

An IBA multivariate-driven provenance investigation of ancient lapis lazuli amulets from the Museo Egizio (Turin, Italy)

EPJ+

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μ-PIXE results of diopside crystals analysis in the Egyptian amulets from Heliopolis

μ-PIXE diopside data of the Egyptian amulets from Heliopolis acquired at the New AGLAE facility. Concentration values and associated errors are reported, together with the relative limit of detection (LOD). K=concentration obtained from the analysis of the K line X-ray peak. L=concentration obtained from the analysis of the L line X-ray peak. - = element cannot be detected.

Sample	Area	NaK			MgK			AlK			SiK		
		conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)
2926	D1	11000	1000	1000	88000	1000	500	21300	700	300	253000	2000	200
2926	D2	14000	2000	2000	84000	2000	1000	25000	1000	800	253000	3000	500
2926	D3	10500	600	700	92100	1000	300	20000	500	200	262000	1000	100
2927	D1	13000	2000	2000	78000	2000	600	31000	1000	500	252000	3000	300
2927	D2	12000	2000	2000	79000	2000	700	34000	1000	400	258000	2000	300
2927	D3	15000	1000	1000	82000	1000	300	33200	800	300	264000	2000	200
3038	D1	9000	2000	2000	87000	2000	500	16000	1000	700	256000	3000	400
3038	D2	7100	400	500	95800	800	200	8600	200	200	261000	1000	80
3038	D3	12000	600	700	82500	900	300	22200	400	200	255000	1000	100
3039	D1	9100	500	600	87500	900	200	27500	500	200	258000	1000	100
3039	D2	7000	2000	2000	86000	3000	500	23000	1000	700	257000	3000	700
3040	D1	8000	1000	1000	90000	2000	600	14800	700	500	260000	2000	300
3040	D2	8400	600	700	88000	1000	300	14900	400	300	260000	1000	100
3040	D3	8000	2000	2000	89000	2000	500	13200	900	800	262000	3000	700
Sample	Area	P K			S K			ClK			K K		
		conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)

2926	D1	2300	400	500	1100	300	400	1500	200	200	1000	100	200
2926	D2	2800	700	900	1100	500	800	2000	300	300	2200	300	300
2926	D3	2700	200	300	1100	100	200	990	90	100	1140	50	40
2927	D1	1400	500	800	2200	300	300	900	200	300	2900	300	200
2927	D2	1200	500	700	1500	300	300	800	200	300	1950	80	60
2927	D3	900	300	500	2300	200	200	1000	100	200	1910	80	70
3038	D1	-	-	1000	2500	300	400	300	200	300	800	200	200
3038	D2	200	100	300	2100	90	100	570	50	80	550	30	30
3038	D3	1700	200	300	2900	100	100	1320	80	100	950	40	30
3039	D1	500	200	300	900	100	100	1040	80	100	1900	40	30
3039	D2	1600	700	1000	2600	500	500	1200	300	300	2000	200	100
3040	D1	100	300	600	900	200	300	600	100	200	800	200	200
3040	D2	800	200	400	800	100	200	660	80	100	580	40	30
3040	D3	-	-	2000	700	300	500	700	200	300	1100	200	200
		CaK			TiK			V K			CrK		
Sample	Area	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)
2926	D1	160000	1000	300	1580	30	20	224	18	30	100	9	13
2926	D2	154000	2000	500	2050	60	40	240	30	60	113	17	30
2926	D3	154300	800	100	1230	20	10	190	12	20	56	6	9
2927	D1	159000	2000	500	2160	40	20	280	30	40	74	12	18
2927	D2	155000	1000	300	2160	40	20	240	20	40	112	10	15
2927	D3	141000	1000	200	1930	40	20	250	20	40	66	9	14
3038	D1	168000	2000	300	1630	40	30	260	30	40	122	15	20
3038	D2	174100	800	90	1031	13	8	261	8	13	110	4	6
3038	D3	166800	800	100	2040	20	10	225	12	20	119	6	7
3039	D1	156700	800	100	1575	17	8	158	10	18	83	4	6
3039	D2	162000	2000	300	2650	80	20	170	40	70	42	17	30
3040	D1	164000	1000	300	1610	30	20	180	20	30	106	10	13
3040	D2	166400	900	200	1850	20	10	295	13	20	134	7	8
3040	D3	174000	2000	400	1080	40	30	240	30	40	132	15	20
		MnK			FeK			CoK			NiK		
Sample	Area	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)
2926	D1	1460	20	10	1470	20	18	-	-	30	92	9	20
2926	D2	1620	40	16	1750	40	36	15	15	30	44	19	50
2926	D3	1108	12	4	1346	14	12	12	5	11	-	-	30
2927	D1	1200	20	10	2150	30	22	18	11	20	212	13	40
2927	D2	1103	19	7	1180	20	19	10	8	16	120	10	30
2927	D3	914	18	7	1400	20	16	11	8	16	9	8	20
3038	D1	1340	30	14	9640	70	26	-	-	100	157	15	40
3038	D2	1361	10	2	1117	9	10	12	3	7	117	4	18
3038	D3	1140	11	5	3314	19	10	8	6	16	133	5	18
3039	D1	1366	11	4	3890	20	12	14	6	17	62	3	10
3039	D2	1030	40	16	6550	80	37	90	30	70	-	-	80

3040	D1	1286	20	9	554	14	18	5	6	11	151	11	30
3040	D2	1651	14	5	791	10	13	4	4	8	153	6	20
3040	D3	1910	30	16	1260	30	31	-	-	40	182	17	40
		CuK			ZnK			GaK			AsK		
Sample	Area	<i>conc (ppm)</i>	<i>err (ppm)</i>	<i>LOD (ppm)</i>	<i>conc (ppm)</i>	<i>err (ppm)</i>	<i>LOD (ppm)</i>	<i>conc (ppm)</i>	<i>err (ppm)</i>	<i>LOD (ppm)</i>	<i>conc (ppm)</i>	<i>err (ppm)</i>	<i>LOD (ppm)</i>
2926	D1	201	9	8	76	7	6	25	6	9	111	23	90
2926	D2	270	19	18	85	15	10	10	11	18	80	50	100
2926	D3	198	6	5	72	4	4	10	3	6	65	15	60
2927	D1	99	9	12	69	8	6	22	6	8	13	10	17
2927	D2	37	6	9	36	6	8	20	4	4	20	6	7
2927	D3	48	6	8	62	6	4	1	5	7	14	6	12
3038	D1	90	10	14	56	10	11	14	7	7	29	16	40
3038	D2	118	3	4	47	2	3	4	2	3	18	3	8
3038	D3	173	4	5	55	3	4	11	2	3	15	5	12
3039	D1	28	2	4	48	3	2	7	2	3	8	2	4
3039	D2	63	13	17	42	14	14	20	10	12	-	-	90
3040	D1	60	6	9	71	7	7	-	-	12	16	9	18
3040	D2	66	4	6	70	4	4	9	2	3	7	4	9
3040	D3	82	11	15	72	11	12	23	8	8	-	-	40
		SrK			Y K			ZrK			Pb # LB		
Sample	Area	<i>conc (ppm)</i>	<i>err (ppm)</i>	<i>LOD (ppm)</i>	<i>conc (ppm)</i>	<i>err (ppm)</i>	<i>LOD (ppm)</i>	<i>conc (ppm)</i>	<i>err (ppm)</i>	<i>LOD (ppm)</i>	<i>conc (ppm)</i>	<i>err (ppm)</i>	<i>LOD (ppm)</i>
2926	D1	110	20	30	-	-	90	110	30	60	2920	80	50
2926	D2	20	40	90	130	70	100	230	90	90	2980	170	100
2926	D3	125	14	16	30	20	40	63	17	30	2410	50	30
2927	D1	100	30	30	20	20	40	190	40	70	90	30	30
2927	D2	74	19	20	42	18	20	150	40	40	-	-	60
2927	D3	90	19	18	28	17	20	110	30	40	40	20	20
3038	D1	40	20	30	-	-	70	170	50	70	260	50	50
3038	D2	71	5	3	20	5	6	74	9	10	158	10	10
3038	D3	86	8	6	23	7	9	111	15	14	226	14	12
3039	D1	61	6	6	8	5	4	133	14	14	24	7	8
3039	D2	90	50	40	-	-	80	-	-	100	280	100	100
3040	D1	69	17	20	-	-	40	70	30	40	190	30	30
3040	D2	105	10	5	3	8	12	270	20	18	132	14	15
3040	D3	50	30	40	30	30	50	130	50	70	130	40	50

μ-PIXE results of diopside crystals analysis in the other Egyptian amulets

μ-PIXE diopside data of the Egyptian amulets from different historical period and unknown place of discovery acquired at the New AGLAE facility. Concentration values and associated errors are reported, together with the relative limit of detection (LOD). K=concentration obtained from the analysis of the K

line X-ray peak. L=concentration obtained from the analysis of the L line X-ray peak. - = element cannot be detected.

		Na			Mg			Al			Si		
Sample	Area	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)
1182	D1	22000	3000	3000	82000	4000	900	27000	2000	1000	251000	4000	1000
1182	D2	14300	500	500	87000	800	200	17300	300	200	257000	1000	90
1182	D3	14000	1000	1000	90000	2000	600	18200	800	400	262000	2000	300
6786_15	D1	16000	1000	900	81000	1000	400	33600	800	300	251000	2000	200
6786_15	D2	12300	900	1000	79000	1000	500	26500	700	400	250000	2000	200
6786_15	D3	14000	1000	2000	72000	2000	700	33000	1000	400	251000	3000	300
1296	D1	25000	2000	1000	72000	2000	900	41000	2000	400	250000	3000	300
1296	D2	22000	2000	2000	71000	2000	900	37000	1000	600	246000	3000	300
1296	D3	21000	3000	2000	70000	3000	700	40000	2000	700	250000	4000	500
6899	D1	10000	2000	1000	59000	2000	700	23000	1000	800	252000	3000	600
6899	D2	19900	900	700	78000	1000	300	30800	700	300	255000	2000	200
6939	D1	6800	500	500	97600	900	200	11900	300	200	259000	1000	100
6939	D2	7200	600	800	93000	1000	300	14800	400	300	258000	1000	200
6939	D3	5900	500	600	98000	1000	300	13700	400	300	258000	1000	100
18205	D1	5900	700	800	97000	1000	400	8700	400	400	263000	2000	200
18205	D2	6900	500	500	97000	900	200	9700	300	200	262000	1000	80
		P			S			Cl			K		
Sample	Area	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)
1182	D1	400	900	1000	2500	600	600	600	400	500	2400	200	100
1182	D2	700	200	300	1900	100	100	920	70	80	1160	30	20
1182	D3	1500	400	600	500	300	400	500	200	200	1120	70	60
6786_15	D1	1000	300	400	2200	200	200	1400	100	200	1240	60	50
6786_15	D2	600	300	500	2200	200	300	1000	100	200	1340	50	40
6786_15	D3	-	-	1000	2600	300	300	1100	200	300	2600	100	80
1296	D1	1800	600	800	2700	500	600	2700	400	300	3000	100	90
1296	D2	900	500	800	2100	400	500	1700	300	200	2400	100	80
1296	D3	2600	800	900	2800	600	700	1900	400	400	2900	100	100
6899	D1	-	-	2000	1700	400	500	2300	400	400	2300	100	100
6899	D2	800	200	400	2600	200	200	2000	100	100	1590	50	40
6939	D1	-	-	500	700	90	100	470	60	90	130	30	30
6939	D2	900	200	400	900	100	200	560	80	100	240	40	40
6939	D3	-	-	600	500	100	200	280	70	100	-	-	50
18205	D1	400	200	500	500	100	200	400	100	100	350	50	40
18205	D2	500	200	300	800	90	100	600	60	90	580	30	30
		Ca			Ti			V			Cr		
Sample	Area	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)
1182	D1	136000	2000	1000	1990	80	30	380	40	70	310	30	30

1182	D2	160300	700	100	1137	16	8	478	10	14	395	7	8
1182	D3	159000	1000	300	1310	30	20	471	22	30	262	14	18
6786_15	D1	153000	1000	200	2270	30	15	254	18	30	180	9	12
6786_15	D2	169000	1000	300	2270	30	14	300	17	30	181	9	11
6786_15	D3	159000	2000	400	5810	80	30	530	40	80	252	18	20
1296	D1	142000	2000	400	3440	90	40	170	30	70	76	14	20
1296	D2	154000	2000	400	3370	60	40	190	30	60	73	13	20
1296	D3	144000	2000	800	2810	80	40	170	40	70	92	17	30
6899	D1	185000	2000	600	3610	90	50	300	50	80	134	19	30
6899	D2	156000	1000	200	2300	30	14	184	15	30	105	7	9
6939	D1	168600	800	100	235	8	8	8	5	8	-	-	8
6939	D2	173600	900	200	223	10	12	16	6	10	2	3	6
6939	D3	171800	900	100	234	9	9	1	4	9	5	3	5
18205	D1	168000	1000	200	785	18	14	143	11	17	74	6	9
18205	D2	171800	800	90	1133	14	7	279	9	14	200	5	6
		Mn			Fe			Co			Ni		
Sample	Area	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)
1182	D1	143	20	30	1240	40	20	-	-	50	90	20	40
1182	D2	293	5	6	2837	14	4	-	-	20	106	4	14
1182	D3	170	10	13	535	12	8	-	-	19	141	10	30
6786_15	D1	1398	18	8	1043	15	17	11	6	11	23	6	15
6786_15	D2	1684	18	9	914	14	18	-	-	16	92	6	17
6786_15	D3	1490	30	14	2920	40	20	-	-	50	60	10	20
1296	D1	1420	40	15	1270	30	30	7	11	20	131	14	30
1296	D2	1390	30	13	2530	30	20	24	13	30	111	12	30
1296	D3	1320	40	20	2330	50	30	-	-	60	83	17	40
6899	D1	1480	40	18	730	30	30	20	12	20	92	19	50
6899	D2	1044	12	6	429	8	12	9	4	6	101	6	18
6939	D1	598	7	4	4576	21	6	-	-	30	133	4	19
6939	D2	569	8	5	3991	22	9	-	-	30	110	5	16
6939	D3	615	8	4	4960	40	8	-	-	40	144	5	20
18205	D1	1275	14	4	721	11	14	-	-	14	111	6	20
18205	D2	1480	11	4	1042	9	11	1	5	7	129	4	16
		Cu			Zn			Ga			As		
Sample	Area	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)
1182	D1	48	15	15	54	13	18	19	10	14	30	20	40
1182	D2	60	3	4	68	3	3	12	2	3	2	3	8
1182	D3	33	6	9	74	7	5	23	5	6	-	-	20
6786_15	D1	35	4	7	49	5	5	11	3	6	12	6	14
6786_15	D2	76	5	6	48	4	5	11	3	5	-	-	30
6786_15	D3	88	9	11	66	9	9	19	7	7	-	-	40
1296	D1	135	13	12	80	12	11	13	7	10	7	16	30
1296	D2	172	11	12	166	12	7	19	7	9	-	-	40

1296	D3	286	19	16	104	15	10	38	10	11	40	20	30
6899	D1	57	13	17	57	13	12	18	8	11	-	-	40
6899	D2	37	3	6	28	3	4	12	3	4	2	5	14
6939	D1	80	3	4	43	2	2	13	2	2	20	3	6
6939	D2	97	4	4	49	3	3	9	2	3	9	4	8
6939	D3	61	3	5	56	3	2	13	2	2	9	4	7
18205	D1	47	4	6	75	4	3	7	2	4	14	4	8
18205	D2	56	2	4	67	3	3	5	2	2	22	3	6
		Sr			Y			Zr			Pb # LB		
Sample	Area	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)	conc (ppm)	err (ppm)	LOD (ppm)
1182	D1	80	60	90	-	-	100	500	200	200	150	80	100
1182	D2	77	6	4	11	5	6	750	20	15	150	9	8
1182	D3	23	14	15	28	19	30	710	80	60	90	20	30
6786_15	D1	92	15	9	4	9	17	120	30	40	142	19	22
6786_15	D2	159	16	14	-	-	30	160	20	30	250	20	16
6786_15	D3	160	30	40	40	20	40	220	50	70	220	40	30
1296	D1	130	40	60	-	-	70	90	60	100	180	50	60
1296	D2	120	30	20	20	20	40	110	50	80	210	40	40
1296	D3	60	40	60	40	60	70	180	90	100	110	70	60
6899	D1	110	40	60	-	-	40	180	80	100	70	50	60
6899	D2	91	12	8	-	-	30	130	20	20	218	18	18
6939	D1	56	6	4	-	-	10	25	8	13	44	8	9
6939	D2	64	9	4	8	5	8	28	10	16	85	11	12
6939	D3	35	6	4	-	-	11	18	8	12	50	10	12
18205	D1	46	9	11	11	7	8	42	13	16	56	13	11
18205	D2	48	5	3	12	5	6	76	10	12	70	8	9