoe. The exact location of these trenches was determined in part by consideration of the plan layout of the site and its surrounding moats, but modified in most cases by negotiation with local villagers and consideration of land tenure and ownership patterns. At each site, one or more backhoe trenches were excavated along a line perpendicular to the trend of the moats, from the edge of the site outwards, usually but not always to a point on the floodplain beyond the outermost moat. These excavations exposed the buried features of the moats, allowing detailed examination and mapping of the lithology, stratigraphy and cross sectional morphology. Samples were also taken for pollen analysis and detailed sedimentological analysis. These detailed sedimentological analyses remain to be completed, and the results will be reported elsewhere as will the pollen analysis. However, lithology, stratigraphy and cross sectional morphology have been recorded, and from these observations several broad conclusions may be reached and are reported here. In the following, the term "channel" is reserved for the subsurface features, whereas the term "moat" refers to the surface expression. The descriptions of moats and channels at each section are presented in order from the archaeological mound outwards.

## RESULTS: SEDIMENT STRATIGRAPHY AND LITHOLOGY

In general, six stratigraphic units are in evidence.

### *Stratigraphic Unit 1: Bedrock*

The bedrock under all the sites comprises a soft red siltstone, generally breaking into angular blocks, and weathering to red and white mottles with white/yellow concretions; the concretions are generally small, but some are large (to c.2 cm in diameter). This bedrock is probably the Mesozoic Maharakham Formation of the Khorat Group, a formation which comprises bedded sandstones, shale, siltstones and mudstones, weathered extensively in the region to beds rich in iron oxide and various clays (Boonsener 1977; Löffler *et al.* 1983; Tuckson *et al.* 1983; Takaya *et al.* 1984; Wongsomsak 1986; Satarugsa 1987; Chong 1988; Nutalaya *et al.* 1989; Udomchoke 1989).

### *Stratigraphic Unit 2: Floodplain alluvium*

The bedrock is overlain by a thin layer of weathered alluvium comprising mixed floodplain sands and clays. These sediments variously consist of layers and lenses of sand, sandy clay and clayey sand. These sediments are generally overlain by soil development which provides a thin upper brown grey "A" horizon, and lower stratified, often bluish or brownish grey horizons with increasing amounts of calcareous concretions and iron nodules and laterite-derived pisoliths with depth. This stratigraphic unit represents the Holocene sedimentary record for this region, which reflects the variability in environmental conditions, in particular climatic conditions, that has prevailed since the last glacial maximum (Boonsener 1977; Löffler *et al.* 1983; Tuckson *et al.* 1983; Wongsomsak 1986; Satarugsa 1987; Chong 1988; Nutalaya *et al.* 1989; Udomchoke 1989). In this region, the superficial sediments are shallow, rarely exceeding 5 m thickness, and at the study sites this depth is rarely more than 2 m. Of the four major sediment types typical of the Holocene – alluvium, flood deposits, wind-blown sand, and lake and swamp sediments – the first is predominantly present here, although some beds may represent former lake and swamp conditions; it is not clear whether the late Holocene aeolian and flood deposits are present in the study area. Elsewhere the alluvium is considered to represent the top of the sequence of sediments with an approximately mid Holocene age, whereas the lake and swamp sequence is dated to early to mid Holocene times.

### *Stratigraphic Unit 3: Channel infill sediments*

This unit is characterised by several types of sediments, predominantly stiff blue/grey clay with occasional fine gravel, but also including lenses of gravel or sand, or recognisably reworked alluvium. The unifying feature of these sediments is that they infill channels cut into the alluvium and in some cases the bedrock. The stiff blue/grey clay tends to occur as infill in channels closer to the sites and they are generally considerably less heavily weathered than either the bedrock or the alluvium. The outer channels tend to be infilled with redeposited alluvium similar to the *in situ* alluvium but depauperate in pisoliths and concretions.

### *Stratigraphic Unit 4: Archaeological sediments*

These are mixed sediments representing the formation of the site mounds, and characterised by the presence of numerous archaeological artefacts, mainly pottery and bones. They are present in the sections largely as a fringe of sediments at the mound end of the sections, where they overlie older exposures of sediments of the other strati-

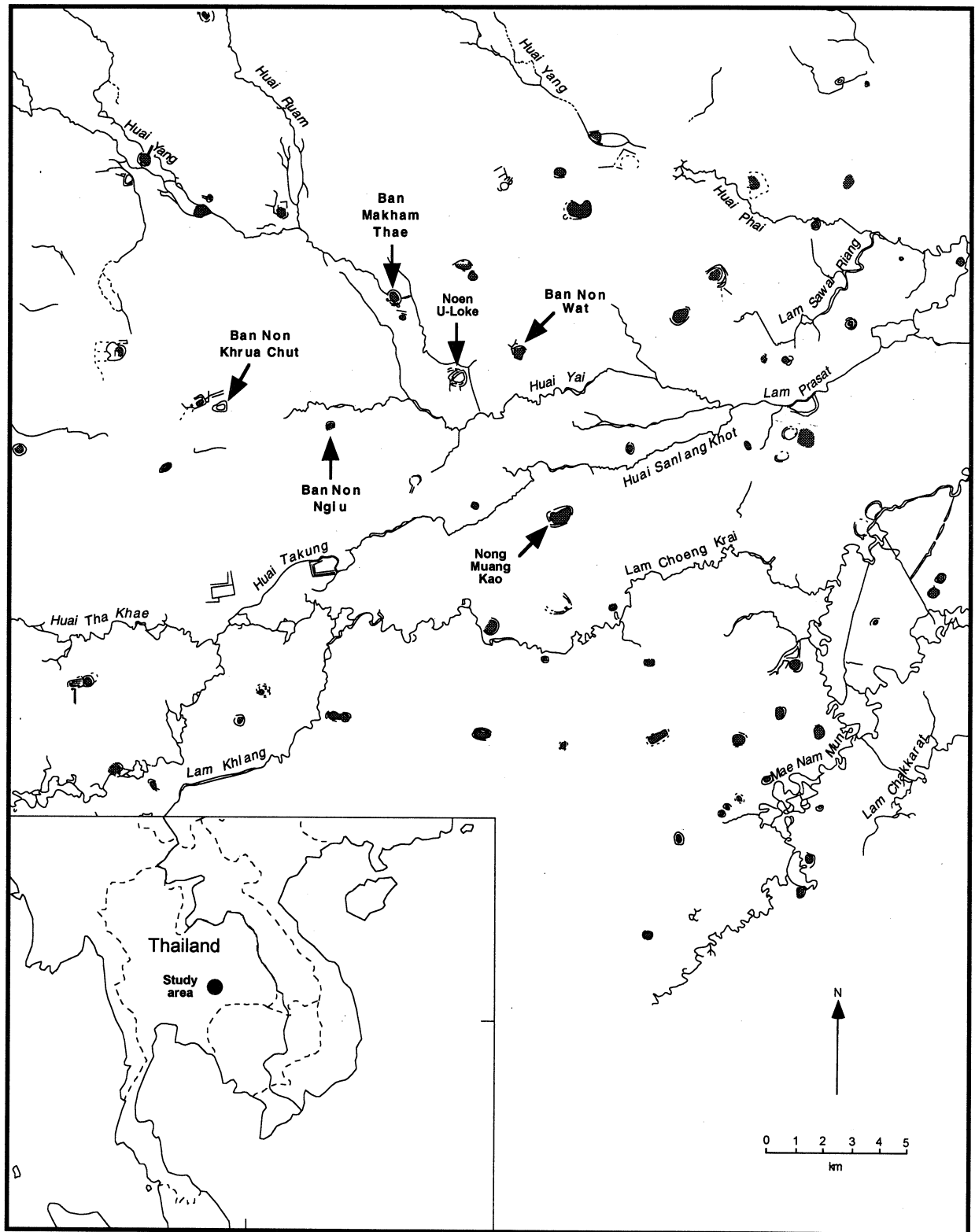


Figure 1: Location map showing the "Origins of the Civilisation of Angkor" archaeological project study area, highlighting the six sites described in this paper.

graphic units. In some cases these archaeological deposits feather into the channel infill sediments (Unit 3) in the innermost moats.

*Stratigraphic Unit 5: Sand*

This unit is characterised by a distinctive, reasonably well sorted, coarse sand. It was located at only two sites, at the base of excavations through a former river channel at Ban Non Ngui, and within two buried channels beneath the edge of the site mound at Noen U-Loke.

*Stratigraphic Unit 6: Spoil*

These are a mix of disturbed sediments located on the mound edge or the moat banks. They are often less consolidated than the other sediments, and comprise variable mixtures of material from the other stratigraphic units. In some cases there is evidence of fragments of bedrock present, while in others the spoil contains archaeological material. This unit represents the redeposition of sediments (Units 1-5) by human agency, and while many represent historic or prehistoric activity some of this disturbance may be attributed to relatively modern farming practices.

RESULTS: SECTION DESCRIPTIONS

The following descriptions summarise the results of trenching across the moats at each of the six sites examined to date: Noen U-Loke, Non Muang Khao, Ban Non Khrua Chut, Ban Non Ngui, Ban Makhham Thae and Ban Non Wat (Figure 1).

*Noen U-Loke*

The site at Noen U-Loke is medium sized (c.300 m diameter), with discontinuous multiple ditches and a possible small enclosure to the northwest (Boyd *et al.* n.d.). Three trenches were cut through the moats, one each to the north, south and east of the mound (Figure 2).

The northern trench (Figure 2, Section 1) was 232 m long and crossed 4 moats, ending in the surrounding fields. There is a possible channel buried and filled with archaeological sediments at the side of the mound with a second channel cut against the side of the mound and filled with grey clay and interfingering of archaeological sediments over alluvium (Unit 2). The first moat is infilled with grey clay (Unit 3) with two channels on either side cut into the underlying alluvium (Unit 2). The first bank is capped with spoil (Unit 6) over a core of alluvium (Unit 2). The second moat has a notably U-shaped channel cut into the alluvium and filled with grey clay (Unit 3). The second bank is all spoil (Unit 6, including bedrock fragments) over an alluvium base. The third moat has two channels cut into the alluvium (Unit 2) and separated by

alluvium rising to the surface in the central region. The first is small and filled with grey clay (Unit 3) with interfingering of spoil at the edge, while the second is larger and is filled with reworked alluvium (Unit 3). The third bank is mainly alluvium (Unit 2) with a small amount of spoil on top. The fourth moat has a single channel filled with reworked alluvium (Unit 3) cut down to bedrock in places. The outermost bank is all alluvium (Unit 2).

The southern trench (Figure 2, Section 2) was 244 m in length and crossed five moats, ending in the surrounding fields. Three channels are buried under the archaeological material at the edge of the mound. The first is filled with a grey clay (Unit 3) and contains pot sherds. This channel may be quite large although it was not possible to determine its full extent as part remains buried under the mound. The two other smaller channels were notably filled with a coarse reddish sand (Unit 5) and also contained sherds. The first moat is infilled with blue/grey clay (Unit 3) overlaying bedrock. In the middle of this moat there is a small channel cut into the bedrock. The first earth bank is topped with disturbed sediments (Unit 6) over a red/grey sandy clay (Unit 2). The second moat also contains grey clay (Unit 3) continuing under the second earth bank of Unit 6. The third moat is relatively narrow and shallow with a thin layer of grey clay (Unit 3) over alluvium. The third bank is spoil (Unit 6) over alluvium (Unit 2) to the base of the trench at 2.2 m. The fourth moat has a grey clay channel infill (Unit 3) over a continuation of the floodplain alluvium (Unit 2), with an increasing amount of hard calcareous and iron nodules at the base, and bedrock (Unit 1) was again encountered. The fourth bank consists of floodplain alluvium (Unit 2) with a concentration of iron nodules towards the base of the unit. The fifth and outermost moat was filled with a dark grey clay (Unit 3) over a light grey sandy clay (Unit 2) with increasing calcareous concretions and iron nodules towards its base. The last bank which separated the moats from the field was capped with spoil (Unit 6), overlying alluvium on bedrock. The field lies on floodplain alluvium (Unit 2) containing increasing amounts of hard calcareous and iron nodules towards the base and overlying bedrock. The important points to note about this trench are that there are three channels buried under the archaeological material at the edge of the mound, and only one of the moats appears to overly a buried channel noticeably cut into the alluvium or bedrock.

The eastern trench (Figure 2, Section 3) was 130 m long and, due to land tenure restrictions, crossed an area of only two moats, ending at the second bank. The first moat has two channels separated by alluvium (Unit 2) rising to the surface. The first channel is shallow and filled with a

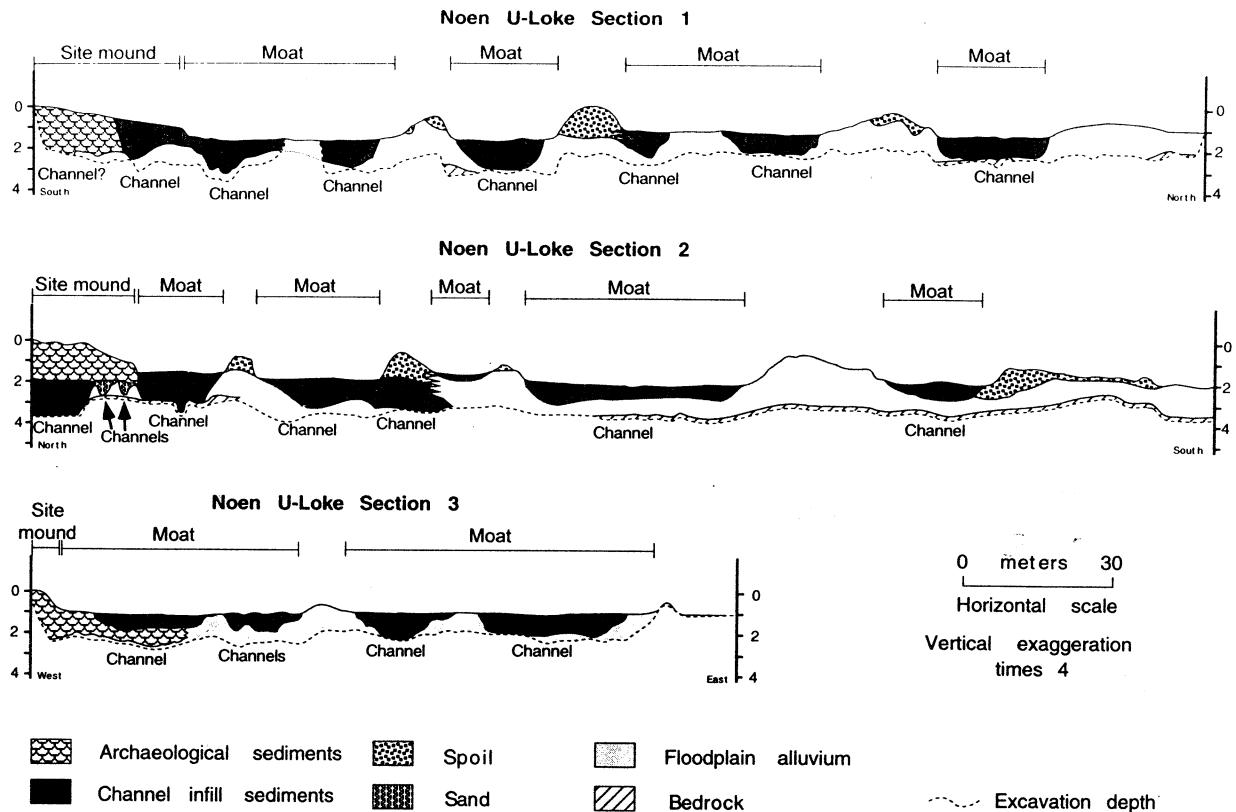


Figure 2: Cross-section of trenches at Noen U-Loke.

mixture of clay and reworked alluvium (Unit 3); it also contains artefacts over archaeological material and alluvium. The second channel is also filled with a mixture of clay and reworked alluvium (Unit 3) over alluvium (Unit 2). The first bank consists entirely of alluvium (Unit 2). The second moat also has two channels separated by alluvium rising to the surface. The two channels are filled with reworked alluvium and it was difficult to distinguish the basal morphology. The outer bank appeared to be alluvium and modern.

#### *Non Muang Khao*

This site is a large and irregularly rounded multiple mound, with several ditches discontinuously surrounding the mound (Boyd *et al.* n.d.). Two trenches were cut through the moats, one to the north and one to the northwest of the mound (Figure 3). The length of the trenches at this site were restricted by land tenure.

The northern trench (Figure 3, Section 1) was 140 m long and crossed two moats finishing on the top of the second bank at the outermost edge of the moats. The first moat is filled with grey clay (Unit 3) with archaeological inwash interfingering at the site edge. The underlying

channel cuts through a layer of alluvium (Unit 2) and into the bedrock (Unit 1). The first bank has a cap of spoil (Unit 6, which may contain some bedrock material) over a core of alluvium (Unit 2). The second moat is very wide and shallow in depth with two small channels on either side of the moat. It is filled with a reworked alluvium (Unit 3) over a thin pisolith rich alluvium (Unit 2). The second bank is capped with spoil over alluvium.

The northwestern trench (Figure 3, Section 2) was 74 m long but did not completely cross the outermost moat. There is a channel partly buried beneath the edge of the mound by archaeological material. This channel is filled with grey clay (Unit 3) over archaeological sediments and bedrock. Away from the edge of the mound the bedrock rises to just below the surface before dropping to form a second channel filled with grey clay (Unit 3). On the far side of the trench the grey clay overlies alluvium (Unit 2) and the bedrock is dropping away.

#### *Ban Non Khrua Chut*

This site is a medium sized mound (c.200 m by 400 m) with two, more or less continuous, encircling moats. A

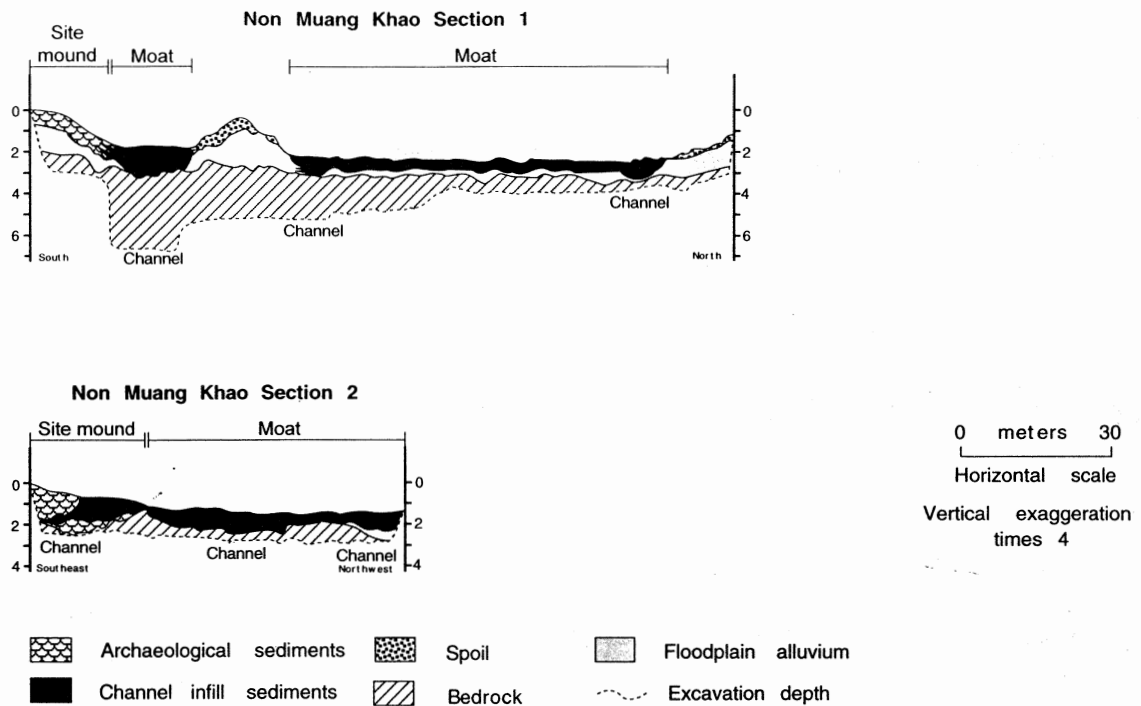


Figure 3: Cross-section of trenches at Non Muang Khao.

single trench was cut through the moats on the northern side of the mound (Figure 4 top).

This trench, on the northern side of the site, was 148 m in length and passed through a small depression on the side of the mound (20 m wide thought to be part of a field created on the side of the mound). It then crossed two moats and into the surrounding fields. The depression is filled with a mixture of spoil and archaeological sediments (Units 6 and 4) over a thin layer of alluvium over bedrock (Units 2 and 1). A single channel filled with blue/grey clay (Unit 3) and containing pottery sherds is cut through the alluvium and into the bedrock. There is some evidence that this channel may have been excavated as the channel fill contains a thin lens of what appears to be red bedrock fragments (washing back into the channel). The bank on the edge of the mound which separates the depression from the first moat consists of spoil sediment over channel infill (Unit 3) and a small amount of floodplain alluvium (Unit 2). The first moat is infilled with a heavy grey clay (Unit 3) and three channels cut into the underlying bedrock. The one closest to the mound also showed evidence of excavation, although the central channel is very small and shows no sign of excavation. The third channel is wider and also had evidence of excavated material (bedrock) washing back into the channel. The bank separating the first and second moats contains spoil (Unit 6) over alluvium (Unit 2) and bedrock. The second moat consists of a

light grey to reddish clay alluvium (Unit 2) with increasing iron nodules at depth above white/red bedrock (Unit 1). The alluvium layer varies in thickness from 0.4-1.1 m to the end of the trench, but there is no evidence of any channels or excavation under this moat. Unfortunately the outer moat bank had been removed in the area permitted to be excavated.

#### Ban Non Ngiu

This is a small more or less circular mounded site (c.200 m diameter) with a single continuous moat. Nearby to the south of the site there is an infilled prehistoric river, thought to be younger than the age of site occupation (Boyd *et al.* n.d.). Two trenches were excavated, one through the former river channel to the south of the site and the other from the northern edge of the mound.

The southern trench (Figure 4, base, Section 1) did not cross any moats but instead crossed the prehistoric river which passes close to the site. A single deep channel with a red/grey sandy clay (Unit 2) lies over a mottled grey clay (Unit 3) which extends to a depth of 3 m. The channel is deepest on the mound side of the trench and gradually became shallower away from the mound. The mottled grey clay (Unit 3) is underlain by a coarse sand deposit (Unit 5) at the base of the infilled river channel. The small amount of spoil sediment in the figure represents modern rice banks.

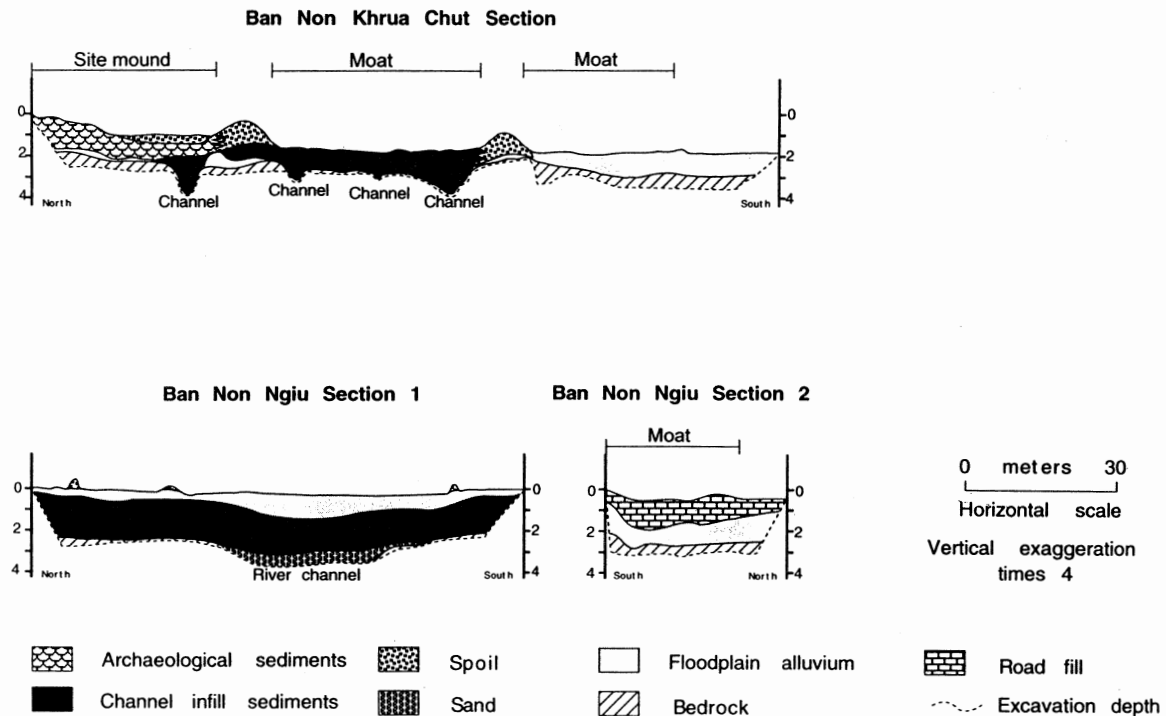


Figure 4: Cross-section of trenches at Ban Non Khrua Chut and Ban Non Ngiu.

The northern trench (Figure 4, base, Section 2) was restricted in size and to a location where the moat had been previously filled for a road by the local land owners. It does, however, section the single moat feature which surrounds this small but highly disturbed site. The surface features of the moat have been essentially eliminated by the use of a fill in the construction of the road. This road-fill is underlain by a reddish sandy clay alluvium (Unit 2), which in turn sits on the bedrock (Unit 1). The morphology of both the surficial moat and any infilled channel is unclear.

*Ban Makham Thae*

This is a medium sized mounded site (c.500 m diameter) with multiple discontinuous moats cut by a small river. A single trench was cut through the moats on the southwest side of the mound (Figure 5).

The trench was 178 m in length and passed through a small depression on the side of the mound (12 m wide, thought to be a field created on the side of the mound), then crossed three moats and ended in the surrounding fields. The undisturbed edge of the mound conceals a large buried channel filled with a heavy grey clay (Unit 3) containing some sherds. Part of this channel remains concealed by the mound but it overlays a thin layer of allu-

vium (Unit 2) and then bedrock (Unit 1). The depression is filled with a mix of grey clay and archaeological material (spoil) which in turn overlays floodplain alluvium with iron nodules increasing with depth to bedrock. The bank which separated the depression from the first moat also consists of a similar spoil deposit. Beneath this spoil layer is another buried channel cut into the underlying floodplain alluvium. The channel is filled with a heavy grey clay (Unit 3) and contains small shells. The first moat is infilled with a grey clay (Unit 3) overlying alluvium and bedrock. The bank separating the first and second moats is capped with a thin layer of spoil over a thick layer of iron nodule rich alluvium on bedrock. The second moat is infilled with grey clay (Unit 3) with interfingering of the alluvium at the edges. This in turn overlays a continuation of the iron nodule rich alluvium, the base of which was not reached at 3.5 m. The bank separating the second and third moats is comprised of alluvium, but has a highly disturbed central region (Unit 6) with a modern irrigation channel running along it. The outermost moat is filled with a continuation of the alluvium. Unfortunately the outer moat bank had been removed in the area permitted to be excavated. There was no evidence of any deep channels or excavation beneath the actual moats.

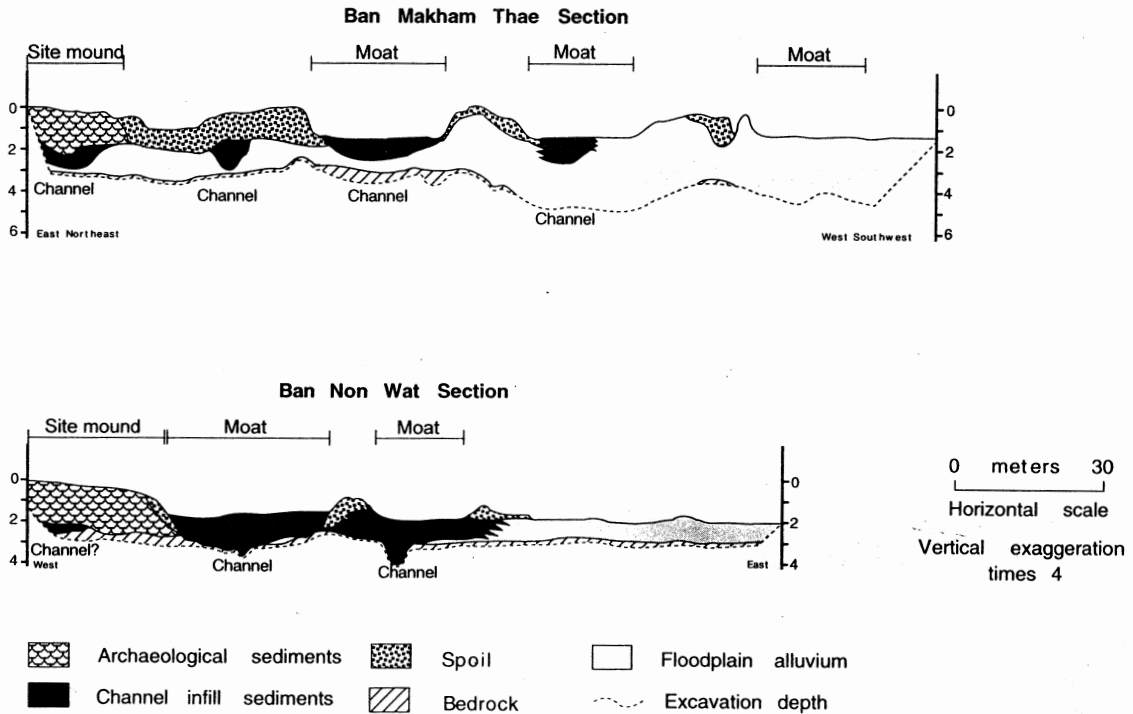


Figure 5: Cross-section of trenches at Ban Makham Thae and Ban Non Wat.

**Ban Non Wat**

This is a medium sized mounded site (c.500 m diameter) with discontinuous multiple ditches (Boyd *et al.* n.d.). A single trench was cut through the moats on the eastern side of the mound (Figure 5).

The trench was 148 m in length, crossed two moats, and possibly a third, finishing in the fields. Archaeological sediments (Unit 4) overlie a thin layer of grey clay (Unit 3) which petered out towards the edge of the mound. This in turn covered white/red bedrock (Unit 1). The first moat is filled with a heavy grey clay (Unit 3) and in the central region of the moat is a small channel cut into the red bedrock material. There is the possibility that this channel has been excavated or cleaned out as it appeared as though some bedrock had been washed back in. The bank between moats 1 and 2 is spoil (Unit 6) and also contained what appeared to be a small quantity of red bedrock fragments. The second moat is filled with a heavy grey clay. (Unit 3) with a deep channel cut into the bedrock. The next bank between the second and possible third moat is also spoil and also contains some bedrock fragments. The channel fill (Unit 3) continues under this bank before becoming indistinguishable from the floodplain alluvium (Unit 2). This floodplain alluvium continues to the end of the trench and contains increasing amounts of iron nodules to

its base above a white/red bedrock (Unit 1). There are no further signs of channels or excavations.

**DISCUSSION**

The excavated trenches represent the first excavations of any significance within the moats themselves, and although detailed sedimentological analysis has not yet been completed it is clear from the sections that the present surface morphology does not reflect the buried structure of these features.

Although it was not possible to excavate for any substantial distance into the side of the site mounds using the mechanical excavator, it has been revealed that there are buried channels beneath the edge of the mounds. In fact with the exception of Ban Non Ngiu, where very limited excavation was allowed by the land owners, all sites examined have revealed the presence of buried channels beneath the actual archaeological mound features. It was not unusual to find archaeological material (such as pottery) within these buried channels which gives a strong indication that they were in existence while the mound was occupied and that the sites later expanded over the top of these now buried channels. It is therefore likely that these buried channels predate the existing moat features and



other more distant buried channels; outermost channels generally contain little if any archaeological material.

Of interest also, is that the surface morphology of the moat features rarely reflects the subsurface section morphology. In general the moats tend to have wide and flat surfaces suitable for the formation of rice fields, whereas the buried morphology often reflects an uneven surface with further (previously unrecorded) incised channel features which are in no way expressed on the surface. These buried features resemble small low-flow channels set in wide shallow flood-flow style channels. At Ban Non Khrua Chut, Ban Non Wat and Noen U-Loke (Section 2), for example, some wide low-flow channels extend under the surface of the present moat banks. Furthermore at Noen U-Loke (Sections 1 and 3) it appears that, in some cases there are two distinct channels confined within a single moat feature. This may have been caused by the modern removal of banks to form larger rice fields. At Ban Non Khrua Chut and Ban Makham Thae, on the other hand, it even appears as though there is no real subsurface expression of the second and third moat features respectively, despite their distinct visibility on aerial photographs and on the ground.

Most of the banks which confine the moat features have a core of *in situ* alluvium, in some cases to an elevation higher than the moat surface, but appear to have been modified or disturbed in some way, as evident by the capping presence of spoil. The origin of the disturbed sediments is not always clear, although in some cases it is evident that small amounts of bedrock material are included, indicating possible limited excavation or cleaning of the buried channel features. Alternately, some of the disturbed bank material may be the result of modern bank construction during the creation of larger rice fields. If this is the case some of the moat features may be more modern than previously thought. Indeed all the moats examined are still used for rice production today as they provided optimal rice-growing conditions, and there are many visible signs of recent structural tidying and maintenance along the edges of banks and site mounds. This is visible as unnaturally steep sides on some of the site edges and raised banks as well as exposures of alluvium on the surface of field edges. Significantly, though, it is apparent that many banks do have a corresponding underlying undisturbed expression of floodplain alluvium which would effectively confine the channel infill sediments.

## CONCLUSIONS

From these observations, several broad conclusions may be reached.

The channels appear to be older towards the mound of the archaeological site and there are usually older channels buried under the site. Those at the mound edges tend to be late Iron Age at the oldest. The outermost may be historic or later in age.

The surficial morphology of the moats usually does not reflect the buried channel sectional morphology. The latter largely resemble small low-flow channels set in wide shallow flood-flow style channels; the flood-flow channels may or may not equate to the surface expression of the moat. In extreme cases, the surficial expression of apparently very convincing moats has no subsurface expression.

In few of the channels is there any evidence for the substantive artificial construction of the channel. Where such evidence is clear, it resembles that of small scale channel maintenance rather than the original cutting of a channel.

The raised banks which line the moats, hitherto regarded as constructed from the sediments dug out of the moats, are not substantially composed of spoil. Rather, they represent the original *in situ* floodplain land surface into which the channels have been cut. While some of these banks have been augmented with channel sediments, there is little evidence for the artificial deposition of the substantial amounts of sediments which would have been excavated from the channels had they been artificially constructed.

There is much evidence that the regularity of shape and patterning of the moats in plan is a recent phenomenon, and probably reflects 20th century landscape tidying.

The conclusion reached in this study is that the surficial moats which have drawn so much attention to these sites largely represent modern landscape processes, in which residual geomorphological features from a former alluvial system provided optimal rice-growing conditions and thus attracted the urge to tidy landscape; these places contain the best soils, are the most expensive land and represent the form of modern field design used to optimise rice production. These modern moats, however, do reflect an underlying geomorphology, one of an evolving fluvial regime somewhat different to that at present. The archaeological sites are intimately linked with this fluvial regime, and undoubtedly the Iron Age occupation was strongly influenced by the fluvial regime (Boyd *et al.* n.d.). The buried channels, however, were probably not constructed, perhaps with a few exceptions where channels were kept clean, but represent stream and river channels of various types. With a change in fluvial regime and the apparent infilling and abandonment of these river channels, the Iron Age occupation in the region came to a halt.

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## REFERENCES

- Boonsener, M. 1977. The Engineering Geology of the town of Khon Kaen, Northeast Thailand. Masters Dissertation No. 1023, Asian Institute of Technology, Bangkok.
- Boyd, W.E., Higham, C.F.W. and McGrath, R.J. n.d. The geoarchaeology of the Iron Age ditched sites of the upper Mae Nam Mun valley, N.E. Thailand. I: Palaeo-drainage and site relationships, derived from aerial photograph interpretation. Submitted to *Geoarchaeology*.
- Chong, K.Y. 1988. Geohydrology of the Town of Khon Kaen, Northeastern Thailand. Masters Dissertation No. GT-87-26, Asian Institute of Technology, Bangkok.
- Higham, C. 1989. *The Archaeology of Mainland S.E. Asia: From 10,000 BC to the Fall of Angkor*. Cambridge: Cambridge University Press.
- Higham, C.F.W. 1996. A review of archaeology in mainland southeast Asia. *Journal of Archaeological Research* 4:3-49.
- Löffler, E., Thompson, W.P. and Liengsakul, M. 1983. Geomorphological development of the Tung Kula Ronghai. In Anon (ed.) *Proceedings of the First Symposium on Geomorphology and Quaternary Geology of Thailand*, pp. 123-30. Bangkok: Department of Geology, Chulalongkorn University.
- McNeill, J.R. and Welch, D.J. 1991. Regional and inter-regional interaction on the Khorat Plateau. *Bulletin of the Indo-Pacific Prehistory Association* 10:327-40.
- Moore, E.H. 1988. *Moated Sites in Early North East Thailand*. Oxford: British Archaeological Reports International Series 400.
- Nutalaya, P., Sophonsakulrat, W., Sonsuk, M. and Wattanachai, N. 1989. Catastrophic flooding - An agent for landform development of the Khorat Plateau: A working hypothesis. In Thiraongkol, N. (ed.) *Proceedings of the Workshop on Correlation of Quaternary Successions in South, East and Southeast Asia*, pp. 95-115. Bangkok: Department of Geology, Chulalongkorn University.
- Quaritch-Wales, H.G. 1957. An early Buddhist civilisation in Eastern Siam. *Journal of the Siam Society* 45:42-60.
- Satarugsa, P. 1987. Engineering geology of Khorat City. Masters Dissertation No. GT-86-29, Asian Institute of Technology, Bangkok.
- Supajanya, T. and Vanasin, P. 1982. *The Inventory of Ancient Settlements in Thailand*. Bangkok: Toyota Foundation.
- Takaya, Y., Hattori, T. and Wichaidit, P. 1984. *Soil salinization in the Khorat Plateau*. Report to the Mekong Secretariat. 37pp.
- Tuckson, M., Thompson, W., Löffler, E., Hartley, A. and Hunter, G. 1983. *Tung Kula Ronghai Salinity Study*. Thailand: Thai-Australia Tung Kula Ronghai Project.
- Udomchoke, V. 1989. Quaternary Stratigraphy of the Khorat Plateau Area, northeastern Thailand. In N. Thiraongkol, (ed.) *Proceedings of the Workshop on Correlation of Quaternary Successions in South, East and Southeast Asia*, pp. 69-94. Bangkok: Department of Geology, Chulalongkorn University.
- Villabhotama, S. 1982. *Archaeological Study of the Lower Mun-Chi Basin* (in Thai). Bangkok: NEDECO.
- Villabhotama, S. 1984. The relevance of moated settlements in the formation of states in Thailand. In D.T. Bayard (ed.) *Southeastern Asian Archaeology at the XV Pacific Science Congress*, pp. 123-8. Dunedin: Otago University, *Studies in Prehistoric Anthropology* 16.
- Welch, D. J. 1983. Preliminary report on archaeological survey and excavations in the Phimai Region, Northeast Thailand. *Bulletin of the Indo-Pacific Prehistory Association* 4:58-70.
- Welch, D. 1984. Settlement patterns as an indicator of socio-political complexity in the Phimai region. In D.T. Bayard (ed.) *Southeastern Asian Archaeology at the XV Pacific Science Congress*, pp. 129-51. Dunedin: Otago University, *Studies in Prehistoric Anthropology* 16.
- Welch, D. 1985. Adaptation to environmental unpredictability: Intensive agriculture and regional exchange at Late Prehistoric centres in the Phimai Region, Thailand. Ph.D. Dissertation, University of Hawai'i, Honolulu.
- Welch, D. J. 1989. Late prehistoric and Early Historic exchange patterns in the Phimai Region, Thailand. *Journal of South East Asian Studies* 20:11-26.
- Welch, D. J. and McNeill, J. R. 1991. Settlement, agriculture and population changes in the Phimai region, Thailand. *Bulletin of the Indo-Pacific Prehistory Association* 11:210-28.

- Williams-Hunt, P.D.R. 1948. Archaeology and topographical interpretation of air photographs. *Antiquity* 22:103-5.
- Williams-Hunt, P.D.R. 1949. An introduction to the study of archaeology from the air. *Journal of the Siam Society* 37:85-110.
- Williams-Hunt, P.D.R. 1950. Irregular earthworks in Eastern Siam: An air survey. *Antiquity* 24:30-7
- Wongsomsak, S. 1987. Quaternary stratigraphy in Northeast Thailand: A stratigraphic research at Changwat Buri Ram. In Anon (ed.) *Proceedings of the CCOP Symposium on Developments in Quaternary Geological Research in East and Southeast Asia during the Last Decade*, pp. 179-96. Bangkok: Committee for Coordination of Joint Prospecting

