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Technical Studies on the White-glazed Shards Excavated from A'ALi in Bahrain

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Introduction

Some Islamic white-glazed shards excavated from an archaeological site, A'Ali of the 9th to 11th centuries in Bahrain on the Arabian (Persian) Gulf were technically studied to find their characteristics and provenance. This site has been excavated by the Japanese excavation team under the direction of Sasaki in 1988 and 1989 (1, 2).

Archaeological site

A'Ali is a ruined village in the central region of Bahrain Island (Figure 1). The main date of A'Ali is the 9th century. A large number of earthenware and glazed Islamic wares

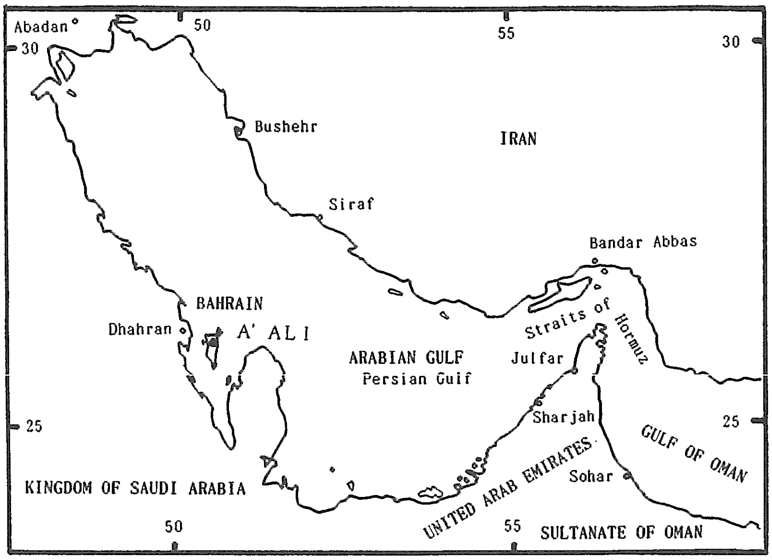

Figure 1 The Position of A'ALI

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were found with some Chinese Changsha ware of 9th century and white porcelain of 11th century. Colours of the glazed Islamic ware are blue-green, white, brown, yellow and polychrome. Blue-green and white wares are creamy yellow fabric and these two types of wares were mainly made in Mesopotamia in the 9th century.

Samples for investigation

Shards of Islamic white glazed ware are studied and these samples are listed in Table 1. Drawings and photos are shown in Figure 2 and Tables 1 and 2.

Table 1 White, blue, and yellow glazed wares and glazed incised ware studied

Sample,Res.No.	Glaze	Type of ware	Produced place
SAA-1 (89-)	G.I	White glazed bowl with creamy yellow fabric	Mesopotamia
SAA-2 (88-163)	G.I	Yellow glazed bowl with light pinkish fabric	Mesopotamia
SAA-3 (88-131)	G.I	Brown glazed incised (sgraffiato) bowl with red fabric	Iran
SAA-4 (88-18)	G.E	Blue glazed bowl with creamy yellow fabric	Mesopotamia
SAA-5 (89-)	G.I	Blue-green glazed(Exterior), and white glazed(Interior) large jar with yellowish green fabric	Mesopotamia
SAA-6 (89-)	G.I	Blue-green glazed(Exterior), and white glazed(Interior) large jar with yellowish green fabric	Mesopotamia
SAA-8 (89-93)	G.I	White glazed bowl with a pattern of palm leaves in cobalt blue. Creamy yellow fabric	Mesopotamia
SAA-9 (89-92)	G.E	Base of a white glazed bowl with creamy yellow fabric	Mesopotamia
SAA-10(89-94)	G.E	Rim of a white glazed bowl with creamy yellow fabric	Mesopotamia
SAA-11(89-52)	G.E	White glazed bowl with creamy yellow fabric	Mesopotamia
SAA-12(89-95)	G.IE	White glazed bowl with coarse brownish fabric	Iran ?
SAA-13(88-58)	G.E	Base of a white glazed jar painted in cobalt blue and copper green with creamy yellow fabric	Mesopotamia
SAA-14(89-96)	G.I	Lustre ware bowl with creamy yellow fabric	Mesopotamia

Res.no. means Registered number. G.I means interior glazes analyzed, G.E, exterior glazes analyzed.

Methods of investigation

First the glazes and the fabrics (body clays) of the shards were studied by X-ray fluorescence analysis, and by X-ray diffraction. Then the glazes and fabrics were chemically analyzed using inductively coupled plasma atomic emission spectroscopy (abbreviated as ICP). Further the body clays were studied for their trace element contents by the instrumental neutron activation analysis (abbreviated as INAA) using the nuclear reactor (TRIGA Mark II) of the Rikyo University in Tokyo. The lead isotope ratios were measured by the Finnegan-Mat 262 mass spectrometer at the Muroran Institute of Technology.

Results and discussion

(A) Chemical compositions of white glazes and body clays

The results of chemical analyses by ICP are given in Tables 2 and 4. Compounds found in the white glazes by X-ray diffraction are given in Table 3.

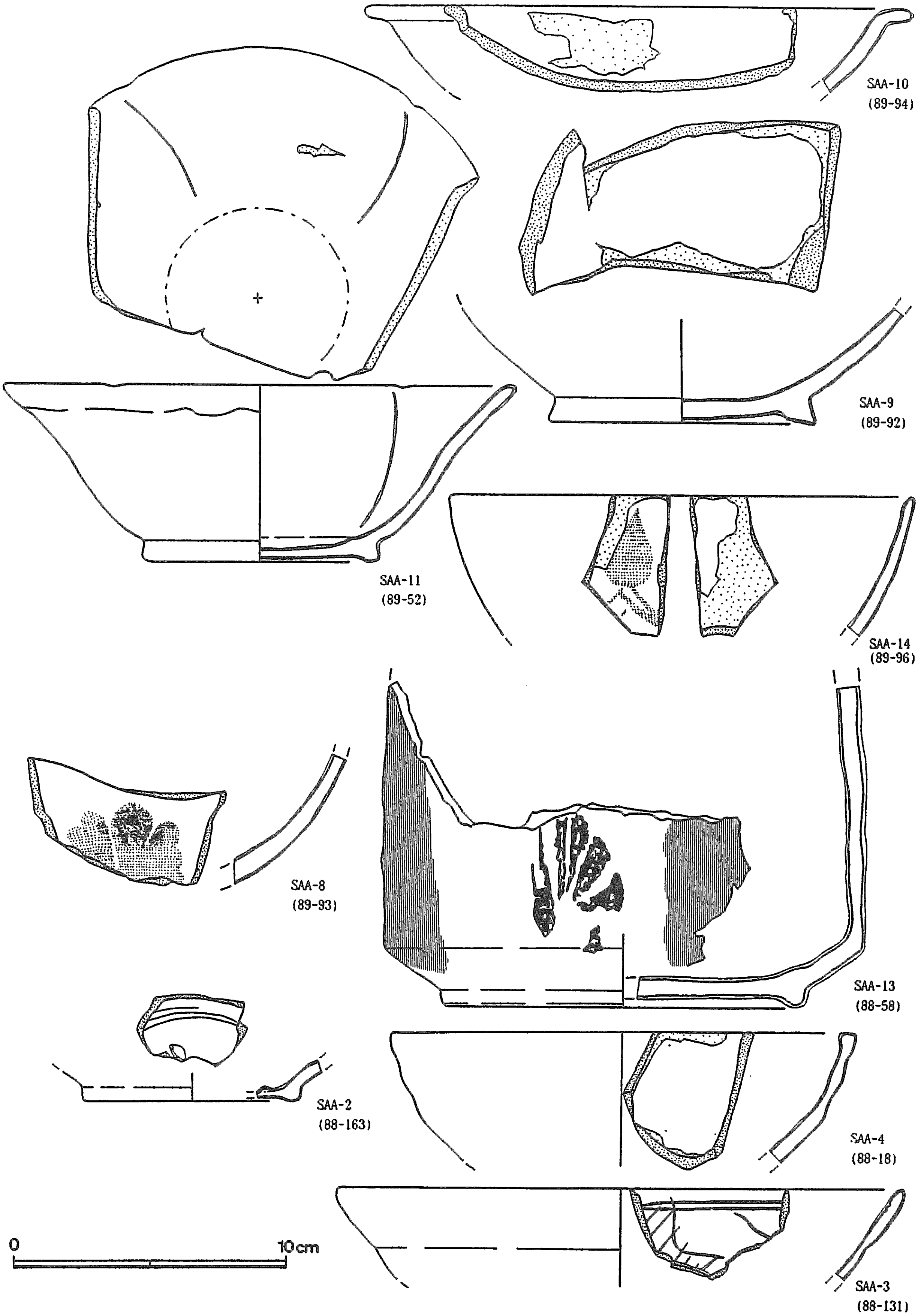

Figure 2 Samples for Analysis

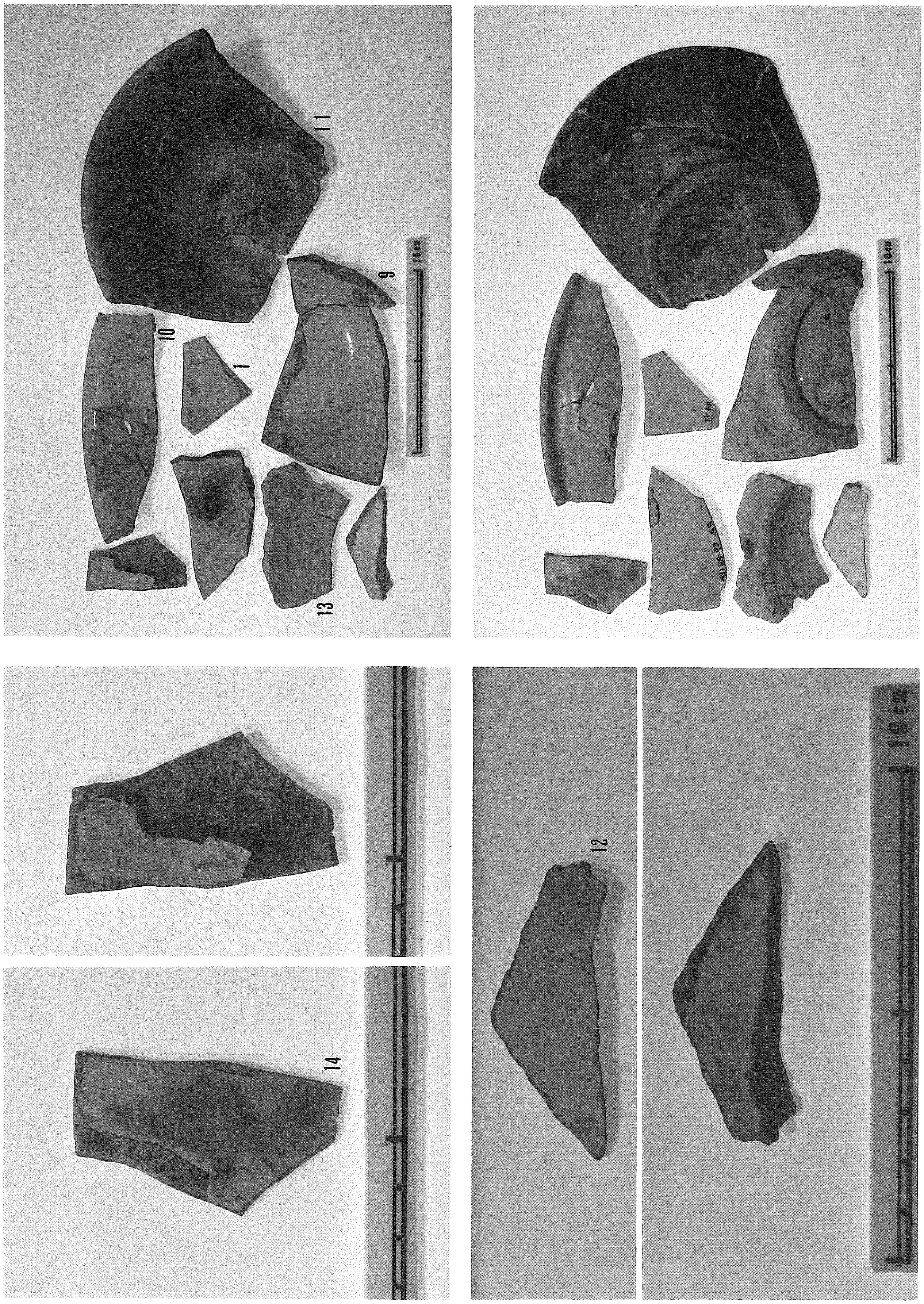

Plate 1 Samples for Analysis from A'ALI

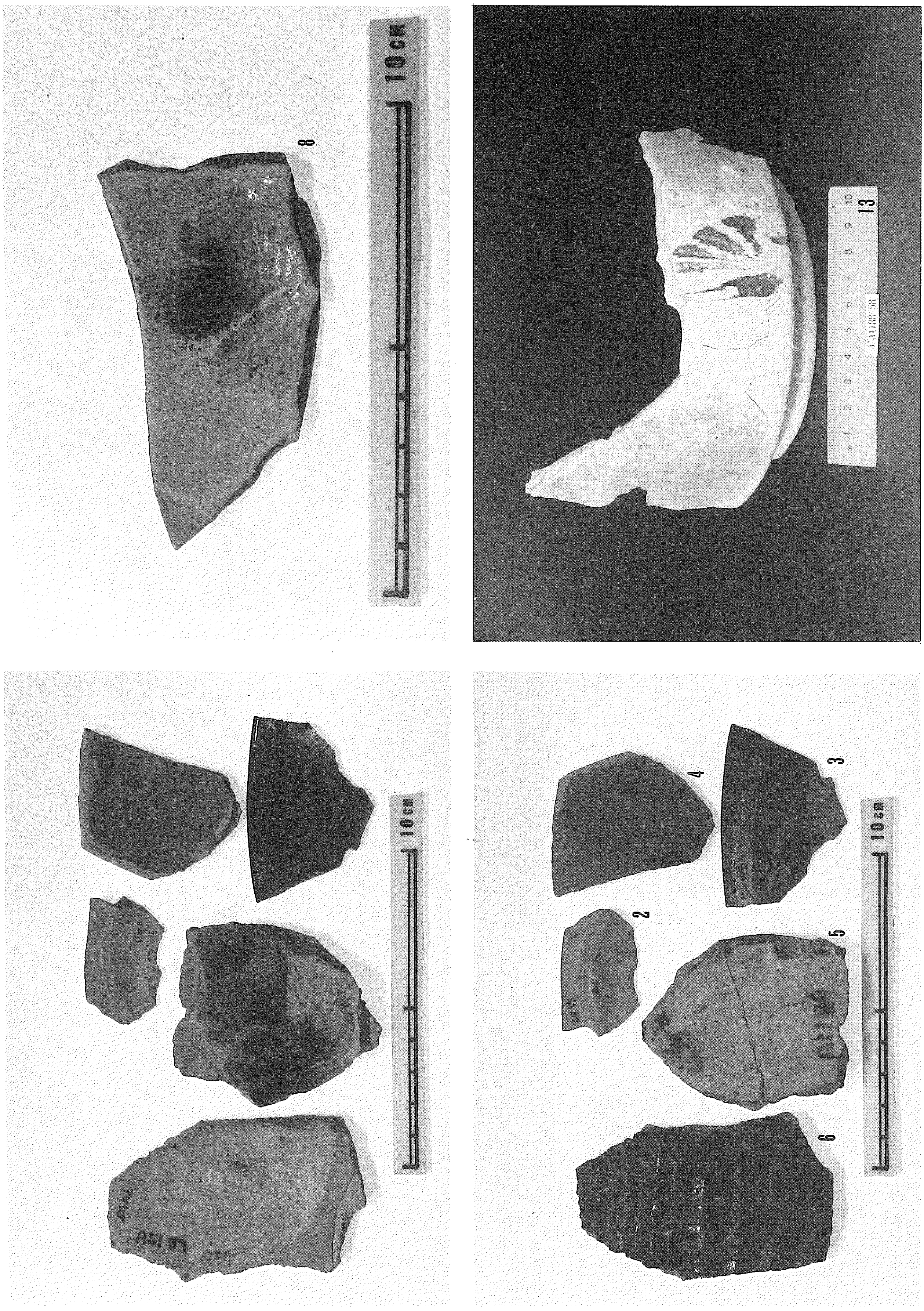

Plate 2 Samples for Analysis from A'ALI

The data in Table 2 show that some of the white glazes contain fairly large amounts of tin and lead, which are the cause of opacity of these glazes. The glazes such as SAA-5G, SAA-6G, SAA-10G and SAA-13G are not tin glazes, because tin and lead found in them seem to be contaminant of the raw materials, and are not intentionally added. It is to be noted that the small amounts of tin in the glazes such as SAA-5G, SAA-6G, SAA-10G and SAA-13G are not detected by X-ray diffraction, and that chemical analysis should be used for its detection in the glazes. The opaque white colours of these shards are due to quartz crystals insoluble in the glazes (cf. Table 3).

Table 2 Chemical compositions (%) of white glazes

Component	SAA-1G	A-5G	A-6G	A-8G	A-10G	A-11G	A-12G	A-13G
Al_2O_3	4.81	–	–	4.58	–	–	–	–
Fe_2O_3	1.71	–	–	1.80	1.6	1.3	0.22	1.3
CaO	6.09	–	–	2.17	–	–	–	–
MgO	2.70	–	–	2.07	–	–	–	–
Na_2O	1.79	–	–	1.20	–	–	–	–
K20	1.83	–	–	1.97	–	–	–	–
PbO	1.70	0.05	0.03	0.03	0.003	0.22	0.61	0.01
SnO_2	9.00	0.1	0.1	0.75	0.17	4.6	6.5	0.69

Silica was not determined due to minute amounts of samples

Table 3 Minerals and compounds present in the glazes

Minerals & compounds	SAA-1G	A-5G	A-6G	A-8G	A-10G	A-11G	A-12G	A-13G
Quartz	+	+	+	+	+	+	+	+
Cristobalite	–	–	–	+	+	+	+	+
Anorthite	–	+	+	–	–	–	–	–
Cassiterite(tin dioxide, SnO_2)	+	–	–	–	–	+	+	–

Table 4 shows that the body clays of some shards are rich in iron, calcium and magnesium. These data agree with the mineral compositions revealed by X-ray diffraction that much quartz, diopside [$CaMgSi_2O_6$] and augite [$Ca(Mg,Fe)Si_2O_6$] are contained in the fabrics (body clays) of shards, SAA-1 and SAA-8.

Table 4 Chemical compositions of fabrics (body clays)
B means body clays (fabrics)

Component	SAA-1B	SAA-8B
SiO_2	43.3	46.7 (%)
Al_2O_3	13.5	13.2
Fe_2O_3	7.30	7.32
CaO	17.0	17.6
MgO	8.29	8.08
Na_2O	2.60	2.08
K_2O	1.91	1.52

In 1979 Whitehouse[3] reported that although some Islamic white glazed pottery had been described as tin glazes, examination of 13 shards from Siraf in Iran by X-ray diffraction and other techniques failed to reveal the presence of tin. He has not published the detailed results yet. Therefore, our results shown above seem to give the detailed information on this important problem.

(B) Trace element contents of body clays

To find the provenance of these two kinds of white glazed pottery with and without tin and lead, instrumental neutron activation analysis (INAA) of the body clays of some shards was carried out. The trace element contents found are given in Table 5.

Table 5 Trace element contents of fabrics (body clays) determined by INAA
(ppm except for Na and Fe expressed in %)

Sample	Na %	Fe %	Rb	Cs	La	Ce	Sm	Eu	Lu	Th	Hf	Co	Sc ppm
SAA-1B	1.37	4.93	40	1.1	26	41	4.8	1.0	0.4	6.7	4.0	24	20
SAA-2B	1.13	4.78	90	2.9	24	38	4.4	1.2	0.4	6.5	3.1	25	20
SAA-3B	1.18	4.85	120	7.8	30	48	5.0	1.3	0.4	11	4.4	22	20
SAA-4B	1.43	4.58	20	1.6	23	40	4.4	1.2	0.3	5.7	3.7	25	19
SAA-5B	1.68	4.55	60	1.9	23	34	4.4	1.3	0.3	6.4	3.4	26	19
SAA-6B	1.50	4.58	70	1.5	24	39	4.4	1.3	0.3	5.9	3.2	27	19
SAA-8B	1.14	5.18	50	3.1	23	39	4.6	0.96	0.4	5.7	3.0	27	21
SAA-9B	1.15	4.39	40	1.1	22	40	4.2	0.98	0.2	5.4	3.4	25	18
SAA-10B	1.14	4.13	290	-	20	41	4.0	1.1	-	5.2	3.8	26	16
SAA-11B	1.27	4.10	60	2.9	20	34	3.4	0.96	0.4	5.2	2.8	21	16
SAA-12B	2.04	3.44	60	1.6	19	19	3.4	0.78	0.4	3.7	6.4	19	14
SAA-13B	1.56	4.97	-	3.7	26	37	4.5	0.81	0.3	5.0	2.2	25	20

The result of the cluster analysis using the data of trace elements of fabrics is shown in Figure 3. The classification is not contradictory to the visual observation about the glazes and fabrics. Judging from the fabrics and cluster analysis SAA-3 and SAA-12 seem to have been made in places other than Mesopotamia, possibly in Iran.

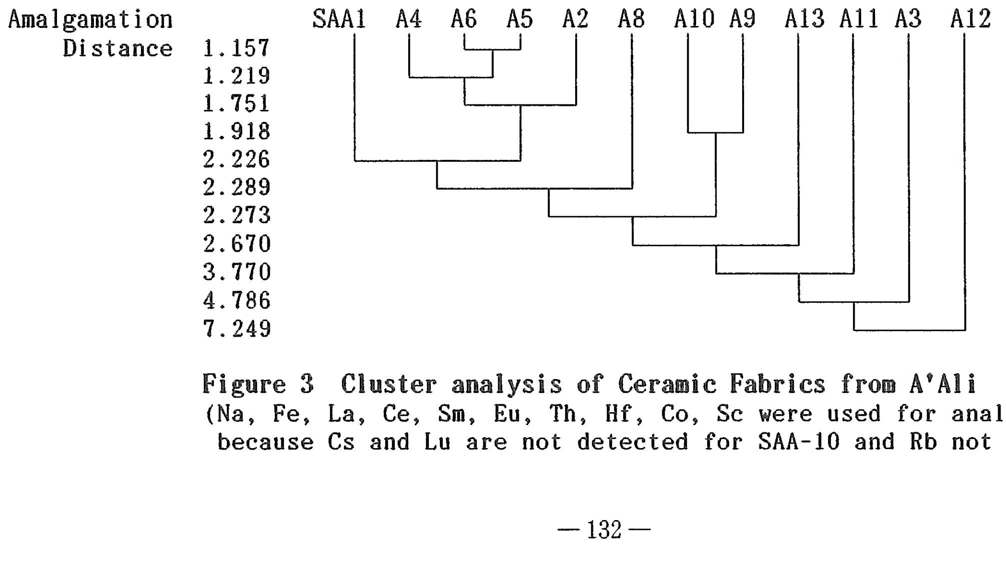

Figure 3 Cluster analysis of Ceramic Fabrics from A'Ali
(Na, Fe, La, Ce, Sm, Eu, Th, Hf, Co, Sc were used for analysis because Cs and Lu are not detected for SAA-10 and Rb not for SAA-13.)

(C) Lead isotope ratios of the glazes

The lead isotope ratios of white glazes measured are shown in Table 6, and the data are plotted in Figure 4.

The lead isotope ratios of the Iranian lead ores are few, and the unpublished data for them obtained by R.H. Brill are plotted in Figure 4 together with his data for Iranian "objects" (mostly glasses and metal objects). The Iranian ores are divided into two groups, I and II. The ores of Group I come from the mines such as Lakan, Ahangaran, Hosseinabad, and those of Group II belong to the mine Nakhlak. The details of the ores and "objects" will be published later by Brill. It is clear from Figure 4 that most of the "objects" used the ores different from Groups I and II, and the origins of these ores used are not known yet. The white glazes of the shards excavated in A'Ali did not use the ores of Groups I and II except for A-6. The isotope ratios of this shard are close to those of an ore of Group I which came probably from Hosseinbad.

Table 6 Lead isotope ratios of white glazed ware excavated at A'Ali

Sample	Pb206/Pb204	Pb208/Pb206	Pb207/Pb206
SAA1	18.920	2.08089	0.83583
SAA5	18.616	2.08883	0.84266
SAA6	18.418	2.09643	0.85211
SAA8	18.659	2.07487	0.83810
SAA10	18.609	2.08365	0.84313
SAA11	18.910	2.06243	0.83088
SAA12	18.811	2.07037	0.83400
SAA13	18.925	2.07114	0.83370

The 2 σ values for Pb^{206}/Pb^{204}, Pb^{208}/Pb^{206}, and Pb^{207}/Pb^{206} are < 0.02%, < 0.01%, and < 0.01%, respectively.

From the archaeological point of view most of these white glazed shards found at A'Ali seem to have been made in Mesopotamia. The lead isotope data in Table 6 and Figure 3 show clearly that these pottery were made using the lead ores of several different mines in the present day Iran. Several more lead mines are supposed to have been working in the 9th century when these pottery were made in Mesopotamia. More information will be necessary on the mines in Iran, Iraq and related areas.

There is no complete fitness between the data of trace element contents of fabrics and lead isotope ratios of glazes. This means that their glazes were made using the materials of different localities from those of their body clays. This problem is to be solved by future studies.

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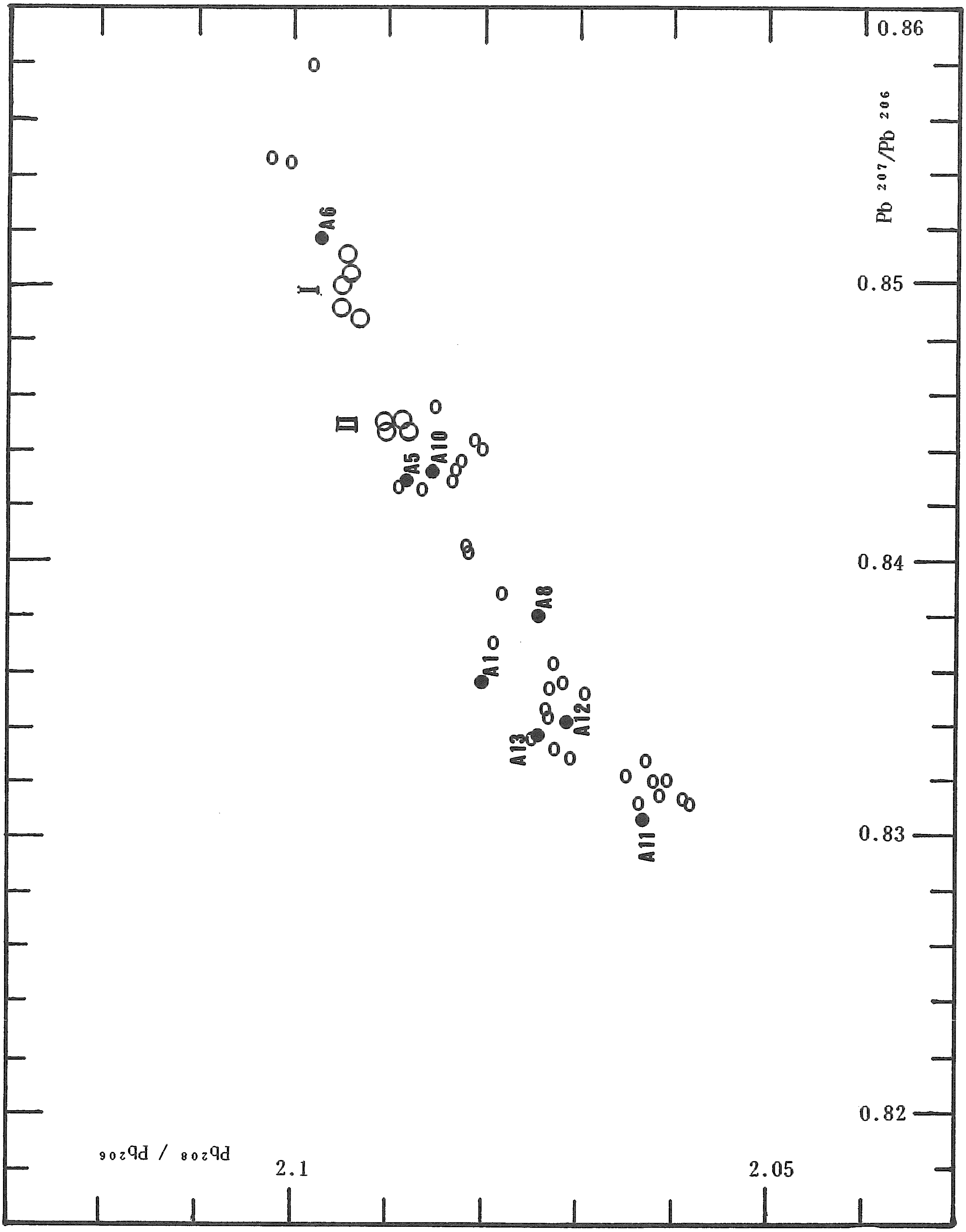

FIGURE 4 LEAD ISOTOPE RATIOS OF ORES AND FINDS

The Symbols ●, ○, ○ denote the pottery shards excavated at A'Ali, Iranian ores, and Iranian "objects", respectively

them permission to analyze the excavated ceramics from A'ALi. We also wish to thank to Dr. R.H. Brill, The Corning Museum of Glass for giving us the important unpublished information on the Iranian ores and "objects". Section drawings were made by Ms Katsura Hato and Mr.Takashi Komatsu. One of the authors (K.Y.) is grateful for the research grant of the Japan Academy.

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バハレン島アーリ遺跡出土の白釉陶器片の科学的研究

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アラビア湾に面する遺跡から、中世の東西両世界を結ぶ貿易によって運ばれた陶磁器が出土する。考古学的方法と自然科学的方法を用いてそれらの陶磁器の材質を探り、産地を推定し、貿易の実態を明らかにするための資料を提供することが、本稿の目的である。

アラビア（ペルシア）湾バハレン島のアーリ遺跡（主として９世紀）は、1988年、89年に佐々木らによって発掘された。多くのイスラームの土器、施釉陶器と、少数の中国産白磁片と長沙窯陶片が出土した。イスラーム陶器の釉は、青緑色、白色、褐色、黄色、および多色であるが、青緑色がもっとも多く、次いで白色が多い。青緑色および白色の釉の胎土の多くは淡黄色であり、この二種類の陶器の大部分は９世紀にメソポタミアで作られた製品である。ここでは白釉陶器片を主にとりあげ、釉の化学分析、蛍光Ｘ線、Ｘ線回折、鉛同位体比、ならびに胎土の化学分析、Ｘ線回折、機器中性子放射化分析の分析結果を報告する。

白釉の一部はSnとPbを含み（表2,3)、これが釉の白濁の原因の一つと推定できる。しかし、SAA5G, 6G, 8G, 10G, 13G のSnとPbは少なく、おそらく不純物と考えられ、これらの白色は釉中の不溶解の石英によると考えられる（表3)。表３は釉の鉱物組成は釉中に石英、灰長石が多く含まれることを示し、それは表４の釉の化学成分と対応する。

イスラーム陶器の基本釉である白釉は、鉛釉の錫呈色といわれてきた。1979年、Whitehouseはイランのシラーフ遺跡出土の白釉陶片がSnを含まないことを簡単に予報として報告し、問題を提起したが、詳細は現在まで発表していない。本報告はこの問題をとりあげた詳細な研究の一部である。

なお、釉中の鉛同位体比は、イラン産製品と推定できる鉛を含む遺物のそれと一致する場合もあるが、鉛鉱石と一致するのは僅かである。さらに、胎土の微量成分（表5)の面からも、それらの産地を現在検討中である。