Provenances and Lithologic Anal Ysis of Mosaic Roman Villas, Nortwestern Libya

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Abstract. *The mosaic of Romans villa pavements of Suq Al-Kadeem, Dar Buk-Ammera, Al-Khums Group villas and Nerids of NW Libya were studied geochemically, petrographically and statistically. XRD analysis results of mortar showed that quartz, calcite, and kaolinite were the cement forming minerals in these villas. X-Ray fluorescence analysis of tesserae, tesserae petrography, and cluster analysis identified that the source rocks of Al-Khums villas might be the south Terhona basalt cone rocks, and North Gharyan basalt flow rocks were the source for Nirds and Dar Buk-Ammera villas. Formation outcrops of Al-Khums limestone, Sidi as-Said, and Nalut were the source rocks for certain sedimentary tesserae. This would help in the conservation of damage pavements.*

Introduction

This study addresses the villas (Fig.1) of Nerids, Al-Khums group (Sidi Abd-ullah, Meheta Al-Tehlia, Suq-Al-Khamis [Observer of Leptis Archaeology,1978]), Dar Buk-Ammera, and Suq Al-Kadeem (Observer of Leptis Archaeology, 1976).

Nerids villa lies on the Mediterranean shoreline east of Tripoli (Oea) within the area of the eastern valley of Al-Ashar, specifically at the end of the 30th km. of Tripoli-Tajura-AlKhums high way (De Vita 1965). Beside the reworked archaeological investigations, this villa is characterized by multi pavements that are marked with special plant and geometrical ornamentations as well as a diagnosing mythological subjects; it was discovered in 1964 and was built in the 2nd century A.D. (Al-Nims 1967a, 1967b).

Located on the Mediterranean shoreline around Liptis Magna (Fig.1), the Al-Khums group villas include Sidi Abd ullah, Meheta Al-Tehlia and Suq-Al-Khamis. Some of them had not been previously studied because those were still under investigation.

Discovered in 1913 by Italian soldiers, and dates back to 98-117A.D., Dar Buk-Ammera villa lies northwest of Zliten city on the Mediterranean shoreline. It is believed to have been constructed during the Trajan period (Al-Nims,1990); and is characterized by nice fresco, plant and animal drawings, mythological objects, and daily life subjects (Al-Nims et. al.,1977).

Suq Al-Kadeem villa lies near Misuratah city adjacent to the Tripoli-Tajurah -- Al-Khums shoreline road; it was discovered in 1976 and characterized by its multi color tessellations that show high shape variety of plants, geometry and designs. This villa is believed to have been constructed in the 2nd century during the Marcus Aurelius period of 161-180A.D. (Observer of Leptis Archaeology, 1976).

The objective of this study is to identify the source rocks of igneous and sedimentary mo-

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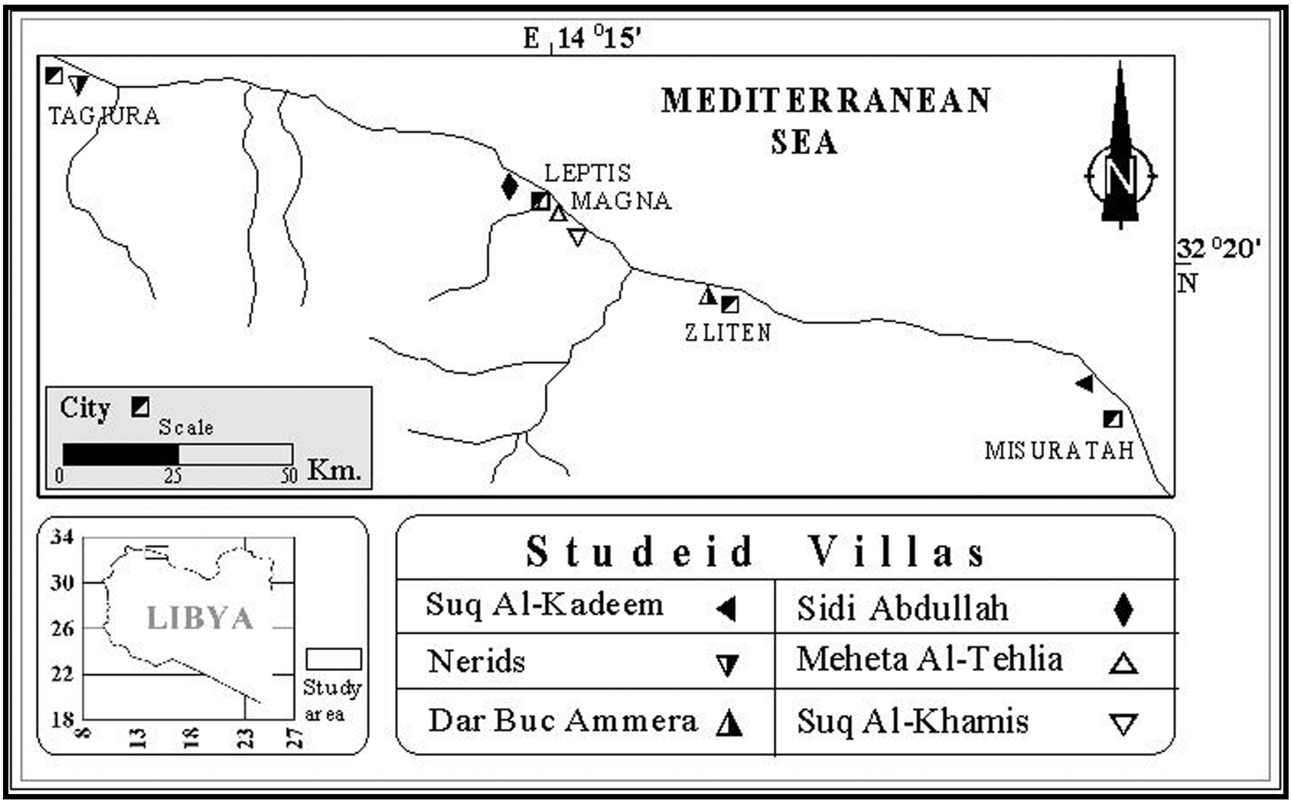

Fig. 1. Locality map of studied villas which spread along the Mediterranean shoreline; reflecting the north western part of Libya (as shown in the lower left part).

saic fragments as well as the source material of the used cement (mortar) in the mosaic structure zones rudus, nucleus, and pavement.

Methodology

In order to suggest the source rock for the studied igneous and sedimentary mosaic chips, a strong similarity (geological) criterion was established for comparison between mosaics and those related source rocks.

Thus 56 thin sections were prepared for petrographic study of carbonate (sedimentary) mosaic samples, and 34 selected slabs were classified with a Rock-Color Chart (munsell color chips). This could assist the study by suggesting the provenance.

X-ray diffraction analysis gave good assistant to estimate the minerals of cement (mortar)constituents. X-ray fluorescence analysis results of igneous, sedimentary and previously analyzed igneous samples had been processed statistically with Q-mode cluster analysis to recognize the type and provenance of used igneous rocks. Also, to classify the studied samples into sedimentary and igneous origin on the basis of R-mode cluster analysis elements controlling factors on sedimentary and igneous rock.

Geology Of Study Area

There are commonly two types of outcrops in the study area (NW Libya): mainly igneous and sedimentary. The igneous outcrops are limited to the vicinity of Gharyan city and Bin-Wlid as well as South Terhona. Most of the igneous outcrops are phonolite intrusion, basalt flow (olivine basalt) and basalt cone (olivine nephilinite).

The sedimentary rock around the study area includes four main formations (Fig.2):

1- Al-Khums Formation is appears on the eastern side of the study area and its outcrops decrease westward; these sediments, deposited during the Middle Miocene, are composed of limestone, algal limestone, calcilutite, calcarenite and clay.

2- Nalut Formation outcrops increase westward, and are limited to an area far a way from the coastline of the Mediterranean south of the study area. These are composed of limestone, dolomitic limestone with cherts band concretion and are Turonian deposits.

3- Sidi as-Said Formation outcrops increase westward and are exposed near the coastline of the Mediterranean. These sediments were Cenomanian deposits.

4- Gargaresh Formations extend specifically along the coastline of the Mediterranean sea and often occur as cliffs continuously attacked by sea tide. These are composed of cross laminated calcarenite used widely in the statumen zone of the mosaic structure.

Mortar Composition

Most representative samples are used to clarify constituents of theoretical mosaic sequence in the sites of the studied villas. These samples represent the available pavement nucleus and rudus. Nerids villa bears witness to the use of mortar constituents which are represented by quartz, calcite and kaolinite (the kaolinite belongs specifically to brick believed by

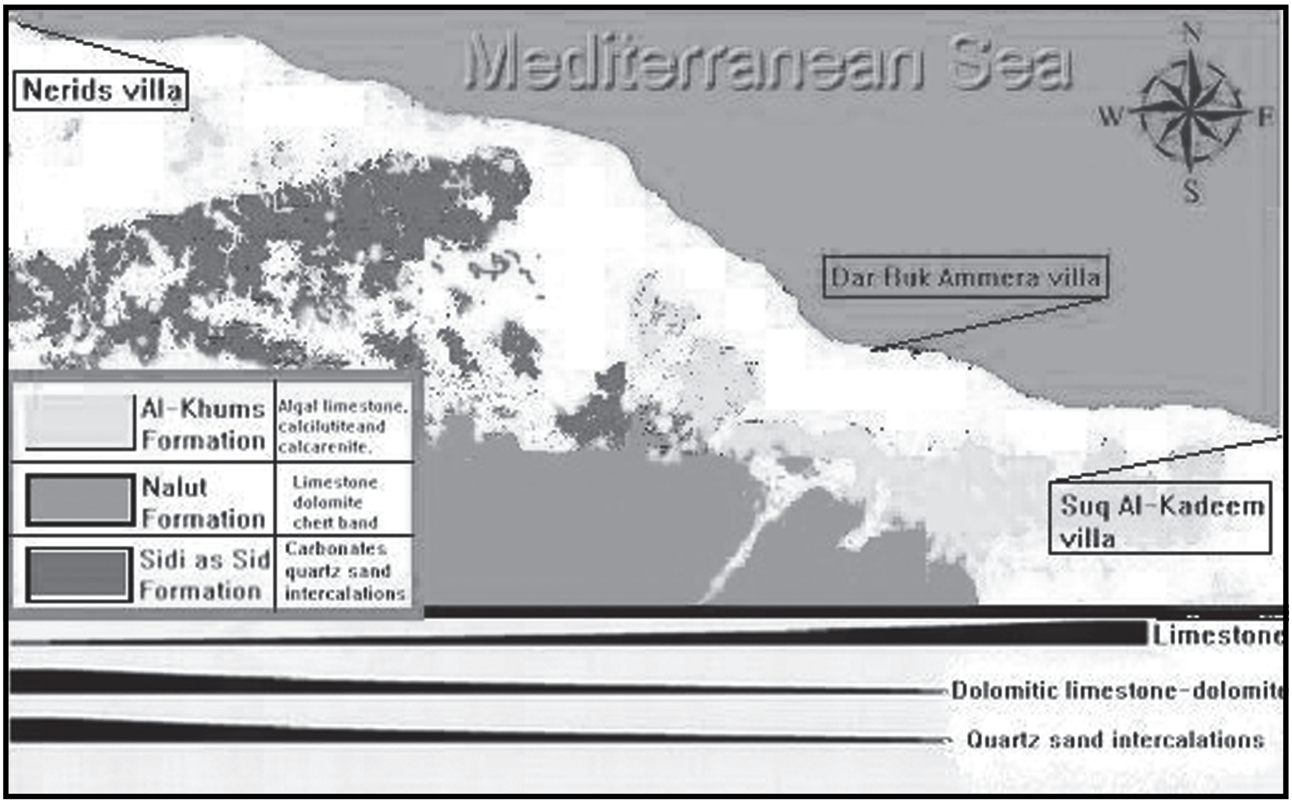

Fig. 2. Geologic map of the study area reflecting formation extent nature (modified after Mann, [1975]).

Frizot (1977) to be a hardening factor for mortar, that will be more active with time for both zones of theoretical mosaic structure nucleus (Fig. 3-I) and rudus (Fig. 3-II). The same was found in Suq Al-Kadeem villa (Fig. 3-VI, VII), but a little difference occurs in Dar Buk Ammera villa (Fig. 3-III, IV,V); namely, a hydromolysite minerals are present reflecting a side effect of chemical weathering activity (Yaouz Zeinel, 2002; personal contact). However, the absence of kaolinite in villa Dar Buk-Ammera zone is expected due to the sampling process which neglects brick fragments in identifying mortar composition without the effect of brick fragments composition.

Mortar and tesserae provenances:

A given relationship was shown between exposed local rocks (around villas) and the materials of mosaic structure (tesserae and mortar). The X-ray fluorescence analysis results for mortar (Table 1) prove that it is made from local sedimentary rock rather than from marble (which might serve as a source material for cement formation [Al-Nims, Mahmoud 2003; personal communication]). The distribution trend of XRF analysis results (concerning SiO2, MgO, and CaO) matched with the same elements of estimated geological exposed rock criteria (Fig.2) around the villas, presenting a strong similarity between them (Fig.4).

A specific relationship was also formed between local sedimentary rock and analyzed sedimentary tesserae (Table 2), showing high coincidence between them. The same distribution trend was shown between tesserae oxides (Fig. 4) and interpreted lithological distribution of nearby sedimentary types. The comparison results of mortar and tesserae demonstrate the usage of local rocks around the studied villas.

Q and R-mode cluster analysis assists in classifying tesserae into place related samples (Fig. 5a) and also illustrates how Q-mode (places related samples) are clustered according to certain oxides (R-mode cluster analysis [Fig. 5b]). Q-mode has shown two main clustered groups, igneous and sedimentary. The igneous group includes the previous (Mann 1975) and present study samples which cluster together by a very high similarity level as TAJ-3 and PAM-23 tesserae linked with v16 (Wadi Guasem is composed of basalt flow [Olivine Basalt]). In other words, the igneous tesserae have been taken from Wadi Guasem (Fig. 6a). Another important link was found between KHUMS18 and v18 which is a sign that it has been taken from the coded place part 18 (Fig. 6b) south of Terhona, which is composed of olivine nephelinite (Basalt cones and stratovolcano).

The floating of plankton in wackstone limestone facies within the second one (Fig. 7b) shows that Al-Khums Formation rock outcrops were the provenance.

Three thin sections represent the most sedimentary type of tesserae within Dar Buk Ammera (Fig. 7-c, d, e); all indicate that Al-Khums limestone Formation outcrops served as a source rock for them, due to its petrographical characteristics of mullasca shells, pellets, plant rootlets, algae, and spicules.

The other three thin sections of Al-Khums group villas tesserae point to two provenances: Al-Khums Formation rocks outcrops for the first thin section, characterized by plant rootlets and spicules (Fig. 7f), and the same provenance also is suggested for pelletal fossiliferous (Forams and Algae) limestone (Fig. 7g); the second provenance was Sidi as-Said Formation rocks, characterized by dolostone face-

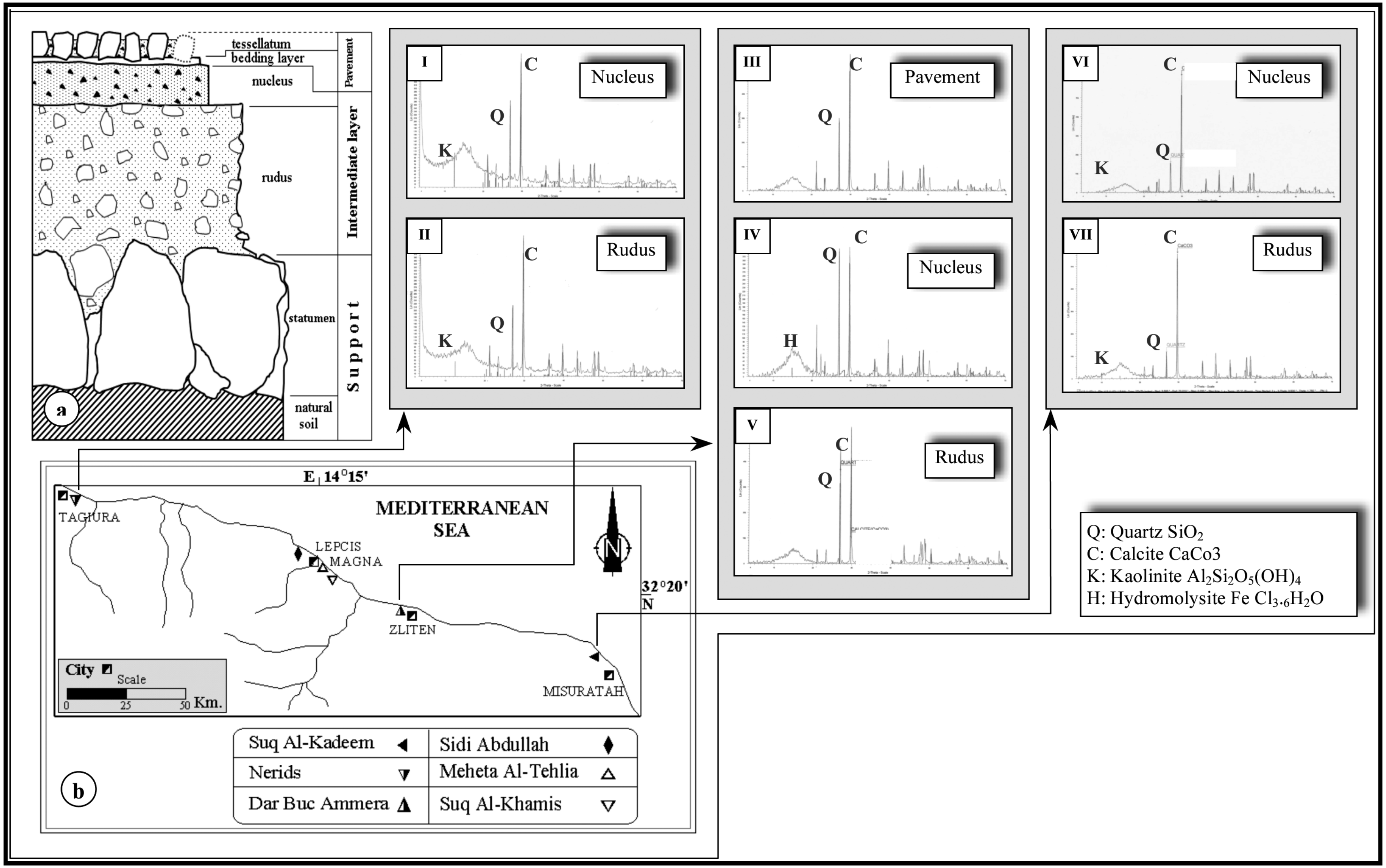

Fig. 3. X-ray diffraction analysis(XRD) of selected samples I-VII from available and exposed zone of mosaic structure (a. Theoretical structure of a mosaic [Bassier 1977]; b. Location map of studied villas: Nerids, Suq Al-Kadeem , and Dar Buk-Ammera). XRD analysis results of samples I-VII which was selected from the studied villas as shown in (b) showed that cementing material (mortar) composition was formed from quartz, kaolinite, and calcite. Hydromolysite is formed due to chemical weathering and is thus neglected as cement forming mineral.

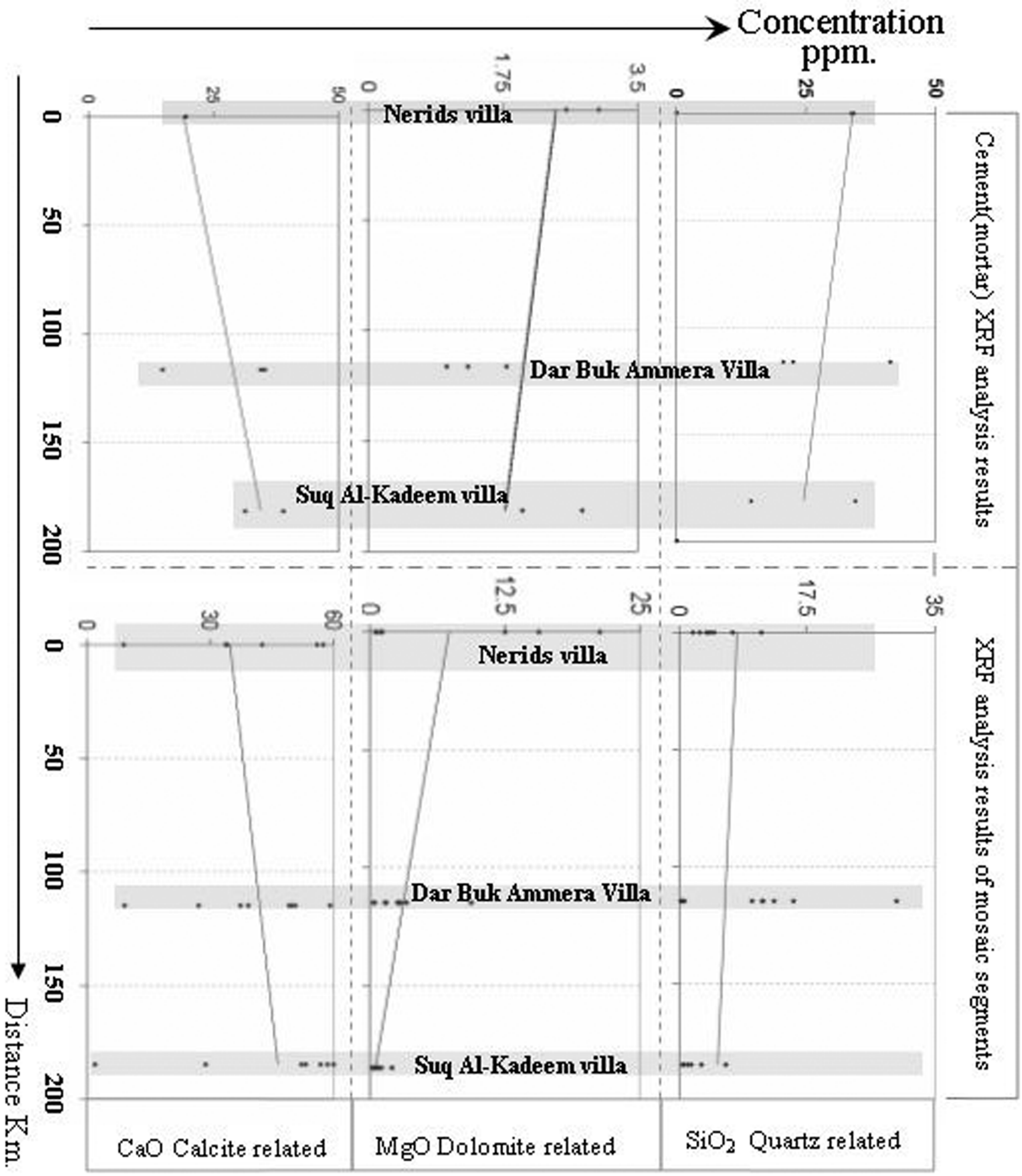

Fig. 4. Distribution of oxides constituents (CaO, MgO, and SiO2) of mortar and tesserae along selected studied shoreline villas, East-West trend.

Key	Villa Name	Mortar Zone	MgO	Al_2O_3	SiO_2	CaO	Fe_2O_3
◀	Suq Al-Kadeem	Nucleus	2	0	14.42	39	0.4
		Rudus	2.78	9.72	34.44	31.34	0.48
▲	Dar Buk Ammera	Pavement	1.02	1.21	22.44	35.19	0.36
		Nucleus	1.79	24.51	41.2	14.74	9.77
		Rudus	1.29	0.12	20.57	34.49	0.24
▼	Nerids	Nucleus	2.57	12.46	34.2	19.45	8.03
		Rudus	3	0	33.71	19.31	5.68

Table 1. XRF analysis results (in ppm.) of cement selected from different mosaic structure zones including rudus, nucleus and pavements.

is of Ain Tobi Member (Fig. 7I).

Conclusion

The Roman used limestone, quartz, and kaolinite to make the mortar of pavement (tessellatum and bedding layer), nucleus and rudus that construct villa mosaic sequence. Mortar materials were selected from the local rocks which were exposed near and around the villas. The mortar has the same constituents in each studied villa and within every mosaic structure zone.

Lithologic similarity between sedimentary tesserae and sedimentary outcrops indicates that Romans, in their villas' construction, depended mainly on the nearby hard rock materials. In the Nirds villa the Romans extensively used tesserae from Sidi as-Said Formation rocks and Nalut Formation rocks. In Dar Buk Ammera villa they mainly used the sedimentary tesserae selected from Al-Khums Formation rocks. Al-Khums group villas seems to have two provenances represented by Al-Khums and Sidi as-Said Formations (Ain Tobi dolomite Member).

Cluster analysis for XRF results clarifies Wadi Guasem (northeast of Gharyan) as the provenance for Suq Al-Kadeem and Dar Buk Ammera igneous tesserae, which were composed of olivine basalt (Basalt flow); South Terhona (around 100 km. to the south) also serves as a source rock for Al-Khums group villas' igneous tesserae which were composed of the olivine nephilinite type (Basalt cones and stratovolcano).

Identifying the geological criteria and provenance for every tesserae type strongly helps in repairing broken or loose tesserae by implementing a fresh one that contains quite similar lithological and petrogaphical criteria.

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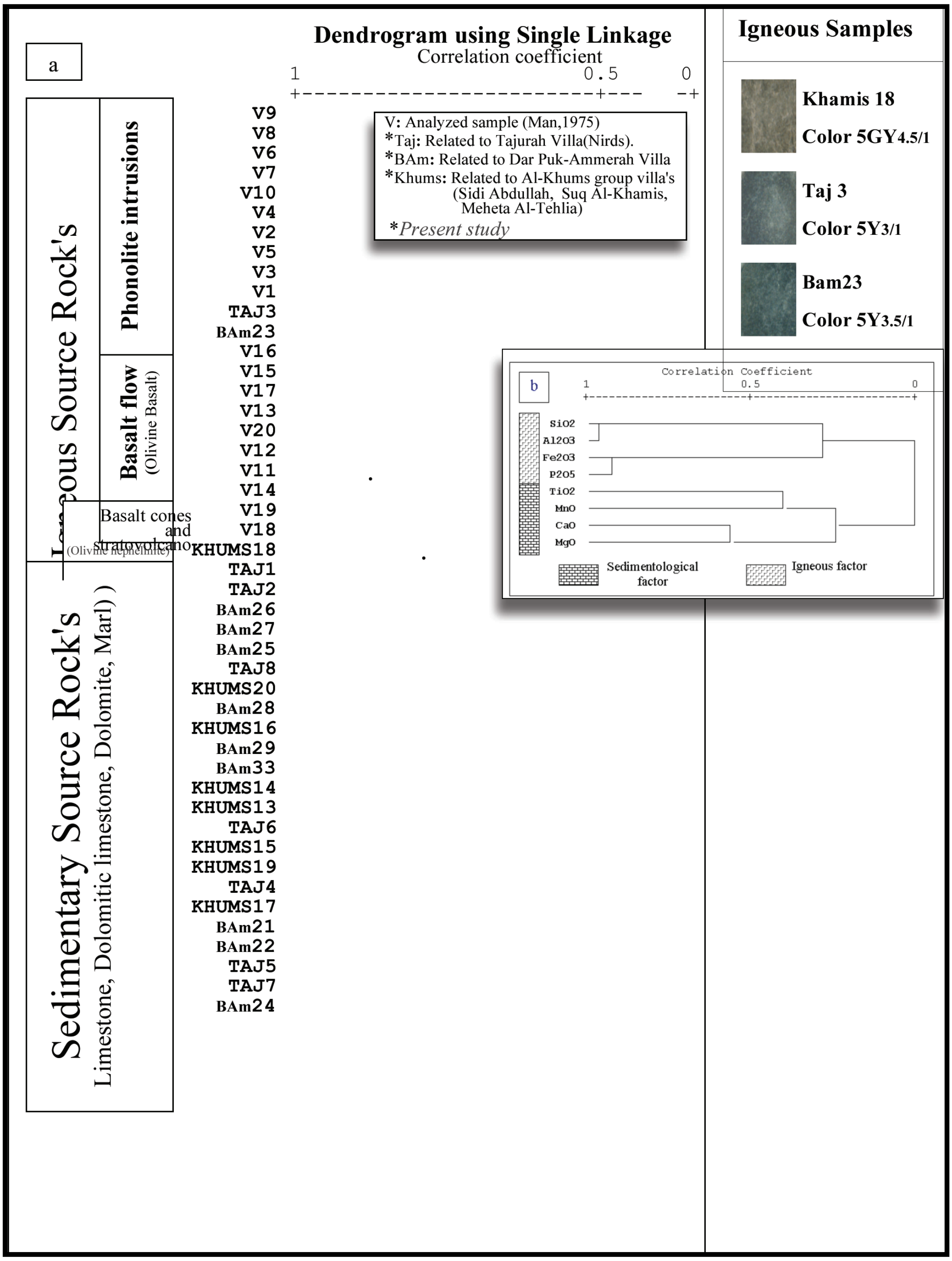

Fig. 5. Cluster analysis of mosaic tesserae, selected from studied villas (mosaic selecting, reflect most related rock types used to create mythological subjects of 2nd and 3rd AD period). The dendogram of letters V1-20 reflect previous analyzed igneous samples picked by Mann (1975) from surrounding igneous rocks outcrops; a. Q-mode cluster analysis of previous and present studied samples, classifying mosaic tesserae into its source rocks. b. R-mode cluster analysis of oxides; it refers to source rock (controlling factors were the SiO_2, Al_2O_3, Fe_2O_3, and P_2O_5 as igneous factor; but the TiO_2, MnO, CaO, and MgO reflect sedimentary factor).

Oxides	Taj1	Taj2	Taj3	Taj4	Taj5	Taj6	Taj7	Taj8	Khamis13	Khamis14	Khamis15	Khamis16	Khamis17	Khamis18	Khamis19	Khamis20
SiO_2	12.273	6.896	58.810	10.694	4.598	7.547	2.398	17.150	4.929	2.614	13.158	0.819	3.475	56.472	13.200	0.920
Al_2O_3	1.593	0.708	17.801	1.656	1.016	0.860	0.367	2.663	1.125	0.609	2.207	-	0.148	16.453	0.783	0.061
Fe_2O_3	2.931	1.553	5.103	1.455	1.598	0.704	20.885	2.625	0.550	1.061	1.202	0.016	1.332	14.292	1.827	0.166
TiO_2	0.045	0.013	1.188	0.096	0.038	0.029	-	0.072	0.039	-	0.088	-	-	0.159	0.041	-
CaO	57.021	55.741	11.276	84.285	71.659	89.286	75.598	75.612	92.004	94.272	82.098	98.736	88.645	2.715	82.336	98.236
MgO	26.038	35.049	5.696	1.717	21.014	1.517	0.692	1.715	1.311	1.358	1.164	0.404	6.305	8.402	1.652	0.598
MnO	0.058	6.896	0.125	0.062	0.077	0.042	0.046	0.078	0.026	0.050	0.025	0.012	0.042	0.050	0.110	0.019
P_2O_5	0.040	_	58.810	0.035	4.598	0.015	0.014	0.085	0.018	0.037	0.058	0.013	0.053	1.457	0.052	0.920

Oxides	BAm21	BAm22	BAm 23	BAm24	BAm25	BAm26	BAm27	BAm28	BAm29	BAm33	V1	V2	V3	V4	V5	V6
SiO_2	20.067	18.456	54.500	39.142	17.320	17.411	15.305	1.104	0.302	0.499	68.067	67.082	68.503	68.622	72.511	66.337
Al_2O_3	1.739	5.268	20.376	12.303	0.712	0.692	0.851	0.121	-	-	25.717	26.970	24.400	25.575	22.800	26.564
Fe_2O_3	2.616	3.994	9.456	8.037	1.477	1.090	1.809	0.121	0.016	0.034	2.868	3.210	3.449	3.369	2.557	3.867
TiO_2	0.147	26.169	0.606	0.494	-	0.040	0.046	-	-	-	0.360	0.378	0.496	0.418	0.283	0.326
CaO	60.697	43.918	10.248	35.753	73.770	76.488	77.422	98.050	98.946	96.979	1.380	1.708	1.912	1.340	1.249	2.115
MgO	14.502	1.829	3.749	3.437	6.546	4.154	4.353	0.573	0.690	2.479	0.300	0.305	0.932	0.357	0.365	0.399
MnO	0.147	0.085	0.167	0.160	0.095	0.068	0.105	0.031	0.010	-	0.192	0.195	0.182	0.197	0.189	0.218
P_2O_5	0.085	0.280	0.897	0.672	0.080	0.057	0.107	-	0.037	0.499	1.116	0.151	0.126	0.123	0.047	0.174

Oxides	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20
SiO_2	67.344	69.700	70.448	70.041	49.614	49.456	50.879	45.641	57.857	57.844	59.315	45.990	45.079	50.593
Al_2O_3	27.211	24.581	24.615	24.849	15.073	15.180	14.339	13.549	17.111	17.337	17.041	14.650	13.598	14.893
Fe_2O_3	3.083	3.374	2.827	2.992	13.995	12.611	12.615	14.610	3.443	4.427	2.460	14.531	15.703	12.799
TiO_2	0.301	0.422	0.000	0.234	2.575	2.084	2.039	2.894	1.722	1.925	2.071	4.135	4.231	2.052
CaO	1.354	1.312	1.735	1.157	10.655	10.390	10.207	12.648	12.295	10.847	10.863	12.588	11.591	10.007
MgO	0.313	0.316	0.206	0.259	7.122	9.411	8.988	9.390	7.049	6.997	7.662	6.696	8.558	8.727
MnO	0.263	0.211	0.133	0.345	0.172	0.189	0.189	0.204	0.128	0.173	0.200	0.228	0.237	0.180
P_2O_5	0.130	0.084	0.036	0.123	0.793	0.678	0.744	1.064	0.395	0.450	0.388	1.183	1.004	0.749

Table 2. X-ray fluorescence analysis (in ppm.) of sedimentary and igneous mosaic tesserae (picked from the studied Villas), as well as the previous X-ray fluorescence of Mann (1975) igneous rock samples (%).

Identifying provenance of sedimentary clustered group need color coding with Munsell color chart. This was made for each segment, converted to thin section for petrographic study under binocular microscope, Representative slides selected for each studied villa, two of them were for Nifids villa composed of sandstone (Fig.07a). These was picked from outcrops of Sidi as Said rocks formation which lithologically characterized by sandstone intercalation contents.

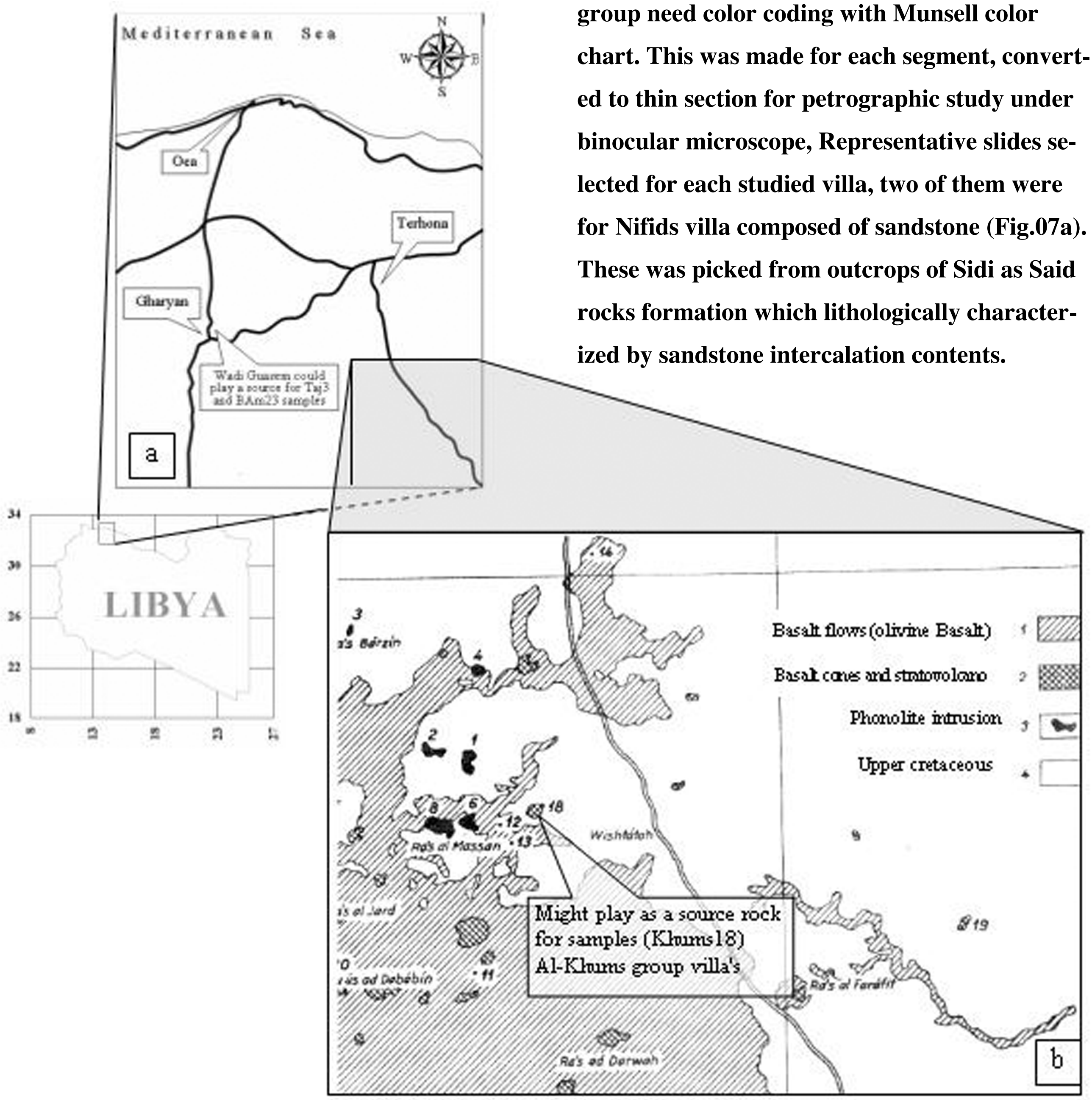

Fig. 6: Prediction of mosaic source rocks (igneous) place interpreted from cluster analysis results; a. Showing the source area of Taj 3 (Suq Al-Kadeem) and sample Bam23 (Dar Buk-Ammer) might be selected from Wadi Guasem,b. The suggested source rock area for mosaic sample Khums18 (Khums group villa's) might be selected from basalt cone which belong to the Terhona southern part that coded as valley18.

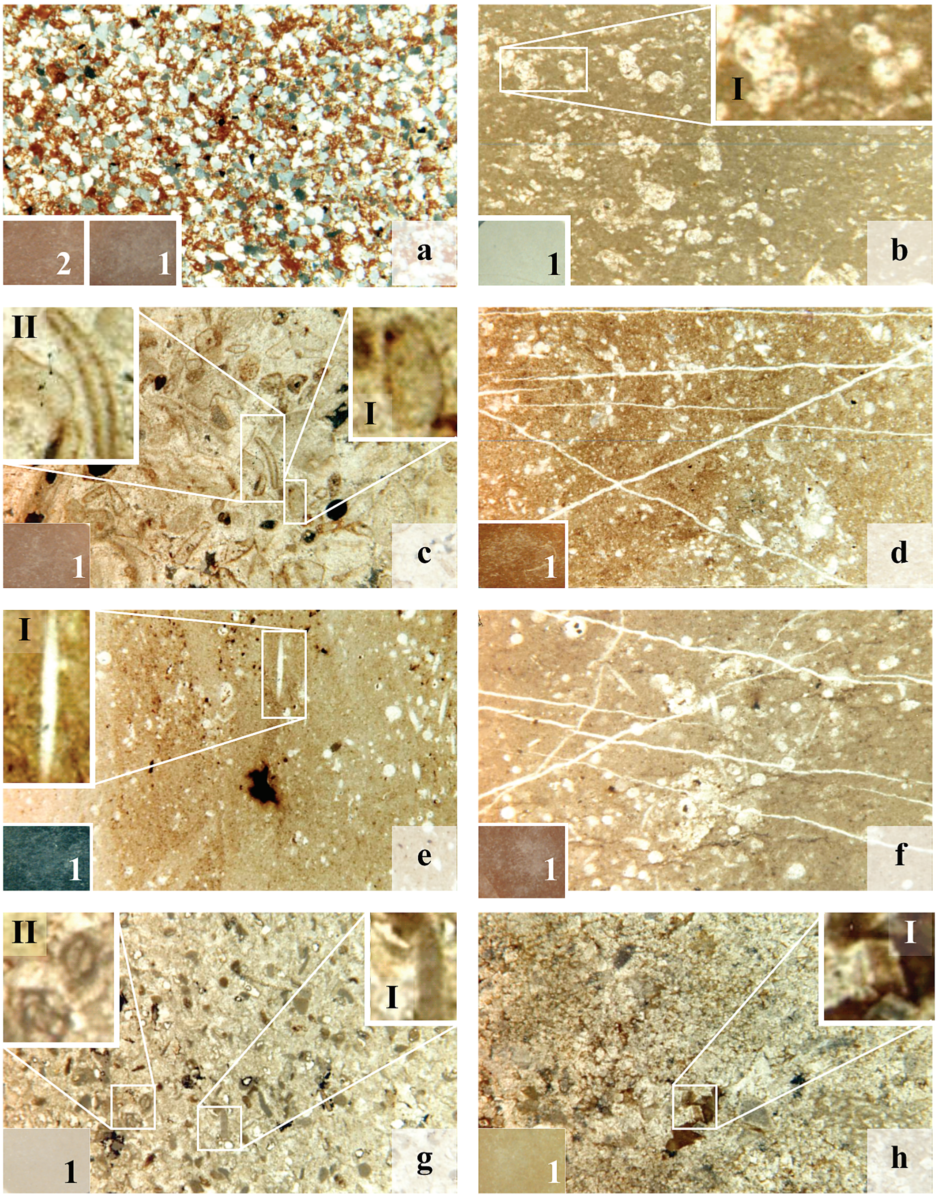

Fig. 7. Selected mosaic thin sections (a, b samples from Nerids Villa; c, d, e from Dar Buk Ammera Villa; and f, g, h from Al-Khums group villas) were picked from the studied villas, a. Sandstone with iron oxide cement showing red color which is coded according to Munsell color chips (rock color chart) as 10R4.5/6 for mosaic segment (a.1) and 5YR4.5/4 for segment (a.2); this thin section might refer to quartz sand intercalations of Sidi as-Said Formation rock (X32). b. Wackestone with planktonic forams component strongly reflects Nalut Formation rock than Al-Khums Formation (because it is scarcely found in the last one) showing color coded 5Y8.5/1 for (b1) (X40). c. Packstone facies including mullasca shells (c.II), pellets (c.I), and recrystallization effect, color coded as 10R3.5/4 for (c.1); these features indicate Al-Khums limestone Formation as a source rock (X20). d. Wackestone facies with plant rootlets as well as some silt size sand with rare spicules, color coded as 5YR4.5/4 for (d.1); this is strongly similar to the lower part of Al-Khums Formation rock (X20). e. Wackestone facies with spicules (e.I) floating within micrite matrix, color coded as 5Y3.5/1 for (e.1), Al-Khums rock Formation is suggested to be a source rock for this sample. f. is the same as d but with abundant spicules and less silt size sand, color coded as 5YR5.5/6 for (f.1), this refers to Al-Khums Formation rock too (X25). g. Packstone facies include pellets, algae (gI), forams (QuniqueloculinaSp. [gII]), color coded as 10YR7.5/2 for (g.1), this indicates that Al-Khums Formation rock serves as a source rock for this sample (X20). h. Dolostone facies shows euhedral dolomite crystals (h.I), subhedral crystal, and anhedral dolomite crystals; color coded as 10R4.5/6 for (h.1), these characteristics identify Sidi as-Said Formation rock as the source rock for this sample (X32).

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ملخص: دُرست أرضيات فسيفساء دارّات السوق القديم، ودار بوك عميرة، ومجموعة الخمس والنيريدات الرومانية الواقعة في شمالي غرب ليبيا، جيوكيميائياً وصخرياً وإحصائياً. أظهرت تحليلات حيود الأشعة السينية (XRD)، أن ملاط أرضيات الفسيفساء مكون من معادن الكوارتز والكالسايت والكؤولينيت. بينما بينت دراسات نتائج تحليلات الأشعة السينية الوميضية (XRF) والتركيب الصخري والتحليل العنقودي، أن مصادر قطع الفسيفساء النارية لدارّات الخمس، جلبت من صخور مخاريط، جنوبي ترهونة البازلتية البركانية، في حين أن صخور الجريان البازلتي لشمال غريان، هي مصدر قطع الفسيفساء النارية، لدارّات النيريدات ودار بوك عميرة. كما لعبت مكاشف تكاوين الخمس الجيري وسيدي الصيد والنالوت الصخرية، كمصادر لقطع الفسيفساء الرسوبية؛ الأمر الذي سيساعد على صيانة أرضيات الدارّات المتضررة.

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