IRON-SMELTING AND SALT-MAKING INDUSTRIES IN NORTHEAST THAILAND

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ABSTRACT

Two sites representing prehistoric technologies of economic significance have been excavated in northeastern Thailand. Ban Dong Phlong was an iron smelting site, rapidly being destroyed by modern activities. Non Tung Pie Pone was a salt making site. The functioning of this site was elucidated with reference to ethnographic observations of salt making practices in the region.

INTRODUCTION

A joint project involving an archaeological study of the iron-smelting and salt-making industries in the northeast of Thailand was conducted by the author and Prof. Srisakra Vallibhotama, Dr Pornchai Suchitta and Achan Chalit Chaikanchit, financed by a grant-in-aid from the International Scientific Research Program of the Japanese Ministry of Education, Science and Culture from 1989 to 1991. The Non Yang site in Chumphonburi District, Surin Province, was excavated during the first season; Ban Dong Phlong in Satuk District, Buriram Province, during the second season; and the Non Tung Pie Pone site in Bua Yai District, Nakhon Ratchasima Province, during the third season. Non Yang is a habitation site, Ban Dong Phlong is an iron-smelting site and Non Tung Pie Pone is a salt-making site. Ban Dong Phlong and Non Tung Pie Pone will be discussed in this paper (see Figure 1 for locations).

Prof. Srisakra Vallibhotama and his team conducted a general survey in the Mun-Chi basin, finding many sites (Vallibhotama 1981). In the lower Mun-Chi basin, there are scattered settlements ranging from villages to cities. Before the arrival of the present population at various settlements, there is evidence of many ancient settlements with land used for subsistence rice growing, mining and commercial industries. One important feature of many ancient settlements in northeast Thailand, especially in the lower Mun-Chi basin, is that they consist of mounds where a very large quantity of potsherds, burnt soil, ash, iron slag and charcoal is found. These settle-

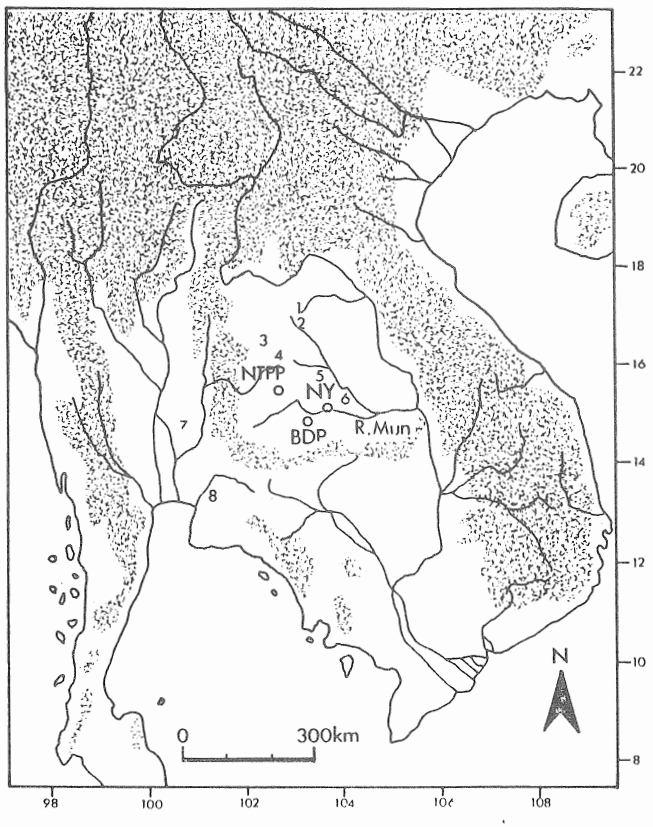

Figure 1: Sites referred to in text. NY, Non Yang; BDP, Ban Dong Phlong; NTPP, Non Tung Pie Pone

ments are more densely distributed in this area than in other parts of Thailand.

THE EXCAVATION OF THE BAN DONG PHLONG IRON-SMELTING SITE

The Ban Dong Phlong site (Figure 2) is situated at Ban Dong Phlong, Tambon Dong Phlong, Satuk District, Buriram Province. It is located south of the River Mun and about 50 km north of Buriram city. It is a big mound rising about 10 m high from the surrounding rice field level. It is surrounded by three moats and earthworks.

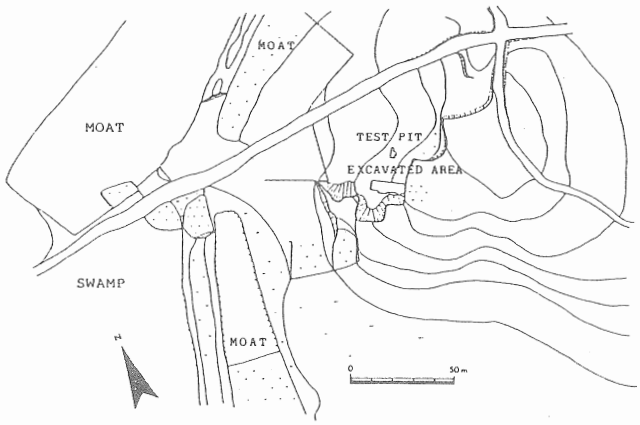

Figure 2: Plan of Ban Dong Phlong

The village name of Dong Phlong originated from Dong Phluang in the Khmer language, which means "the forest of a lot of *heo*". In Thai, *heo* is a kind of small black tuber. The ancestors of the present villagers moved to settle here from another village about 1 km east of Dong Phlong about fifty years ago. The former village was called Muang Pluang.

A large number of potsherds and pieces of iron slag are found on the surface and the cut faces of the mound. The western part of the mound was demolished by removing the soil for road construction in 1987. Villagers also destroyed it to take slag for the road pavement and to flatten and level the slope of the mound. The author visited the site in April 1987. In November 1987 he visited again and came across the scene of demolition by the villagers. One iron-smelting furnace had been exposed by the digging and a quantity of charcoal piled near the furnace. The site had been further damaged by the villagers' activities when visited in July 1990. The excavation started in October 1990 and ceased in December 1990. The site was already largely destroyed by the villagers' activities when the author visited again in July 1993.

Excavation

One main trench measuring 5 x 16 m with two small extensions (Figure 3) was dug in the centre of the site, together with a 3 x 2 m test pit 14 m to its north. Excavation was by natural layers.

Figure 3: Trench layout at Ban Dong Phlong. Left: iron-smelting structures; right, burials predating the iron smelting

The excavation exposed many structures related to iron-smelting activities, with older burials located beneath the iron-smelting layers. Seven cultural layers were recognized. They were numbered sequentially from upper to lower. Seventeen iron-smelting furnaces, one dump pit for debris, one burnt wooden structure like a hut, many postholes and seven human burials were revealed.

Layer 1

A group of small iron-smelting furnaces was found about 10 cm under the present ground surface just after we started the excavation. This group, Furnace Group S1, comprises one subgroup of six furnaces, A to F, and another subgroup of two furnaces, G and H. Furnaces G and H are located a little south of furnaces A to F. All the shafts of the furnaces had been completely destroyed.

Furnace A: The shaft was completely destroyed. Only a small part of the bottom remained, with a small amount of iron slag. The construction of Furnace A destroyed Furnace B.

Furnace B: This furnace has an ellipsoidal plan and its condition is the best of all the layer 1 furnaces. The

melting hardened the inside wall of the furnace. No tuyères were found. A half destroyed clay bustle pipe, 2 or 3 cm in diameter and 25 cm long, was found at the east wall of the furnace.

Furnace C: Only the bottom remains. The construction of Furnace B completely destroyed other parts of Furnace C. Its tuyère seems to have been inserted into the east wall.

Furnace D: This furnace was destroyed by Furnace B, the clay floor of which covers Furnace D. The floor was surfaced with clay around the shaft. A small ditch for the bustle pipe was found at the eastern part of the shaft.

Furnace E: Only the base remains, covered with clay. One tuyère 6 cm in diameter seems to have been set at the lower part of the eastern side of the shaft.

Furnace F: Only a small part of the bottom remains.

Furnace G: This has an ellipsoidal plan. A tuyère was put into the north wall of the shaft. One tap hole to tap slag was prepared at the western part of the base.

Furnace H: This furnace was partly destroyed by the construction of other furnaces. Its plan and structure are similar to those of Furnace G.

The furnaces A to F were constructed after G and H, as shown by the fact that the latter were covered with clay floor surfaces which were prepared for the construction of A to F, and their structures resemble those of the furnaces in layer 2. The sequence of the furnaces in layer 1 is as follows; H-G-E-C, F-D-B-A. The cross-sections of the furnaces show thin burnt soil layers. This means that they were abandoned after short term use and repeatedly reconstructed in the same place.

Layer 2

Many structures relating to prehistoric iron-smelting activities were unearthed in layer 2. We excavated seven furnaces, one dump pit for debris and one burnt wooden hut annexe to the iron-smelting atelier.

Furnace S5 (Figure 4): This furnace is the most interesting of all found at Dong Phlong. Its plan is oval and measures 25 cm along the short axis and 32 cm along the long axis. The wall of the furnace is made of clay. It has been heated and hardened by high temperatures. Its western part especially, opposite the location of the tuyère, has been glazed by heat. No tuyère remains. One big tap pit was connected with the bottom of the shaft by a tunnel. On the ground surface, a clay wall which contains grass fibre as temper was constructed between the furnace and the tap pit. It remains 11 cm long, 10 cm high and 6 cm thick. It does not encircle the furnace but stands mainly to the east.

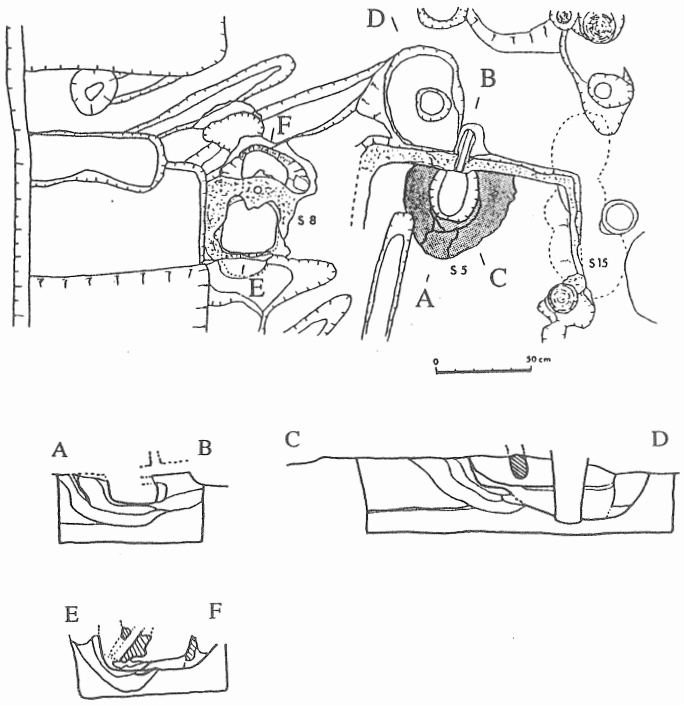

Figure 4: Plan and sections of Furnaces S5 and S8.
S5 has a tap pit and clay wall, S8 has a tap pit

This wall seems to have been designed to separate the bellows from intolerable heat. A clay pedestal on which to set the bustle pipe is located in the wall. Its cross-section is semi-circular and it measures 6 cm in diameter and 25 cm long. One carbonized wooden pillar that was covered by clay to prevent fire stood at the southeastern end of the wall. The cross-section of the furnace shows that it was used more than three times. Slag remains at the bottom.

Furnace S6 was partly damaged by a pit dug from the upper layers. Some parts of the wall, the bottom and the part of the shaft of a tuyère remain. This furnace has a rectangular pit to tap the slag. Slag and a few sherds were found at the bottoms of the shaft and the tap pit.

Furnaces S8A and S8B (Figure 4) are situated close to and north of Furnace S5. Furnace S8A damaged most of Furnace S8B. The former consists of a shaft, a tap pit and a tuyère. Iron rust remains on the wall of the shaft just opposite to the tuyère and iron slag remains at the bottom. The tuyère was inserted into the furnace at an angle of about 45 degrees and built into the bridge between the shaft and the tap pit. The shaft is connected to the tap pit by a tunnel dug at the bottom

of the lower part of the shaft. The tap pit has two walls, one of which was dug first and the other of which was repaired. Furnace S8A was used more than twice.

Furnace S9A destroyed Furnace S9B. Furnace S9A represents another type of the smelting furnaces found at the Ban Dong Phlong site. It does not have a tap pit but consists of only a shaft. Neither a tuyère nor a bustle pipe remain. The northeastern part of the wall was prepared for setting in a tuyère. Slag and some clay from the fallen wall were found in the furnace. A lump of iron slag remains at the bottom.

Furnace S15 is located under the clay wall of Furnace S5 and was damaged by the construction of Furnace S5. It consists of a shaft and a tap pit. Iron adhering to the west wall provides evidence that a tuyère was present in the east part of the wall. The floor around the furnace was paved with clay. The bridge between the shaft and the tap pit was destroyed by a pit that was dug later. A trace of repair work on the shaft reveals that this furnace was used repeatedly.

Another interesting find is a large pit to dump rubbish relating to the iron-smelting activities. It was filled with more than ten tuyères, burnt clay blocks, a huge amount of iron slag and a few small potsherds. They were dumped into this pit after cleaning the ateliers when the whole process of manufacturing iron was finished. The plan of this pit is circular, 95 cm in diameter and 85 cm deep. It spreads at the bottom like a flask.

One burnt hut foundation was also excavated. It has wooden pillars and clay walls mixed with fibre or rice straw as temper. Burnt clay, carbonized fallen pillars and charcoal were found in the eastern end of the trench. This structure was used as an annexe to the iron-smelting atelier, perhaps as a hut in which the smiths could take a rest. It was burnt down by fire. Some bones of water buffalo and deer antlers were also found inside the structure.

Layer 3

Two furnaces were found in Layer 3. Furnace S3 is located west of Furnace S1. Only one third of the wall remains. The bottom was not recognizable.

Furnace S16 was found underlying Furnace Group S1. Furnace SlG damaged the eastern part of furnace S16. Furnace S16 consists of a shaft and a tap pit. No tuyère was found. The northern part of the wall of the furnace was concave and smoothed with clay in order to set a tuyère. It measures 25 cm in diameter and 15 cm deep at present. The upper part of the tap pit was already broken. A tap hole connects between the shaft and the tap pit. Both the shaft walls and the tap pit were plastered with clay and were heated to high temperatures. Based on the cross-section of the furnace, it was not used for a long time.

Before the iron-smelting factory was constructed in this area, the site was used as a cemetery. No structures for iron-smelting activities were found in the cemetery levels. Seven human burials were excavated in the main trench and the test pit, but these are not discussed here.

IRON-SMELTING ACTIVITIES AT BAN DONG PHLONG: A SUMMARY

Seventeen furnaces were excavated at the Ban Dong Phlong site. They belong to three different periods. Twelve radiocarbon dates are available on charcoal, determined by the Japan Isotope Association. The twelve dates, using a half life of 5568 years, are listed in Table 1 (printed after end of text).

Based on the radiocarbon dates, the iron-smelting activities at the Ban Dong Phlong site occurred during the third through the first centuries BC, mainly concentrated in the second century BC A typological study comparing the pottery of Ban Dong Phlong with that of Non Yang supports this estimated date. We found the same type of pottery as that in Dong Phlong from cultural layer 3 to the lowest layer at Non Yang, here dated to the fourth to second centuries BC (Nitta 1991; 12-15, p l.32).

The furnaces found at Dong Phlong are all clay shaft furnaces with piston bellows. Basically, they resemble those of the 6th and the 14th centuries that Pornchai Suchitta (1983:183-6) excavated at Ban Di Lung, Lopburi Province. Metallurgical analysis of pieces of iron slag collected from the furnaces at Ban Dong Phlong was carried out by Prof. Isamu Taguchi in the Department of Museum Sciences, National Museum of Japanese History. The final report has not yet been published but a preliminary report (Taguchi 1992) suggests that the slag was formed not from refining metal but from smelting iron ore (Tables 2 and 3). Sample No. 4, collected at the bottom of Furnace S4, is very important. It is a half-melted and half-deoxidized nodule of material. CT scanning and electron microscopic analysis revealed that a surface coating of oxidized iron covers a core of clay. Such nodules were used as source material. When I revisited Dong Phlong in July 1993, after the site had been completely destroyed by the villagers, I found many such half-melted iron nodules from the furnaces. Iron nodules of this type are distributed over a large area in northeast Thailand and are easily collected.

Another important problem is the difference between furnace types. There are two different types of furnaces at Dong Phlong; one consists of a shaft and a tap pit, the

other of a shaft without a tap pit. Slag from both types of furnaces is the result of the smelting of wrought, low-carbon iron. At the moment I cannot explain the reason why different types of furnaces were used for the same kind of processing.

No charcoal for fuel was found in the excavations, although I found a lot of charcoal piled up from the villagers' diggings in 1987. Clearly they used charcoal to make iron as fuel and deoxidizer. However, no finished iron implements or fragments were found.

THE EXCAVATION OF THE NON TUNG PIE PONE SALT-MAKING SITE

The Non Tung Pie Pone site is situated at Ban Ngiu Mai, Tambon Ban Ngiu Kao, Bua Yai District, Nakhon Ratchasima Province. It is located in the Upper Mun basin about 50 m north of the main road, Route 202, between Amphoe Bua Yai and the Ban Sida intersection. It is a site that consists of two connected small mounds. The whole site measures about 5.5 m high and 120 m north-south by 75 m east-west (Figure 5). The mounds are surrounded by barren land and rice paddy fields. In the dry season, salt rises to the surface in the barren land and the surface of the area is covered with salt.

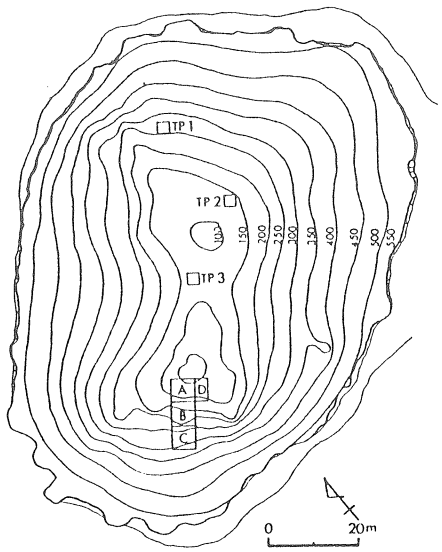

Figure 5: The site of Non Tung Pie Pone

The name of Non Tung Pie Pone means "the mound where a spirit lives". Many sherds of roughly made cord-marked pottery are scattered on the surface and along the edges of the mound. Almost all of them are heavily burnt and eroded. No potsherds dating to the historic age were found. This suggests that the mound is a prehistoric salt-making site. Nitta visited the site many times after his first visit in 1987.

Another salt-making mound, Non Sung, which means "high mound", is located about 250 m west of Non Tung Pie Pone. Non Sung has been destroyed by road construction. Many salt-making potsherds are scattered around here on the surface. Salt-making is still conducted by the local people in the area during the dry season. These people do not use a tree trunk trough for filtration but instead a clay-walled pit dug in the ground, just like the structures excavated at Non Tung Pie Pone. I was fortunate enough to be on the scene when one 65 year-old woman, Khun Mo, and her 75 year-old husband began making salt near the site at the end of our excavation. Ethnographic data on local salt-making were also collected near the site in December 1991 (Nitta 1992: 66-7).

Excavation

A 5 m by 15 m trench was laid out from the present top of the mound down the south slope. It was divided into three sections, with the northeast section enlarged. Excavation was carried out by natural layers. Nine phases of salt-making activity were exposed, in the form of water storage tanks used for the filtration of salty water, hearths for boiling the salty water and other kinds of fire pits, pots installed near the structures, and post holes of temporary dwellings.

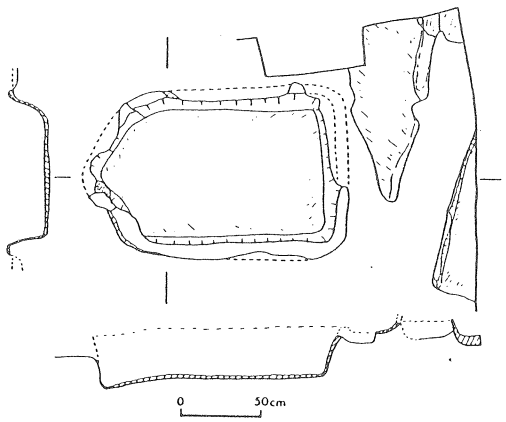

Figure 6: A water storage tank at Non Tung Pie Pone

The water storage tanks (Figure 6) were containment areas for water drawn from a well or other source, used in the process of filtering the salt from the soil. The walls and floors of these tanks were thinly plastered with clay

to prevent leaking. They are usually square or rectangular in plan, although one example is pentagonal.

Filtration troughs (Figure 7) were used to filter the saline water and had walls made of clay mixed with rice straw or grass as temper, burnt to make them hard. Soil containing salt crystals was put into a trough and water poured on it. The salt dissolved in the water and the saline water ran off through the bottom of the trough. A

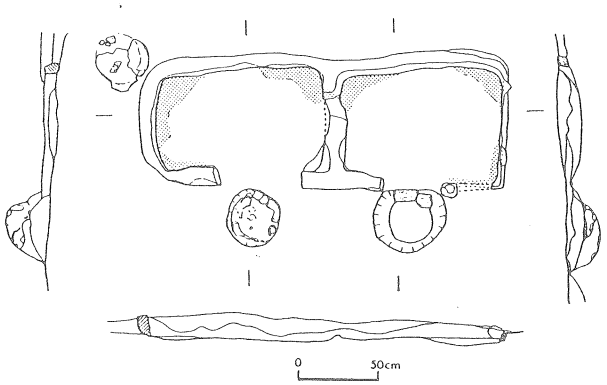

Figure 7: Filtration trough at Non Tung Pie Pone

filtration facility usually consisted of two or three troughs in a north-south line, each with a gap in its south wall next to a pot placed in the ground and used to collect the saline water.

A hearth was then used to evaporate the salty water, although only one such hearth was found, in the north section of the trench. It had no special structure. Many sherds of salt-making pottery were found scattered around in the burnt soil. Some firepits were also used for cooking or unidentified uses.

The excavation revealed a stratigraphy of ten major layers, showing that the mound was almost entirely constructed by the dumped soil from the salt-making activities.

The Date of the Salt-Making at Non Tung Pie Pone

Most of the artifacts in the site are sherds of cord-marked salt-making pottery, simple bowls with round bottoms made by the paddle-and-anvil technique. They measure about 20 to 30 cm in diameter and about 15 cm deep. Ordinary cord-marked vessels were also collected, together with several sherds of Phimai Black. Long bones and ribs of large animals, such as ox and deer, and many snail shells were also recovered. These might be the remains of food for the workers.

Only one radiocarbon date (charcoal) is available for the site, collected in the seventh layer. It was dated by the Japan Isotope Association in 1992:

N-6308: 1740±185 BP (AD 210±185)

The sherds of Phimai Black ware also confirm that the salt-making dates to around the second to third centuries AD. No typological variation can be seen in the pottery.

MODERN SALT-MAKING ACTIVITIES AT NON TUNG PIE PONE

According to ethnographic data collected in Roi Et province (Nitta 1989) and also near the site, the method of salt-making can be reconstructed. Prehistoric salt-making required a large extent of saline land, an easy water supply and a sufficient amount of wood as fuel. The troughs used for filtration and the water tanks were plastered with clay. Each trough had a bamboo spout at the bottom of the central part of its south wall, together with filters of rice husks and bundles of grass. The collected salt-rich sand was put in the trough and water poured over it. The resulting salty water flowed down the spout into a pot placed in a pit outside the wall of the trough. After the filtration was finished, the soil was dumped as a small mound nearby. The saline water collected was then boiled over a fire for a long time to crystallise out the salt. Each season, the salt-making facilities were repaired or reconstructed on the same spot, resulting in the site rapidly becoming a high mound of dumped soil.

CONCLUSION

Ban Dong Phlong is the earliest iron-smelting site so far excavated in Thailand. Pornchai Suchitta excavated another, at Ban Di Lung in Lopburi Province, belonging to the 6th and the 14th centuries. The Khorat Plateau has inexhaustible iron deposits.and it was possible to use the widely distributed, extensive beds of sedimentary soils covered with laterite concretions (Boonsener 1986: 249-61). Iron nodules that contain a low percentage of iron, for example about 60% at Dong Phlong, were also used for iron-smelting. The same situation can be recognized at Ban Krabuang Nok in Nakhon Ratchasima Province (Indrawooth *et al.* 1990).

Iron had spread widely before the Christian era in the northeast. Bronson supposes that iron-smelting in Thailand was not imported from China but originated in Thailand, beginning by the 5th century BC (Bronson 1985: 210-11). I cannot discuss the origin and earliest dating at present. I only say that iron production was conducted on a very large scale and iron had already spread widely in the Khorat Plateau late in the first mil-

lennium BC. Many iron-smelting sites of this period are distributed not only along the River Mun, but also along the Chi River and around Loei.

Salt production also exploited the special geological conditions in the northeast. A very thick rock salt layer that originated from sealed sea water exists deep underground in the Khorat Plateau. Another pebble layer containing salt extends over a wide area several meters deep below the surface. Salt dissolves from this pebble layer and rises to the surface by capillary action. In terms of dating, Higham excavated the Bo Phan Kan salt-making site in Roi Et province and estimated that the activity began in the fifth century BC (Higham 1977).

There are several reasons why the prehistoric people began to make salt. Their main food, rice, lacked sodium, an essential nutrient, so they had to use salt to satisfy this nutritional deficiency. Salt was also much in demand to preserve foods, especially freshwater fish and red meat. Salt was not produced everywhere in Southeast Asia, even in the coastal regions. Salt-making requires concentrated saline water, dry weather, an adequate supply of wood as fuel and vessels to boil the salty water. The Khorat Plateau was one of the rare regions that satisfied these condition.

The development of rice cultivation, iron-smelting, bronze casting and salt-making all strengthened the economic foundations and increased the populations of northeast Thailand. These commodities were much in demand not only on the Khorat Plateau, but also elsewhere in Southeast Asia, and were transported along river routes. The people in the northeast adapted to an environment poorly suited for agriculture, hence they exploited its geological resources and accumulated wealth by exporting iron and salt.

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Table 1: Radiocarbon dates (5568 year half-life) from Ban Dong Phlong.

N-6158:	2010±120 BP	(60±120 BC)	Charcoal collected in Furnace S4.
N-6159:	2160±85 BP	(210±85 BC)	Carbonized pillar of the clay wall of Furnace S5.
N-6160:	2090±85 BP	(140±85 BC)	Carbonized pillar of the clay wall of Furnace S5.
N-6161:	2070±85 BP	(120±85 BC)	Carbonized pillar collected in the pit southeast of Furnace S5 in Layer 2.
N-6162:	2120±175 BP	(170±175 BC)	Charcoal collected in Furnace S6.
N-6163:	2040±80 BP	(90±80 BC)	Carbonized pillar south of Furnace S6 in Layer 2.
N-6164:	2260±85 BP	(310±85 BC)	Carbonized pillar east of Furnace S8 in Layer 2.
N-6165:	2050±80 BP	(160±80 BC)	Charcoal collected in Furnace S15.

Table 1 (cont'd)

N-6166:	2010±95 BP	(60±95 BC)	Charcoal from the 6th layer in the subtrench. This sample was collected in-the burial layers.
N-6167:	2110±135 BP	(160±135 BC)	Charcoal from the 6th layer in the subtrench.
N-6168:	2210±85 BP	(260±85 BC)	Charcoal collected in layer 2 at the southwest corner of grid A in the main trench.
N-6169:	210±80 BP	(260±80 BC)	Charcoal collected in layer 2 in grid A2 in the main trench.

Table 2. Metallurgical analysis of iron slag and melted iron or iron nodules collected at Ban Dong Phlong (Metallurgical analysis was carried by Prof. Isamu Taguchi, Museum Science Department, National Museum of Japanese History, Sakura, Japan)

	FeO	SiO2	Al203	MnO	CaO	MgO	K20	TiO2	V2O3	CuO	P	S
No.1	0.60	35.36	12.79	0.00	0.70	0.00	0.55	0.00	0.00	0.00	0.00	0.00
No.2	3.88	34.92	9.96	0.00	0.86	0.00	0.38	0.00	0.00	0.00	0.00	0.00
No.3	7.77	31.68	9.S9	0.00	0.69	0.00	0.27	0.00	0.00	0.00	0.00	0.00
No.4	3.79	35.68	9.01	0.00	0.30	0.70	0.29	0.00	0.00	0.00	0.22	0.00
No.S	0.08	30.65	8.79	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.17	0.00
No.6	1.12	66.33	4.20	0.01	2.15	1.13	3.66	0.00	0.00	0.00	1.19	0.21
No.7	2.92	42.55	13.26	0.00	0.68	0.04	0.55	0.00	0.00	0.00	0.00	0.00
No.8	8.79	34.74	6.15	0.00	0.14	0.00	0.18	0.00	0.00	0.00	0.00	0.00
No.9	7.75	42.38	4.03	0.00	3.77	0.00	2.06	0.00	0.00	0.00	0.00	0.00
No.10	3.58	21.39	1.49	0.12	1.57	0.93	0.30	0.00	0.00	0.00	0.41	0.21
No.11	9.87	40.13	6.62	0.07	1.64	0.14	1.53	0.00	0.00	0.00	0.00	0.00

(No. 1: Slag from Furnace 1-A, No. 2: Slag from Furnace 1-B, No. 3: Slag from Furnace 1-B, No. 4: Slag from Furnace 1-H, No. 5: Iron Nodule from Furnace 4, No. 6: Melted Iron Nodules and Clay Wall from Furnace 5, No. 7: Slag from Tappit of Furnace 5, No. 8: Slag from Furnace 6, No. 9: Slag from Furnace 8-A, No. 10: Slag from Furnace 8, No. 11: Slag from Furnace 16.)

Table 3. Results of the analysis detailed in Table 2 above

Sample	Result of Analysis
No. 1	Smelting slag from iron ore
No. 2	Smelting slag from iron ore
No. 3	Smelting slag from iron ore
No. 4	Smelting slag from iron ore
No. 5	Iron nodules
No. 6	Melted iron nodules and clay wall
No. 7	Smelting slag and clay wall
No. 8	Smelting slag from iron ore
No. 9	Smelting slag from iron ore
No. 10	Semi-deoxidized iron ore and clay wall
No. 11	Smelting slag from iron ore