

Neutron activation analysis of pottery samples from Abila of the Decapolis

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Instrumental neutron activation analyses have been performed on samples of pottery from Abila of the Decapolis (northern Jordan) ranging in age from Early Bronze to Islamic (Abassid). Preliminary results suggest several groupings of samples from each of twelve major archaeological periods, implying a common source of raw materials for ceramic manufacture at Abila for specimens within each grouping, and different sources of raw materials for specimens from different groupings.

Background

Approximately 30–40 samples of pottery from each major archaeological period ranging from Early Bronze to Islamic (Abassid) were collected from the Abila of the Decapolis archaeological site during the summers of 1992, '94, '96, and '98. Abila is located in northern Jordan, approximately fifteen kilometers north-northeast of the city of Irbid and five kilometers south of the Yarmouk River (Fig. 1).

The samples were collected with the intention to submit them for instrumental neutron activation analysis (INAA) to measure trace element concentrations, in the expectation that differences in the clay used for ceramic manufacture during different archaeological periods at Abila would be expressed in differences in trace element patterns in those samples. If that expectation were to be realized, it might be possible to identify sources of clay used for ceramic manufacture during those time periods by similarities in chemical compositions, or at least to eliminate those deposits of clay that differ from the pottery samples in chemical composition as possible sources of raw materials for ceramic manufacture at Abila during those archaeological periods.

This is a preliminary report of the results of INAA of some of those samples.

Experimental

Two or three samples from each of the archaeological periods of interest have been analyzed. Some of these analyses were performed at the Ford Reactor of the Phoenix Laboratory at the University of Michigan, and the remainder were performed at the University of Missouri Research Reactor (MURR), following procedures used at most other laboratories.^{1–3}

The results of INAA from the University of Michigan were integrated with those from the University

of Missouri for preliminary statistical analysis of the data. The goal of the statistical analysis is to recognize compositionally homogeneous groups within the analytical database. Whether a group is discriminated easily from other groups can be evaluated visually in two dimensions or statistically in multiple dimensions. Based on the “provenance postulate,” such distinguishable groups are assumed to consist of the manufactured products using clays from geographically restricted sources or source zones. The location of sources or source zones may be inferred by comparing the composition of unknown groups to that of known sources of raw materials. The results of the analyses are given in Table 1.

Results and discussion

The small number of samples from each archaeological period severely limited the scope of statistical analyses that could be performed meaningfully,^{4–6} and consequently the results reported here are tentative.

Some groupings of samples from different archaeological periods are suggested by the bivariate plot of hafnium and lanthanum, as shown in Fig. 2.

Group A consists of specimens of Terra Sigillata, a well-known style found throughout the Mediterranean region, and the chemical composition found in this study is consistent with that of similar ware found in the Eastern Mediterranean region.⁷ Group C includes Umayyad gray and Umayyad painted specimens; Group D includes Early and Late Byzantine specimens; Group E includes Early and Late Roman specimens. Group B might suggest a continuum of more diverse ceramics from Early Bronze, Middle Bronze and Abassid ceramics. Because of the small number of samples, no estimates could be made of the probabilities of inclusion of the samples in these groupings, and the dashed lines are suggestive only.

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Several clay samples were also analyzed. Most of these were collected as surface samples from various locations within the Abila excavation site. One sample from a pit at Al Fihas, just west of Amman, Jordan was analyzed; this clay is used for ceramic manufacture in modern times. The compositions of these clay samples, designated as "CM0xx," are shown along with those of pottery samples on the bivariate plot in Fig. 3.

A few of the clays are depleted in many elements, including both lanthanum and hafnium. Others are scattered among the pottery samples on the bivariate plot. The clay from Al Fihas (CM002) lies within the grouping of Early and Late Byzantine specimens. These

results suggest the possibility of some groupings of ceramics at Abila by archaeological period, with the implication of similar sources of raw materials within such groupings and different sources of raw materials for different groupings. The small number of samples analyzed prohibits definitive conclusions as to this suggestion. No complementary mineralogical studies have been done to examine the ceramic recipe(s) and types of paste and tempers making up the pottery.

Additional INAA analyses and other studies of the Abila samples are needed to provide more meaningful statistical data analysis and to confirm the groupings suggested by this study.

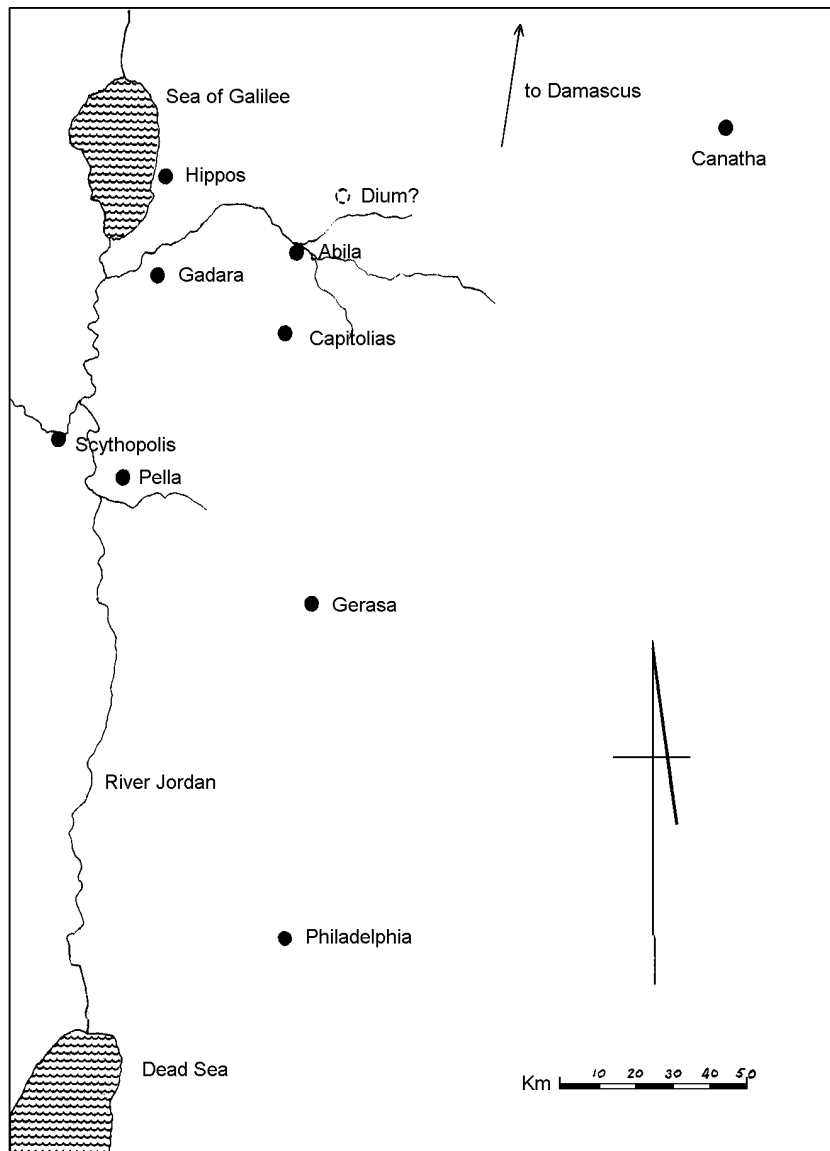


Fig. 1. Map of the Decapolis region

Table 1. Results of analyses of pottery and clay samples from Abila by INAA

Period	ID	As	La	Lu	Nd	Sm	U
Iron-1	A-II-3	13.6023	23.2496	0.2601	18.2051	3.9238	2.3625
Clay	CM002	6.1183	74.5276	0.6570	63.7409	12.9800	3.3847
Late Byzantine	A-LZ-11	3.6061	63.0143	0.6346	40.9070	7.6335	15.2562
Late Roman	A-LR-27	4.2473	51.3121	0.7933	42.6796	9.2520	12.3974
Clay	CM005	4.1411	11.8368	0.1865	11.9147	2.2007	2.5730
Umayyed Gray	A-UG-27	1.8329	48.0298	0.6579	39.9044	8.1650	3.6480
Early Roman	A-ER-3A	5.2769	36.3099	0.4244	34.0460	6.5180	3.2404
Clay	CM008	19.9810	47.6099	0.5920	43.1654	8.3110	3.4696
Hellinistic White	A-HW-7	3.7783	47.4640	0.7250	39.1349	8.3449	12.8188
Early Bronze	A-EB-4	6.0366	24.7865	0.3727	23.6775	4.6868	3.0283
Clay	CM011	4.2030	8.8426	0.1461	7.1219	1.6712	2.2709
Early Bronze	A-EB-2	4.8882	20.5038	0.2407	19.5337	4.1747	3.3958
Early Roman	A-ER-2	6.6830	49.5234	0.7435	40.7278	8.9515	10.0235
Clay	CM014	3.5461	16.0535	0.2469	17.1071	4.1207	0.0000
Umayyed Painted	A-UP-38	2.8155	47.6216	0.5373	34.1166	6.3669	5.0512
Terra Sigillata	A-TS-7	4.7390	20.2707	0.2875	18.2427	4.0493	1.8141
Late Byzantine	A-LZ-7	9.8589	66.4365	0.5984	55.4237	11.6629	4.9004
Middle Bronze	A-MB-3	4.7172	37.5697	0.4563	30.3409	5.6950	3.7290
Clay	CM019	8.7129	43.5144	0.6951	40.8228	8.0948	3.9953
Abassid	A-AB-4	8.3400	25.9755	0.4076	24.8963	5.4410	2.2056
Middle Bronze	A-MB-2	7.0813	27.7229	0.3638	25.7130	5.5119	3.4396
Umayyed Gray	A-UG-10	26.0573	46.0154	0.5411	42.5097	8.2790	5.6186
Early Byzantine	A-EZ-8	7.6691	72.4140	0.7267	64.7050	13.3463	4.1205
Abassid	A-AB-1	6.3693	30.9020	0.3891	22.3228	6.1889	3.7896
Abassid	A-AB-2	4.3183	42.1912	0.6975	37.2515	6.5299	10.0975
Early Bronze	A-EB-1	7.0878	33.3696	0.4198	31.2982	6.7000	2.0442
Early Roman	A-ER-1	9.2452	47.5237	0.8724	40.4543	7.3284	16.0688
Early Byzantine	A-EZ-1	8.8312	68.2303	0.5452	60.8347	11.1796	3.8465
Hellinistic White	A-HW-1	7.2068	41.2374	0.7236	37.6112	6.4531	10.8122
Hellinistic White	A-HW-4	10.8316	22.7757	0.2897	10.0486	4.4816	1.4437
Iron-1	A-II-1	5.7633	45.2254	0.6661	36.2837	7.5178	6.5063
Late Roman	A-LR-1	2.4791	55.2782	0.4982	50.5230	8.7288	2.9187
Late Roman	A-LR-27	6.5645	49.7459	0.7597	39.9728	8.2611	9.3032
Middle Bronze	A-MB-1	7.7551	36.5062	0.4741	38.4746	7.3318	2.9221
Terra Sigillata	A-TS-1	6.3809	19.6687	0.3026	12.5134	4.0110	1.6626
Terra Sigillata	A-TS-2	7.5688	20.6925	0.2788	19.6423	4.1696	1.6745
Umayyed Gray	A-UG-3	6.3928	48.0120	0.5463	53.7503	8.8291	3.1797
Umayyed Painted	A-UP-1	6.0559	38.6706	0.5285	29.5419	5.7440	5.0542
Umayyed Painted	A-UP-6	5.3351	44.3546	0.4773	35.2862	6.1590	3.3926
Clay	CM043	5.8648	26.6751	0.3497	22.6219	4.9679	2.5220
Clay	CM044	2.7177	5.6258	0.1225	2.6349	0.8331	2.3446
Early Roman	A-ER-2	5.9413	49.6018	0.7631	47.0291	8.2180	10.0704
Clay	CMO46	4.2804	26.9172	0.3859	23.6622	5.1490	0.0000

Table 1. Continued.

Period	ID	Yb	Ce	Co	Cr	Cs	Eu
Iron-1	A-II-3	1.7075	43.8862	21.4972	250.5014	6.2912	0.8640
Clay	CM002	4.9091	144.4847	24.0749	189.5444	3.8855	3.1364
Late Byzantine	A-LZ-11	4.5181	110.4199	13.0180	85.5723	4.7028	1.4073
Late Roman	A-LR-27	5.4680	70.8050	15.7780	220.0696	2.4744	2.0644
Clay	CM005	1.2995	19.2660	5.7789	83.9189	0.6107	0.4753
Umayyad Gray	A-UG-27	4.2926	101.7518	15.3181	111.0918	3.5539	1.7552
Early Roman	A-ER-3A	2.7129	75.0222	22.6857	140.3371	7.8123	1.3111
Clay	CM008	4.0232	102.8927	21.4336	84.8781	9.8116	1.5056
Hellenistic White	A-HW-7	4.7992	59.2268	13.2727	173.4191	1.3349	1.7924
Early Bronze	A-EB-4	2.3307	46.1308	13.0017	105.3186	0.8700	1.0255
Clay	CM011	1.0128	13.4741	4.1303	69.8236	0.4492	0.3442
Early Bronze	A-EB-2	1.6656	39.0681	16.7678	116.8582	1.4879	0.9477
Early Roman	A-ER-2	4.9427	69.8955	16.3989	236.1958	2.6503	1.9527
Clay	CM014	1.7020	30.1630	33.0608	175.7466	0.6711	1.2923
Umayyad Painted	A-UP-38	3.8742	86.4168	7.0485	81.6022	3.1252	1.3160
Terra Sigillata	A-TS-7	2.0770	39.5821	27.8517	314.2084	4.9955	0.9564
Late Byzantine	A-LZ-7	4.1875	130.3828	27.6383	177.5377	5.3450	2.6430
Middle Bronze	A-MB-3	3.0475	71.4336	11.9563	110.3775	4.6804	1.1560
Clay	CM019	4.7578	71.5177	20.3727	145.8613	2.5558	1.8512
Abassid	A-AB-4	2.8210	52.1121	17.1420	216.5578	5.8472	1.2203
Middle Bronze	A-MB-2	2.5111	50.4332	18.7044	171.2375	0.8790	1.3045
Umayyad Gray	A-UG-10	3.9634	93.1360	13.7648	111.1285	3.4402	1.7879
Early Byzantine	A-EZ-8	5.4193	138.1778	33.9939	201.2653	4.0917	3.2331
Abassid	A-AB-1	2.7261	58.4927	22.4909	181.2281	1.0659	1.4764
Abassid	A-AB-2	4.2360	50.5286	12.8989	201.1062	0.9607	1.5697
Early Bronze	A-EB-1	2.9814	68.7736	20.5299	123.7266	3.9696	1.5005
Early Roman	A-ER-1	5.2460	57.9726	11.4410	197.1222	1.5020	1.7895
Early Byzantine	A-EZ-1	3.9410	126.9427	23.0643	205.5712	3.4763	2.5414
Hellenistic White	A-HW-1	4.4085	48.2103	13.1297	227.6059	1.7814	1.5237
Hellenistic White	A-HW-4	2.3472	41.8088	27.8071	582.7133	1.2480	1.0439
Iron-1	A-II-1	4.2112	68.2970	16.3637	236.1195	2.9200	1.6680
Late Roman	A-LR-1	3.6459	110.8033	8.0877	111.0659	5.5225	1.6188
Late Roman	A-LR-27	5.0262	68.7268	15.5070	218.7765	2.8465	1.9250
Middle Bronze	A-MB-1	3.0541	75.2793	28.4896	179.7663	1.7780	1.6739
Terra Sigillata	A-TS-1	1.8730	36.2947	31.5936	364.2096	5.0926	0.9101
Terra Sigillata	A-TS-2	1.9635	44.0613	32.1255	340.5676	5.7142	0.9862
Umayyad Gray	A-UG-3	4.0220	94.7148	17.4598	118.2818	3.4937	1.8022
Umayyad Painted	A-UP-1	3.5032	73.4954	11.8224	122.2587	3.8904	1.2204
Umayyad Painted	A-UP-6	3.3673	83.7909	8.4137	84.7660	3.1702	1.2347
Clay	CM043	2.5304	50.6841	14.8543	117.7409	1.4631	1.0998
Clay	CM044	0.7348	9.0571	2.5721	58.4868	0.1883	0.1823
Early Roman	A-ER-2	4.8858	69.9497	16.5878	237.4774	2.4764	1.8576
Clay	CM046	2.6717	50.2017	13.1545	155.8818	1.6246	1.0784

Table 1. Continued.

Period	ID	Fe	Hf	Ni	Rb	Sb	Sc
Iron-1	A-II-3	38954.0586	2.6497	180.6051	86.8133	1.1934	14.6595
Clay	CM002	45839.1680	13.2648	80.0925	71.6967	0.2669	22.5938
Late Byzantine	A-LZ-11	13867.7129	12.7251	0.0000	42.7403	0.5516	16.0906
Late Roman	A-LR-27	33363.2344	3.7419	95.8512	39.1818	0.6400	15.8721
Clay	CM005	11453.4180	2.0207	56.2944	23.7508	0.5041	3.9992
Umayyed Gray	A-UG-27	32844.2891	13.0393	48.6207	60.4005	0.5355	16.4471
Early Roman	A-ER-3A	49310.5859	4.3101	93.7438	138.1751	0.6738	17.7567
Clay	CM008	49763.0391	6.8274	86.9851	171.4338	1.2454	17.4655
Hellinistic White	A-HW-7	24706.2832	1.9042	88.2863	13.6924	0.5266	14.2299
Early Bronze	A-EB-4	26302.3906	5.5314	74.9419	26.8847	0.5712	8.6694
Clay	CM011	7830.1597	1.2873	39.5789	16.1970	0.4259	2.8726
Early Bronze	A-EB-2	31745.7109	4.2329	83.9203	60.2262	0.5129	9.3845
Early Roman	A-ER-2	34849.9258	4.3308	84.6169	42.7211	0.7651	16.0493
Clay	CM014	49765.7773	2.8635	110.2861	8.3051	0.1987	14.3598
Umayyed Painted	A-UP-38	19947.6328	11.8827	39.6036	44.9818	0.4305	14.4035
Terra Sigillata	A-TS-7	51042.5469	2.8522	296.9793	70.0550	0.7678	20.1552
Late Byzantine	A-LZ-7	52792.4453	10.0935	88.2380	82.6057	0.3193	22.4774
Middle Bronze	A-MB-3	27928.5059	7.9456	0.0000	66.9968	0.4683	17.2029
Clay	CM019	37323.9844	7.1927	75.8858	50.5580	0.6724	13.3257
Abassid	A-AB-4	41669.0742	4.4448	90.7079	96.1599	0.6963	21.6378
Middle Bronze	A-MB-2	38305.8594	4.9698	90.6729	40.0623	0.4206	11.9781
Umayyed Gray	A-UG-10	34180.8125	10.6921	0.0000	63.3831	0.4229	17.1031
Early Byzantine	A-EZ-8	45551.8281	11.6351	138.6138	56.1425	0.3004	20.6168
Abassid	A-AB-1	48128.9500	6.3902	93.3406	20.3588	0.6836	13.7294
Abassid	A-AB-2	24312.6700	1.7654	82.5668	13.5771	0.6025	12.6228
Early Bronze	A-EB-1	48448.4900	6.8917	34.4011	70.1682	0.4682	18.2903
Early Roman	A-ER-1	28019.1400	3.0778	46.8839	35.5647	0.9540	13.4582
Early Byzantine	A-EZ-1	50132.1200	10.8744	58.4752	57.2316	0.3251	19.8568
Hellinistic White	A-HW-1	26651.8700	2.1146	71.8295	18.3615	0.6742	12.3507
Hellinistic White	A-HW-4	47703.9600	3.5534	193.9319	39.6592	0.6701	18.1837
Iron-1	A-II-1	36562.2600	5.1416	84.0748	47.2827	0.8660	14.7109
Late Roman	A-LR-1	26438.9100	8.1791	22.2100	68.6317	0.4777	18.0885
Late Roman	A-LR-27	34862.1800	3.7189	57.9203	39.4973	0.8045	15.6009
Middle Bronze	A-MB-1	50519.9000	8.4919	85.4326	41.8567	0.8030	15.5246
Terra Sigillata	A-TS-1	53926.6400	3.0185	269.2587	77.0195	0.8372	20.6163
Terra Sigillata	A-TS-2	55343.5700	3.2938	309.7874	68.7772	0.9760	20.9891
Umayyed Gray	A-UG-3	40109.3000	12.8503	35.2187	52.2495	0.6551	16.6773
Umayyed Painted	A-UP-1	32037.6700	11.3605	56.4804	45.7491	0.4934	16.3665
Umayyed Painted	A-UP-6	22625.3600	11.3365	22.8898	43.7214	0.4189	14.5314
Clay	CM043	31656.4600	5.9262	48.2538	41.0586	0.4160	9.8369
Clay	CM044	4315.3960	0.5699	32.5983	6.4294	0.6262	1.7993
Early Roman	A-ER-2	36318.2000	4.3945	100.7322	50.6770	0.8692	16.1008
Clay	CMO46	28583.8900	7.6757	70.8255	29.1988	0.6458	9.2884

Table 1. Continued.

Period	ID	Sr	Ta	Tb	Th	Zn	Zr
Iron-1	A-II-3	469.9532	0.7001	0.5192	8.1543	81.9650	63.8211
Clay	CM002	237.7264	4.4546	1.7614	13.6430	160.7465	324.9060
Late Byzantine	A-LZ-11	191.9294	2.4923	0.9482	17.2915	38.2861	308.8834
Late Roman	A-LR-27	750.7582	0.9492	1.4051	7.9581	139.2931	142.4234
Clay	CM005	432.6264	0.3611	0.3455	2.1323	113.1301	61.9383
Umayyad Gray	A-UG-27	181.4364	1.9570	1.1101	14.6190	66.3778	255.2799
Early Roman	A-ER-3A	258.5904	1.2825	0.7205	11.6148	116.6274	92.6900
Clay	CM008	34.8241	1.4179	1.0587	14.1459	101.5909	176.3041
Hellenistic White	A-HW-7	927.2224	0.6539	1.2198	6.8440	145.0723	117.9410
Early Bronze	A-EB-4	249.3246	0.8954	0.6578	5.1706	107.9041	132.0574
Clay	CM011	405.5576	0.2309	0.2274	1.3961	80.9210	46.2995
Early Bronze	A-EB-2	613.2440	0.7512	0.7601	5.2505	112.1632	97.3794
Early Roman	A-ER-2	708.6336	1.0558	1.2721	8.0687	143.2516	163.4249
Clay	CM014	250.4572	0.7569	0.5758	1.8556	115.6648	67.6861
Umayyad Painted	A-UP-38	280.6652	1.8311	0.9123	13.0026	42.1054	264.0468
Terra Sigillata	A-TS-7	343.5256	0.7353	0.5989	6.2601	100.7422	56.3204
Late Byzantine	A-LZ-7	239.1383	3.2360	1.4994	15.4110	94.4541	253.2447
Middle Bronze	A-MB-3	146.5274	1.3080	0.9855	9.7652	67.2281	188.5724
Clay	CM019	418.5302	1.2716	1.3939	7.6010	114.8527	170.4776
Abassid	A-AB-4	457.0492	0.8455	0.7433	8.4443	82.1671	98.5712
Middle Bronze	A-MB-2	557.6002	1.1137	0.7310	4.9993	153.6571	129.4572
Umayyad Gray	A-UG-10	178.2724	1.6101	1.1895	12.8892	67.0773	241.1114
Early Byzantine	A-EZ-8	345.5092	4.0272	2.1508	13.5013	166.7634	273.3246
Abassid	A-AB-1	795.1818	1.4991	0.7588	5.6715	131.8585	237.7157
Abassid	A-AB-2	798.4609	0.6362	1.1893	6.3427	186.7148	138.3639
Early Bronze	A-EB-1	0.0000	1.3656	0.9189	8.7830	79.8615	249.6392
Early Roman	A-ER-1	676.7936	0.7034	1.4466	6.3340	98.4883	193.4724
Early Byzantine	A-EZ-1	261.8593	3.9200	1.4827	13.2017	177.5057	372.9652
Hellenistic White	A-HW-1	933.4485	0.5721	1.0044	5.7969	159.4716	134.9690
Hellenistic White	A-HW-4	241.1610	0.7663	0.7113	6.2164	79.3085	0.0000
Iron-1	A-II-1	984.4187	1.1007	1.1732	8.1706	193.7690	179.3866
Late Roman	A-LR-1	163.0094	1.7551	1.0445	17.8214	45.8870	257.7942
Late Roman	A-LR-27	543.7010	0.9852	1.3957	7.9536	136.7138	182.5227
Middle Bronze	A-MB-1	443.0224	1.5970	0.9806	7.7699	129.4676	250.2919
Terra Sigillata	A-TS-1	337.6048	0.7678	0.5927	6.5370	88.5359	97.9801
Terra Sigillata	A-TS-2	225.2731	0.7298	0.5301	6.6836	101.3349	0.0000
Umayyad Gray	A-UG-3	184.3631	1.9046	1.0030	14.0256	53.3082	354.4091
Umayyad Painted	A-UP-1	249.2842	1.5307	0.9160	11.2108	64.5619	411.7407
Umayyad Painted	A-UP-6	186.2349	1.7195	0.7574	12.9696	27.5084	307.4905
Clay	CM043	251.0266	1.0533	0.6906	5.8160	102.5232	146.0984
Clay	CM044	378.0593	0.1278	0.1990	0.7128	50.2711	22.8102
Early Roman	A-ER-2	557.7848	1.0821	1.2938	8.4225	174.4646	248.0251
Clay	CM046	273.1360	1.0162	0.6655	5.7409	147.8872	257.4460

Table 1. Continued.

Period	ID	Al	Ba	Ca	Dy	K	Mn
Iron-1	A-II-3	60113.7695	856.2820	131982.4531	2.4078	19348.5254	674.0001
Clay	CM002	113902.5313	294.3336	2896.3464	6.5382	6911.0176	21.7081
Late Byzantine	A-LZ-11	129196.7656	256.6710	55768.2383	9.6337	18955.0254	598.8311
Late Roman	A-LR-27	64820.3789	1650.9086	225077.4531	7.7512	5263.1978	622.1385
Clay	CM005	15052.7139	322.1738	296107.0625	1.7947	5097.2451	292.6514
Umayyed Gray	A-UG-27	87626.2344	409.0029	15883.3262	6.4143	13105.1719	454.6999
Early Roman	A-ER-3A	90453.5391	186.1581	54692.4453	4.1808	21017.88.48	1104.3701
Clay	CM008	90354.6563	553.1213	2038.1333	6.3622	31843.0859	230.1479
Hellinistic White	A-HW-7	67029.7031	623.4318	285522.7188	7.0728	4067.7488	659.5120
Early Bronze	A-EB-4	37057.4844	1328.9076	178697.6875	3.3161	3295.1218	564.7064
Clay	CM011	10153.3945	316.3199	345445.1250	1.5282	1835.8027	197.4072
Early Bronze	A-EB-2	43107.6211	1266.8694	94841.6719	3.3187	23413.1172	449.3202
Early Roman	A-ER-2	72030.8203	1338.5431	203238.8125	7.5398	9079.7461	589.9100
Clay	CM014	53126.3984	204.6146	158415.4531	3.2580	2701.3696	869.1824
Umayyed Painted	A-UP-38	85524.9219	507.4625	92920.2656	5.5315	10074.7324	222.6821
Terra Sigillata	A-TS-7	67806.1875	501.4960	103305.2422	2.9263	18423.1035	794.4264
Late Byzantine	A-LZ-7	128123.9453	423.7006	61488.4336	8.4028	16288.5596	368.8337
Middle Bronze	A-MB-3	102073.3203	394.0394	53128.3047	4.7615	14280.9668	200.2224
Clay	CM019	59320.3242	1010.3036	114894.8828	7.3478	7694.7378	955.9766
Abassid	A-AB-4	68343.2266	301.2693	84466.6406	4.1533	20603.4141	699.9299
Middle Bronze	A-MB-2	47880.3867	695.6170	159163.3750	4.0434	14628.9365	644.7753
Umayyed Gray	A-UG-10	87679.7656	535.6899	44604.1055	6.8343	16717.3535	484.3105
Early Byzantine	A-EZ-8	128351.8984	381.3881	60865.9063	10.9112	15631.8320	825.6835
Abassid	A-AB-1	54568.7400	1212.2500	162619.4000	4.2856	6806.8420	926.9972
Abassid	A-AB-2	59100.6400	1325.5390	229518.5000	6.3543	9592.9880	494.3617
Early Bronze	A-EB-1	87344.4900	503.3343	77444.7000	5.6578	23173.3700	822.5346
Early Roman	A-ER-1	52589.9700	2357.5310	189168.2000	8.7306	0.0000	531.9710
Early Byzantine	A-EZ-1	120760.8000	443.7121	72287.8600	7.9972	17707.7500	779.6356
Hellinistic White	A-HW-1	51815.0700	1036.9880	247787.9000	6.5064	0.0000	590.1552
Hellinistic White	A-HW-4	69022.4600	1133.5890	111487.6000	4.8400	0.0000	1109.9270
Iron-1	A-II-1	68240.5200	1462.3700	163828.2000	7.7154	8804.1650	595.9327
Late Roman	A-LR-1	111156.5000	452.9623	33054.8700	6.1950	24217.7700	68.9963
Late Roman	A-LR-27	70836.7000	1422.4230	190046.8000	8.0985	9751.8380	648.2492
Middle Bronze	A-MB-1	61986.2000	1543.6440	105464.1000	5.8172	9293.3020	1114.0010
Terra Sigillata	A-TS-1	68846.0000	589.9631	96615.3800	3.3788	15543.8700	785.6464
Terra Sigillata	A-TS-2	71312.8100	220.1013	108647.1000	3.1331	14351.0300	805.7841
Umayyed Gray	A-UG-3	85316.2000	375.9106	20013.1400	6.8494	11647.4100	545.1735
Umayyed Painted	A-UP-1	85278.7900	461.2532	75914.0800	5.3580	15487.7500	220.9477
Umayyed Painted	A-UP-6	85147.9500	427.4229	63592.3900	5.0787	14481.3100	173.7047
Clay	CM043	46380.2700	388.2336	154727.0000	5.1371	7190.4180	692.6090
Clay	CM044	5989.7390	294.8095	318901.6000	1.2511	2032.2610	70.1384
Early Roman	A-ER-2	51854.4141	1193.6467	193001.8438	15.6147	9384.3369	902.6589
Clay	CMO46	38028.5703	360.3398	180811.6406	4.1882	4289.1011	419.9061

Table 1. Continued.

Period	ID	Na	Ti	V
Iron-I	A-II-3	3905.1331	3185.9045	96.5569
Clay	CM002	470.1130	11848.8613	107.1770
Late Byzantine	A-LZ-11	1389.3386	12227.9385	146.6175
Late Roman	A-LR-27	1417.3403	3232.5349	100.0183
Clay	CM005	958.7057	1607.0775	43.4602
Umayyed Gray	A-UG-27	1383.0073	9133.8936	115.7732
Early Roman	A-ER-3A	7648.3281	3951.1790	118.7971
Clay	CM008	1322.3099	6423.0942	196.4411
Hellinistic White	A-HW-7	2021.7220	1988.6115	90.6586
Early Bronze	A-EB-4	1750.7947	3560.9036	65.3754
Clay	CM011	586.1945	946.5595	29.5488
Early Bronze	A-EB-2	2092.9021	3162.5540	89.1755
Early Roman	A-ER-2	1712.2941	3906.2278	115.6974
Clay	CM014	7068.7549	4644.0830	101.7559
Umayyed Painted	A-UP-38	758.5022	7675.3931	72.4083
Terra Sigillata	A-TS-7	6977.1050	3794.6018	98.6841
Late Byzantine	A-LZ-7	1306.0299	12360.5195	179.8117
Middle Bronze	A-MB-3	965.2076	6299.5151	131.3100
Clay	CM019	1216.5845	5474.5781	133.5365
Abassid	A-AB-4	9306.0195	4237.2354	142.1001
Middle Bronze	A-MB-2	5548.0425	5907.1870	111.9911
Umayyed Gray	A-UG-10	1316.4690	6786.4243	129.6473
Early Byzantine	A-EZ-8	1589.4413	11365.4922	129.1320
Abassid	A-AB-1	8624.3060	7015.1820	131.3916
Abassid	A-AB-2	2223.1620	2297.4000	88.5707
Early Bronze	A-EB-1	1627.3400	6207.5370	135.6602
Early Roman	A-ER-1	1853.4570	3026.6550	120.1393
Early Byzantine	A-EZ-1	1184.1940	11559.8100	142.1657
Hellinistic White	A-HW-1	2345.0080	2168.0190	116.5574
Hellinistic White	A-HW-4	13959.2100	4968.0850	137.1823
Iron-I	A-II-1	1705.8590	4194.0120	150.5228
Late Roman	A-LR-1	819.9796	7718.5580	121.0205
Late Roman	A-LR-27	1809.1670	4064.5920	118.6671
Middle Bronze	A-MB-1	4509.5250	8427.7790	147.2756
Terra Sigillata	A-TS-1	6755.0730	4318.1710	117.9938
Terra Sigillata	A-TS-2	9525.6390	4536.5380	120.3941
Umayyed Gray	A-UG-3	1724.6780	8614.8650	132.7135
Umayyed Painted	A-UP-1	1174.9070	6943.4340	117.5490
Umayyed Painted	A-UP-6	862.0997	7028.6200	78.5077
Clay	CM043	1253.9090	4656.9940	89.4015
Clay	CM044	1636.8890	364.5789	19.7017
Early Roman	A-ER-2	1722.2987	3640.8020	145.4596
Clay	CMO46	1183.7070	4354.4849	76.1899

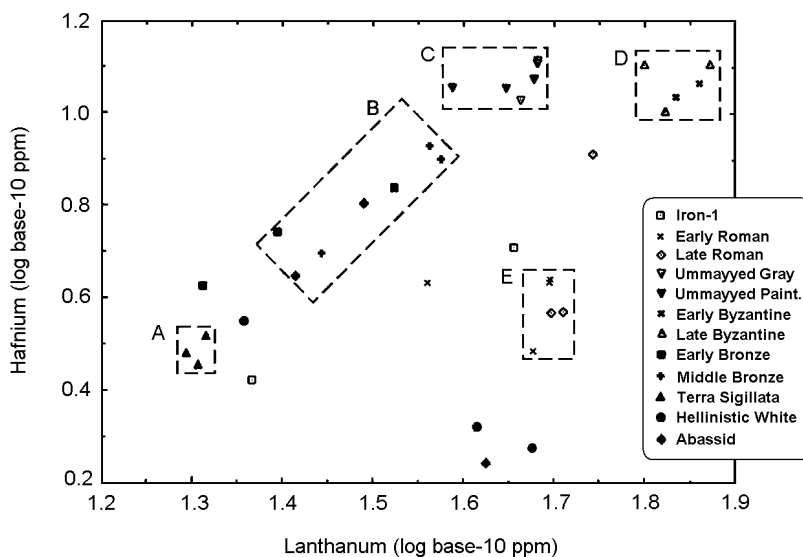


Fig. 2. Bivariate plot of base-10 logged lanthanum and hafnium showing five possible compositional groups

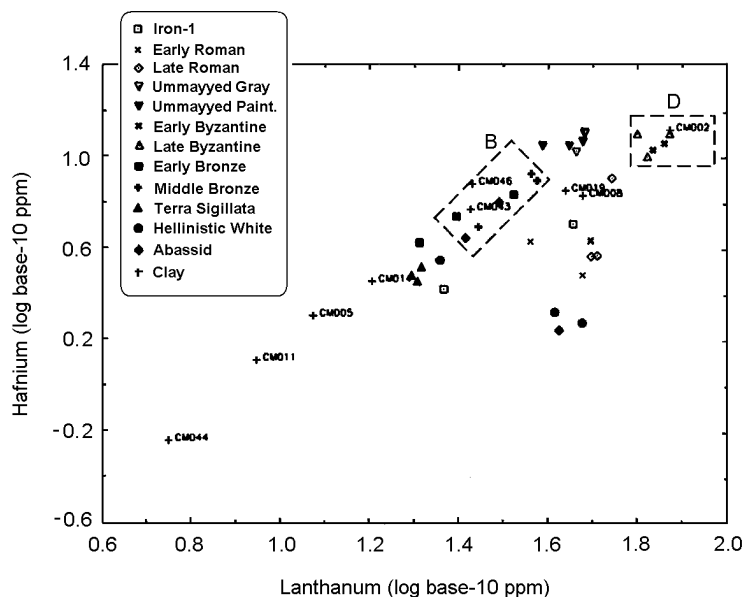


Fig. 3. Bivariate plot of base-10 logged lanthanum and hafnium showing the similarity of three clay sources to two compositional groups

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References

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