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Physics for Cultural Heritage: Traditional Iron Smelters Flourished in the South Eastern Part of the Valley of Manipur

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***Abstract* – This paper discusses the preliminary data of iron smelting site found in the ancient iron smelting site of Tummu Ching, Kakching, Manipur. Excavation at Tumu Ching (lat. 24° 28' 38" N., long. 93° 57' 28" E.) a small hillock at a height of 776 m. above sea-level, near Kakching ~ 70 km. from Imphal, the capital city of Manipur has revealed plenty of iron slag in an area of ~ 0.5 km^2. Baked sediments adhered to a broken piece of a slag has been dated by TL dating. The equivalent dose of the quartz extracted yield (3.37 ± 0.01) Gy. This corresponds to an age of (1600±100) years; the period when king Khamlangba ruled the valley from 300 to 500 CE.**

***Keywords* – Iron Slag, Haematite, Goethite, Tuyere, TL, EDX, XRF.**

I. INTRODUCTION

No part of nature is excluded from the domain of physics. The hands in the picture belongs to a Physicist and the small sample of the blackish iron slag is collected from the ancient iron smelting site of *Tumu Ching, Kakching, Manipur* which forms a part of the Culture flourished in the area. When we speak of science we often have physics in mind and imagine of complex educations and machines that physicists deal with. On the other extreme when one thinks of culture normally it does not come to our mind that science by its very nature itself is a cultural trait. Every culture famous or lesser known or even unknown have its own material culture, material that are associated with it may be a piece of fabric, a lock of hair, a piece of pottery or a piece of metal. These materials remain of the past cultures can be studied by scientific techniques that are used by material scientists of today. This area constitutes the subject Archaeometry distinctly different from the well-known discipline of Archaeology.

II. PRELIMINARY ANALYSIS

Based on the artifacts found and the scientific analysis conducted to date, it is accepted that the ancient iron smelting site at Tummu Hills, Kakching, Manipur, functioned as an iron smelting area, from the 3rd until the 5th century CE. This is based on the discovery of furnaces, burnt clay, iron slags, iron ore, tuyere, iron artifact, stone tools, pottery, beads, ash, charcoal and others.

Fig. 1. Samples of iron slag from various portions of the smelting site at Tummu Ching, Manipur (left). A large molten matrix of one such sample (right)

The iron slags found in this site has no particular form. Among the physical characteristics of the remaining iron is dark color, dense, spongy, metallic or rusty figure. The iron ores found here consist of hematite and magnetite. The presence of laterite is associated with iron ore (hematite and magnetite) brought to the site, and it has no significant role as raw material to produce iron.

Scientific analysis used for this study include the application of scanning electron microscopy (SEM), energy dispersion X-ray (EDX), X-ray fluorescence (XRF) and X-ray Diffraction (XRD), mainly used to analyze the mineralogy, microstructure and micro fabric of artifacts such as soil samples, burnt clay, iron ore, iron slags and tuyere.

III. EXPERIMENTAL

The three samples of iron slag S1, S2 and S3 collected from three different parts of the smelting site have been analyzed by using physical techniques of scanning electron microscopy and their corresponding energy dispersive x-ray spectroscopy. The results are presented in table 1.

Table 1. Results of SEM-EDX analysis of iron slags samples

Oxides	S1	S2	S3
Al_2O_3	7.64	3.29	13.53
SiO_2	50.36	3.41	59.51
K_2O	--	--	0.21
TiO_2	0.69	--	0.33
MnO	0.29	--	0.31
Fe_2O_3	40.93	93.29	26.07
Fe	28.65	65.30	1.249
FeO	36.83	83.96	23.463

Table 2. Results of XRF analysis of iron ore samples

Oxides	A1	A2	A3
SiO_2	17.294	20.08	15.38
TiO_2	0.236	0.36	0.237
Al_2O_3	0.053	12.23	6.91
Fe_2O_3	70.947	64.898	69.131
Na_2O	-1.726	-2.731	0.044
K_2O	0.439	0.333	0.324
CaO	0.083	0.046	0.057
MgO	12.779	4.805	7.857
Fe	49.663	45.425	48.392

Table 3. Results of SEM-EDX analysis on blade of the tuyere

Oxides	Orange region	Black region
Al_2O_3	15.82	18.94
SiO_2	33.91	47.09
K_2O	0.20	0.30
CaO	0.87	0.80
TiO_2	0.35	0.31
Fe_2O_3	48.86	32.56

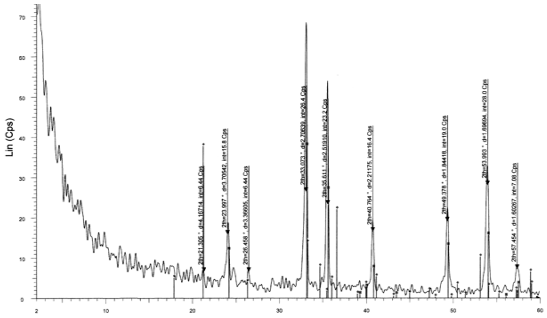

Fig. 2. Results of XRD for the Iron Ore Samples

IV. Results And Discussions

Table 1 shows SEM-EDX result of three samples of iron slags. There are three different percentages of each mineral and the highest content of iron was found in samples **S2**. While, Table 2 shows the results of XRF analysis of three samples of iron ore found on site. Composition of Al_2O_3 and MgO in iron ores revealed that it was sourced from three different locations. However, these three iron ores are low grade ore based on the amount of iron, which is less than 50%. The results of XRD analysis of this iron ore show a present of hematite and goethite. XRF analysis of tuyere given in table 3 clearly showed that it was made of clay and sand. This tuyere has been used during the process of iron smelting based on high content of Fe_2O_3 element in the tuyere.

Based on TL dating, this site was actively used from the 3rd –the 5th century CE. The site was assumed to be used for 300 years because of its strategic location and within close vicinity to the source of fuel and iron ore. Based on the production of iron slags (more than 60,000 pieces), this site was assumed to produce iron on a large scale. It is most likely that ancient people who live here know how to choose a location for smelting iron, since it is close to the sources of iron ore, fuel and water (transport).

Area of the furnace revealed iron, coal and ash. The presence of burnt clays, as well as very dark and fine texture of soil clearly shows the effects of the combustion. These clays assumed to be used as the raw material for furnace wall.

When the melting process starts, reduction reactions occur and lead to the changes of important elements between the elements of smelting and element in the furnace wall. Scientific analysis on soil samples of this area is under progress, in order to prove significant changes in the composition of the soil. In normal condition of clay, oxygen should have same amount with silica and carbon.

Furthermore, burnt clays were found associated with the tuyere, brick and iron slags. The actual form of the furnace is yet to be identified. However, based on the discovery and distribution of burned clay and tuyere, it is assumed that the furnace was circular in shape, with a diameter of approximately 50 – 60 cm width and a height of about 50 - 70 cm.

Iron ore at site underwent a process of cleaning, preparation and smelting based on the discovery of artifacts and remains of furnaces. The process of cleaning and preparation demonstrated by the discovery of iron ore in the small size and the discovery of several stone tools such as a mortar and anvil that were used to prepare an iron ore.

Based on ethnographic research records, big chunks of iron ore from the mining process were pounded to a smaller size during preparation process, in order to accelerate chemical reaction occurs in smelting process. Small iron ore has a large surface area for reduction process. Then, the iron ore will be sintered to remove impurities (minerals such as silica and carbon) to help increase chemical reaction during the smelting process.

The site produced iron ingots from the smelting process. However, this form of iron bars cannot be identified since there was a lack of evidence found in the study site, since it was assumed to be marketed and traded. This is based from earlier reports that the port also has a trade of old iron.

Early hypothesis suggests that this site underwent a “Direct Process”, or the 'Bloomery Process”. The difference of composition shows that the smelting process undergoes several stages. The changes in the percentage of mineral content may be caused by several factors, including the uses of different sources of iron ore, difference in the amount of air combusted into the furnace, different temperature and different work stages.

Based on the XRD analysis of an iron ore, hematite and goethite were used as raw material to produce iron. Based on the XRF analysis, SiO_2, TiO_2, Al_2O_3, Fe_2O_3, K_2O and CaO are the elements contained in the tuyere. The results of XRF analysis indicate the presence of iron oxide (FeO) at the one end of the tuyere. Its presence was the result of overheating, in which vitrification (glass like) can be clearly seen at one end of the tuyere. This indicates that one end of the tuyere was connected to the furnace, thus proving its function.

The presence of flux is also an indicator to the

technology of iron smelting process. Flux was used as a catalyst in the iron smelting process and helps to extract Fe ion out from iron ore to produce pure iron. Among material that can be used as flux are limestone, sand, shells and materials in the iron ore.

Based on the finding of shells near the furnace, there is possibility that it was used as a flux in the smelting process. XRF analysis of iron slags should be carried out to detect the presence of the calcium oxide (CaO) to substantiate this hypothesis. The discovery of pieces and bits of charcoal suggest its use as fuel for smelting iron. Chunks and bits of charcoal can be found in the smelting area and in the remaining pieces of iron slags.

Ancient society of *Kakching* area has the knowledge to use iron ore sourced from nearby areas. The location of iron ore sources could not be ascertained because the scientific analysis was not performed yet. Ancient society did not choose iron ore based on the high iron content, such as magnetite, but it is based on the convenience factor to obtain iron ore. This is probably due to the mining technique which utilized stone or metal tool to acquire iron, preferably laterite or hematite. As a result, the ancient miners choose iron ore source which is easily obtained and processed, found on the ground surface or near the foothills.

Scientific studies such as scanning electron microscopy (SEM), energy dispersion X-ray (EDX), X-ray Diffraction (XRD), X-ray fluorescence (XRF) and petrographic and polishing section are being carried out on samples of soil, burnt clay, iron ore, iron slags, iron ore, tuyere and samples from the iron ore resources. This analysis is important to understand the mineralogy, microstructure and micro fabric among artifact.

V. Conclusion

From the above discussion, it is clear that iron was smelted at large scales in the traditional styles and techniques in the South Eastern Part of Manipur. The people of the region were mostly engaged in some way or the other, in the various processes of iron smelting work. The ancient people fondly used iron swords as weapons for all occasions which traditionally flourished till today as a unique culture. History tells us that the people of Kakching worshiped Lord Khamlangba, a local deity who is believed to be the founder of iron smelting works in the area. The people still continue to worship the same in yearly festivals called Ibudhou Khamlangba Haraoba, a celebration performed in appreciation of the "God of Iron". Physics has contributed in studies of the cultural heritage of Manipur.

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Author's Profile

Born to Md Minhajuddin and Lei Bibi in 1968 at Sangaiyumpham, Thoubal District, Manipur, **Dr Md Raheijuddin Sheikh** (also known as Shamu) began his journey in creative writing from the age of 16 (sixteen). His first literary work in Manipuri *Awaba Sheishak* was published in 1986 with the grants from Manipur State Kala Akadami, Imphal. He has authored 11(eleven) academic books, 34(thirty four) radio plays which were all broadcast from All India Radio, Imphal 5(five) films scripts, 9(nine) documentaries and 2(two) science serial plays under the Bigyan Prasar, New Delhi. He did BSc (Physics Hons) from D M College of Science, Imphal; MSc in Physics

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He was awarded the First Prize in the All India Radio playwrights' Competition – 2000 in the General Category for the play *Khongu Nanggee Banshi*. He also bagged the Best Scriptwriter Award in the 16th Rupamahal Drama Festival 2015 held at Rupamahal Theatre, Imphal. He is a member of the Board of Secondary Education, Manipur (BOSEM) and Syllabus & Curriculum Drafting Committee of the Board, Member of Physics Academy of the North East (PANE), Manipur Association for Promotion of Science (MAPS), Centre for Scientific Culture Manipur (CSCM), Writers Union, Manipur (WUM) and Postal Forum, Manipur.

Some of his academic books published with ISBN by the reputed publishers in the National and International levels are -

1. "Scientific Methods for Cultural Heritage Research"
2. "Education for Employment"
3. "My Date with the Pretty Slag"
4. "Physics for Cultural Heritage"
5. "Skilling the Youths in Manipur"
6. "Selected Science Plays"
7. "Mass Media in Conflict Zones"
8. "Dating with River Terraces"
9. "The Mirror" and
10. "The Q- Line"

Dr Sheikh is currently serving as Director DDU KAUSHAL Kendra at D M Community College, D M College of Science, Imphal.