Material Characterisation and Analysis of Historic Coins and Cannon

A thesis

Submitted to
Indian Institute of Science Education and Research, Pune in
partial fulfillment of the requirements for the
BS-MS Dual Degree Programme by
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April, 2019

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Certificate

This is to certify that this dissertation entitled **Material Characterisation and Analysis of Historic Guns and Coins** towards the partial fulfilment of the BS-MS dual degree programme at the **Indian Institute of Science Education and Research, Pune** represents study/work carried out by **Nitesh Verma** at **Indian Institute of Science Education and Research, Pune** under the supervision of **Dr. Pushkar Sohoni**, Assistant Professor, Department of Humanities and Social Sciences, during the academic year 2018-2019.

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Expert: Dr. Tejas Garge, Director, Directorate of Archaeology & Museums, Maharashtra State

This thesis is dedicated to my mother

Declaration

I hereby declare that the matter embodied in the report entitled **Material Characterisation and Analysis of Historic Guns and Coins** are the results of the work carried out by me at the **Department of Humanities, Indian Institute of Science Education and Research, Pune**, under the supervision of **Dr. Pushkar Sohoni** and the same has not been submitted elsewhere for any other degree.

Student

Nitesh Verma

Supervisor

Dr. Pushkar Sohoni

Acknowledgment

First of all I would like to thank my supervisor Dr. Pushkar Sohoni, Assistant Professor, Humanities and Social Sciences, IISER Pune, for giving me a chance to work with him and helping and guiding me throughout the year. I would like to thank Dr. Tejas Garge, Director, Directorate of Archaeology & Museums, Maharashtra State, for providing me the samples of cannons. Thanks to Dr. Nirmalya Ballav, Professor, Chemistry, IISER Pune, for letting me work in his lab. A special thanks to Shammi Rana, PhD student, Chemistry, IISER Pune, for helping me throughout the project in all the technical work. Thanks to all the technical staff who helped me with the instruments. In the end I would like to thank all my dear friends and family members for supporting me throughout the course of 5 years of BS-MS programme at IISER Pune.

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ABSTRACT

This study characterises samples of metals from historic guns and coins from different locations in India, using various techniques. Following are the various techniques used in addition to other methods of basic physical examination:

1. PXRD – Powdered X-Ray Diffraction
2. FESEM - Field Emission Scanning Electron Microscope
3. FTIR – Fourier Transform Infrared Spectroscopy
4. EDXS – Energy Dispersive X-Ray Spectroscopy

These studies will help in creating a database for better understanding the history of metallurgy in India, and also to corelate technological advancements and historic choices with political and social events.

PART I - COINS

A. INTRODUCTION

The coinages of South Asia have been extensively studied as the objects of collections, and as data for archeological and historical research. The divergence in these two instrumental approaches have been expounded elsewhere: the valorization of coin-types by collectors and the analysis of hoards and coinage volume by scholars have been critically studied by John Deyell and others.[1] Several decades earlier, D.D. Kosambi had pioneered a statistical approach to the study of coins, in which the wear of coins over time was the means of understanding circulation.[2] Yet, all these approaches to the study of coinage and economic history have generally excluded a scientific metallurgical analysis of coins. Non-destructive methods for alloy composition and metallurgical research have generally been inaccessible to large coin collections, whether private or public. The British Museum had pioneered some metallurgical studies of coins in the last quarter of the twentieth century.[3] This was later followed by the monograph *Metallurgical Analysis of Chinese Coins at the British Museum.*[4] It is only in the past two decades that the potential of techniques such as EDXRF (energy dispersal X-ray fluorescence) for coins in South Asia has been recognized.[5] As a pilot project, the metallurgical analysis of the copper coins of the Bahmanis (1347-1526 CE) will be undertaken. A period of almost two hundred years for a single dynasty would be useful in addressing and answering multiple questions: What is the characteristic elemental composition of Bahmani coinage over a period of time? Are there significant changes in metal composition and content over time? If there is a change in elemental composition of coins over two hundred years of the same polity, can it be mapped onto economic and social

[1] John Deyell, *Living without Silver: The Monetary History of Early Medieval North India* (New Delhi: Oxford University Press, 1990).
[2] D.D. Kosambi, 'Scientific Numismatics' in *Scientific American* vol. 214 no. 2 (1966), 102-108.
[3] Joe Cribb, Michael Cowell and Sheridan Bowman, 'Two Thousand Years of Coinage in China: An Analytical Survey' in *Historical Metallurgy*, vol. 23 no.1 (1989), 25-30.
[4] Joe Cribb, Michael Cowell, Helen Wang, and Sheridan Bowman (eds.), *Metallurgical Analysis of Chinese Coins at the British Museum* (London: The British Museum Press, 2005).
[5] P.K. Nayak, T.R. Rautray, and V. Vijayan, 'EXRDF: A Non-destructive Technique for Multi-Elemental Analysis of Coins' in *Indian Journal of Pure and Applied Physics*, vol. 42 (May 2004), 319-322; Rajive Kumar, Anita Rani, and Ram Mehar Singh, 'Elemental Analysis of One-Rupee Indian Coins by using EDXRF Technique' in *Journal of Integrated Science and Technology*, vol. 2 no. 1 (2014), 1-4.

events? Is it possible to create scientific standards for determining fakes and forgeries based on elemental analysis?

The Barid Shahs who succeeded the Bahmanis counterstruck the coinage of the latter, and often completely effaced the original patterns of the coins. Therefore, while we do know of the Bahmani fabric of the counterstruck coins of the Barid Shahs, it can be corroborated by examining the metal and confirming the same characteristics. The generated data will be of a new generation of information regarding medieval coinage, which have so far only been recorded as impressionistic and visual descriptions.

The coins to be examined are all from the private collection of Dr. Pushkar Sohoni, and do not need an additional layer of bureaucracy to accessor test. There were total of 10 coins for which we have some historical information, taken largely from a standard catalogue of sultanate coins.[6] All the coins labeled with the suffix A are Bahmani coins, and those with the suffix B are Bahmani coins counterstruck by the Barid Shahs. All these coins have been identified and the numerical component of the label indicates that they are the same coin type, e.g. 1A and 1B are the same coin type, the second one being counterstruck by the Barid Shahs. The material composition and structure of the samples have been analysed. Here are images of the coins examined:

	1A
	2A

[6] Stan Goron and J.P. Goenka, *The coins of the Indian sultanates: covering the area of present-day India, Pakistan, and Bangladesh* (New Delhi: Munshiram Manoharlal, 2001).

	3A
	4A
	5A
	1B
	2B
	3B

	4B
	5B

B. Methods

1. Physical measurements - The coins were weighed on the weighing machine with up to 4 decimal corrections. The least count of the Vernier Calipers was looked up. Two readings of diameter of the coin with difference of 90 degrees (with least count) was recorded using Vernier Calipers, and the average of the two readings with added correction (No zero error in our case) was taken as the diameter of the coin. The process was repeated for all the coins. The least count of the screw gauge was looked up. The thickness of the coin was recorded twice using screw gauge, the least count was added and the average of the two readings with added correction (which was 0.17mm in our case) was taken as the diameter of the coin. The process was repeated for all the coins.

2. PXRD - The Powder X-Ray Diffraction (PXRD) test was done on the samples and the data was recorded. Two of the samples were already in the powdered form. The mortar pestle was cleaned with Acetone and the unpowered sample was powdered in it. The cleaning process of mortar pestle was repeated so that there are no impurities in the other sample. The samples were then placed in the PXRD machine one after the other and the data was collected.

3. FTIR - The IR test was also been done on the same samples. To do the IR test, first, the Potassium Bromide (KBr) was dried in the oven for 30 minutes to make sure that there is no moisture in the KBr. The mortar pestle was cleaned by acetone. Then very little amount of the sample was mixed and crushed in mortar pestle with KBr and the pallet was made. The process was repeated for all the samples. Firstly, a reference reading was taken in IR machine without any sample. Then the pallet was placed in the IR machine and the data was recorded. The process was repeated for all the samples. The baseline correction was also done on the collected data. The original and corrected data both were saved.

4. FESEM - Note: An official technical member from IISER Pune was handling the FESEM instrument. The carbon tape was put over the sample handler. The powdered sample was placed over the carbon tape. The sample handler was then placed inside sucking machine so that the sample is tightly stuck to the tape. The sample handler was then placed under the FESEM machine. The images at different resolutions were taken.

5. EDXS - This text was done on the sample which were taken under FESEM. This test shows the elemental composition.

6. Statistical Tests - Inspired by the mathematical techniques used in previous research, we analysed 130 other Bahmani coins from the collection of Dr. Pushkar Sohoni.[7] We weighed all the coins and plotted a frequency chart for all the coins with a resolution of 0.1 grams to find their mint weight.

[7] Philip Wagoner and Pankaj Tandon, 'The Bahmani "Currency Reform" of the Early Fifteenth Century in Light of the Akola Hoard' in *American Journal of Numismatics*, vol. 29 (July 2018), pp. 227-268.

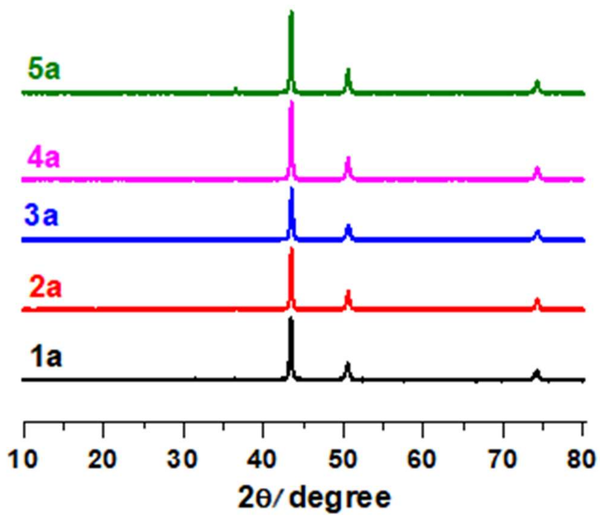
C. RESULTS AND DISCUSSION

1. Physical Measurements - The following tables shows the physical measurements of the coins:

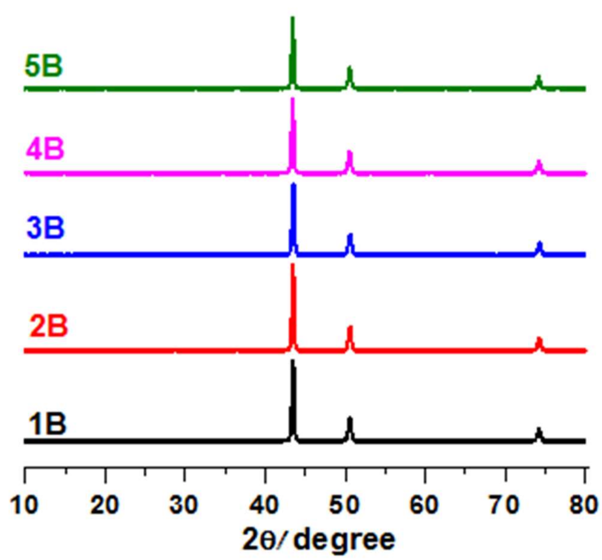
Coin	Weight (gm)	Diameter in mm (Reading 1) [Main Scale *least count]	Diameter in mm (Reading 1)	Diameter in mm (Reading 2)	Diameter Reading	Average Diameter in mm	Thickness in mm
1A	16.3758	22+(5.3*0.02)	22.106	20+(4.0*0.02)	20.08	21.093	5.68
2A	15.7969	22+(5.3*0.02)	22.106	22+(7.3*0.02)	22.146	22.126	4.71
3A	16.1573	21+(8.1*0.02)	21.162	22+(2.4*0.02)	22.048	21.605	5.18
4A	13.6643	20+(9.1*0.02)	20.182	21+(2.0*0.02)	21.04	20.611	5.96
5A	7.9529	17+(8.0*0.02)	17.16	17+(6.0*0.02)	17.12	17.14	5.09
1B	15.0923	21+(7.1*0.02)	21.142	20+(4.4*0.02)	20.088	20.615	5.28
2B	15.3739	22+(3.4*0.02)	22.068	22+(4.0*0.02)	22.08	22.074	6.01
3B	15.2375	21+(8.0*0.02)	21.16	21+(7.0*0.02)	21.14	21.15	5.9
4B	14.8234	22+(7.3*0.02)	22.146	23+(0.0*0.02)	23	22.573	4.29
5B	7.3001	17+(8.0*0.02)	17.16	17+(7.0*0.02)	17.14	17.15	3.57

2. **PXRD** - The following figures shows the PXRD spectrum of the collected samples:

1) A - Series



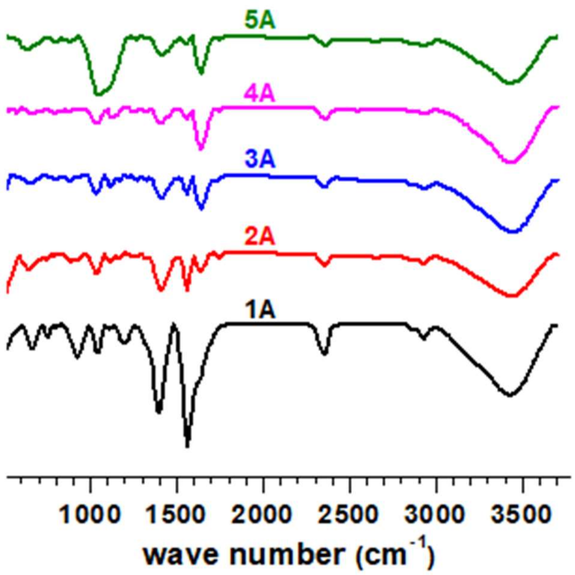
2) B - Series



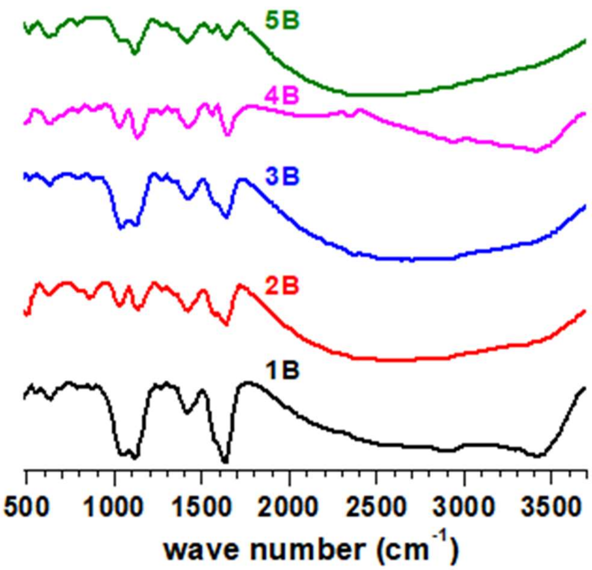
As we can see in the above images, the PXRD spectrum shows same peaks on all the samples of the coins which includes both A and B Series.

3. **FTIR** - Following images shows the graph of IR spectrum (corrected) for the known coins:

1) **A - Series**

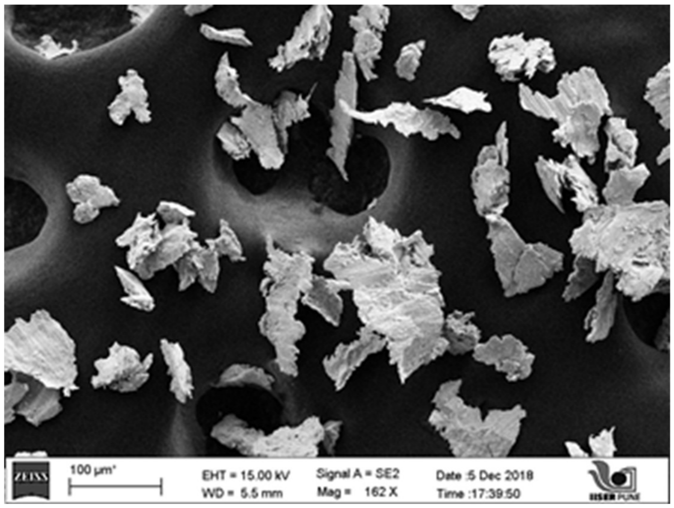
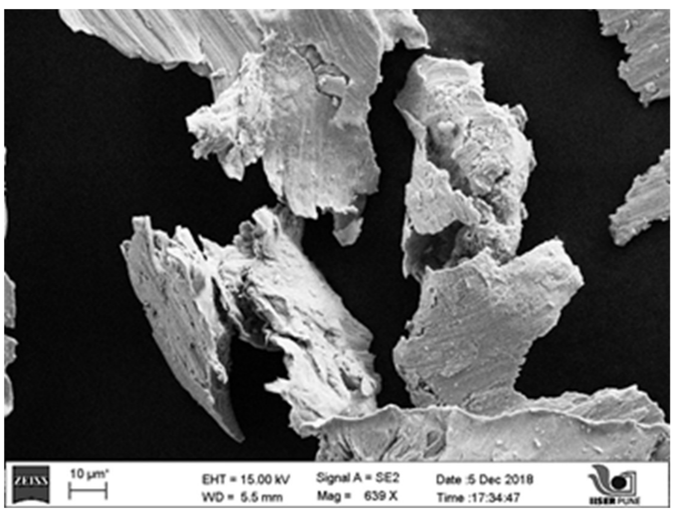


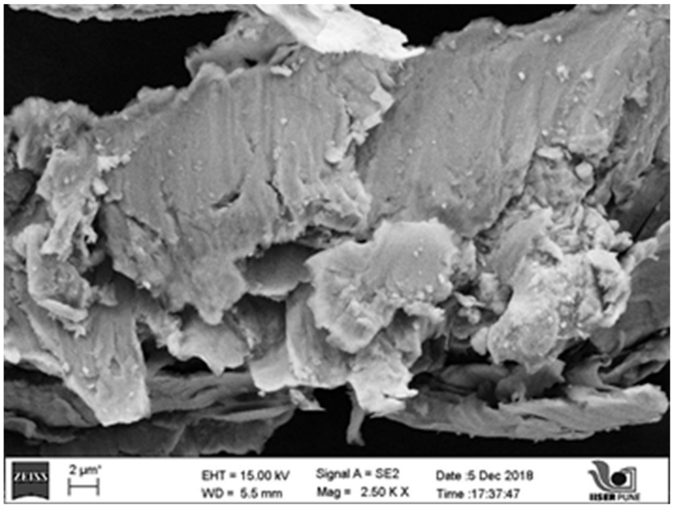
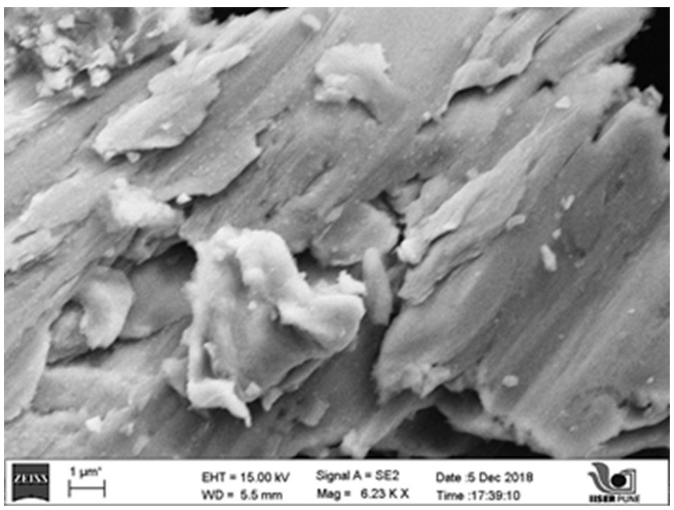
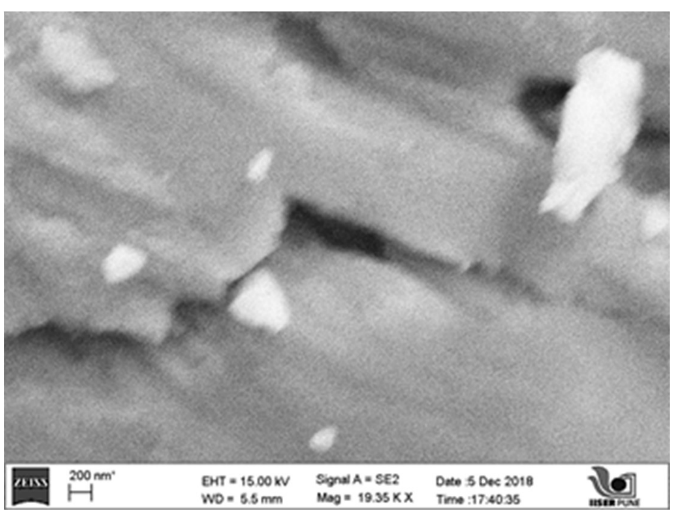
2) **B - Series**



As we can see in the above images, the FTIR spectrum shows same peaks on all the samples of the coins which includes both A and B Series.

4. **FESEM** - Since all the samples shows the same elements and properties, we have taken the FESEM images of one of the coin. Following are the images of coin under different resolutions:

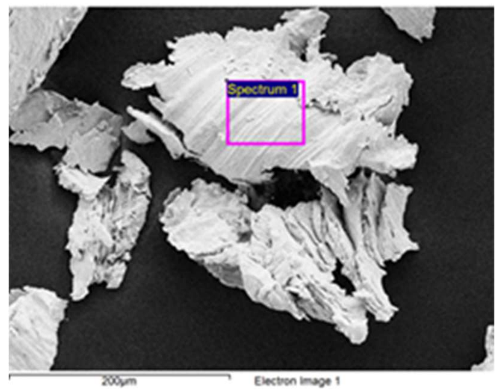
	100µm
	10µm

<table>
<tr><td>
</td><td>2µm</td></tr>
<tr><td>
</td><td>1µm</td></tr>
<tr><td>
</td><td>200nm</td></tr>
</table>

5. **EDXS** - The EDXS was done on the sample under the FESEM. The following table shows the elemental composition (in percentage) of the coin:

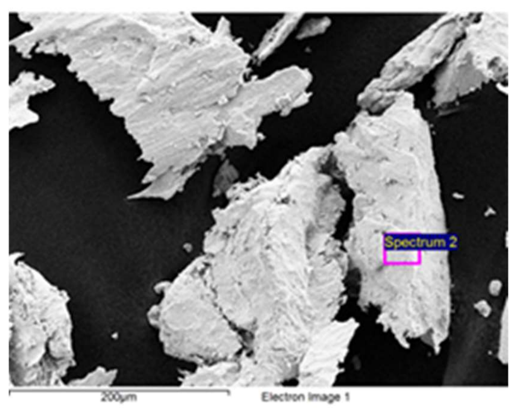
1) Coin 1A

Element	Atomic %
O (Oxygen)	5.43
Cu (Copper)	93.64
Pb (Lead)	0.93
Total	100



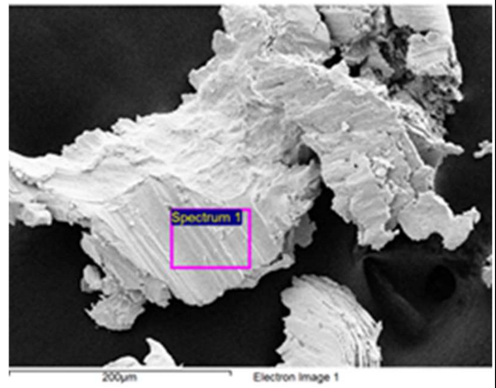
2) Coin 2A

Element	Atomic %
O (Oxygen)	16.48
Cl (Chlorine)	1.02
Fe (Iron)	0.03
Cu (Copper)	82.46
Total	100



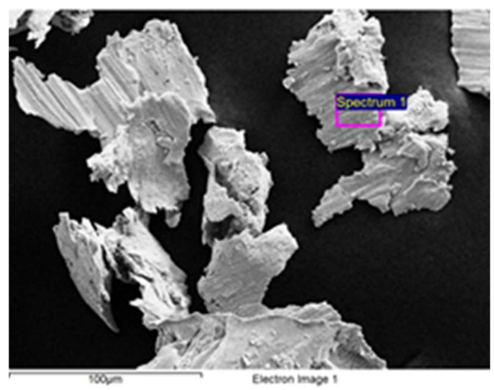
3) Coin 3A

Element	Atomic %
O (Oxygen)	10.03
Cu (Copper)	89.46
Fe (Iron)	0.52
Total	100



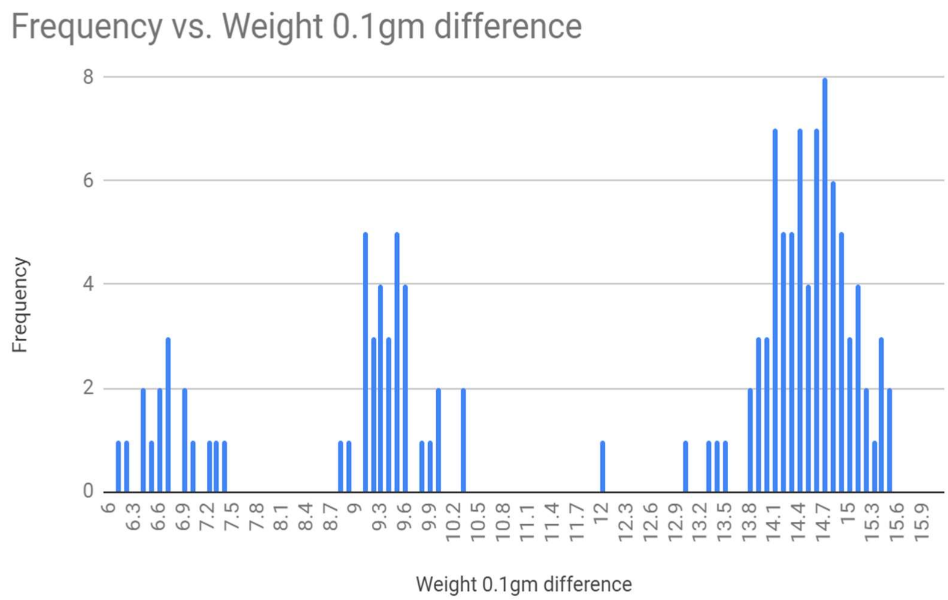
4) Coin 4A

Element	Atomic %
O (Oxygen)	11.56
Cl (Chlorine)	1.65
Cu (Copper)	86.74
Fe (Iron)	0.05
Total	100



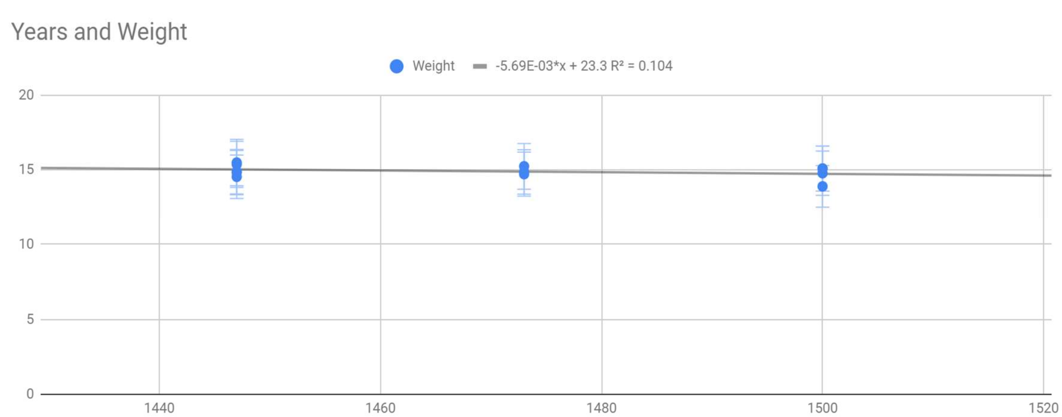
As we can see in the above tables, the major constituent of the coins is copper which is above 80%. Oxygen has lower percentage of around 10% to 12% which is present in the form of oxides. Rest of the elements are impurities.

6. The following figure shows the frequency distribution of coins against weight at 0.1gm difference:



We can clearly see three distributions. This implies that there were three types of coins from Bahmani Sultanate. Over the years, coins lose their weight attributing to movements from hand to hand.

7. Twelve coins were identified from the collection using the data shown in Appendix I. Using the data we created a scatter plot of the weight of the coins against the year in which they were used. The trendline shows that the weight has been continuously decreasing over time because of circulation. The following figure shows trend of weight.



The equation of the trend line is:

$$Y = -5.69*10^{-3}X + 23.3$$

Putting the value of X=1422, which was the time of Ahmad Shah I, we get the value of Y=14.93882.

The R^2 value is 0.104.

The following table shows the weight of the coins in the standard catalogue and also the control group. The difference in weight has been plotted.

Weight (Measured)(gm)	**Weight (Book)(gm)**	**Difference**
13.9	16	2.1
14.54	16.5	1.96
14.88	16.5	1.62
15.09	16.5	1.41
15.49	16.5	1.01
14.86	16.5	1.64
14.72	16.5	1.78
14.78	16.5	1.72
15.09	16.5	1.41
15.37	16.5	1.13
15.24	16.5	1.26
14.82	16.5	1.68

The average weight difference is 1.56 gm.

D. CONCLUSION

From the data collected from FTIR and PXRD, we can clearly see that all the coins have exactly same chemical composition and structure.

The data from EDXS shows that the major constituent of the coins is copper which is above 80%. Oxygen has lower percentage of around 10% to 12% which is present in the form of oxides. Rest of the elements are impurities.

We can clearly see three distributions from the frequency chart which implies that there were types of coins from Bahmani Sultanate.

From the data plotted in the weight vs. years plot and the equation we have concluded that the mint weight (average) of the coins of stack near 15gm is 14.93882 gm.

Using the methods demonstrated in the paper by Wagoner Tandon and D.D. Kosambi, it is concluded that the average drop in weight of the coin of ideal weight of around 16 gm is 1.56 gm.

Using FESEM is not a suitable method for such projects. FTIR and EDXS are very useful techniques if the knowledge and understanding is good.

PART II - CANNON

A. INTRODUCTION

Since the advent of gunpowder in India since the fourteenth century, large artillery pieces have been deployed in various locations in India. From handheld guns to large cannon, such weapons were cast in India since at least the sixteenth century. Ranging in geography from the west coast of India to the north-east, there exist several thousand extant guns. The techniques used to manufacture these guns varied by region and period. Inscriptions on many of these guns provide firm dates (for example, guns from western India),[8] but most of them do not have any written information. For such pieces, an analysis and characterization of the metal might provide leads, perhaps even suggesting the origin and casting technologies of the period. There are precisely dated guns that can serve as control groups, for which fully or partially recorded histories are available.

The samples under consideration in this study have been obtained from Dr. Tejas Garge, Director, Department of Archaeology and Museums, Maharashtra State. These samples are from Shivsagar in Assam, and some stylistic and visual studies have previously been completed on them. There are three main objectives to this research:

1. To create a standard system of reference using guns that can be attributed to specific dates on the basis of inscriptions, textual evidence, or stylistically and technologically.
2. Using the available samples, create a map of typical gun material composition in order to test and corroborate the narrative of historically unrecorded guns.
3. Potentially, it will be possible to come up with a hypothetical model of the history of transmission of gun technology across India in the early modern period, based on material analysis, if more samples are obtained in the future.

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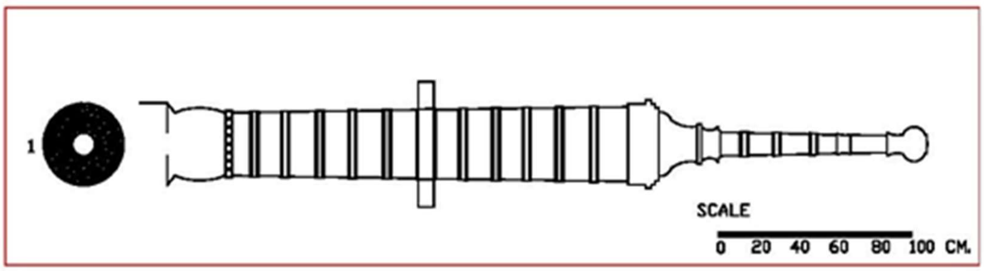
[8] Tejas Garge, *Cannon from the Western Coast of India: Rewdanada (Chaul), Korlai, Janjira & Padmadurga* (Vasco-da-Gama, Goa: Bandekar Charitable Trust, 2015).

The main methods to be potentially used for the project are PXRD (structure), Raman Scattering (composition), FESEM (morphology and composition), FTIR (bonding). Such extensive testing has never been done on samples of historic metals in India, and earlier studies have been extremely basic.[9] This study was conducted over four samples.

Apart from architectural remains, a group of 'Eight Cannons of the Ahom Period' is a centrally protected monument by the archaeological Survey of India (ASI). These cannon were placed near District Commissioner's office across the lake near the sivasagar group of temples at Sivasagar. In 2001-2002, during the renovation of the Commissioner's office, these guns were shifted to Talatalghar, Joysagar (a protected monument of the Archaeological Survey of India). At present five large cannons of this group are placed under two sheds within the perimeter of the Talatalghar. The remaining three cannons are stored in the ASI sub-circle office, Sivasagar along with one additional gun recovered from the same town. Though there are passing references about Ahom cannon in the historic literature, there was no attempt to document these pieces, which completely changed the course of military history in this region.

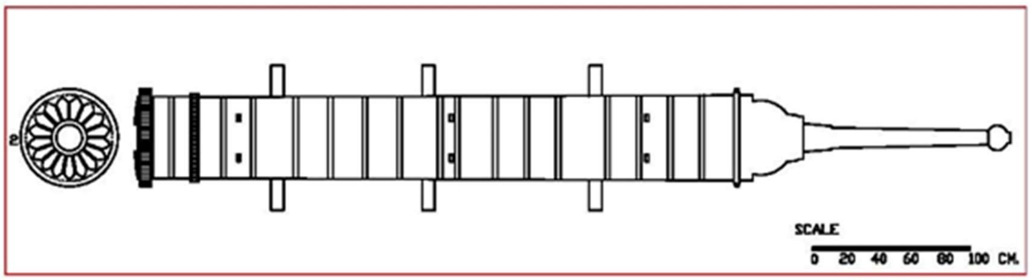
[9] R. Balasubramaniam, A. Saxena, Tanjore R. Anantharaman, S. Reguer, and P. Dillmann, *A Marvel of Medieval Indian Metallurgy: Forge-Welded Iron Cannon,* JOM January 2004, page 17-23.

Cannon 1



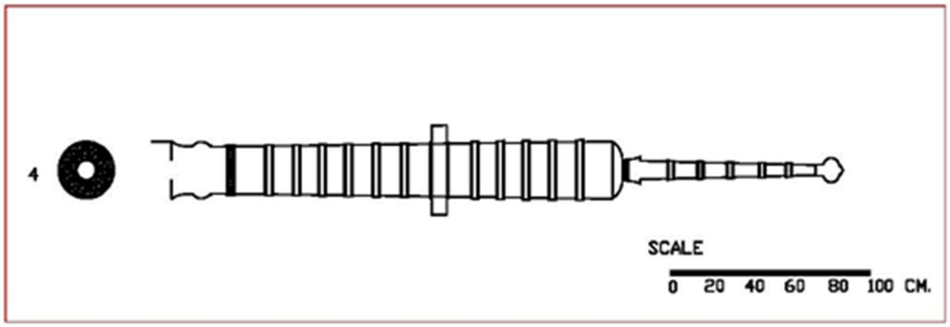
The cannon shown in the figure was manufactured with forged iron rings forming a tapering cylinder towards muzzle and towards muzzle the average thickness of the cannon was 32 cm while average thickness at the breech end was 35 cm. The shape of the muzzle was like a long iron rod with several reinforcement rings. The shape of the foresight of the cannon was like a block which was beatified with ornaments. Two projected ears were missing and was represented by the holes on the top portion of muzzle. The outer diameter of the muzzle face is 42cm and the bore is 12 cm. There are 13 reinforcement rings on the cannon. The first reinforcement ring is decorated with circular embedded balls. The average thickness of reinforcement ring is 5cm. The 7th reinforcement ring is 11 cm thick as it accomodate trunnions with 14 cm length and 7.5 cm diameter. The last reinforcement ring has multiple tubular rings on both the sides. Between foresight and backsight, the vent hole is slightly off the alignment placed towards the right. The cascable is formed in shape of thick ascending rings. The rings are put together in form of a long cylindrical rod. On the cascable, there are 6 reinforcement rings and also a pot shaped tail at the rear as an attachment. The cannon has four lines of Devanagari inscriptions.

Cannon 2



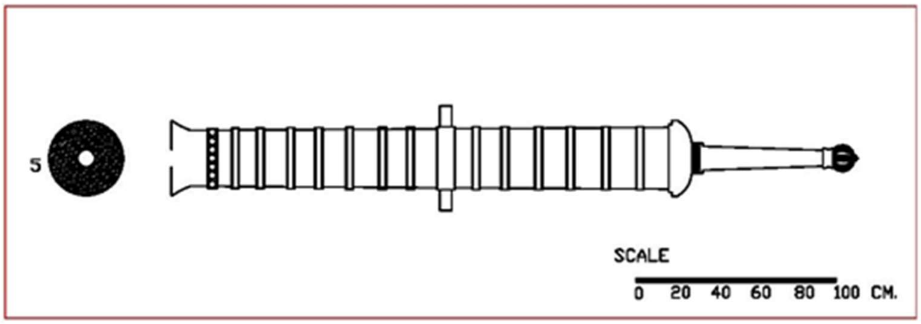
This cannon has a length of 5.54 m and it is one of the largest among the 4 known samples.This cylindrical cannon has circular rings made of wrought iron on its surface. The muzzle face of this cannon has outer diameter of 62 cm and inner diameter of 17 cm and has a thick projecting ring adorned with parallel lines.
The first reinforcement ring has a form of a adorned strap with conical shape in the middle and circular balls on either sides.To handle the reinforcement rings, they contained multiple forged hooks of wrought iron. The cannon is unique because it has three sets of trunnions which is rare among the forge welded cannons. The first pair of trunnions is located at a distance of 85 cm from the muzzle. On average, length of these trunnions is 19 cm and diameter is 8 cm. The second pair of trunnions is located almost in the middle of the cannon at the distance of 98 cm away from the first set. These trunnions are again 19 cm in length and 6.5 cm in diameter. The 3rd set is located 105 cm away from the second set close to end of chase. There were 16 reinforcement rings over the barrel. The cascable has multiple cylindrical pieces forged together. Over the last cylindrical part of the cascable, a circular knob shaped ring has been added. By straight cones descending into cascable, the rear projected part of the breech is formed. This portion is decorated with design of flower petals. The cylinders forming cascable are thicker towards breech and thinner towards the rear end.

Cannon 4



This cannon is manufactured by forging circular rings together. The diameter of cascable is 26 cm and the muzzle diameter is 23 cm. This cannon diminishes gradually from cascable to muzzle.The muzzle has shape that of a mythical animal: a composite form of elephant and crocodile. The projected front part is shaped like the trunk of an elephant and the rear portion like an elephant head, but ears are broken. Incised eyes are seen on either side of the barrel. This cannon has 13 reinforcement rings. The first ring has many circular ring of balls. The 8th ring is 9.5 cm thick and it has cylindrical trunnions of average length of 9 cm and diameter of 6 cm. First reinforcement ring is 3.5 cm thick and rest of them have average thickness of 2.5 cm. The barrel is incised with beautiful floral and geometrical designs which are like a series of triangles and multiple ‘U’s filled with copper. In some places this incision is seen and in some its lost. Cascable of the cannon is 88 cm long and is cylindrical in shape with descending diameter. It is provided with 5 reinforcement ring depicted like 3 segmented bangles. The tail is ghat/pot shape knob with flat end. The breech projection of the cannon is made with thick metal sheet which is now broken. It shows that this breech projection was hollow originally. This cannon is inscribed with Devanagari letters between 8th and 12th reinforcement ring of 3 lengths. The muzzle diameter is 28 cm while the bore is 9.9 cm.

Cannon 5



This cannon is of forge welded variety. It ascends from muzzle (diameter = 28 cm) to breech (diameter = 31 cm). It has 15 reinforcement rings. The 7th ring is not found and the 10th is broken. The 9th ring has thickness of 9 cm, it has accommodating trunnions which are 9.5 cm long, having 6 cm diameter. The average thickness of the remaining rings is 4 cm. The first ring on muzzle is decorated with a series of beads while the last is shaped like a rope around breech ending in pentagon shaped back-sight. The muzzle is decorated with incised floral structures filled with copper.

The breech projection at the back of the cannon has concentric rings having floral petals. The cascable of the cannon has shape like an octagonal rod, and it is long. It has a 6-line Devanagari inscription between 11th and 14th reinforcement ring. The muzzle of the cannon has diameter of 37.5 cm and the bore has diameter of 9 cm. A hole over the muzzle represents a missing foresight. The vent hole is slightly off the alignment between backsight and foresight.

The following table shows the measurements and dimensions of the four cannons.

	Muzzle	Cascable	Breech	Trunion	Outer dia of Muzzle face	Inner dia of bore hole	Reinforcement Ring	Total Length
1.	30 cm	1.26 m	35 cm	14 cm (Length) 7.5 cm (dia)	42 cm	12 cm	7th reinforcement ring-11 cm thick as it provides trunion. Rest is 5 cm in thickness.	3.95 m
2.	2.01 m	1.72 m	-	1st set-19 cm (Length) 8 cm (dia). 2nd set-19 cm (Length) 6.5 cm (dia)	62 cm	17 cm	--	5.54 m
4.	28 cm (Length) 23 cm (dia)	88cm (Length, 26 cm (dia)	-	9cm (Length) 6 cm (dia)	28 cm	9.9 cm	1st reinforcement ring is 3.5 cm thick, while rest of them is 2.5 cm. 8th reinforcement ring is 9.5 cm thick by accomodating trunion.	3.38 m
5.	28 cm (dia), Muzzle to trunion length -142.5 cm	Trunion to cascable length- 112 cm	31 cm (dia)	9.5 cm (Length) 6 cm (dia)	37.5 cm	9 cm	9th reinforcement ring is 9 cm. Rest of the rings are 4 cm.	3.45 m

B. METHODS

1. PXRD - The Powder X-Ray Diffraction (PXRD) test was done on the samples and the data was recorded. Two of the samples were already in the powdered form. The mortar pestle was cleaned with Acetone and the unpowdered sample was powdered in it. The cleaning process of mortar pestle was repeated so that there are no impurities in the other sample. The samples were then placed in the PXRD machine one after the other and the data was collected.

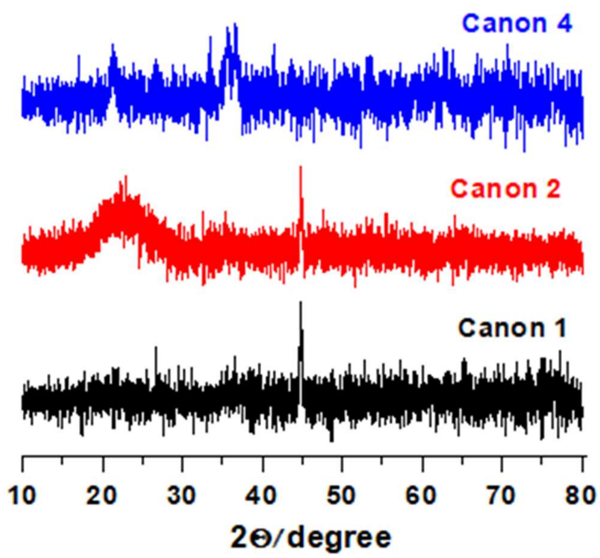
2. FTIR - The IR test has also been done on the same samples. To do the IR test, first, the Potassium Bromide (KBr) was dried in the oven for 30 minutes to make sure that there is no moisture in the KBr. The mortar pestle was cleaned by acetone. Then very little amount of the sample was mixed and crushed in mortar pestle with KBr and the pallet was made. The process was repeated for all the samples. Firstly, a reference reading was taken in IR machine without any sample. Then the pallet was placed in the IR machine and the data was recorded. The process was repeated for all the samples. The baseline correction was also done on the collected data. The original and corrected data both were saved.

3. FESEM - Note: An official technical member from IISER Pune was handling the FESEM instrument. The carbon tape was put over the sample handler. The powdered sample was placed over the carbon tape. The sample handler was then placed inside sucking machine so that the sample is tightly stuck to the tape. The sample handler was then placed under the FESEM machine. The images at different resolutions were taken.

4. EDXS - This text was done on the sample which were taken under FESEM.

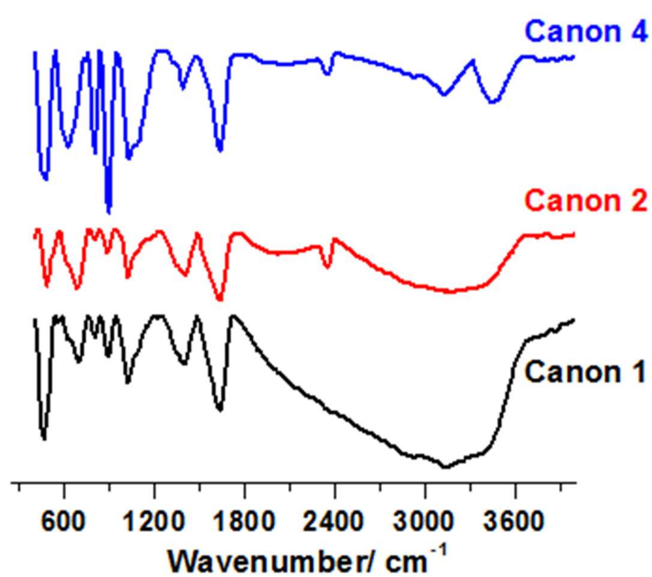
5. RESULTS AND DISCUSSION

1. PXRD - The following figures shows the PXRD spectrum of the collected samples:



The above figure shows that Cannon 1 and Cannon 2 have similar structure while cannon 4 is different.

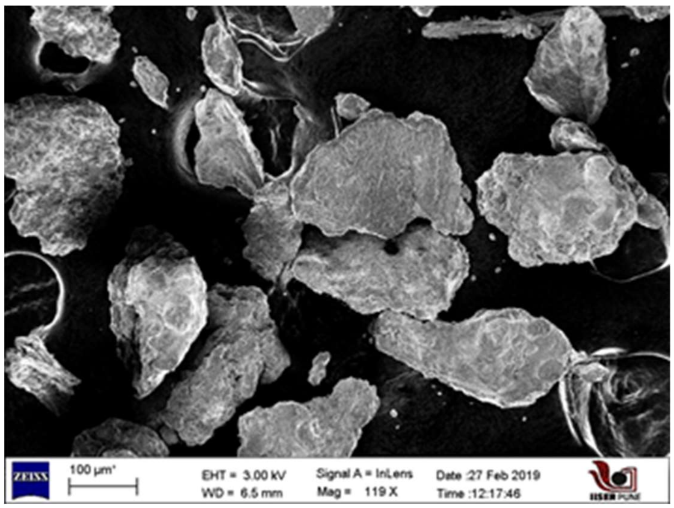
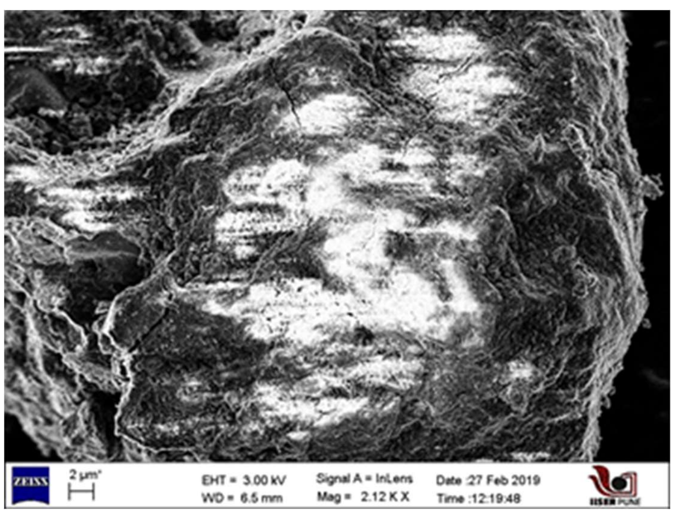
2. FTIR - The following figures shows the IR spectrum of the collected samples:

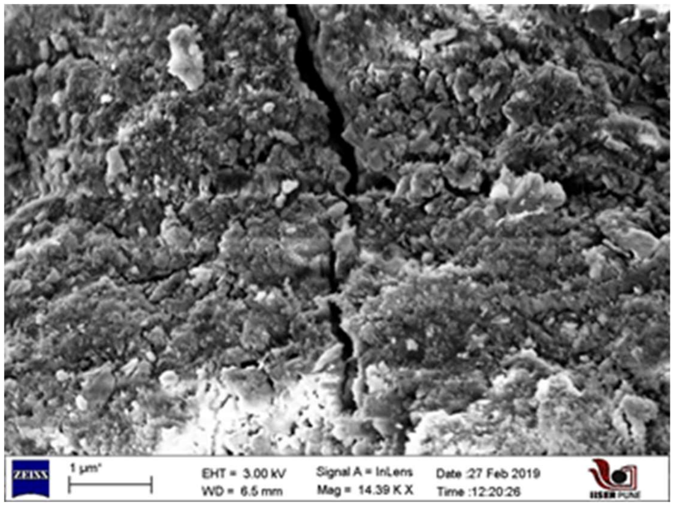
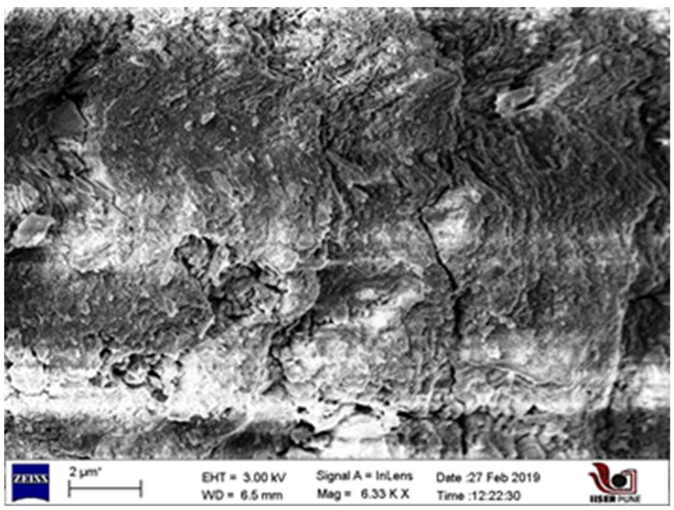


The above figure shows that cannon 1 and cannon 2 have similar chemical bonding. While cannon 4 is a little different.

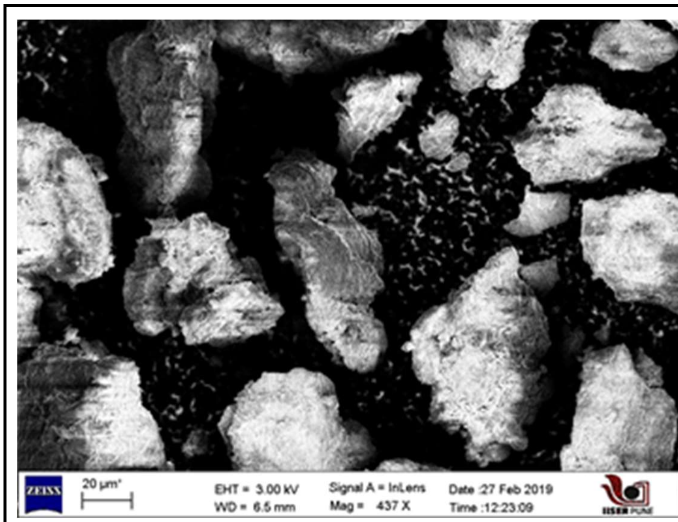
3. **FESEM** - The following figures shows the images of collected samples at different resolutions:

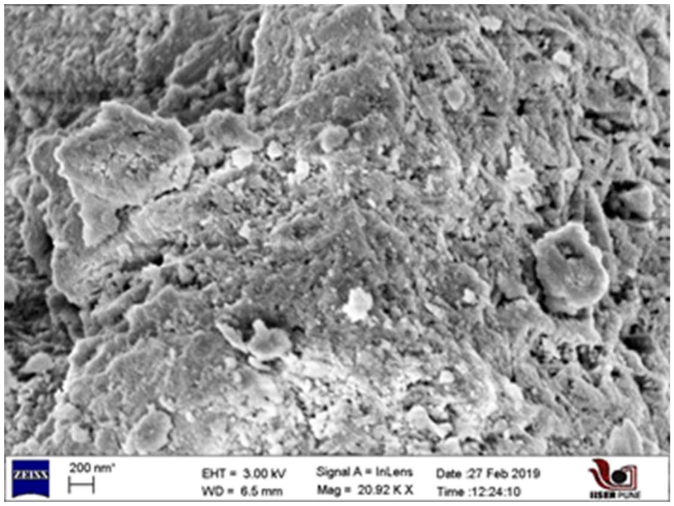
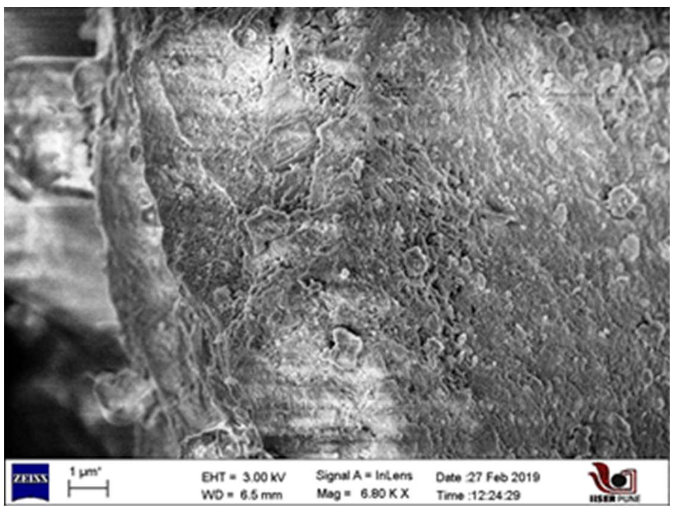
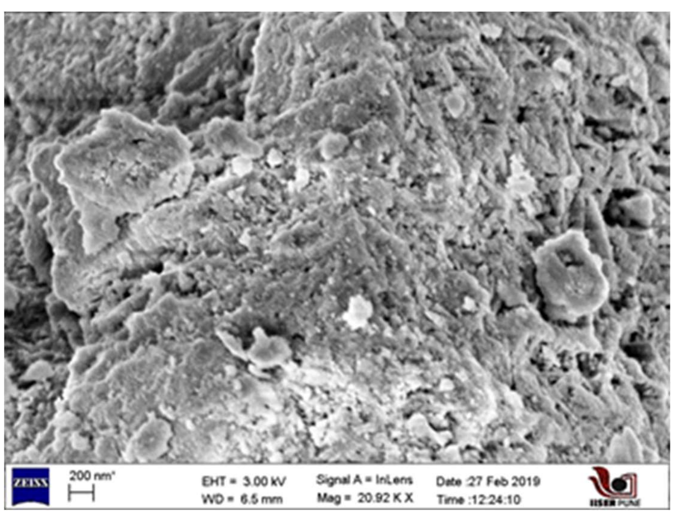
1) **Sample 1**

	100µm
	2µm

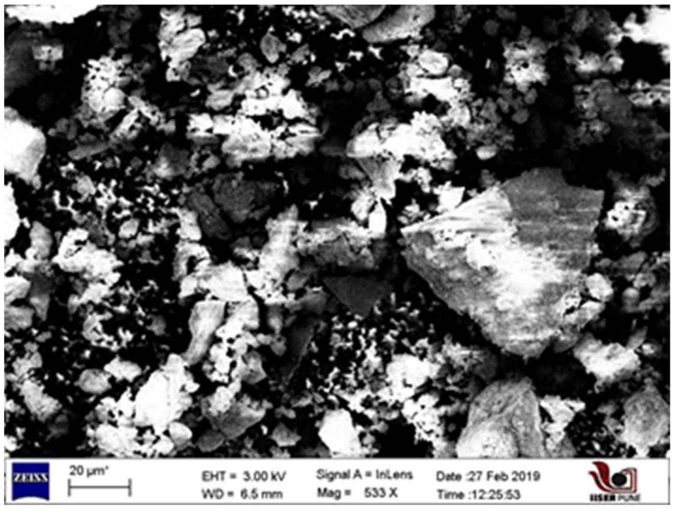
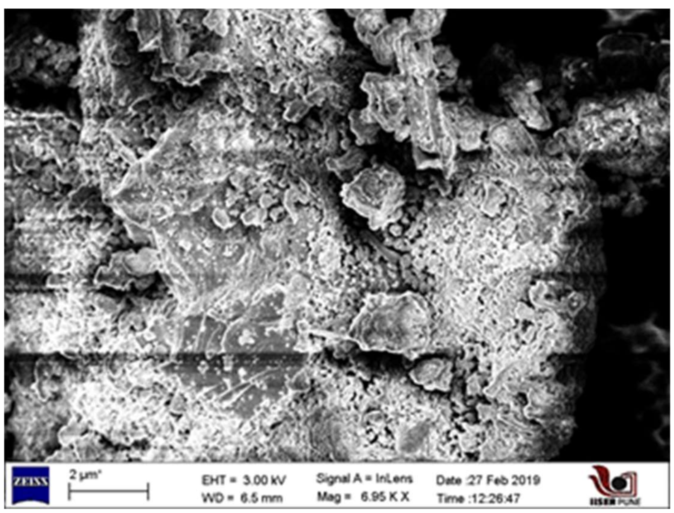
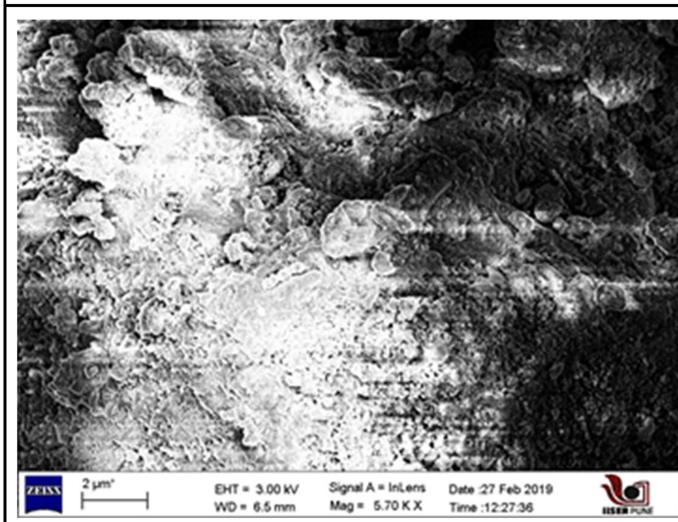
<table>
<tr><td>
</td><td>1μm</td></tr>
<tr><td>
</td><td>2μm</td></tr>
</table>

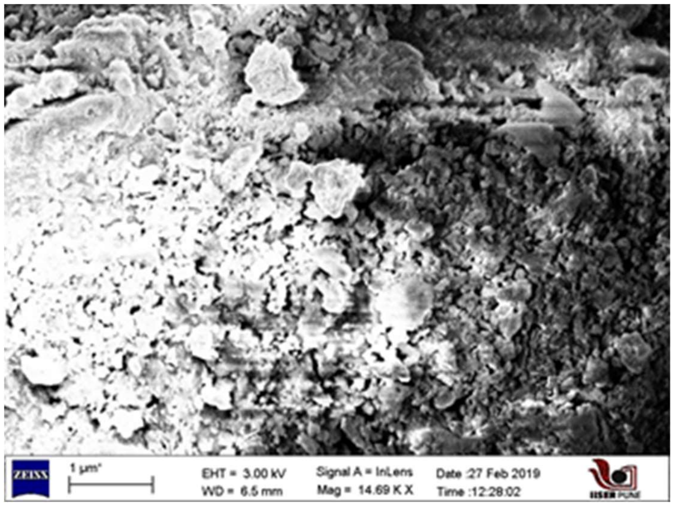
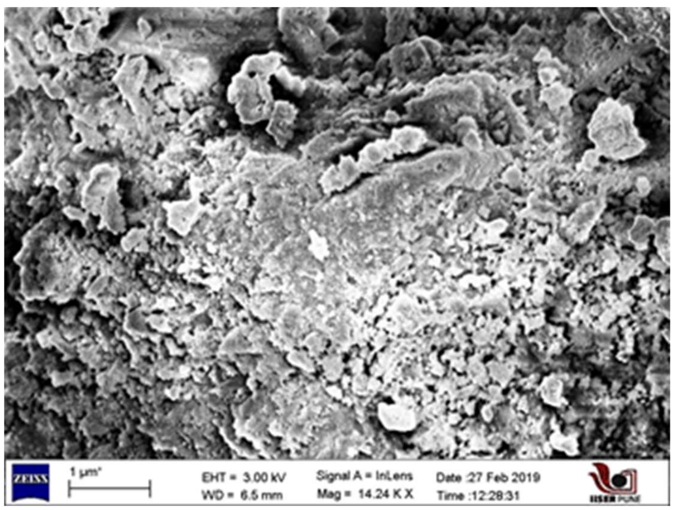
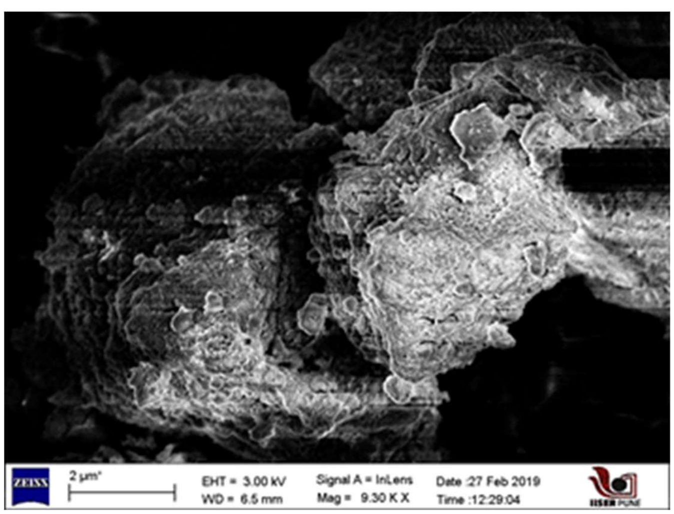
2) Sample 2

<table>
<tr><td>
</td><td>20μm</td></tr>
</table>

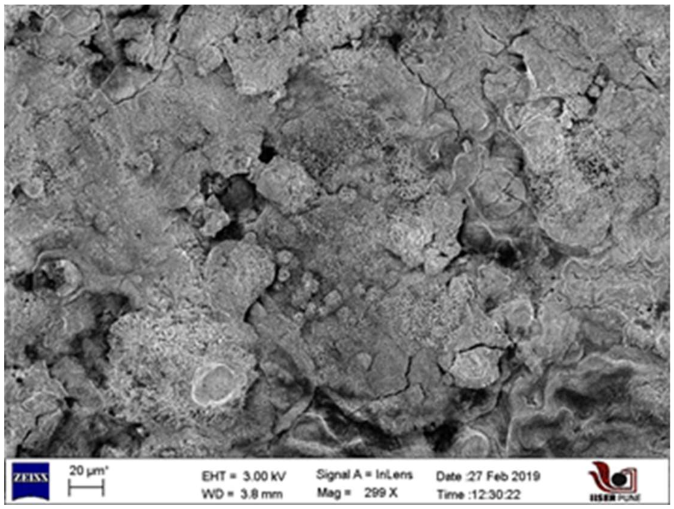
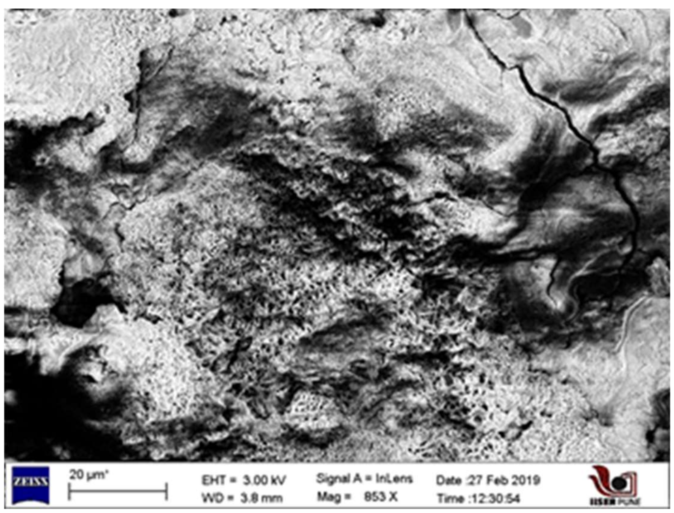
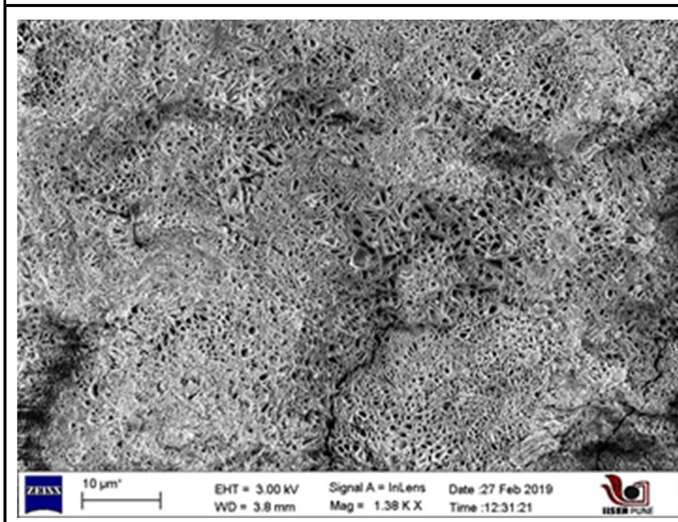
	200nm
	1µm
	2µm

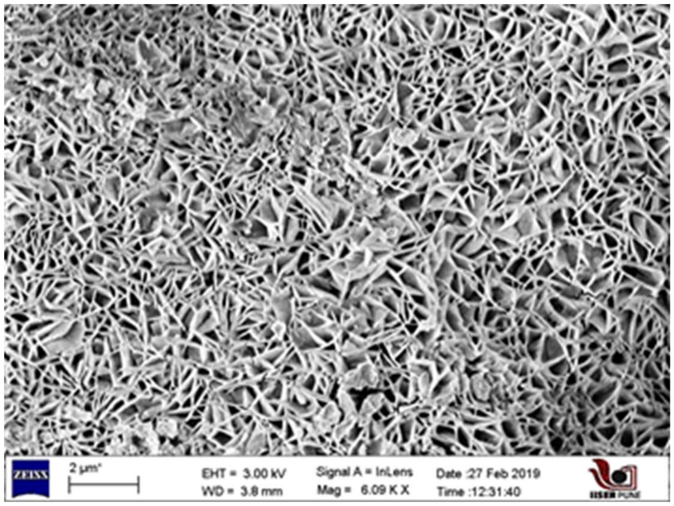
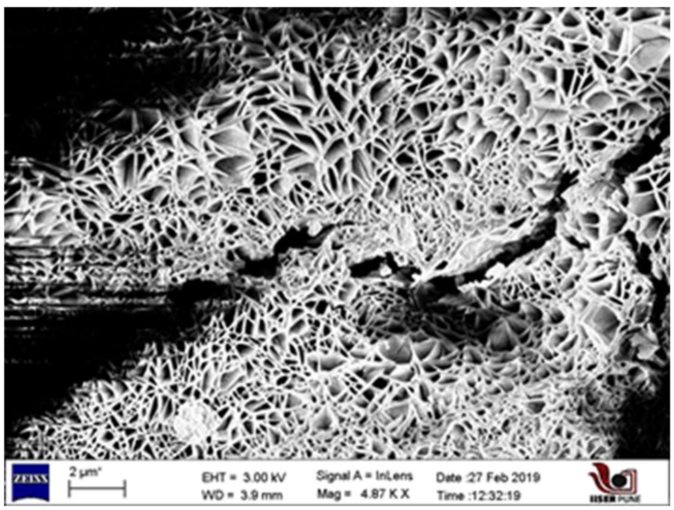
3) Sample 4

	20µm
	2µm
	2µm

1 µm EHT = 3.00 kV WD = 6.5 mm Signal A = InLens Mag = 14.69 K X Date :27 Feb 2019 Time :12:28:02	1µm
1 µm EHT = 3.00 kV WD = 6.5 mm Signal A = InLens Mag = 14.24 K X Date :27 Feb 2019 Time :12:28:31	1µm
2 µm EHT = 3.00 kV WD = 6.5 mm Signal A = InLens Mag = 9.30 K X Date :27 Feb 2019 Time :12:29:04	2µm

4) Sample 5

	20µm
	20µm
	10µm

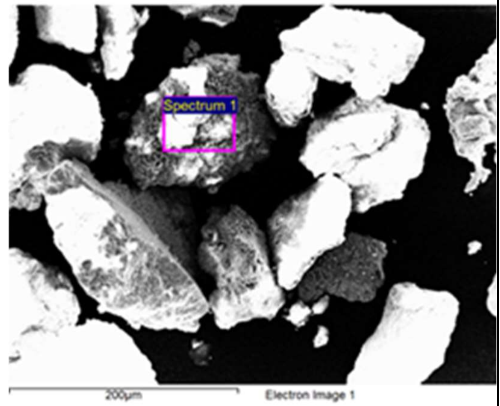
	2μm
	2μm

The images from sample 1 shows cracks in the structure. Since the powder of the samples 1, 2 and 4 were extremely rusty, the FESEM images of those samples didn’t show proper structure. While for cannon 5 we can clearly see the pores and cracks in the sample.

4. EDXS - The following tables shows the percentage composition of the elements in the collected samples:

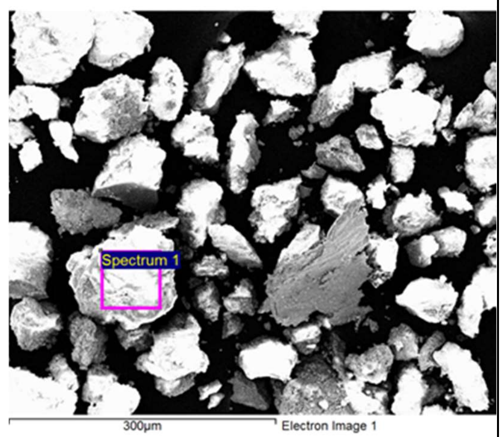
1) Sample 1

Element	Atomic %
C (Carbon)	18.11
O (Oxygen)	57.46
Ca (Calcium)	0.38
Fe (Iron)	24.04
Total	100



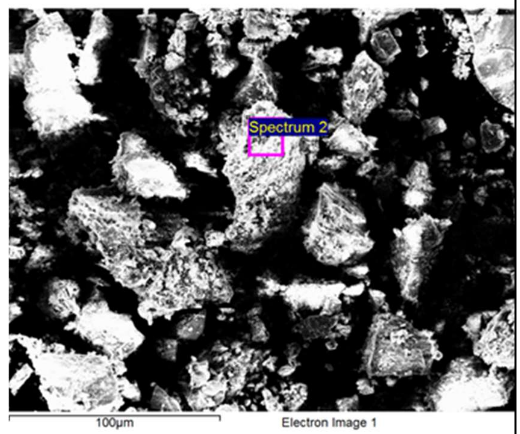
2) Sample 2

Element	Atomic %
C (Carbon)	13.45
O (Oxygen)	54.20
Cl (Chlorine)	1.48
Fe (Iron)	30.87
Total	100



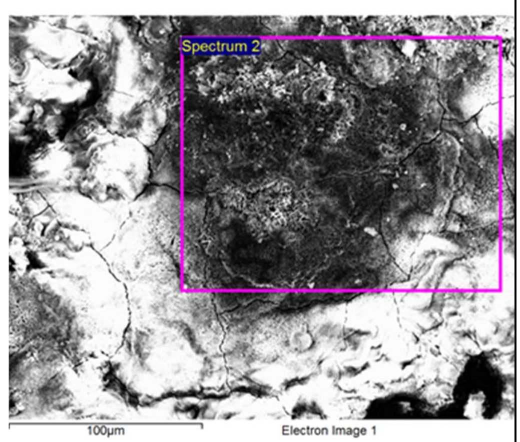
3) Sample 4

Element	Atomic %
C (Carbon)	14.39
O (Oxygen)	51.16
Si (Silicon)	0.33
Fe (Iron)	34.12
Total	100



4) Sample 5

Element	Atomic %
C (Carbon)	14.32
O (Oxygen)	64.76
Cl (Chlorine)	0.19
Fe (Iron)	20.72
Total	100



The above tables show the EDXS data in which we can see that the percentage of oxygen is 50% to 65% which very high relative to other elements. The major constituent of the elements on the cannons (excluding oxygen) are carbon and iron. Carbon is around 13% to 18% whereas iron is around 20% to 34%.

C. CONCLUSION

From the data collected from FTIR and PXRD, we can see that Cannon 1 and Cannon 2 have similar structure and chemical bonding while cannon 4 is different. The data from EDXS shows that the percentage of oxygen is 50% to 65% which very high relative to other elements. The major constituent of the elements on the cannons (excluding oxygen) are carbon and iron. Carbon is around 13% to 18% whereas iron is around 20% to 34%. Since percentage of oxygen is higher, it implies that there were lots of oxides in the samples.

The powder of the samples 1, 2 and 4 were extremely rusty, the FESEM images of those samples didn't show proper structure. While for cannon 5 we can clearly see the pores and cracks in the sample.

Using FESEM is not a suitable method for such projects. FTIR and EDXS are very useful techniques if the knowledge and understanding is good.

APPENDIX

Kings	1 ghani	2/3 ghani	½ ghani	1/3 ghani
Ahmad I	BH73 (15-16.5gm)		BH74 (8-8.6gm)	BH75 (5gm), BH76 (4.8-5.5gm)
Ahmad II	BH84 (15.5-16.5gm)	BH85 (10.6-11.5gm)	BH87 (7-8gm)	BH88 (5-5.5gm)
Humayun	BH97 (16-16.5gm)	BH98 (10.6-11gm)	BH99 (8-8.2gm)	BH100 (5.4-5.5gm)
Ahmad III	BH104 (16.2-6.6gm)	BH105 (10.4-11.2gm)	BH106 (8gm)	BH107 (5-5.5gm)
Mohammad III	BH113 (16.5gm), BH114 (16.2-16.5gm)	BH115 (10.5-11.5gm)	BH116 (8-8.5gm)	BH117 (5.5gm), BH118 (5.3-5.5gm)
Mahmud	BH123 (15.5-16.5gm), BH124 (15.5-16.5gm), BH125 (16.5gm), BH126 (15-16gm), BH145 (14.9gm)	BH128 (10.6gm), BH129 (10.5gm), BH130 (10.6gm), BH131 (11gm), BH132 (10-11gm), BH146 (9.4gm), BH147 (9.5gm), BH148 (8.5-10gm)	BH134 (8.4gm), BH135 (8gm), BH136 (8gm), BH137 (8.4gm)	
Walliullah	BH155 (16.2-16.5gm), BH156 (16.5gm)	BH157 (10.5-11gm)	BH158 (8gm)	
Kalimullah	BH161 (16.5-17gm), BH162 (16.5gm), BH163 (17gm)	BH164 (11.11.5gm)	BH165 (8-8.6gm)	

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