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The Petrography and Mineralogy of Technical Plaster and Local Juss

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ABSTRACT

The petrography and mineralogy of two types of technical plaster, an English dental stone and two types of local juss were studied.

The petrography of the studied thin sections, revealed that technical plasters consist of dispersed prismatic, monoclinic crystals, with ill-defined edges (Bassanite of the β-hemihydrate). Dental stone consists of more packed, prismatic monoclinic crystals with well defined and sharp edges (bassanite of the α-hemihydrate). Some crystals are pseudo-hexagonal. Bassanite of local juss in thin sections is identical to that of technical plasters.

X-ray diffraction studies proved that technical plasters consist of about (95%) bassanite and (5%) gypsum, compared with (99%) bassanite and (1%) gypsum for the English dental stone. Local juss consists of anhydrite (63-70%), bassanite (20%) and gypsum (10-17%). The three mineral phases, in the final product, the juss, exist as a mechanical mixture, rather than transformation phases. The occurrence of a phase is a function of the distance of raw material, the gypsum from fire source.

بتروغرافية ومعدنية الجبس الفني والجص المحلي

الملخص

تم دراسة بتروغرافية ومعدنية نوعين من الجبس الفني وحجر الأسنان (Dental stone) الإنكليزي . ونوعين من الجص المحلي.

أوضحت الدراسة البتروغرافية للشرائح الرقيقة بأن الجبس الفني يتكون من بلورات متباعدة، موشورية أحادية الميل، ذات حافات غير منتظمة (باسنايت من نوع β-hemihydrate). وأما حجر الأسنان الإنكليزي يتكون من بلورات موشورية أحادية الميل أكثر تراصاً وذات حافات منتظمة (باسنايت من نوع α-hemihydrate). وبعض البلورات سداسية كاذبة .والباسنايت في الشرائح الرقيقة للجص المحلي فهو مطابق تماماً للباسنايت الموجود في الجبس الفني.

وقد أثبتت دراسات الأشعة السينية الحائدة (XRD) بأن الجبس الفني بنوعيه يتكون من باسنايت (95%) وجبسوم (5%) مقارنة مع حجر الأسنان الإنكليزي الذي يتكون من باسنايت (99%) وجبسوم (1%).

ويتكون الجص المحلي بنوعيه من انهايدرايت (63-70%) وباسنايت (20%) وجبسوم (10-17%). إن الأطوار المعدنية الثلاثة في المنتوج النهائي، الجص، توجد بشكل خليط ميكانيكي وليس بشكل أطوار تحولية . وأن وجود أي طور من هذه الأطوار يعتمد على مسافة المادة الخام، الجبسوم، من مصدر النار.

INTRODUCTION

Local juss samples were collected from the main juss production area in Nineva district, situated at a distance of about (12 km) north west of Mosul city.

The raw material, the gypsum is being extracted from a nearby quarry, where the gypsum belongs to the Fat'ha Formation (Middle Miocene). There are around (30) plants for juss production in the area. Each plant locally called a "Koor" which strictly means a furnace.

Two types of juss which were studied; plastering juss (P. J.) which is white and fairly pure, and building juss (B. J.) which is off-white and not very pure (Table 1). Ten samples of each type of juss from two well known koors were collected and studied.

Table 1: Proportions of Calcium Sulphate Phases by Normative Calculations and from XRD Peak Heights, for Technical Plasters (Ah and Ma), Dental Stone and for the Two Types of Juss (P. J. and B. J.).

Type of Plaster	Normative Calculations (%)			Peak Heights (%)		
	Anhydrite	Bassanite	Gypsum	Anhydrite	Bassanite	Gypsum
Ahlia (Ah)	0.0	93.3	6.7	0.0	95.2	4.8
Malej (Ma)	0.0	96.6	3.4	0.0	96.0	4.0
Dental Stone	0.0	98.6	1.4	0.0	98.0	2.0
Plastering Juss (P. J.)	70.0	20.0	10.0	70.0	20	10.0
Building Juss (B. J.)	63.0	20.0	17.0	63.0	20	17.0

In order to study the effects of distance on the calcination product of the raw material gypsum from the fire source, twelve samples of burnt (calcined) but not crushed gypsum were collected from different parts or levels of the dome of the koor, i.e. two samples from each level (Fig.1). The details of the parts of the koor and dome are given in Alrawas (2002).

Two well known plaster producing plants in Baghdad the Ahlia (Ah) and Malej (Ma) were chosen for sampling of technical plasters. Ten bags of the powdered technical plaster each weighting around (30 kg.) representing the two plants (5 bags of each) were purchased from the local market.

Two samples were taken from each bag by the quartering method, so that each type of technical plaster was represented by ten samples.

One kilogram of an English dental stone (D. S.), type "Kaffir" was purchased from a medical supply bureau in Mosul and used as a standard reference, being of very high purity plaster (Table 1).

Powdered samples were prepared for X-ray diffraction (XRD) and petrographical (thin section) analyses. The (XRD) spectrometer used was Philips (PW1310), with Cu K□

radiation source and (Ni) filter, at the Building and Glass Research Center, Baghdad.

The temperature of fire source was measured by means of a radiation pyrometer (type "pyro", Karl Kolb, Germany) from the College of Engineering, University of Mosul.

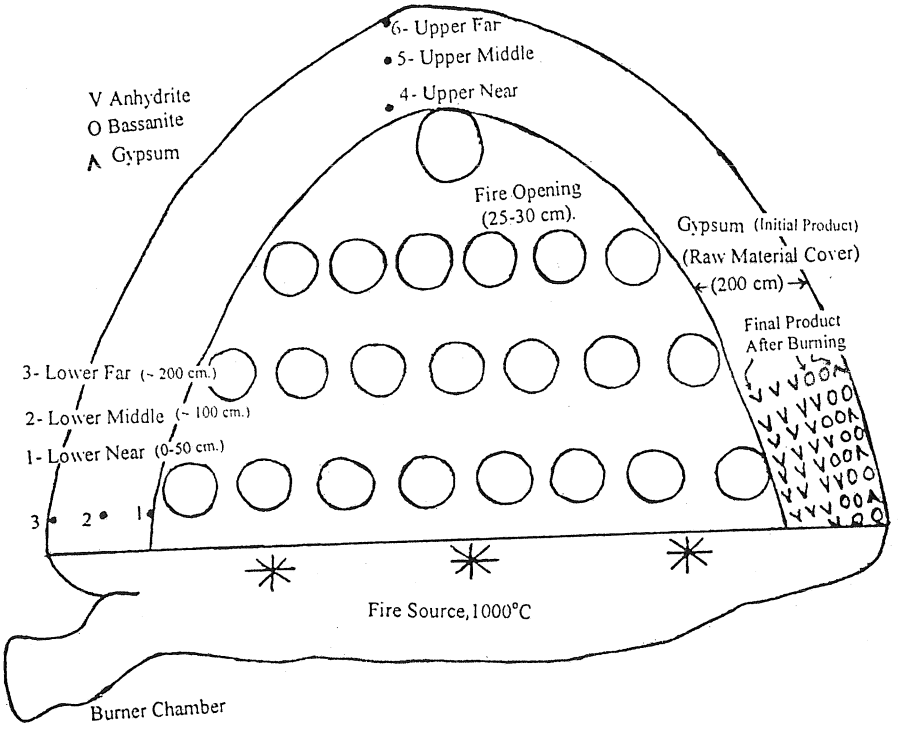

Fig.1: Sкetch diagram for the parts of the Koor, showing the levels of collected samples relative to fire openings and the distribution of the three calcium sulphate phases (anhydrite, bassanite and gypsum) within the cover as a function of distance from fire openings (front cover removed for details).

Peak heights from the X-ray diffractograms were used for the calculation of the three calcium sulphate phases, anhydrite, bassanite and gypsum. In the case of multi-phase mixture observed, all peaks for each phase rather than one major peak, were used. This is to cancel most of the inherited imperfections, like crystallization, grain size and instrumental factors. That is to minimize these deviations between individual peak value and the mean value of peaks (Brindley and Brown 1980).

The purpose of this work is to study and compare the petrography and mineralogy of local juss and technical plaster and relate differences in mineralogy to the different methods of production of each type. Also to study the effects of calcinations (burning) of the raw material gypsum, situated at different distances from fire openings in the dome, on the mineralogy of the final products, the juss.

TERMINALOGY

Bassanite:

Is a mineral consisting of calcium sulphate hemi-hydrate ($CaSO_4 . 0.5H_2O$) and crystallizing in the monoclinic system, synonym hemi-hydrate.

Dental Stone:

Is a high quality plaster of Paris, produced by heating gypsum under high pressure. It consists largely of bassanite of the type α-hemihydrate. It has superior physical and mechanical properties in comparison with ordinary plaster.

Hemihydrate:

Is a chemical name for bassanite ($CaSO_4 . 0.5H_2O$) ; it is of two types:

α-hemihydrate and β -hemihydrate, with identical x-ray diffractograms but different physical and mechanical properties.

Juss or Local Plaster:

The name juss was derived from the Assyrian word Jasso . It is a low grade plaster of Paris, produced in northern Iraq by the old traditional "Koor" method. Gypsum boulders are placed on the dome surface of the Koor. Burner is at the base and on the side of the Koor, with a temperature of about (1000 °C). Heat is transferred to the gypsum through openings in the dome. Heating continues for at least (24) hours. The final product, the juss, consists mainly of anhydrite with minor amounts of bassanite and gypsum.

Plaster of Paris (Plaster):

Is a commercial name for calcined gypsum, having the ability of setting and hardening when mixed with water and consists mainly of the mineral bassanite of the type β-hemihydrate.

Technical Plaster:

Is a plaster of Paris produced by calcining gypsum in rotary kilns at a temperature of about (170 °C), with rather short calcining period from half to three hours. It mainly consists of bassanite of the β-hemihydrate. Synonym technical gyps or gyps.

PETROGRAPHY AND MINERALOGY

Using the polarizing microscope, thin section studies have shown that Ahlia and Malej technical plasters consist of subhedral colourless monoclinic crystals, with ill-defined edges, low relief, moderate birefringence with bright interference colours, orange and red of the first order, up to second order blue and ranging in size from (15) to (60) microns. (Plate 1). This is bassanite of the β-type hemihydrate. Dental stone consists of similar crystals but are more packed and with sharp edges. Some crystals are pseudo-hexagonal (Plate 2). This is bassanite of α-type hemihydrate. (McCabe, 1985; Anusavice, 1996). Bassanite of local juss in thin section is identical in optical properties to that of technical plasters, but with much smaller grain size (Plate 3).

The mineralogy of technical plasters (Ahlia and Malej) and dental stone, revealed by X-ray diffraction, shows that the three plasters have very similar diffractograms, consisting predominantly of the mineral bassanite with very small amounts of gypsum ($CaSO_4 . 2H_2O$) and could be represented by one diffractogram (Fig.2). In fact dental stone is an almost pure bassanite.

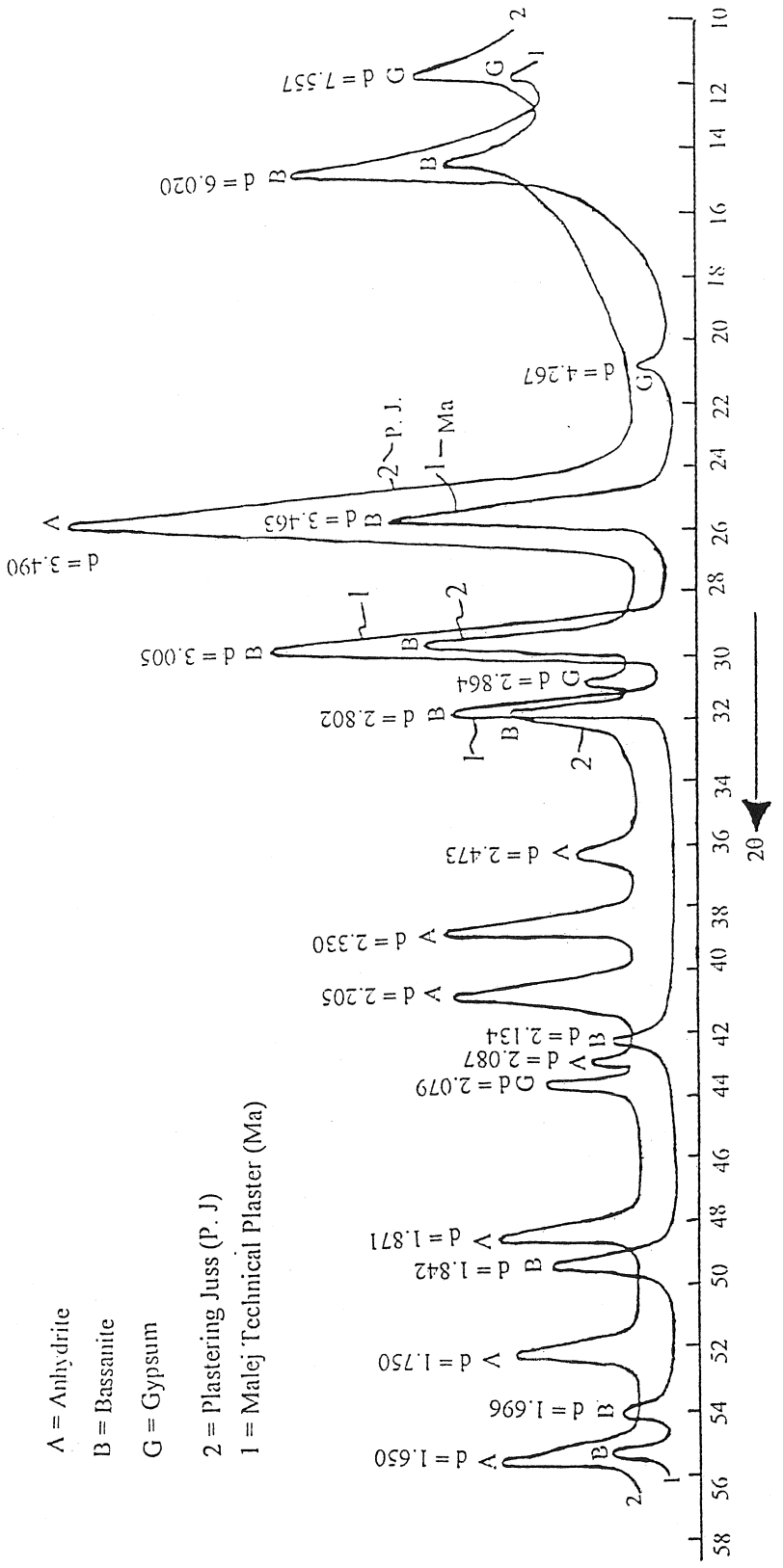

Fig.2: X-ray diffractograms for Malej technical plaster (1) and Plastering juss (2).

The petrography and mineralogy of local juss are both related to the distance of the raw material, the gypsum from fire openings (Total distance, 200 cm. is the cover of the raw material, Fig.1). Samples near the fire openings (0-50 cm.), whether from lower (Lower Near) or from the upper part of the dome, i.e. Upper Near (Fig.1.) consist entirely of anhydrite. Under the microscope anhydrite is of the bascillar type, consisting of long parallel to sub-parallel slender prismatic crystals, with high relief and weak twinkling. Birefringence is strong with third order orange, red and blue bright interference colours (Plate 4). The X-ray diffractogram shows that these samples consist entirely of anhydrite (Fig.3). On the other hand, samples from the middle part, that is almost (100 cm.) away from the fire openings (Lower Middle and Upper Middle, Fig.1) and as far as (150 cm.) from fire openings, consist predominantly of anhydrite with small amounts of bassanite, which could only be identified through the diffractogram (Fig.3).

The last (50 cm.) of the cover, represented by (Lower Far) and (Upper Far) samples (Fig.1.) consist predominantly of bassanite with minor amounts of gypsum (Fig.3). The chemical compositions of the three types of calcined Gypsum are given in table (4). Due to the relatively far distance of the raw material, the gypsum, from fire openings, anhydrite is absent, but some gypsum relicts have been retained, (i.e., not calcined) gypsum crystals are relatively large, subhedral to anhedral, with low relief, weak birefringence and having first order white and grey interference colours. The matrix consists of rather fine grained bassanite (Plate 3).

It may be concluded that the petrography and mineralogy of the final product, the local juss, whether for plastering (P. J.) or for building (B. J.) are the result of mechanical mixing of the three calcium sulphate phases (anhydrite, bassanite and gypsum) with anhydrite being the predominating phase (Fig.2).

NORMATIVE CALCULATIONS

When plaster consists of the two phases, bassanite and gypsum, then water content (H_2O^+) is always more than (6.2%), which is the theoretical value for (H_2O^+) in bassanite. So that gypsum content can be calculated by subtracting (6.2) from total (H_2O^+) and multiplying the result with 4.778 (Aljubouri 1993, Aljubouri and Sulayman, 1996).

However the use of 6.2% (H_2O^+) in bassanite assumes there is (100%) bassanite and this is not true, so the method of successive approximation is used. This method progressively reduces the amount of bassanite from (100%) and increases the amount of gypsum until a fixed value for bassanite is reached (Alrawas, 2002).

The results of normative calculations for the three plasters (Ahlia, Malej and Dental Stone) are shown in Table (1). These results are in good agreement with that obtained from peak heights, suggesting that the two methods are in support of each other and are fairly accurate.

In the case of the two types of juss, building and plastering juss, they consist of a mixture of anhydrite, bassanite and gypsum, with anhydrite being the dominant phase (Fig.2). Their content of (H_2O^+) is less than (6.2%), so that it is impossible to determine the relative proportions of bassanite and gypsum from (H_2O^+). The only way is to use a semi-

normative calculation. That is to use a value either for bassanite or gypsum, which has been worked out from peak heights, to calculate the value of the other phase.

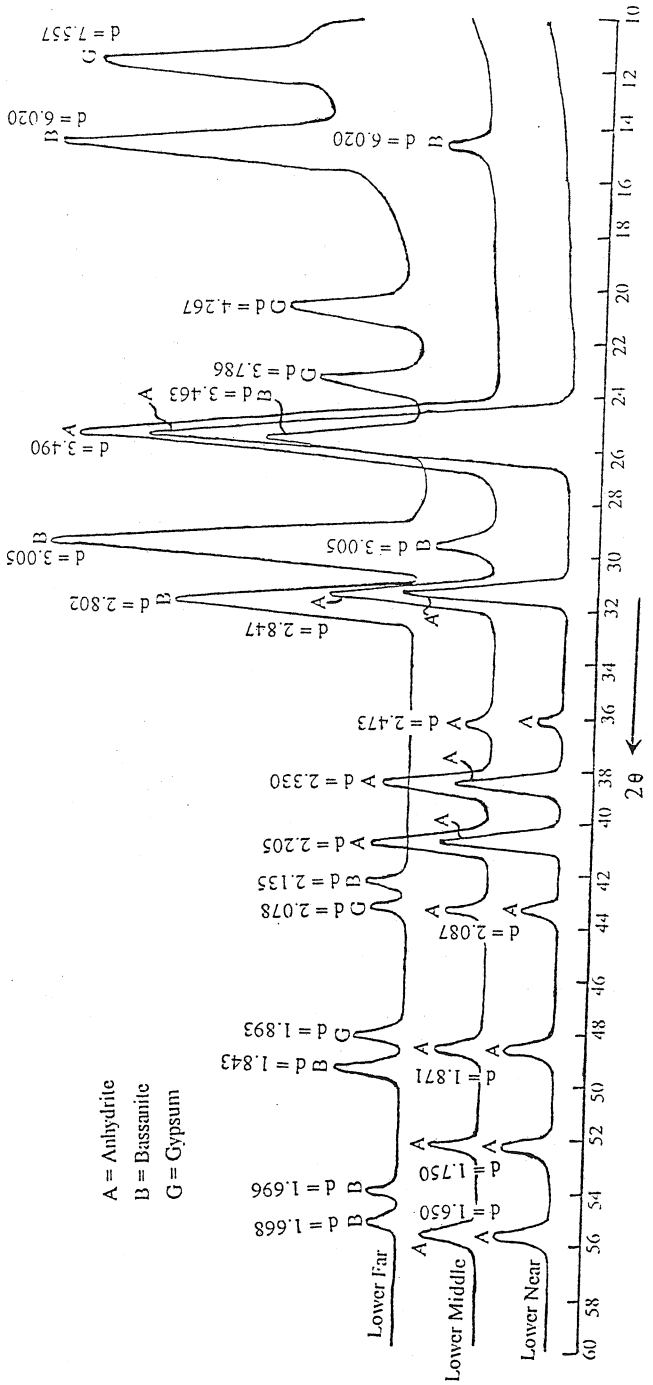

Fig.3: X-ray diffractograms for the raw material gypsum at different distances from the opening. Lower raw material at the lower part of the Koor.
Near, middle and far: raw material near (0-50 cm.), middle (~ 100 cm.) and far distances (~ 200 cm.) from fire openings respectively.

For example, in the case of plastering juss (P. J.), peak heights have given (Anhydrite 70%, bassanite 20% and gypsum 10%, table 1). If gypsum value is used, then it is possible to calculate the amount of bassanite (19.5%) from this value. If the value of the calculated phase is close to that deduced from peak heights, as the case with (P. J. and B. J.) then the method of peak heights is fairly accurate.

In the case of samples taken from different distances from fire source, those very near (0-50 cm) to fire openings (Lower Near and Upper Near, Fig.1 and Table 4) consist entirely of anhydrite (Table 2).

Samples at half-way (100 cm) and as far as (150 cm.) away from fire openings (Lower Middle and Upper Middle), consist mainly of anhydrite (about 93%) with some bassanite (7%). Bassanite, can be calculated by converting all (H_2O^+) content into bassanite (bassnite% = H_2O % x 16.129).

Samples near the top of gypsum cover, i.e. further from fire source and at a distance of about (200 cm) from fire openings (Lower Far and Upper Far, Fig.1 and Table 2) consist mainly of bassanite (73%) with minor amounts of gypsum (27%). Gypsum can be calculated by using the excess water for bassanite, i.e. the same method used for the technical plasters Ahlia and Malej and for Dental Stone (Table 1).

Table 2: Proportions of Calcium Sulphate Phases as a Function of Distance from Fire Openings (For Sample Locations See Figure 1).

Raw Material (Gypsum) Location	**Normative Calculations (%)**			**Peak Heights (%)**		
	Anhydrite	**Bassanite**	**Gypsum**	**Anhydrite**	**Bassanite**	**Gypsum**
Lower Far and Upper Far	0.0	72.5	27.5	0.0	64.4	30.6
Lower Middle and Upper Middle	92.7	7.3	0.0	91.8	8.2	0.0
Lower Near and Upper Near	100.0	0.0	0.0	100.0	0.0	0.0

Table 3: Average Chemical Compositions (%) of Technical Plasters (Ah and Ma). Dental Stone, Plastering Juss, Building Juss and Theoretical Bassanite (Alrawas, 2002).

Material	**CaO**	**SO_3**	**H_2O^+**	***I. R.**	**Total**
Ahlia	37.62	53.93	7.20	0.86	99.61
Malej	37.84	54.29	6.70	0.77	99.60
Dental Stone	38.30	55.07	6.40	0.0	99.83
Plastering Juss	39.41	56.52	3.30	0.38	99.61
Building Juss	38.47	54.40	4.80	2.10	99.77
Bassanite $CaSO_4.0.5H_2O$	38.64	55.16	6.20	0.0	100.00

* I. R. = Insoluble Residue.

Table 4: Average Chemical Compositions (%) of Calcined Gypsum, at Different Distance from Fire Openings. For Sample Location, See Figure 1. (Alrawas, 2002).

Raw Material (Gypsum) Location	**CaO**	**SO_3**	**H_2O^+**	***I. R.**	**Total**
Lower Far and Upper Far	36.79	52.55	10.30	0.0	99.64
Lower Middle and Upper Middle	40.60	58.60	0.45	0.0	99.65
Lower Near and Upper Near	41.05	58.68	0.0	0.0	99.73

* I. R. = Insoluble Residue.

DISCUSSION

Ahlia (Ah) and Malej (Ma) technical plasters are similar, not only in chemical composition (Table 3) but in petrography and mineralogy (Plate 2 and Fig.3). Ahlia contains more water (7.2%) than Malej (6.7%) and hence more gypsum (6.7%) than Malej (3.4%).

Dental stone has similar chemical composition (Table 3), petrography and mineralogy to the two technical plasters (Plate 3 and Fig.6). However, there are important difference in physical and mechanical properties (Alrawas, 2002, P. 50). H_2O^+ content of dental stone (6.40%, table 3) is very close to the theoretical (6.20) for bassanite. The excess (0.2%) H_2O^+ gives (1.4%) gypsum. This means that dental stone is almost pure bassanite.

The two types of juss, the building juss (B. J.) and plastering Juss (P. J.), both contain the three phases of calcium sulphates, anhydrite, bassanite and gypsum (Fig.3) ;anhydrite is the dominating phase, being (63 and 70%) in (B. J. and P. J.) respectively. Building Juss contains more water (4.8%) than plastering Juss (3.30%, Table 3.) and hence contains more gypsum (17%) compared with (10%) in plastering Juss. The amount of bassanite (20%) is the same in both types of Juss (Table 1).

Samples very near to the fire openings, whether at the lower (Lower Near) or at the upper part of the Koor, i.e. Upper Near (Fig.1 and Table 4) consist of (100%) anhydrite (Fig.3). This is of no surprise, since the measured flame temperature of fire source is around (1000 °C).

Considering that the required temperature for conversion of gypsum ($CaSO_4.2H_2O$) to bassanite ($CaSO_4.0.5H_2O$) is between (140 and 170 °C) and above 170 °C bassanite is converted to anhydrite. (Deer, et al., 1966, Kostov, 1968, Philips and Griffen, 1981). Because of the very high temperature of the Koor, the converted anhydrite, from gypsum persists but with decreasing proportions for a distance of at least (150 cm.) of the cover above the Koor (total distance is 200 cm.). Samples at about (100 cm.) from fire openings (midway), i.e. Lower Middle and Upper Middle, figure 1, consist of anhydrite (93%) and bassanite (7%) (Table 2).

On the other hand, samples from the top of the gypsum cover, i.e. at farthest distance from fire openings (Lower Far and Upper Far, Fig.2 and Table 4) consist of bassanite (73%) with minor amounts of gypsum ,7% (Table 2). Anhydrite has disappeared due to the increased thickness of the cover, causing a drop in temperature gradient.

CONCLUSIONS

Petrographical studies revealed that the technical plasters Ahlia and Malej, consist of monoclinic, dispersed, prismatic bassanite crystals, with ill-defined edges, of the type β-hemihydrate. On the other hand dental stone which also consists of monoclinic, prismatic bassanite crystals, but are more packed and with well defined edges of the type α-hemihydrate. Some crystals are pseudo-hexagonal.

X-ray diffraction studies proved that both technical plasters consist mainly of bassanite (> 90%) with small amounts (< 10%) of gypsum. Dental stone consists of about (99%) bassanite and only about (1%) gypsum.

The local Juss is a mechanical mixture of anhydrite (63-70%), bassanite (20%) and gypsum (10-17%). Initially, i.e. before mixing, the type of calcium sulphate phase produced

through the heating of gypsum cover of (200 cm.) depends on the distance of the raw material gypsum from fire openings. Due to the very high temperature of fire source, the transformed phase anhydrite, from gypsum persists for almost three quarters (150 cm.) of total thickness of the cover, followed by transformed bassanite, then lastly by untransformed gypsum as distance increases.

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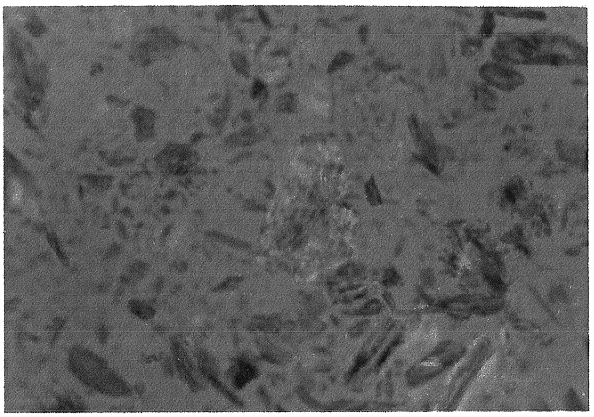

Plate 1

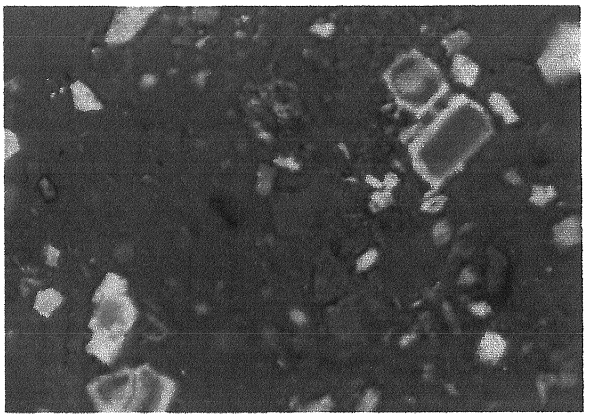

Plate 2

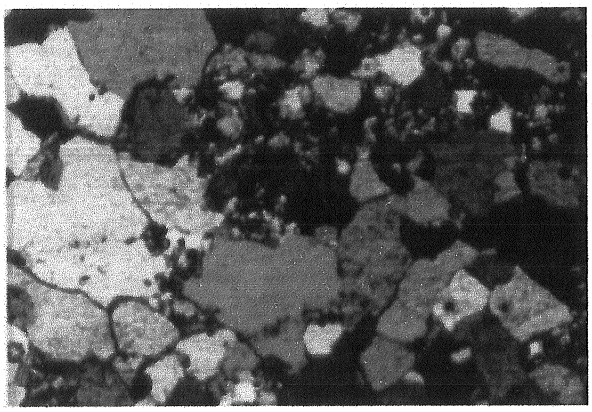

Plate 3

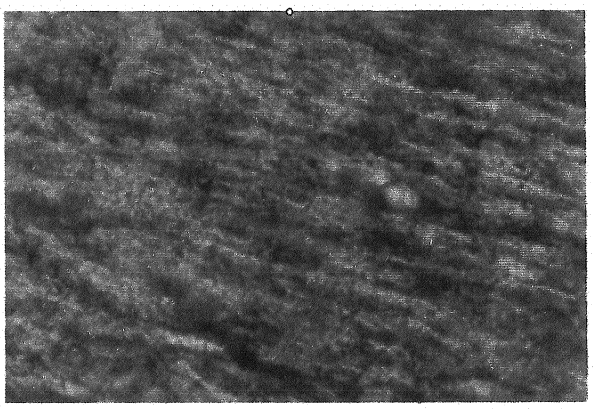

Plate 4

Plate (1). Technical plaster, monoclinic prismatic bassanite crystals, with ill-defined edges of the type β-hemihydrate, crossed polars (X 200).

Plate (2). Dental Stone, Monoclinic Prismatic Bassanite Crystals, with sharp edges of the type α hemihydrate. crossed polars (X 200).

Plate (3). Local Juss at Far Distance(~200 cm. , Lower Near) from fire openings, consisting of fine grained Bassanite as a matrix with large gypsum crystals. crossed polars (X100)

Plate (4). Local Juss at Near Distance(~0-50 cm. , Lower Near) from fire openings, consisting entirely of Bascillar Anhydrite. long slender Parallel to subparallel prismatic crystals. crossed polars (X 100).