ARCHAEOLOGICAL EXPERIMENTS OF IRON SMELTING AT SUNGAI BATU ARCHAEOLOGICAL COMPLEXES, BUJANG VALLEY, KEDAH, MALAYSIA

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Abstract. This archaeological experiment study of furnace, tuyere and bellow making to conduct iron smelting experiments is aimed at obtaining information related to the iron smelting process that is likely to have been carried out in Sungai Batu Archaeological Complex. This archaeological experiment study was conducted through a knowledge transfer program (KTP) at the Sungai Batu Complex conducted in 2013 involving 18 participants and two instructors. This experiment involves the use of soil taken in the Sungai Batu river to produce furnaces and tuyere while bellow are made from wood, plywood and cloth. The raw material of iron smelting, namely iron ore, was taken after the survey activities were carried out near Kampung Batu 5, UiTM Merbok and Tupah Hill areas while the charcoal for iron smelting was used by rubber wood in the rubber plantation near the Sungai Batu Archaeological Complexs. The iron smelting experiments conducted have shown the difference in smelting results with the discovery of iron bloom which explains the possible differences in smelting techniques and technology to produce the iron ingots. Although the results of the experiments show differences with the actual results at the iron smelting site but the data can be used in the development of archeotourism at the Sungai Batu Archaeological Complex to provide a overview of iron smelting techniques that may be used in this area in the past.
Keywords: *KTP, archaeological experiment, Sungai Batu Archaeological Complex, archaeotourism*

Introduction

Archaeological research at the Sungai Batu Archaeological site (*Figure 1*) have enabled for the first time records of the iron smelting industry, river jetty, administrative and rituals sites of Kedah Tua Kingdom to be examined, identified and given chronometric dating used since 788 century BCE (Beta 516413) (*Figure 2*) in iron smelting activities (Halim, 2019; Mokhtar, 2019). The determination of the chronometric date uses radiocarbon method on charcoal samples at one of the sites of Kedah Tua iron smelting workshop in the Sungai Batu Archaeological Complex which is still in-situ in the area near the base of the furnace (Mokhtar, 2019).

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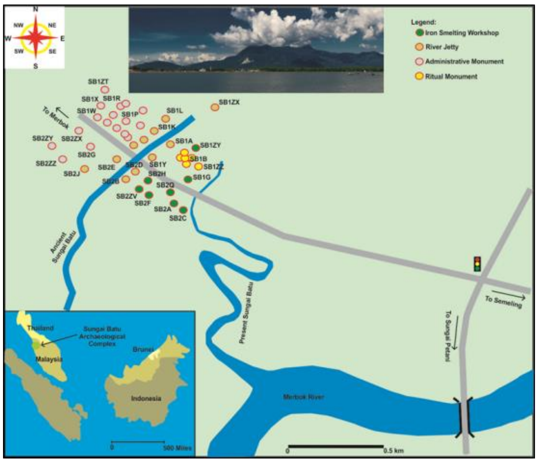

Figure 1. *Iron industry, river jetty, administrative and ritual sites that have been conducted systematically research in the Sungai Batu Archaeological Complex*
Source: Saidin (2016).

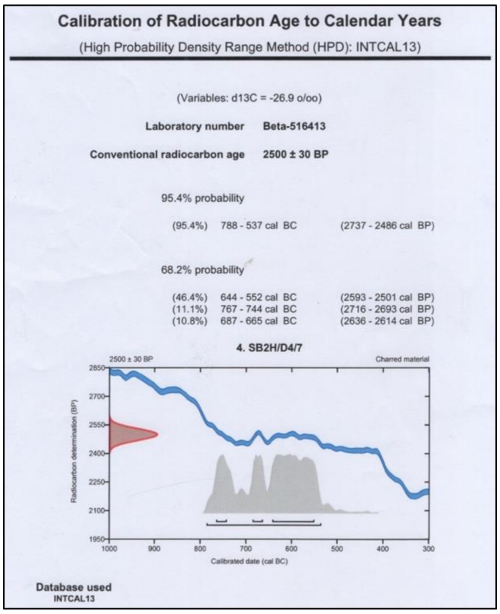

Figure 2. *Charcoal sampling (Beta 516413) conducted at the iron smelting site has given a 95.4% percentage probability which corroborates the initial data of the iron smelting industry at the Sungai Batu Archaeological Complex has started earlier than the second century AD*
Source: Halim (2019).

This is because archaeological research from 1840 to 2009 has not been able to record evidence of such industry and architecture although there are records from al-Kindi, al-Biruni (Gilmour and Hoyland, 2012), I-Tsing (I-Tsing, 1896), Pattinapalai Poetry (Thilakavathy, 2019), Silappadikaram (Braddell, 1936), Kathasaritsagara, Kaumudimahotsava (Wheatley, 1961) and inscriptions (Sastri, 1935) which describe the role of Kedah Tua in the trade and export of early world iron ingots. Previous studies have only recorded findings of Hindu-Buddhist religious structures (*Figure 3*) (Wales, 1940) and trade artifacts (Leong, 1973) that most of the sites are given relative dating since the fifth century AD.

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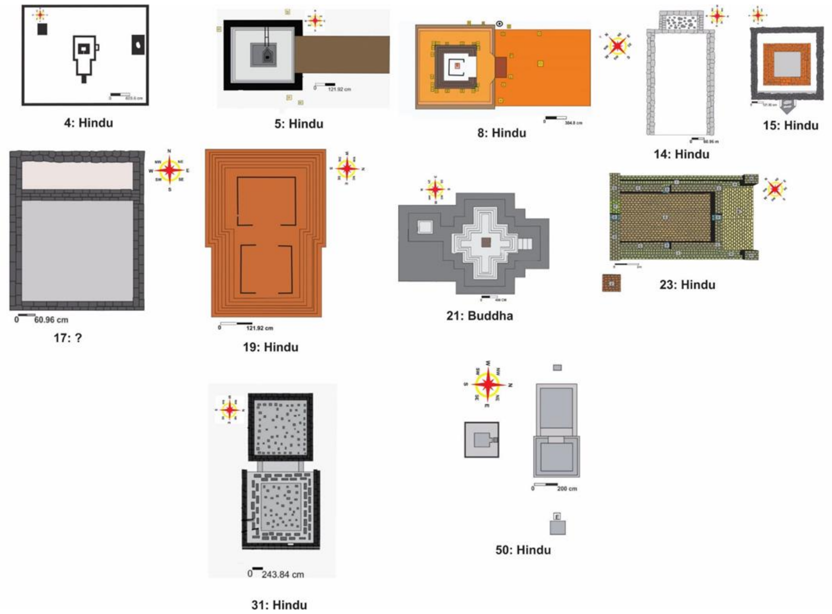

Figure 3. *Structure of Hindu-Buddhist religious monuments in Lembah Bujang for the Kedah Tua Kingdom.*
Source: Wales (1940).

Archaeological research at the Sungai Batu Archaeological Complexs until 2022 is the only one to reveal complete evidence of the heavy industry of Kedah Tua up to the architecture of the river jetty and administrative buildings that managed its trade affairs. To develop this site, especially in the national archeotourism sector, some initial steps were taken to provide trained and certified tour guides. Therefore, the KTP archeology education-based knowledge transfer program at the Sungai Batu Archaeological Site was established in 2013 with the main purpose of providing knowledgeable tourist guides to the historical and archaeological evidence at the Sungai Batu Archaeological Complex in general and Lembah Bujang in particular. In order to strengthen the knowledge of tour guides related to industrial evidence in this complex, archaeological experiments related to iron manufacturing and smelting technology were applied during the Knowledge Transfer Programme (KTP). These archaeological experiments were conducted with the main purpose of obtaining a initial description of earlier societies through archaeological research as interpreted by Humphris et al. (2018), Chuenpee et al. (2014) and Humphris, (2010). Therefore, the experiment archaeological research is able to record primary data related to smelting technology of the Kedah Tua community and it can be processed and applied in offering a full tourism package "iron smelting demonstration" at the Sungai Batu Archaeological Complex in particular.

In general, the Knowledge Transfer Program (KTP) was started in 2013 until 2015 which involved 18 participants from the Kuala Muda district. This program is organized by the Center For Global Archaeological Research (CGAR), University Sains Malaysia, Penang. Through this program, participants will be exposed to archaeological research procedures, in-depth archaeological experiments and also undergo a tour guide course held in collaboration with The Northern Corridor Implementation Authority (NCIA) under the Merbok Area Tourist Guide Program grant. The course is conducted to qualify them to get a green badge "green badge" and become a certified tourist guide in the district of Kuala Muda for the natural heritage category. In order to maximize the knowledge of KTP participants in archaeological research and archaeological

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experiments, the participants were exposed to information for all sites that have been studied at the Sungai Batu Archaeological Complex. Information was disseminated through group discussions, on-site scholarly discussions and conducting ethnoarchaeological experiments of brick making and iron smelting at the Sungai Batu Archaeological Site to obtain primary data on how smelting and construction activities were carried out. Therefore, this paper will discuss in more detail one of the archaeological experimental, namely iron smelting to carry out for data collection efforts during the Knowledge Transfer Program (KTP) conducted from 2013 to 2015.

Materials and Methods

This research is based on the the iron smelting workshop evidence recorded at the Sungai Batu archeological site (*Figure 4*). Excavations at the site that found iron ore as the raw material of iron smelting, iron slag and iron ingots, tuyeres and furnace bases. The existence of a combustion furnace clearly strengthened the interpretation it served as an iron smelting workshop. Based on the excavation evidence, several observations and measurements related to the size of the furnace base, tuyere were conducted in detail to obtain primary data related to the measurement of the furnace structure at the iron smelting site to be used as a guide during archaeological experiments. Besides, several soil samples at the base of the furnace, iron ore and iron ingots were also sampled and chemical analysis was carried out to obtain information on the raw materials of the furnace and tuyere. Charcoal found near the furnace area was also analyzed to obtain data on the type of trees used for the purpose of iron smelting in this complex. After the information was obtained, survey activities were carried out to obtain the raw material of clay for the purpose of making furnaces and tuyere, iron smelting catalyst material and iron smelting fuel to enable experiments to be carried out more thoroughly. Thus *Figure 5* is the working stage of the fieldwork methodology used in the ethnoarchaeological experiments conducted in 2013-2015.

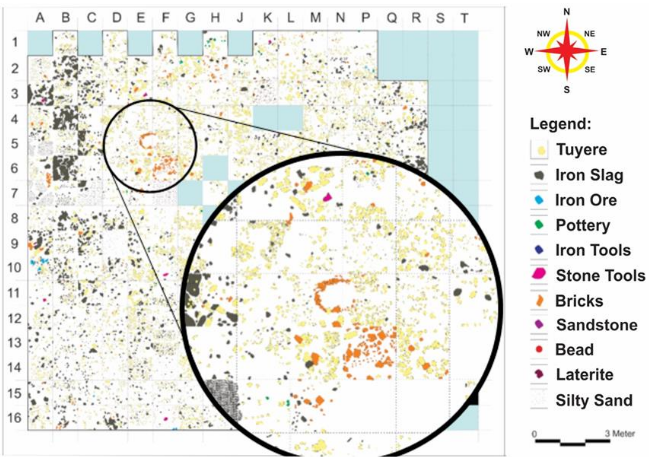

Figure 4. *The excavation process revealed the findings of an iron smelting workshop with the presence of iron ore, iron slag, furnace and tuyere at the site.*
Source: Yusof (2016).

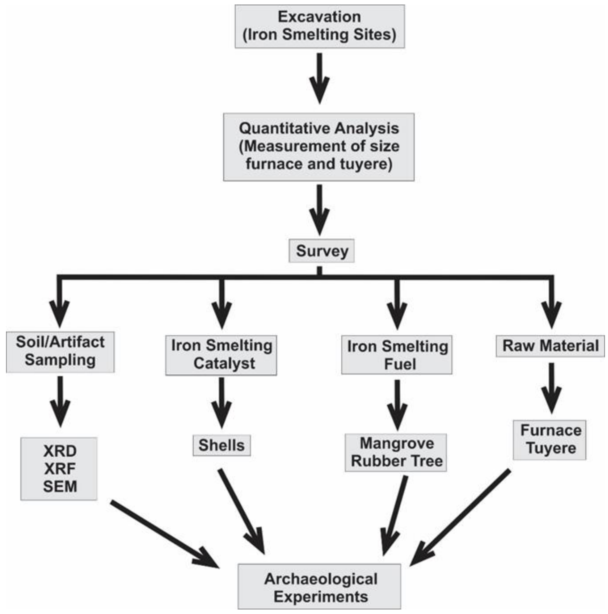

Figure 5. *Archaeological experiment flow chart of iron smelting at the Sungai Batu Archaeological Complex.*

Results and Discussion

The Knowledge Transfer Program (KTP) at the Sungai Batu Archaeological Complex has conducted experiments on the production and manufacture of furnaces, tuyere, wind pumps to be used in the experimental process of iron smelting. The experiment was conducted with the main purpose of exposing KTP participants to the production technology of furnaces, tuyere and wind pumps used in iron smelting activities.

Finance and tuyere experiments making

In order to maximize the knowledge related to the information on the architectural design of the furnace that is likely to be used in the Kedah Tua iron smelting activity at the Sungai Batu Archaeological Complex, the furnace manufacturing experiment was conducted. Mokhtar (2019) study at the iron smelting site at the Sungai Batu Archaeological Complex and Muztaza (2015) in Jeniang was used as the main reference regarding the architectural appearance of the furnace to be erected (*Figure 6*) by KTP participants. The furnace structure is an enclosed architecture and has only open openings at the top and a small portion at the base in addition to being able to withstand high combustion temperatures (Rostoker and Bronson, 1990). It is also constructed in the presence of a hollow cylinder shaped tuyere to conduct air. It is also constructed in the presence of a hollow cylinder shaped tuyere to conduct air (oxygen) during the smelting process (Tylecote, 1962). Archaeological studies at the Sungai Batu Complex have so far been able to record the findings of bases with a diameter of between 190 to 100 cm which suggest that they are of the domed furnace type (*Table 1* and *Figure 7*). This is because a not too wide furnace base is required for a domed furnace structure as it is only built at a height of about one meter only (Marks et al., 2020). This is in contrast to the shaft-type furnace structure which requires a wider and wider furnace base to accommodate the height of the constructed furnace to exceed a height of two

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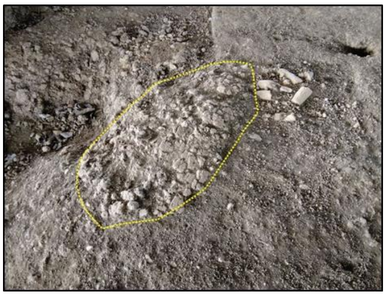
meters (Domergue and Fabre, 2017). Until 2022, there is only one find of a furnace base at the SB1G site that has a remnant of a wall structure as high as 48 cm with a base diameter of 158 cm and a width of 95 cm which suggests the furnace represents a shaft type (Mokhtar, 2019).

***Table 1**. Evidence of the discovery of furnace bases at iron smelting sites of Kedah Tua at Sungai Batu Archaeological Complex.*

No	Sites	Classification	Reference
1	SB1G	The base of furnace I is about 48 cm high and a width of 95 cm. Based on the remnants of the furnace, it is suggested that this furnace I is shaft shaped.  The base of the furnace II has a length of about 146 cm and a width of 96 cm. It is likely that this furnace is dome shaped with a height of about one meter. 	Mokhtar (2019)
2	SB1ZY	The base structure of the furnace at this site is about 140 cm long, 83 cm wide and 15 cm thick, which suggests that the furnace is a dome type with a height of about 100 cm. through the air pump (tuyere). 	Mokhtar (2019)

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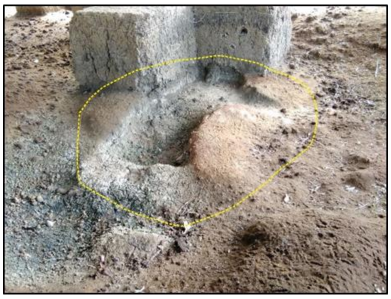
3	SB2A	The base of the furnace consists of soil and bricks measuring about 110 cm long and about 90 cm wide. Therefore the shape of the furnace structure at this site is dome shaped. 	Mokhtar (2019)
4	SB2C	The base of the furnace at this site is produced using soil measuring about 100 cm with a width of about 90 cm. The wall thickness of the furnace is estimated at about 18-20 cm. 	Yusof (2013)
5	SB2F	The base of furnace I consists of soil and burnt bricks. The length of the base of the furnace is 114 cm with a width of 110 cm. Based on the width of the furnace base, it is suggested that the architecture of furnace I is dome shaped.  The base of the furnace II has a length of about 100 cm with a width of about 90 cm. The thickness of the soil layer for the base of this furnace is about 20-26 cm.  The base of furnace III was also built using clay. The length of the	Mokhtar (2019)

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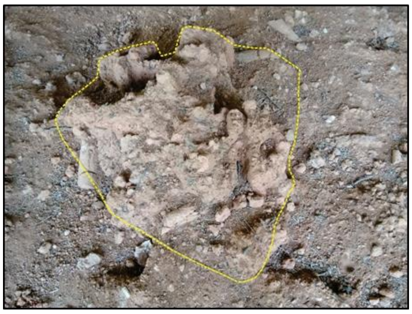
		base of the furnace is 190 cm with a width of 130 cm. The thickness of the soil layer of the base of the furnace is around 10-16 cm which suggests the architecture of furnace III is dome-shaped with a height of between 100-150 cm. 	
6	SB2H	The structure of the furnace at this site is characterized by the shape of a crater surface with a diameter of up to five meters. The base structure of the furnace is in the middle of the crater surface with respect to the length of the furnace reaching 153 cm and a width of about 53 cm. It is made of soil. 	Mokhtar (2019)

Figure 6. *Remains of the furnace base at the SB1ZY site, Sungai Batu and the furnaces in Kampung Gading, Jeniang are used as the main reference regarding the form of the furnace to be erected.*
Source: Mokhtar (2019); Muztaza (2015).

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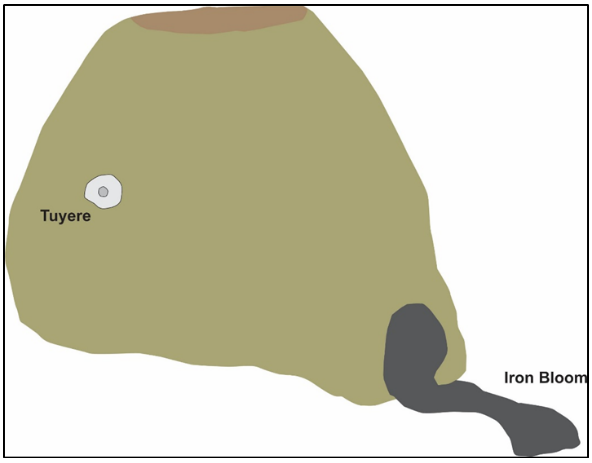

Figure 7. *Reconstruction plan of the furnace structure at the Sungai Batu iron smelting site based on evidence of the in-situ furnace bases.*

The use of raw materials from the riverbanks of the ancient Sungai Batu was proposed based on XRF, XRD and SEM analysis of the samples which revealed the similarity of the elements and mineral content of both the furnace and soil samples. XRD analysis has revealed the presence of quartz, phyllites and soil minerals (muscovite, montmorillonite and illite) which are also reinforced by SEM analysis which clearly shows the presence of subsidual and subcircular quartz which explains the raw material taken in river environment (Mokhtar, 2019). XRF analysis also showed that the silica and alumina content dominated the sample between 62.94% and 10.33-15.54% which explains the use of raw materials in the area around Sungai Batu as the raw materials for furnace manufacturing. Therefore ethnoarchaeological experiments of furnace making were carried out using alluvial raw material (soil) taken from the riverbanks of Sungai Batu and mixed with sand and hay as temper. After that, the process of kneading the soil is done by mixing a little water. The mixture was arranged into a spiral structure on the ground to form a circle for the furnace. Tuyere is also produced using soil that is shaped to form a circle and has a length of about 22 cm. This tuyere is formed using PVC pipe as a mold which is cut according to the size of the tuyere (*Figure 8*). The clay joint will be formed in a circle by sticking to the PVC pipe which eventually allows a circular opening space in the tuyere to be formed. During the process of forming the base of the furnace is carried out with a diameter of one meter, the structure of the mouth of the furnace is also built which serves as a place to drain the slag after smelting. When the base part of the furnace structure is dry and strong then the top of the furnace was built up until it reached a height of 93 cm.

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Figure 8. *The tuyere production process uses PVC pipe that acts as a mold.*

Once the construction of the furnace reached a height of 25-30 cm, as many as four tuyeres was placed on (*Figure 9*) the furnace wall to facilitate the process of channeling oxygen into the furnace. After the furnace reaches a height of about 93 cm, an opening space with a diameter of 40 cm is produced with the main purpose as a place to insert iron ore, charcoal, sand and shells for smelting purposes. Once the furnace structure is completed, the furnace will be left to dry for five to seven days (depending on weather conditions) before being burned to harden the furnace wall structure (*Figure 10*). The purpose is so that the furnace wall does not crack and collapse as a result of the sudden evaporation of water content when the furnace is used in high temperature smelting activities.

Figure 9. *The process of attaching the tuyere to the furnace wall to complete the shape of the built furnace.*

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Figure 10. *The process of burning the furnace structure after it is left to dry to strengthen the construction of the furnace.*

Bellow experiments making

The study of Mokhtar (2019; 2012) and Muztaza (2015) at the Sungai Batu and Jeniang archeological sites did not record any findings of bellow used in iron smelting activities in the area. For the bellow production experiment, the reference from the study of Bandama (2010) has been used as a yardstick related to the shape of the wind pump used in iron smelting activities in Africa. Bandama (2010) has provided information that the shape of bellow used in iron smelting activities is circular in shape, fastened with animal skin and pumped by hand (*Figure 11*). Such a shape is also described by Gilboa et al. (2018) at the Levant site which is used as a guide for the production of wind pumps for this archaeological experiment. Based on that information, bellow made from a combination of plywood, PVC pipe and fabric began to be produced. The air pump is of the pressure type using hands to pump oxygen into the furnace through the tuyere. It is circular in shape with a height of about 50 cm, has an air chamber and a handle that acts as a device to pump oxygen into the furnace. For the purpose of this ethnoarchaeological experiment this bellow is then connected into a tuyere in the furnace wall using PVC pipe (*Figure 12*) during the smelting of iron is carried out.

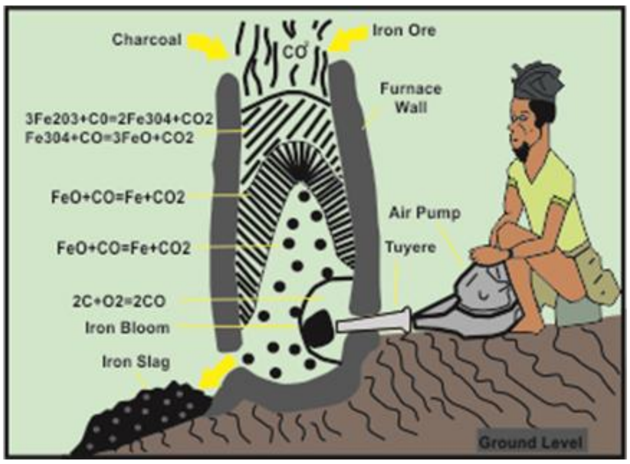

Figure 11. *Illustration of iron smelting using a hand pump.*
Source: Bandama (2010).

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Figure 12. *Experimental process of iron smelting using an air pump.*

Survey raw materials of iron smelting

Survey activities were also carried out to enable iron smelting experiments to be carried out. The areas of Kampung Batu 5, UiTM Merbok and Bukit Tupah (*Figure 13*) are areas involved in survey activities to obtain the basic material for smelting iron, namely iron ore (*Figure 14*). This area was selected as a survey area based on the survey and mapping of smelting base materials by Mokhtar (2019; 2012) which provides information related to the potential of the area in supplying iron smelting base materials at the Sungai Batu Archaeological Complex. The research of the raw material of iron smelting used the iron ore mineral distribution map by Bradford (1972) and the Sungai Petani Map produced in 1943 because the map still clearly shows the route and flow of the river compared to the map produced in 1970. According to Mokhtar (2019), distance sampling method based on the area near the Sungai Batu Archaeological Complex and river flow is a priority in the survey to obtain data related to the location of the base material of iron smelting. The tools used during the sampling were GPS, notebooks and magnets for the purpose of testing the magnetic properties in the iron ore whose findings were recorded during the survey. The iron ores that were sampled during the survey activities were of the types of magnetite ($Fe^{2+}Fe^{3+}{}_2O_4$), hematite (Fe_2O_3) and goethite (α-Fe3+O(OH)). This is because the three types of iron ore are dominantly found in the iron smelting workshop at the Sungai Batu Archaeological Complex. The XRF analysis carried out on the iron ore clearly revealed that the mean Fe content of the iron smelting site in this area ranged from 57.86% to 66.40% with the largest standard deviation of 4.53 (Mokhtar, 2019).

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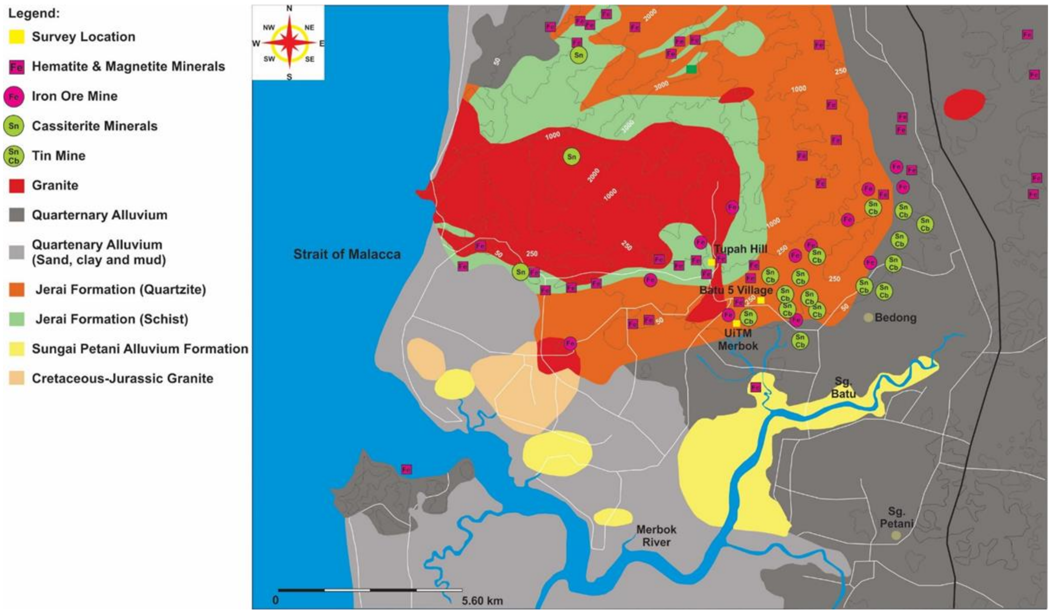

Figure 13. *Areas involved in survey activities to obtain the basic material of iron smelting, namely iron ore to meet the needs of iron smelting experiments at the Sungai Batu Archaeological Complex.*
Source: Bradford (1972).

Figure 14. *Successful survey activities record the findings of iron ore used in iron smelting experiments.*

The mean percentage of silica (SiO^2) is around 2.02% to 5.79% with a standard deviation of 1.74. The percentage of alumina (Al_2O_3) is between 1.12% to 5.33% (Mokhtar, 2019). Based on the XRF analysis, it is clear that the chemical composition of iron ore reveals a range that is almost the same as the iron ore in the vicinity of Mount Jerai in the area involved in the survey activities. In addition, XRF analysis of iron ore also recorded the presence of potassium oxide (K_2O), manganese oxide (MnO_2), phosphorus oxide (P_2O_5) and low carbonate oxide ($C(=O)(O–)_2$) elements that matched the iron ore content in the samples in the Gunung Jerai area. This analysis also

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proves that the iron ore used in iron smelting activities is of high quality based on the high percentage of iron compared to other mineral content (Mokhtar, 2019).

Survey of iron smelting fux materials

The study of Isa et al. (2018) has been able to record the use of flux materials in the iron smelting process at the Sungai Batu Archaeological Complex. The flux materials are sand and shells. The use of shells as a flux material was also reinforced by the discovery of shell piles at the iron smelting site at the Sungai Batu Archaeological Complex itself (Yusof, 2016). Based on the morphology of the shell, which has no burning effect and is peeled for cooking, it is suggested that it be used as a flux in iron smelting activities to allow temperatures as high as 1,200ºC to be obtained. This is because by applying bloomery smelting technology along with the use of sand and shell flux enables temperatures as high as 1,200ºC to be achieved (Mokhtar, 2019). In addition, the results of XRF analysis on bases furnace samples also revealed a content of magnesium oxide (MgO) between 0.1701.06% and calcium oxide (CaO) between 0.25-0.66% also strengthen the possibility of sand and shells after being used as flux in iron smelting activities (Mokhtar, 2019). In addition, SEM analysis on bases furnace samples also revealed the effects of cracking and recrystallization on quartz minerals (*Figure 15*) suggesting the use of flux agents in iron smelting (Mokhtar, 2019). Therefore, survey activities to obtain sand and shells are carried out to complete the materials required in iron smelting activities. The survey activity was conducted in the river area near Sungai Batu Besi Village, which is approximately one kilometer from the Sungai Batu Archaeological Site (*Figure 16*). In the area, the shells and sand were sampled for the purpose of iron smelting experiments that will be conducted.

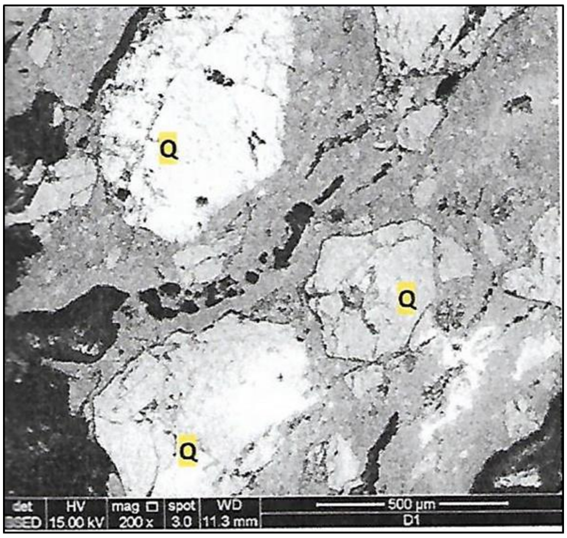

Figure 15. *SEM analysis on bases furnace samples showing the presence of quartz recrystallization (Q) which suggests the presence of flux use in iron smelting activities. Source: Mokhtar (2019).*

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Figure 16. *Survey activities carried out to obtain samples of shells and sand for iron smelting experiments.*

Iron smelting fuel survey

Mokhtar (2019) has reported the possibility of mangrove wood having been used in iron smelting activities at the Sungai Batu Archaeological Complex based on SEM-EDX analysis of the moisture of charcoal samples. In addition, the presence of elemental calcium (CaO) in the analyzed charcoal samples is also an indication that the fuel used is from a plant type most likely from the mangrove wood type. The results of the analysis revealed a carbon content of around 50.51-68.81% which is close to good charcoal quality. Photomicrographic analysis of charcoal (*Figure 17*) also clearly shows that it is derived from hardwood based on dense and hollow texture (porosity). This is because good quality charcoal should have at least 70% fixed carbon and less than 15% voltile matter. According to Mokhtar (2019) the low percentage of carbon is because it has been used in iron smelting activities that cause chemical reactions between fuel and iron ore. Apart from using SEM-EDX analysis, the charcoal was also sent to the genetic laboratory of the Forest Research Institute of Malaysia (FRIM) to identify plant species through deoxyriboneucleic acid DNA analysis was also conducted to identify the type of charcoal used in smelting activities at the Sungai Batu Archaeological Complex. Based on the results of SEM-EDX and DNA analysis, the study on the topographic map of shift 16 in 1970 was used to survey the remaining mangrove trees around Sungai Merbok which is expected to be the main fuel for iron smelting in this complex. Although the results of the analysis show that Merbok mangroves are most clearly used as iron smelting fuel in this complex, this survey activity only involved the use of rubber wood as fuel for ethnoarchaeological experiments conducted (*Figure 18*) and did not involve cutting mangrove trees. This is done for the purpose of conservation and sustainability of the mangrove trees which at present its area has been reduced to 3,000 ha from its original area of more than 6,000 ha due to development (Ong, 2003). After that the rubber tree wood obtained will be cut to a size of about 20-30 cm using a saw and burned in a furnace (*Figure 19*) to produce charcoal for iron smelting experiments. The rubber wood is burned between 4-5 hours until it turns into charcoal which allows ethnoarchaeological experimental activities of iron smelting to be carried out.

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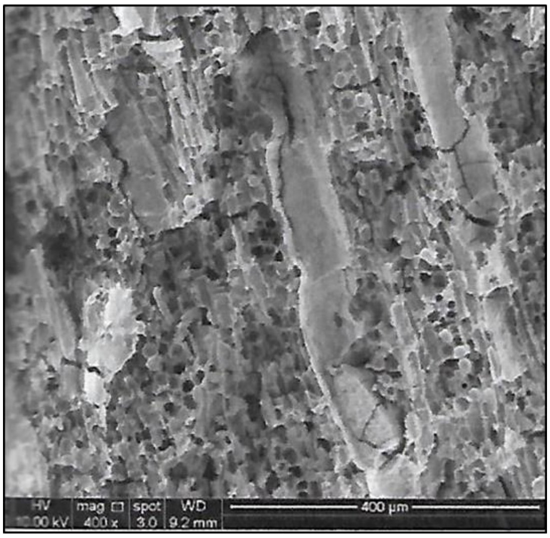

Figure 17. *Charcoal photomicrograph of an iron smelting workshop site showing iron smelting fuel taken from hardwood.*
Source: Mokhtar (2019).

Figure 18. *Survey activities to obtain fuel for iron smelting experiments.*

Figure 19. *Rubber wood is burned in a furnace to produce charcoal.*

Archaeological experiments of iron smelting

Once the furnace structure, tuyere, wind pump, smelting material, catalyst and burner were obtained through survey and reconstruction, then iron smelting experiments were carried out. Isa et al. (2018) stated that iron smelting at Sungai Batu Archaeological

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Complex generally involves five main processes namely: (1) iron ore mining, (2) ore cleaning and preparation, (3) smelting process, (4) iron ingot forming and (5) production of iron tools by forging. The smelting is carried out directly (bloomery) which involves the extraction of iron directly from iron ore (Rostoker and Bronson, 1990). This iron smelting experiment started with the cleaning and preparation of iron ore because the first stage in the smelting process was carried out through survey activities. This stage involves the process of cleaning iron ore from soil residues and knocking it into chunks of smaller size before roasting (*Figure 20*). The purpose of the iron ore being roasted is to get rid of silica and carbon in order to accelerate the chemical reactions occurring during smelting (Rostoker and Bronson, 1990). After that the roasted iron ore will be melted together with catalyst materials such as sand and shells using rubber tree charcoal. These experiments involved charcoal and iron ore mixing volume ratios of 1:3 and 1:5 (*Figure 21*) as suggested by Isa et al. (2018). The smelting process lasts for seven to eight hours and requires a melting temperature between 1200 to 1400°C. After the smelting process takes about seven to eight hours, it is found that the molten iron slag has not yet flowed out. Therefore, the structure of the furnace was broken to see and examine the condition of the iron ore that has been melted. Research on the results of iron smelting experiments shows that it is still brittle and easily broken if compared to iron blooms at the Sungai Batu Archaeological site. This is because the iron blooms are more solid, precise and have good smelting quality and high quality (*Figure 22*) with over 60% Iron oxide (Fe) content (Mokhtar, 2019).

a b

Figure 20. *The process of breaking iron ore into small lumps (a) and the roasting process (b).*

Figure 21. *The process of weighing charcoal and iron ore before an iron smelting experiment is carried out.*

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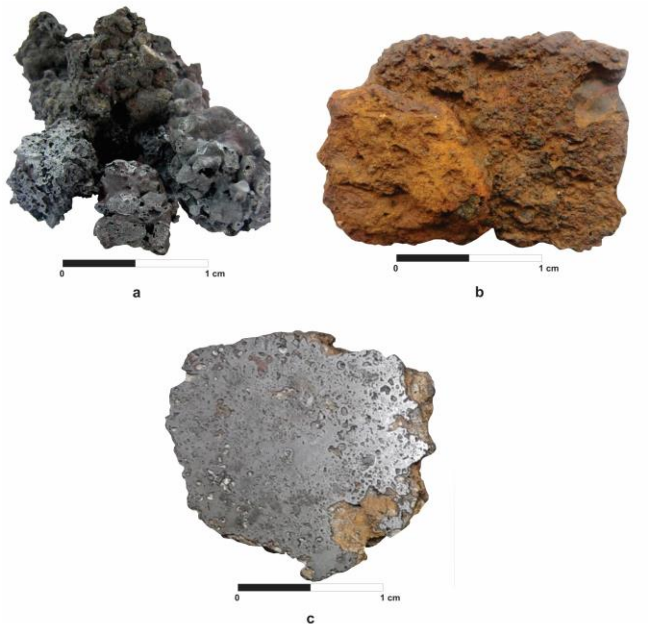

Figure 22. *Iron smelting experiments (a) which revealed brittle and hollow results (a) which showed differences with iron ingots found at iron smelting sites (b) which showed that they were more solid and of high quality (c).*
Source: Mokhtar (2019)

This indicates that iron smelting experiments carried out with the prescribed ratio of iron ore and coal need to be re-examined and modified as well as the optimal combustion temperature needs to be adjusted to obtain better smelting results using a Bimetal thermometer temperature measuring device. Non-uniform smelting temperatures are believed to be the cause that causes the molten iron ore not to flow out. Although the archaeological experiments of iron smelting did not give the same results as the evidence of iron blooms at iron smelting sites, but the information obtained is primary data that can be improved in further experiments. The most important thing from the archaeological experiments is that the iron smelting demonstration archeology package is offered to tourists at the Sungai Batu Archaeological Complex itself which can give tourists an initial understanding of how the iron ore smelting stage was done by the early people in this area who generally represent the iron industry community Kedah Tua.

Decelopment of the archaeotourism sector at the Sungai Batu Archaeological Complex

Archaeological experiments of iron smelting have been able to provide primary data related to basic materials and smelting procedures which eventually led to the offering of archeotourism packages at the Sungai Batu Archaeological Complex. The result is a guided tour package and a full package (*Figure 23*) which involves activities such as site visits, iron smelting experiments and brick making and excavation. All these activities involve the cooperation of KTP who has been certified as a nationally recognized tourist guide. Through the tour package offer, KTP participants who have obtained a green badge and are recognized as professional tour guides in the Kuala Muda district (*Figure 24*) can participate directly in all activities offered in the tour package, especially in the Sungai Batu Archaeological Complex area. This means that

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for the first time in the Kuala Muda district, there is a group of local people who are trained and able to be the front line to the empowerment of tourism products that have been mapped in the Kuala Muda district specifically. Apart from being involved in the tourism package activities offered, KTP is also directly involved in assisting in exhibition and festival programs organized by the state government and non-governmental organizations (NGOs). KTP also assists in the process of preparation and work of royal visits, ministers, chief ministers, members of parliament, foreign delegations and media filming that can promote this archeological site to foreign tourists. Based on KTP's consistent involvement in tourism activities and promotion of district tourism products, it can be considered that the knowledge transfer program really has a positive impact in providing qualified and knowledgeable tour guides from locals in Kuala Muda in general and Kedah in particular.

Figure 23. *Full tour package offered at Sungai Batu Archaeological Complex such as guided tour (a), excavation (b), iron smelting experiment (c) and brick making (d) involving by KTP directly.*

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Figure 24. *KTP participants who have completed a tour guide course and are recognized as professional tour guides in the Kuala Muda district.*

Conclusion

The knowledge transfer program (KTP) based on archaeological research and tourist guide courses established from 2013 to 2015 has successfully achieved its objectives and is able to produce many certified tourist guides in the Kuala Muda district. KTP's intellectuality in archeology, history and culture in the Kuala Muda district is the best added value that a natural heritage tour guide should have. Therefore, it is not an exaggeration to suggest that the existence of such a program allows Kedah Tua smelting and manufacturing technology to be identified and classified through archaeological experiments and the results disseminated to the community through tourism packages created. As a result, successful district tourism ambassadors have been able to be formed through this knowledge transfer program which will definitely help the state and the country in the development of the archeotourism sector.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research.

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