Open Archaeology 2017; 3: 202–221 | DE GRUYTER OPEN

Original Study

Frederick S. Pirone*, Robert H. Tykot

Trace Elemental Characterization of Maltese Pottery from the Late Neolithic to Middle Bronze Age

https://doi.org/10.1515/opar-2017-0012
Received March 12, 2017; accepted May 30, 2017

Abstract: The aim of this research was to determine the provenance of Maltese ceramics and to determine the role pottery played in Maltese prehistoric trade and interaction networks. This study involved 236 Maltese ceramic samples, 19 geological clay samples from Ġnejna Bay & Selmun along with 18 ceramic samples from Ognina, Sicily, and four Sicilian clay samples from the outskirts of Siracusa that were non-destructively analyzed using a portable X-ray fluorescence (pXRF) spectrometer in order to determine their trace elemental compositions (Th, Rb, Sr, Y, Zr and Nb). The results of this analysis were statistically analyzed using principal component analysis in order to ascertain relationships in the chemical compositions among the samples. The results of this analysis indicate that the majority of all the Maltese ceramic samples have a local Maltese provenance and that pottery played a more significant role in defining the nature of Malta's trade relationships during the Bronze Age. The following study has provided new insights into Malta's role in trade and interaction networks from the late Neolithic to the Bronze Age and has allowed for new ideas in explaining the cultural change observed from the Temple Period to the Bronze Age.

Keywords: Ceramics, Mediterranean, Interaction, Trade, Connectivity, Archaeometry, Portable X-ray fluorescence

1 Introduction

The insular nature of the Maltese archipelago provides a unique opportunity to explore trade and cultural change from the late Neolithic to the Bronze Age in the central Mediterranean. It is hypothesized that during the period in which the Maltese islands were experiencing a form of isolation—owing either to their distance from Sicily and other populated locations, to the conscious formation of an inwardly-focused culture, or to a combination of these factors—it is unlikely that pottery played a significant role as either an import or export in the archipelago's exchange relationships with other communities in the central Mediterranean. Accordingly, it is proposed that ceramics were only significant in the interaction networks between Malta and its neighbors during periods when the archipelago was culturally connected to Sicily.

Except for a limited number of archaeometric studies (Barone et al. 2015; Molitor 1988; Mommsen et al. 2006), analysis of similarities among ceramic wares produced in Malta and elsewhere that allow

Article Note: This article is a part of Topical Issue on Portable XRF in Archaeology and Museum Studies, edited by Davide Tanasi, Robert H. Tykot & Andrea Vianello

***Corresponding author: Frederick S. Pirone,** Department of Anthropology, University of South Florida, Tampa, Florida 33620, United States, E-mail: Pirone@mail.usf.edu
Robert H. Tykot, Department of Anthropology, University of South Florida, Tampa, Florida 33620, United States

archaeologists to draw conclusions about the nature of Malta's connectivity to other communities has been based on macroscopic observation. The present study builds on these few archaeometric studies by determining the provenance of ceramic samples based on their trace elemental composition for a wider number of archaeological sites with attention given to Malta's Tarxien and Tarxien Cemetery phases.

Table 1. Malta's prehistoric chronology (adapted from Malone et al. 2009).

Cultural Phase	Approx. Date	Contemporary Cultures in:	
		Sicily	Aeolian Islands
Neolithic			
Għar Dalam	*c.* 5000-4300 BC	Stentinello	Trichrome, Serra d'Alto
Grey Skorba	*c.* 4500-4400 BC		
Red Skorba	*c.* 4400-4100 BC	Diana	Diana
Early Temple Period			
Żebbuġ	4100-3700 BC	San Cono, Piano Notaro, Piano Vento	Piano Conte
Mġarr	3800-3600 BC		
Ġgantija	3600-3100 BC		
Full Temple Period			
Tarxien (+Saflieni)	3100-2400 BC	Serraferlicchio, Conca D'Oro, Malpasso, Beaker	Piano Quartara
Break in Dated Cultural Sequence			
No Dated Sites, No Distinct Cultural Evidence	2400-2000 BC		
Early Bronze Age			
Tarxien Cemetery	2000-1500 BC	Naro, La Muculufa, Castelluccio, Beaker	Capo Graziano
Middle Bronze Age			
Borġ in-Nadur	1500-700 BC	Thapsos	Milazzese

Specifically, in order to address the question of the role that pottery played in the prehistoric trade of the Maltese islands, ceramic sherds were analyzed using a Bruker III-V handheld portable X-ray fluorescence device, which revealed the relative abundance of six trace elements, namely thorium, rubidium, strontium, yttrium, zirconium, and niobium. The trace elemental composition of the Maltese pottery was compared with that of 18 Sicilian ceramic sherds and clay samples from both Malta and Sicily. This research was part of a broader study that analyzed the trace elemental composition of Maltese ceramics from the archipelago's initial cultural period when Malta was first settled during its Għar Dalam phase to Malta's Borġ in-Nadur phase (Pirone 2017). The current paper, however, focuses on the trace elemental data related to Malta's Tarxien, Tarxien Cemetery, and Borġ in-Nadur phases and explores the role Maltese ceramics played within the broader exchange networks of the central Mediterranean during these time periods.

The results of this research suggest that neither ceramics nor raw clay materials played a significant role in overseas trade during Malta's period of cultural isolation, which was at its height during the Tarxien phase. On the other hand, there is evidence to suggest ceramics played a more active role in Malta's interaction networks during periods of connectivity with Sicily. Specifically, this study provides the first chemical evidence that Malta exported pottery to Sicily during Malta's Borġ in-Nadur phase. The findings presented here thus contribute to our understanding of Malta's role in trade and interaction networks from the late Neolithic to the Bronze Ages and offers an opportunity to consider new approaches to exploring the cultural change that becomes apparent at the end of the Maltese Temple Period.

Further, the prehistory of Malta is one best understood within the context of mobility and changing relationships within a broader interaction sphere, more specifically, the central Mediterranean. Traditionally, the nature and intensity of Malta's interaction with Sicily, the Central Mediterranean, and the broader Mediterranean world has been based on traditional methods comparing ceramic repertoires in various localities and identifying items of exchange in the archaeological record that are foreign to the Maltese islands such as for example obsidian and alabaster (Trump 1966), flint (Vella 2016) and greenstone axes (Skeates 2002). These goods have taken on various degrees of significance as symbols of status for an emerging elite in a society becoming increasingly more stratified over time and eventually becoming culturally distinct from its neighbors within the central Mediterranean (Bonanno et al. 1990; Robb 2001; Vella 2016).

The Maltese islands are centrally located in the Mediterranean. This has allowed Malta to play a strategic role in history uniting the eastern and western portions of the Mediterranean and Europe with Africa (Fig. 1). The Maltese archipelago is approximately 90 km south of Sicily, 290 km from the northern coast of Africa and only about 224 km to Calabria, Italy. It is possible to see Mount Etna from Malta on a clear day.

Figure 1. Map of the location of the Maltese archipelago within the Mediterranean and archaeological sites included in this study.

2 Methodology

The chemical characterization of archaeological materials has played an important role in the study of prehistoric societies. This is especially true in research focused on examining ancient exchange and interaction networks. Clay sources can be distinguished based on their minor and trace elemental composition; to be more specific, the trace elemental composition of pottery reflects the geochemical composition of the individual clay sources that ancient potters accessed in the production of their ceramic wares (Mommsen et al. 2006; Tykot 2004, 2016). Therefore, comparison of the trace elemental composition of Maltese ceramics with clay samples from Selmun and Ġnejna Bay on the island of Malta should make possible the identification of imported pottery.

In particular, the use of a portable or hand-held x-ray fluorescence spectrometer (pXRF) has become increasingly more popular in ceramic sourcing studies in recent years due to a number of advantages that include the ability to non-destructively analyze ceramic materials on location such as at excavations or at museums where ceramic collections are housed or on display and the overall affordability in analyzing a large number of artifacts within a relatively short period of time. While these advantages are attractive to researchers, it is important to note that non-destructively analyzing ceramic surfaces has a technical disadvantage compared to homogenized powder samples. However, a number of non-destructive ceramic studies have been performed taking into account the heterogeneous nature of clay types, surface treatment and decoration such as the application of slip or paint and temper added (Hunt, Speakman 2015; Speakman et al. 2011; Tykot 2016; Tykot et al. 2013). These studies provide examples in how to address the issue of heterogeneity in non-destructively analyzing only ceramic surfaces. For ceramics in this study, careful attention was given to analyze ceramic surface with relatively flat areas and that showed no signs of slip or application of paint or decoration. Additionally, multiple spots on both the inside and outside surfaces of each sherd were analyzed and attention was given in order to avoid analyzing locations where there were visible inclusions.

A total of 236 Maltese ceramic samples from six temple sites (Borġ in-Nadur, Ġgantija, Mnajdra, Skorba, Ta' Ħaġrat, and Tarxien) and the burial contexts of Ħal-Saflieni and Tarxien Cemetery were included in the current study (Fig. 2). These samples were analyzed using a Bruker Tracer III-SD pXRF instrument and compared with results obtained for the trace elemental compositions determined for 18 ceramic samples from Ognina, Sicily, the 19 geological clay samples from Ġnejna Bay & Selmun, and four geological clay samples taken from the northern outskirts of Siracusa, Sicily. The analyses was conducted on all the Maltese and Sicilian ceramic and geological samples using the setting 40kV/10μA and filter (12 μm Al, 1 μm Ti, 6 μm Cu), providing greater precision and sensitivity for trace elements thorium (Th), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb). The Bruker Tracer III-SD was positioned upright on a plastic stand and the samples carefully balanced on top (Fig. 3). Both the inner and outer surfaces and the edges when possible for each of the ceramic samples were analyzed for 120 seconds (Tykot et al. 2013).

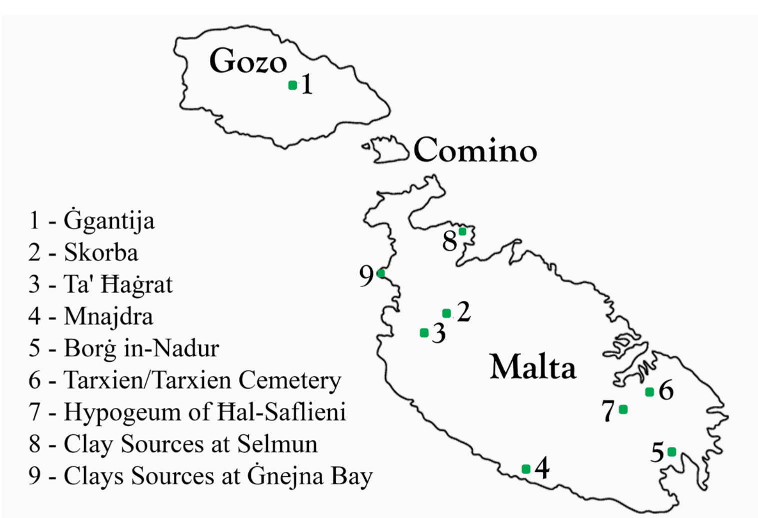

Figure 2. Map of Maltese islands showing the locations of the archaeological sites and locations of clay outcrops included in this study.

Figure 3. The Bruker Tracer III-SD portable X-ray fluorescence spectrometer (pXRF) analyzing a ceramic sherd at the National Museum of Archaeology, Valletta, Malta (photograph by Fred Pirone).

Quantitative values in ppm for each trace element were obtained by calibrating the raw data using the 2008 MURR calibration software package. Robert Speakman and Michael Glascock developed the 2008 MURR calibration using empirical calibration schemes based on obsidian to calibrate the Brucker pXRF using the obsidian "Green" filter (Speakman, Shackley 2013:1437). The peak intensities for the K_α peaks of Rb, Sr, Y, Zr, Nb, and L_α peak of Th were calculated as ratios to the Compton peak of Rhodium and converted to parts per million (ppm). The calibrated values obtained for each of the trace elements were then averaged for each sample (See Table 2 and 3) and statistically analyzed using Principal Component Analysis (PCA) applying a Direct Oblimin rotation. The IBM SPSS Statistics 23 software package was used to conduct the statistical analysis. Values for each of the trace elements were first transformed using base log.10 before running the PCA.

Table 2. Trace elemental data for ceramic materials (ppm).

USF Number	Site	Phase	Th	Rb	Sr	Y	Zr	Nb
19059	Ġgantija	Tarxien	10	99	785	20	171	17
19060	Ġgantija	Tarxien	9	99	882	22	167	21
19061	Ġgantija	Tarxien	9	47	449	19	106	9
19062	Ġgantija	Tarxien	8	34	263	21	94	12
19063	Ġgantija	Tarxien	13	98	307	21	144	19
19064	Ġgantija	Tarxien	14	119	615	22	171	19
19065	Ġgantija	Tarxien	11	110	582	25	146	15
19066	Ġgantija	Tarxien	7	71	495	21	96	14
19067	Ġgantija	Tarxien	8	58	328	19	62	8
19068	Ġgantija	Tarxien	11	97	569	23	158	19
19069	Ġgantija	Tarxien Cemetery	13	90	474	37	273	25
19070	Ġgantija	Tarxien Cemetery	10	85	452	21	108	14
19071	Ġgantija	Tarxien Cemetery	12	88	443	29	117	13
19072	Ġgantija	Tarxien Cemetery	10	71	294	27	150	16
19073	Ġgantija	Tarxien Cemetery	12	104	366	23	139	16
19074	Ġgantija	Tarxien Cemetery	13	101	264	21	162	20
19075	Ġgantija	Tarxien Cemetery	14	101	144	52	323	27
19076	Ġgantija	Tarxien Cemetery	13	111	555	23	148	16
19077	Ġgantija	Tarxien Cemetery	11	103	483	23	143	16
19078	Ġgantija	Tarxien Cemetery	13	102	445	24	141	17
19079	Borġ in-Nadur	Tarxien	10	90	494	24	137	17
19080	Borġ in-Nadur	Tarxien	4	41	644	24	126	10
19081	Borġ in-Nadur	Tarxien	7	62	529	22	87	10
19082	Borġ in-Nadur	Tarxien	7	44	1258	13	90	2
19083	Borġ in-Nadur	Tarxien	9	89	645	19	134	13
19084	Borġ in-Nadur	Tarxien	7	52	726	20	101	8
19085	Borġ in-Nadur	Tarxien	10	118	641	21	170	17
19086	Borġ in-Nadur	Tarxien	11	74	354	22	105	12
19087	Borġ in-Nadur	Tarxien	14	100	697	20	161	18
19088	Borġ in-Nadur	Tarxien	12	74	708	24	186	17
19089	Borġ in-Nadur	Tarxien	10	87	661	19	125	11
19090	Borġ in-Nadur	Tarxien	9	65	432	19	105	10
19091	Borġ in-Nadur	Tarxien	11	94	849	21	167	13
19092	Borġ in-Nadur	Tarxien	13	79	556	27	122	11
19093	Borġ in-Nadur	Tarxien	10	71	638	20	104	9
19094	Borġ in-Nadur	Tarxien	8	96	692	22	132	11
19095	Borġ in-Nadur	Tarxien	11	56	317	18	73	8
19096	Borġ in-Nadur	Tarxien	7	63	465	17	84	7
19097	Borġ in-Nadur	Tarxien	11	66	401	22	131	13
19098	Borġ in-Nadur	Tarxien	7	64	628	24	127	12
19099	Borġ in-Nadur	Tarxien	7	69	492	18	97	9
19100	Borġ in-Nadur	Tarxien	9	85	578	21	128	10
19101	Borġ in-Nadur	Tarxien Cemetery	14	107	431	23	184	20
19102	Borġ in-Nadur	Tarxien Cemetery	13	94	664	22	163	17
19103	Borġ in-Nadur	Tarxien Cemetery	14	82	657	24	154	16
19104	Borġ in-Nadur	Tarxien Cemetery	12	89	672	22	144	14
19105	Borġ in-Nadur	Tarxien Cemetery	12	119	630	22	176	15
19106	Borġ in-Nadur	Tarxien Cemetery	10	68	423	21	117	13
19107	Borġ in-Nadur	Tarxien Cemetery	10	116	753	22	170	18
19108	Borġ in-Nadur	Tarxien Cemetery	12	116	661	21	160	21
19109	Borġ in-Nadur	Tarxien Cemetery	9	98	554	23	150	17
19110	Borġ in-Nadur	Tarxien Cemetery	15	98	765	25	164	17
19111	Borġ in-Nadur	Borġ in-Nadur	19	122	884	24	168	19
19112	Borġ in-Nadur	Borġ in-Nadur	10	94	961	22	177	15
19113	Borġ in-Nadur	Borġ in-Nadur	14	90	273	27	195	25
19114	Borġ in-Nadur	Borġ in-Nadur	13	112	791	22	170	18

USF Number	Site	Phase	Th	Rb	Sr	Y	Zr	Nb
19115	Borġ in-Nadur	Borġ in-Nadur	14	118	678	25	203	20
19116	Borġ in-Nadur	Borġ in-Nadur	12	107	874	23	192	18
19117	Borġ in-Nadur	Borġ in-Nadur	10	81	587	18	122	11
19118	Borġ in-Nadur	Borġ in-Nadur	9	89	884	20	173	14
19119	Borġ in-Nadur	Borġ in-Nadur	11	99	782	24	163	17
19120	Borġ in-Nadur	Borġ in-Nadur	11	99	889	22	165	19
19121	Borġ in-Nadur	Borġ in-Nadur	13	93	450	21	150	18
19122	Borġ in-Nadur	Borġ in-Nadur	11	90	673	22	161	16
19123	Borġ in-Nadur	Borġ in-Nadur	11	99	627	22	137	14
19124	Borġ in-Nadur	Borġ in-Nadur	23	81	534	24	147	15
19125	Borġ in-Nadur	Borġ in-Nadur	11	92	626	20	153	17
19126	Borġ in-Nadur/ Mycenaean Sherd	Borġ in-Nadur	12	136	523	22	129	8
19161	Ħal Saflieni	Sleeping Lady (Saflieni)	9	70	292	25	164	17
19162	Ħal Saflieni	Tarxien	9	90	493	19	157	17
19163	Ħal Saflieni	Tarxien	9	82	795	18	139	13
19164	Ħal Saflieni	Tarxien	8	89	844	19	141	13
19165	Ħal Saflieni	Tarxien	11	93	689	21	149	20
19166	Ħal Saflieni	Tarxien	15	83	1057	23	140	10
19167	Ħal Saflieni	Tarxien	11	88	610	25	213	14
19168	Ħal Saflieni	Tarxien	8	60	659	19	123	9
19169	Ħal Saflieni	Tarxien	11	104	722	22	150	18
19170	Ħal Saflieni	Tarxien	13	106	822	22	148	17
19171	Ħal Saflieni	Tarxien	7	48	425	18	73	8
19172	Ħal Saflieni	Tarxien	6	70	412	22	104	11
19173	Ħal Saflieni	Tarxien	9	66	1098	19	110	8
19174	Ħal Saflieni	Tarxien	10	56	646	23	83	9
19175	Ħal Saflieni	Tarxien	8	78	461	18	79	8
19176	Ħal Saflieni	Tarxien	9	62	561	20	106	11
19177	Ħal Saflieni	Tarxien	9	50	508	30	113	4
19178	Ħal Saflieni	Tarxien	9	82	695	21	127	13
19179	Ħal Saflieni	Tarxien	12	95	811	19	122	13
19180	Ħal Saflieni	Tarxien	8	59	837	25	83	9
19181	Ħal Saflieni	Tarxien	11	101	692	18	111	13
19182	Ħal Saflieni	Tarxien	12	93	874	19	140	17
19183	Ħal Saflieni	Tarxien	10	68	674	21	108	12
19184	Ħal Saflieni	Tarxien Cemetery	13	114	476	26	144	18
19185	Ħal Saflieni	Tarxien Cemetery	13	99	283	32	224	25
19186	Ħal Saflieni	Tarxien Cemetery	7	86	1245	17	140	9
19187	Ħal Saflieni	Tarxien Cemetery	16	101	336	30	159	16
19188	Ħal Saflieni	Tarxien Cemetery	9	81	1007	17	137	11
19189	Ħal Saflieni	Borġ in-Nadur	11	90	532	22	164	21
19190	Ħal Saflieni	Borġ in-Nadur	12	56	1352	22	187	16
19191	Ħal Saflieni	Borġ in-Nadur	12	87	1203	20	145	11
19192	Ħal Saflieni	Borġ in-Nadur	15	68	495	26	193	23
19193	Ħal Saflieni	Borġ in-Nadur	12	89	325	26	197	19
19208	Mnajdra	Tarxien	8	48	322	19	92	10
19209	Mnajdra	Tarxien	10	85	761	21	136	15
19210	Mnajdra	Tarxien	9	66	366	22	136	14
19211	Mnajdra	Tarxien	11	95	310	20	136	15
19212	Mnajdra	Tarxien	11	101	606	21	152	20
19213	Mnajdra	Tarxien	11	80	253	22	135	18
19214	Mnajdra	Tarxien	11	65	319	22	110	14
19215	Mnajdra	Tarxien	8	79	335	21	114	13
19216	Mnajdra	Tarxien	12	71	541	18	122	12
19217	Mnajdra	Tarxien	9	92	606	21	146	15
19218	Mnajdra	Tarxien	10	90	529	22	143	17

USF Number	Site	Phase	Th	Rb	Sr	Y	Zr	Nb
19219	Mnajdra	Tarxien	9	97	857	22	181	19
19220	Mnajdra	Tarxien	8	61	460	24	142	11
19221	Mnajdra	Tarxien	9	73	837	17	157	13
19222	Mnajdra	Tarxien Cemetery	17	94	755	22	140	13
19275	Skorba	Tarxien	11	102	525	22	153	19
19276	Skorba	Tarxien	7	58	643	21	80	9
19277	Skorba	Tarxien	10	109	715	25	166	18
19278	Skorba	Tarxien	7	71	347	18	86	10
19279	Skorba	Tarxien	8	93	590	17	124	13
19280	Skorba	Tarxien	7	89	579	22	113	11
19281	Skorba	Tarxien	9	76	797	35	121	11
19282	Skorba	Tarxien	11	90	694	36	118	9
19283	Skorba	Tarxien	9	71	434	25	105	11
19284	Skorba	Tarxien	7	70	288	21	77	10
19285	Skorba	Tarxien	8	87	969	17	137	12
19286	Skorba	Tarxien	10	93	1038	20	171	14
19287	Skorba	Tarxien	9	67	513	18	90	10
19288	Skorba	Tarxien	8	55	509	22	81	11
19289	Skorba	Tarxien	11	84	697	18	112	12
19290	Skorba	Tarxien	11	95	725	21	152	15
19291	Skorba	Tarxien	8	81	686	33	106	10
19292	Skorba	Tarxien	8	60	630	20	79	7
19293	Skorba	Tarxien	9	72	626	18	109	11
19294	Skorba	Tarxien Cemetery	13	110	426	22	164	19
19295	Skorba	Tarxien Cemetery	10	101	568	22	166	16
19296	Skorba	Tarxien Cemetery	12	93	609	18	137	15
19297	Skorba	Tarxien Cemetery	13	99	691	20	158	15
19298	Skorba	Tarxien Cemetery	11	99	553	21	157	19
19299	Skorba	Tarxien Cemetery	14	114	689	22	169	18
19300	Skorba	Tarxien Cemetery	11	95	390	21	152	18
19301	Skorba	Tarxien Cemetery	9	77	835	20	147	12
19302	Skorba	Borġ in-Nadur	11	105	311	24	138	17
19341	Ta' Ħaġrat	Tarxien	7	65	583	18	135	11
19342	Ta' Ħaġrat	Tarxien	15	117	652	22	151	17
19343	Ta' Ħaġrat	Tarxien	12	89	886	21	140	14
19344	Ta' Ħaġrat	Tarxien	13	91	475	25	144	15
19345	Ta' Ħaġrat	Tarxien	12	115	516	25	158	21
19346	Ta' Ħaġrat	Tarxien	10	98	560	22	162	19
19347	Ta' Ħaġrat	Tarxien	13	103	615	25	163	19
19348	Ta' Ħaġrat	Tarxien	11	91	512	21	127	14
19349	Ta' Ħaġrat	Tarxien	10	73	626	23	134	14
19350	Ta' Ħaġrat	Tarxien	8	54	398	16	85	7
19351	Ta' Ħaġrat	Tarxien	12	79	550	25	125	11
19352	Ta' Ħaġrat	Tarxien	13	60	568	21	91	10
19353	Ta' Ħaġrat	Tarxien	8	56	481	23	90	7
19354	Ta' Ħaġrat	Tarxien Cemetery	10	88	527	16	112	10
19355	Ta' Ħaġrat	Tarxien Cemetery	14	115	550	24	192	20
19356	Ta' Ħaġrat	Tarxien Cemetery	12	108	447	27	234	25
19357	Ta' Ħaġrat	Tarxien Cemetery	10	66	610	23	138	13
19358	Ta' Ħaġrat	Tarxien Cemetery	10	81	428	23	156	14
19359	Ta' Ħaġrat	Tarxien Cemetery	12	87	319	24	161	17
19360	Ta' Ħaġrat	Tarxien Cemetery	13	89	339	23	138	15
19361	Ta' Ħaġrat	Tarxien Cemetery	9	63	260	19	108	12
19362	Ta' Ħaġrat	Tarxien Cemetery	11	84	305	18	119	13
19363	Ta' Ħaġrat	Tarxien Cemetery	12	89	434	21	147	16
19364	Ta' Ħaġrat	Tarxien Cemetery	12	97	293	27	153	15
19365	Ta' Ħaġrat	Tarxien Cemetery	16	93	751	22	174	16
19366	Ta' Ħaġrat	Tarxien Cemetery	13	107	574	22	164	20

USF Number	Site	Phase	Th	Rb	Sr	Y	Zr	Nb
19367	Ta’ Ħaġrat	Tarxien Cemetery	9	78	611	20	116	12
19368	Ta’ Ħaġrat	Tarxien Cemetery	10	105	871	23	178	18
19369	Ta’ Ħaġrat	Tarxien Cemetery	7	55	1308	15	95	3
19370	Ta’ Ħaġrat	Tarxien Cemetery	11	81	479	21	133	14
19371	Ta’ Ħaġrat	Tarxien Cemetery	13	93	306	26	156	17
19372	Ta’ Ħaġrat	Tarxien Cemetery	12	100	278	24	152	17
19373	Ta’ Ħaġrat	Borġ in-Nadur	6	96	514	22	148	18
19374	Ta’ Ħaġrat	Borġ in-Nadur	14	114	501	24	178	21
19375	Ta’ Ħaġrat	Borġ in-Nadur	13	100	491	25	181	19
19376	Ta’ Ħaġrat	Borġ in-Nadur	10	40	719	25	195	23
19377	Ta’ Ħaġrat	Borġ in-Nadur	14	101	554	22	150	18
19378	Ta’ Ħaġrat	Borġ in-Nadur	15	111	635	23	182	21
19379	Ta’ Ħaġrat	Borġ in-Nadur	12	96	732	22	170	18
19380	Ta’ Ħaġrat	Borġ in-Nadur	16	87	379	25	147	17
19381	Ta’ Ħaġrat	Borġ in-Nadur	15	97	629	26	168	20
19382	Ta’ Ħaġrat	Borġ in-Nadur	12	85	708	22	182	18
19383	Ta’ Ħaġrat	Borġ in-Nadur	15	116	736	23	169	18
19384	Ta’ Ħaġrat	Borġ in-Nadur	12	98	600	23	162	20
19385	Ta’ Ħaġrat	Borġ in-Nadur	15	112	638	24	174	17
19386	Ta’ Ħaġrat	Borġ in-Nadur	15	103	1080	22	189	18
19387	Ta’ Ħaġrat	Borġ in-Nadur	10	100	695	24	187	19
19388	Ta’ Ħaġrat	Borġ in-Nadur	14	99	398	26	182	20
19389	Ta’ Ħaġrat	Borġ in-Nadur	9	66	475	19	108	12
19394	Tarxien	Tarxien	9	57	324	28	303	22
19395	Tarxien	Tarxien	7	76	679	21	110	8
19396	Tarxien	Tarxien	12	103	514	22	147	16
19397	Tarxien	Tarxien	12	121	467	23	154	15
19398	Tarxien	Tarxien	7	57	831	18	98	9
19399	Tarxien	Tarxien	12	58	558	22	68	8
19400	Tarxien	Tarxien	7	56	721	21	74	5
19401	Tarxien	Tarxien	10	85	561	20	104	10
19402	Tarxien	Tarxien	9	60	1110	18	96	6
19403	Tarxien	Tarxien	11	100	617	22	154	14
19404	Tarxien	Tarxien	9	42	525	23	79	6
19405	Tarxien	Tarxien	7	46	310	24	90	10
19406	Tarxien	Tarxien	9	65	226	25	184	15
19407	Tarxien	Tarxien	9	64	353	19	125	12
19408	Tarxien	Tarxien	9	72	443	19	94	8
19409	Tarxien	Tarxien	8	67	194	21	134	18
19410	Tarxien	Tarxien	10	56	270	26	140	17
19411	Tarxien	Tarxien	11	72	256	26	201	21
19412	Tarxien	Tarxien	8	63	434	24	116	12
19413	Tarxien	Tarxien Cemetery	12	106	286	24	173	18
19414	Tarxien	Tarxien Cemetery	12	100	673	22	150	14
19415	Tarxien	Tarxien Cemetery	11	114	514	21	159	17
19416	Tarxien	Tarxien Cemetery	7	83	929	18	158	14
19417	Tarxien	Tarxien Cemetery	12	92	261	29	150	18
19418	Tarxien	Tarxien Cemetery	9	99	292	24	201	17
19419	Tarxien	Tarxien Cemetery	8	102	674	23	185	18
19420	Tarxien	Tarxien Cemetery	10	91	819	20	148	13
19421	Tarxien	Tarxien Cemetery	9	90	921	15	150	14
19422	Tarxien	Tarxien Cemetery	10	93	361	22	154	18
19423	Tarxien	Tarxien Cemetery	11	94	365	18	194	18
19424	Tarxien	Tarxien Cemetery	13	98	316	34	218	19
19425	Tarxien	Tarxien Cemetery	14	91	580	25	179	18
19426	Tarxien	Tarxien Cemetery	12	97	395	28	199	17
19427	Tarxien	Tarxien Cemetery	12	102	370	35	198	18
19428	Tarxien	Tarxien Cemetery	10	96	396	25	148	16

USF Number	Site	Phase	Th	Rb	Sr	Y	Zr	Nb
19429	Tarxien	Tarxien Cemetery	12	101	521	24	186	19
19430	Tarxien	Tarxien Cemetery	12	111	802	21	160	16
19431	Tarxien	Tarxien Cemetery	14	127	237	33	216	24
19432	Tarxien	Tarxien Cemetery	14	92	367	36	238	21
19433	Tarxien	Tarxien Cemetery	13	104	719	23	169	18
19434	Tarxien	Tarxien Cemetery	11	87	1104	19	160	15
19435	Tarxien	Tarxien Cemetery	12	99	464	38	320	24
19436	Tarxien	Tarxien Cemetery	11	103	546	18	165	14
19437	Tarxien	Tarxien Cemetery	13	92	272	27	180	17
19438	Tarxien	Tarxien Cemetery	10	86	985	17	115	9
19439	Tarxien	Tarxien Cemetery	8	96	473	22	160	16
27212	Ognina	Borġ in-Nadur	13	98	492	21	134	13
27213	Ognina	Thapsos	6	40	252	18	140	8
27214	Ognina	Thapsos	6	56	494	17	98	6
27216	Ognina	Thapsos	9	72	293	23	182	15
27217	Ognina	Thermi	8	80	284	22	184	16
27218	Ognina	Thapsos	10	77	213	24	223	14
27219	Ognina	Thapsos	11	92	594	22	148	18
27221	Ognina	Thermi	9	74	333	19	142	13
27223	Ognina	Thapsos	10	63	406	20	163	14
27225	Ognina	Borġ in-Nadur	7	67	1562	12	103	2
27226	Ognina	Borġ in-Nadur	12	100	456	20	133	13
27227	Ognina	Castelluccio	13	79	406	19	147	12
27228	Ognina	Castelluccio	11	81	351	21	157	16
27229	Ognina	Thapsos	11	58	313	19	122	11

Table 3. Trace elemental data for geological clay materials (ppm).

USF Number	Site	Location	Th	Rb	Sr	Y	Zr	Nb
19440	Gnejna Bay	Cliff Side	10	88	739	19	111	9
19441	Gnejna Bay	Cliff Side	9	100	637	16	122	15
19442	Gnejna Bay	Cliff Side	9	99	711	16	117	10
19443	Gnejna Bay	Cliff Side	8	96	638	18	114	13
19444	Gnejna Bay	Cliff Side	9	92	806	14	104	10
19445	Gnejna Bay	Cliff Side	7	97	669	15	97	11
19446	Gnejna Bay	Top of Cliff	13	129	442	21	126	14
19447	Gnejna Bay	Top of Cliff	9	123	454	21	149	13
19448	Gnejna Bay	Top of Cliff	12	137	457	22	134	16
19449	Gnejna Bay	Top of Cliff	11	127	493	21	129	15
19450	Selmun	Cliff Bottom	6	84	820	15	117	10
19451	Selmun	Cliff Bottom	7	83	880	17	135	12
19452	Selmun	Cliff Bottom	13	83	915	14	134	7
19453	Selmun	Cliff Bottom	5	68	937	19	122	7
19454	Selmun	Cliff Bottom	8	76	1163	15	129	7
19455	Selmun	Top of Cliffs	9	106	439	20	120	14
19456	Selmun	Top of Cliffs	10	97	518	16	108	10
19457	Selmun	Top of Cliffs	9	82	559	18	108	11
19458	Selmun	Top of Cliffs	10	93	410	18	105	15
27243	Siracusa	Siracusa Clays	8	33	484	16	68	1
27244	Siracusa	Siracusa Clays	6	31	493	14	69	5
27245	Siracusa	Siracusa Clays	8	33	483	16	52	6
27247	Siracusa	Siracusa Clays	11	33	485	14	53	3

3 Results

The results of the PCA (Fig.'s 4 to 9) shows that the majority of the Maltese and Sicilian ceramics included in this study can be separated into groups based on whether the clay used to produce the ceramic wares were from a Sicilian or Maltese clay source. The results further suggest that either raw clay materials or finished pottery moved with individuals traveling between Sicily and Malta during the Bronze age and potentially prior in the Tarxien Phase of the Maltese Temple Period (Pirone 2017). Variation within each of the groups consisting of ceramics made from either a Maltese or Sicilian clay source is best interpreted as the use of multiple clay outcrops in the pottery production.

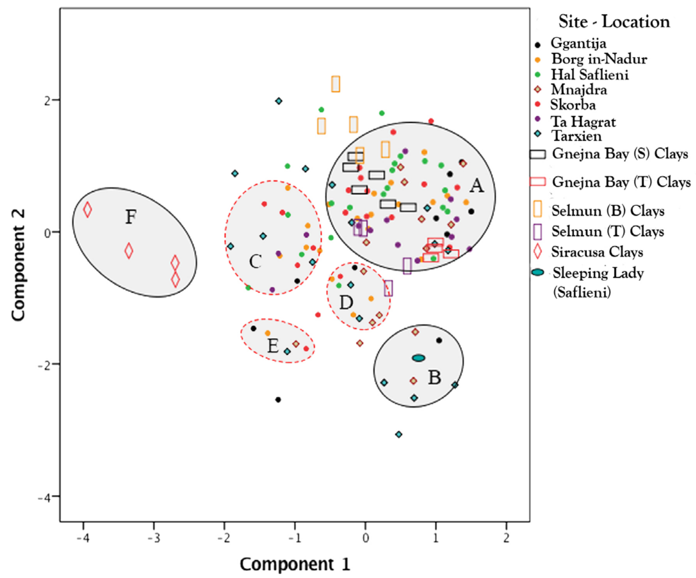

Figure 4. Bivariate scatterplots of principal component scores for Tarxien phase samples and Maltese and Sicilian clay samples. Ellipses are made artificially.

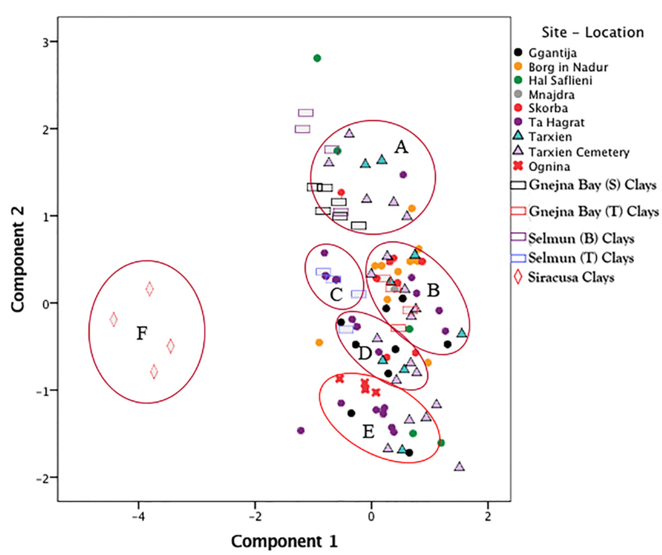

Figure 5. Bivariate scatterplots of principal component scores for Tarxien Cemetery phase samples and Maltese and Sicilian clay samples. Ellipses are made artificially.

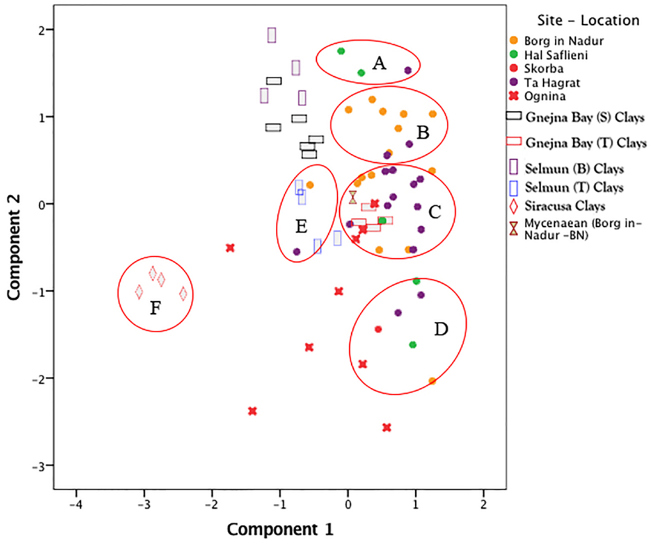

Figure 6. Bivariate scatterplots of principal component scores for Borġ in-Nadur phase samples and Maltese and Sicilian clay samples. Ellipses are made artificially.

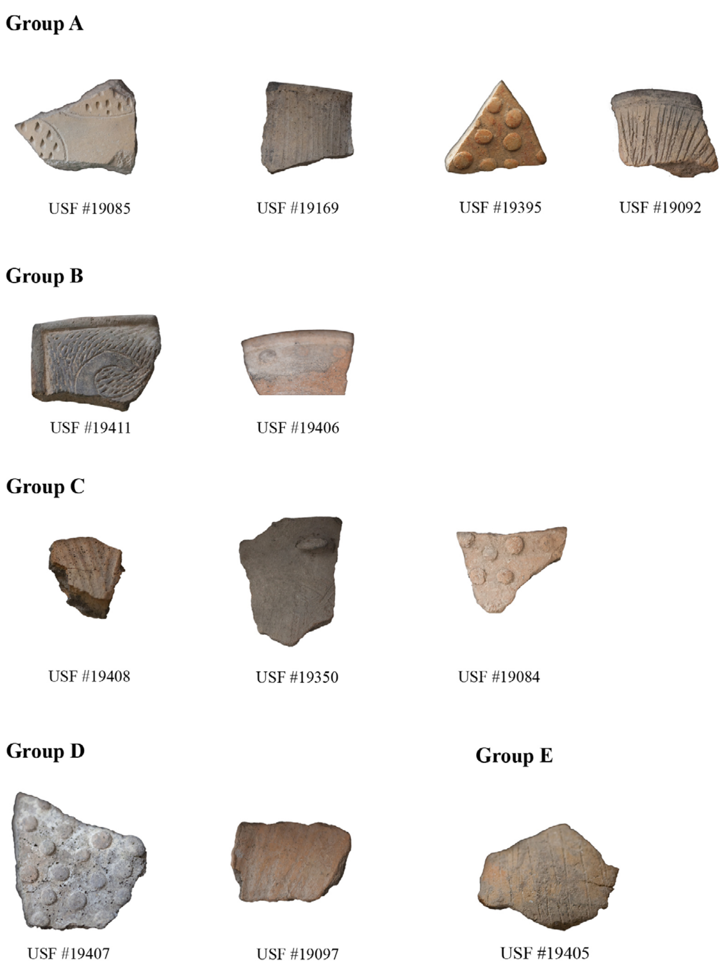

Figure 7. Selection of sherd examples from the Tarxien phase and group assignments based on the principal component analysis depicted in Figure 3 (Not to scale). Sherds Photograph by Fred Pirone.

Figure 8. Selection of sherd and pottery examples from the Tarxien Cemetery phase and group assignments based on the principal component analysis depicted in Figure 4 (Not to scale). Sherds, Vessels and Figurines Photograph by Fred Pirone.

The results of the pXRF data on all the Maltese ceramic and geological samples show that the majority of Maltese wares were made with clays from a Maltese source and come from clay outcrops that have a trace elemental composition similar to that observed for the clay from outcrops located at Ġnejna Bay. There also appears to be another clay provenance that is suggested by the clustering pattern of the Maltese ceramics that have a similar chemical composition as the clays sampled at Ġnejna Bay except for having a higher Sr composition. The majority of ceramic samples from Skorba cluster together in this area. This could potentially suggest another clay source that was not sampled such as one found around Skorba and Ta' Ħaġrat. However, it is also possible that these samples represent clays that came from a part of the clay outcrops at Ġnejna Bay that have higher Sr levels. The calcium carbonate content of the clays varies throughout the Maltese clay formation but generally increases as the clay comes in greater contact with the underlying globigerina limestone (Pedley, pers. comm. 2013; Pedley et al. 2002). Changes in the amount of carbonate materials such as calcite affect the amount of Sr that is present (Chen et al. 2006). This can be seen with the Sr composition for the geological samples in this study. The Sr composition is greater for the geological samples that were taken from lower levels within the clay outcrop that are in closer proximity to the underlying globigerina limestone. Therefore, it is possible that the ceramic samples that plot above the clay samples taken from the top of the cliff at Ġnejna Bay do not represent a separate location on the island of Malta but a lower level not sampled at Ġnejna Bay.

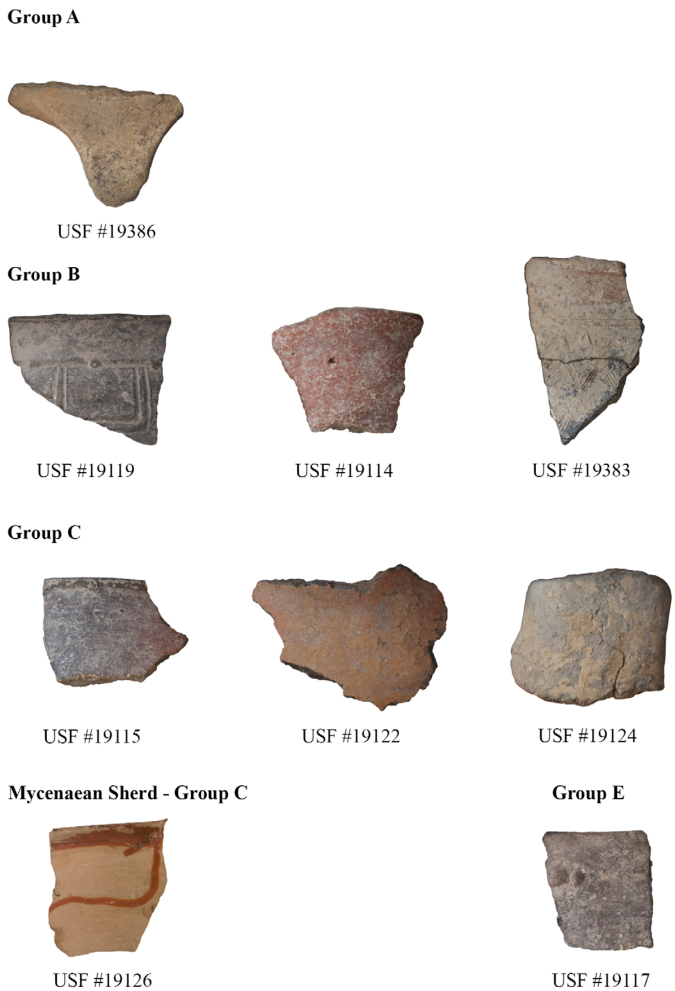

Figure 9. Selection of sherd examples from the Borġ in-Nadur phase and group assignments based on the principal component analysis depicted in Figure 5 (Not to scale). Sherds, Vessels and Figurines Photograph by Fred Pirone.

The remaining ceramic samples appear to have trace elemental compositions similar to the chemical compositions of the outcrops located at Selmun and a third clay source that was not sampled but has a comparatively lower Sr composition than all the clay samples analyzed. This latter provenance can be observed for the Tarxien phase (Fig. 4). The majority of the ceramic samples that plot in this group are from the temple sites Tarxien and Mnajdra. The lower Sr compositions for the ceramic samples in this third group suggests that the clay source the potters accessed to make these wares had to have a comparatively lower calcium carbonate content from what is observed at Ġnejna Bay and Selmun area. This other source potentially is from an ancient clay outcrop no longer accessible or from a clay source not sampled for this study.

Finally, the ceramic samples of the Tarxien phase wares indicate that the ancient potters used additional clay sources for their raw materials from the previous phases. This is based on these samples clustering in different patterns from the majority of the Maltese ceramic and clay samples (Fig. 3). The samples that plot in this area have comparatively lower Rb and Zr compositions, and it was determined that these samples on average are statistically different from the majority of the Maltese ceramic and clay samples (Pirone 2017). There are three possible explanations that can account for this observation: 1) the clay source for these samples is a local Maltese outcrop that was not sampled or an ancient outcrop no longer accessible; 2) the clay source is foreign; or 3) the samples represent a mixing of clays from both Maltese and foreign clay sources. It should be noted that the decorative features and forms observed for these sherds are common

Maltese decorative motifs association with the Tarxien phase. While a local source cannot be ruled out, it is possible that these samples were made from clays imported into Malta as raw materials. However, a more comprehensive survey of clay sources from the central Mediterranean is required to confirm this hypothesis.

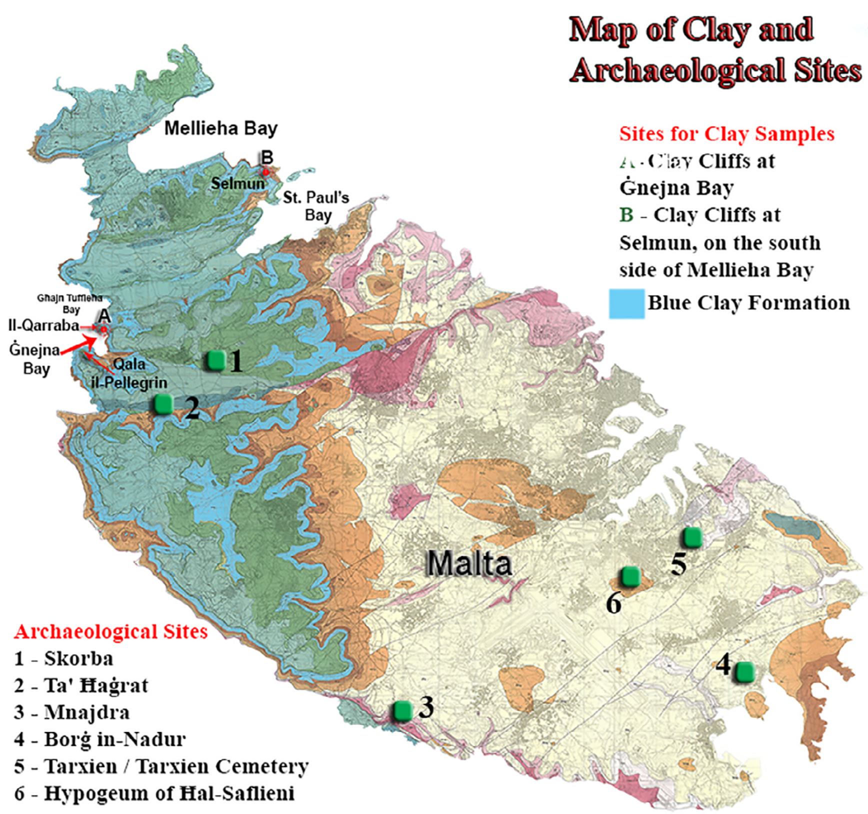

Figure 10. Map of the locations clay sources were sampled with archaeological sites on the island of Malta. (Adapted from the Geological Map (1:25,000) made for the Oil Exploration Directorate Office of the Prime Minister of Malta,1993 and NASA orbital photograph of Sicily and the Maltese Islands, March 14, 2004).

4 Discussion

Malta appears to have had interaction with Sicily and other localities in the central Mediterranean throughout its prehistory; therefore, the Maltese archipelago potentially was never truly completely isolated from the rest of the central Mediterranean. Previous evidence suggests that the Maltese inhabitants had some level of trade and interaction with surrounding areas (Copat et al. 2010; Trump 1966; Vella 2016). The present study adds support to this position. Despite Malta's unique cultural trajectory experienced during its Temple Period, there have been generally two types of archeological evidence supporting the Maltese maintaining relationships with other communities in the central Mediterranean. This would include imported goods being recovered from levels associated with each of the chronological phases of Malta's prehistory such as obsidian, pumice, greenstone and flint (Trump 1966; Skeates 2002; Vella 2016). Additionally, similarities in the material culture between Malta and other locations in the central Mediterranean during the Maltese Neolithic period and Bronze Age such as similar decorative styles and forms observed among the ceramic repertoires and similarities in cultural forms such as funerary traditions and architecture have been noted in the archaeological literature (Evans 1959, Evans 1971; Leighton 1999; Malone et al. 1995; Trump 1966). However, the magnitude and nature of these external interactions may have evolved and changed over time (Copat et al. 2010).

During the Ġgantija phase of the Temple Period, the Maltese began to focus their attention on megalithic construction. This can be seen with the new temple construction and expansion of subterranean tombs throughout the archipelago. Ceramics samples associated with this phase were also analyzed and it was determined in a prior study that their trace elemental composition suggested that the Maltese used predominately local clay sources found on the islands of Malta and Gozo with no evidence of foreign imports (Pirone 2017). In comparison, the trace elemental composition of the Tarxien phase samples suggests a slightly different story than what was observed for the Ġgantija phase. The Maltese appear to have expanded the number of clay sources they accessed to make their ceramic wares. This is suggested by both changes in the patterning and the diversity of the clusters forming based on the trace elemental compositions for each of the samples. In particular, some of the groups may actually represent sherds made from non-local clays because they have chemical compositions that are statistically different from the majority of the Maltese ceramics and clay samples. However, this cannot be conclusively determined without a more comprehensive survey of clay sources being sampled both on Malta and other locations throughout the central Mediterranean.

One alternative in explaining the presence of these additional clay sources (i.e., Fig. 4, Groups C and E) is that they represent ceramics made later in the Tarxien phase. The later segment of the Tarxien phase may have been a period when the Maltese began to shift away from its focus on monumental construction and ritual intensification to a focus on outside contacts. This may have been due to changing environmental conditions in the region that served as a catalyst for people who begin to move around and migrate to new locations throughout the central Mediterranean. For example, Recchia & Fiorentino (2015) discuss the introduction of Thermi wares into Malta toward the end of the Tarxien phase and suggest that the introduction of this ware type into Malta may be due to small groups of people potentially migrating from Peloponnesus. They suggest that changing environment conditions may have caused these small groups of people to eventually settle in Malta and live alongside the local Temple Period people (Recchia, Fiorentino 2015:13). If this is indeed the case, it is possible these small groups of people could have brought with them into Malta clay from outside sources as they moved around the central Mediterranean. It is also possible that these “outsiders” could have either traded these clays with the local Maltese potters who used them to make ceramics based on the prevailing cultural traditions or these “outsiders” could have begun the process of opening up the door to new trade relations that included ancient Maltese potters obtaining clays from outside sources. Admittedly, these notions are mere conjecture at this point but they do provide an interesting hypothesis in explaining the sherds that appear to be made from clays that have a trace elemental composition statistically different from the majority of the Tarxien phase ceramics and all the Maltese clays sampled for this study.

The Maltese Bronze Age begins with the onset of the Tarxien Cemetery phase. The Tarxien Cemetery phase is considered a break from the previous cultural practices observed in the Temple Period (Evans 1971). Differences in cultural practices include the abandonment and the repurposing of the megalithic temples (Pace 2004; Bonanno 1999), introduction of cremation as a communal burial rite (Evans 1959), development of new architectural practices seen with the construction of dolmens (Evans 1959; Dixon 1998), the first signs of the use of copper (Maniscalco 2000), and changes in the pottery repertoire including the adoption of richly incised monochrome pottery (Evans 1971). Specifically with regard to ceramics, the pottery repertoire shows no signs of continuation from the previous Tarxien phase (Bonanno 1993; Evans 1971; Trump 1966). The fabric becomes less refined and there are new types and shapes, some of which are unique and distinct in their artistic quality (Evans 1959).

The pXRF results in the current study included data on the trace elemental compositions of two samples from Castelluccio wares and two samples from sherds identified as Thermi wares (Raneri et al. 2015). All these samples were from sherds recovered at Ognina, Sicily, and were determined to be made with clays local to Sicily (Tanasi, pers. comm. 2016). The results in the present study show that there are Maltese ceramics samples that have similar trace elemental compositions to these Ognina ceramic samples. Therefore, this would suggest that these ceramics recovered from archaeological sites in Malta may be imports into the Maltese archipelago. This would lend support to Evans’ observations about the similarities between Maltese pottery and Sicilian Castelluccio wares and Trump’s observations about Thermi wares indicating Malta and Sicily shared cultural connections during this time period.

The Borġ in-Nadur phase follows the Tarxien Cemetery phase and marks Malta's middle Bronze Age. During this time period, the first fortified settlements appear, burials are no longer made in megalithic structures, and the first pieces of bronze have been recovered at the site-type for this phase (Murray 1923; Tanasi 2009; Trump 1961). The pottery shows a technical continuity with the previous Tarxien Cemetery phase but differences can be found in the number of shapes, color and decorations employed in the Borġ in-Nadur phase (Evans 1971; Tanasi 2011, 2015). Molitor (1988:227-28) determined that the wares for both the Tarxien Cemetery and Borġ in-Nadur phases showed a dramatic departure from the proceeding Temple Period in terms of the coarseness of the clay, the firing temperature, the slipping process and forms. However, the pXRF data in the present study suggests that the ancient potters used the same local clay sources as in the preceding periods except for the additional clay sources identified being used in the Tarxien phase discussed above, which do not appear to be clay outcrops accessed during the Bronze Age.

Overall, the results of the pXRF data show that pottery played a new role in the trade and interaction networks between Malta and the rest of the central Mediterranean. Ognina samples associated with Malta's Borġ in-Nadur phases have trace elemental compositions that suggest their provenance is Maltese. This lends additional support to Malta's reemergence into the broader central Mediterranean interaction sphere and the active role of the Maltese islands as a trading partner with Sicily. Further, the pXRF data from this study provides the first time there is chemical evidence to conclusively support Maltese pottery being found in Sicily (Raneri et al. 2015). This further suggests that Maltese ceramics played a role as an exported good among the items that were traded within the exchange and interaction relationships between Malta and Sicily.

Among the Borġ in-Nadur phase sherds that were sampled, one sherd is of particular note. This sherd is a fragment of a Mycenaean LH IIIA2-IIIB1 drinking cup or kylix (Fig. 11) that was recovered from a reused portion of the prehistoric temple at Borġ in-Nadur referred to as the "Double Chapel" (Blakolmer 2005:658; Murray 1929:25; Sagona 2011:410; Tanasi, Vella 2014:65). The discovery of this sherd and one other recovered from Tas-Silġ (Blakolmer 2005:658; Evans 1971:227) has served as evidence suggesting the Mycenaeans on some level had contact with Malta by the time of the Borġ in-Nadur Phase. However, the trace elemental data for the Borġ in-Nadur Mycenaean sherd suggests it was made with clays from a Maltese source. This lends support to the hypothesis that Malta's involvement with the Mycenaean merchants, who were regularly visiting places further north like the Aeolian Islands, was indirect in nature (Blakolmer 2004; Tanasi, Vella 2014).

Figure 11. Photograph of Mycenaean Sherd recovered from the Double Chapel at Borġ in-Nadur. Photograph by Fred Pirone.

5 Conclusion

The foregoing research provides chemical support to what has been observed archaeologically about Maltese prehistoric pottery and its relationship with other contemporary wares from Sicily, the Aeolian Islands and Southern Italy. This research shows that pottery played a more significant role in Malta's trade relations during Malta's Bronze Age. The results further indicate that the vast majority of Maltese ceramics were made with clays from local sources and that there was overlapping in the trace elemental signatures for ceramics samples associated with each of the sites included in this study. This suggests that the Maltese temple communities shared access to the same raw clay materials throughout Malta or that the temple communities shared a limited number of ceramic workshops that served most of the island's pottery needs. The pXRF data further suggest that no ceramic imports can be clearly identified during the Tarxien phase of the Temple Period. This collaborates archaeological observations based on shapes, decorative styles and finishing treatments that indicate the Maltese developed a unique pottery style having no counterparts anywhere in Sicily or elsewhere in the central Mediterranean. On the other hand, there appears to be additional clay resources being used for some of the ceramics during the Tarxien Phase that are statistically different in their trace elemental compositions from the majority of the Maltese ceramic samples and all the Maltese clay samples included in this study. This suggests that either the clay is from a source that was not sampled for this study, that the clay is from a source no longer accessible during modern times, or that the clay is from an outcrop outside of the Maltese islands. Finally, this research provides conclusive evidence in support of Maltese Borġ in-Nadur style pottery being found in Sicily (Raneri et al. 2015).

Overall, the results from this study support current archaeological theory with regard to Malta's involvement in trade and interaction networks throughout its prehistory but also offers some new observations that includes additional clay sources being used in the pottery production during Malta's Tarxien phase and the Mycenaean sherd recovered at Borġ in-Nadur having a trace elemental composition indicating it is a local Maltese reproduction of a Mycenaean vessel. However, the nature of the additional clay resources being used during the Tarxien phase requires more research that includes petrographic analysis and a more systematic survey of raw clay materials throughout the central Mediterranean.

Acknowledgments: The present research was made possible through the generosity, kindness and guidance of several individuals and institutions to whom I am greatly appreciative. I would like to give a special thanks to Heritage Malta and the National Museum of Archaeology in Valletta, Malta for the assistance and permission to study the Neolithic to Bronze Age pottery and for hosting my research at the museum in May of 2013. I particularly like to thank Sharon Sultana, Senior Curator of the National Museum of Archaeology, and Vanessa Ciantar, Assistant Curator of the National Museum of Archaeology. I also would like to thank the Laboratory for Archaeological Science & Technology (L.A.S.T.) for providing the Bruker Tracer III-SD pXRF instrument and assistance in analyzing the trace elemental data. Finally, I would like to thank Louis Pirone, Lucille Pirone, Maria Pirone and especially Jamie Pirone for providing all the funding for this research project.

References

Barone, G., Mazzoleni, P., Raneri, S., Tanasi, D. & Giuffrida, A. (2015). Archaeometric Characterization of Middle Bronze Age Pottery from the Settlement at Borg in-Nadur. In D. Tanasi and N.C. Vella (Eds.), The late prehistory of Malta: Essays on Borġ in-Nadur and Other Sites. (pp. 99-111). Oxford: Archaeopress.

Blakolmer, F. (2004). Interrelations between Prehistoric Malta and the Eastern Mediterranean: A View from the Aegean. In Exploring the Maltese Prehistoric Temple Culture (EMPTC), Malta 25-27 September 2003.

Blakolmer, F. (2005). Relations between Prehistoric Malta and the Aegean: Myth and Reality. In R. Laineur and E. Greco (Eds.), Emporia: Aegeans in the Central and Eastern Mediterranean. Aegaeum. (pp. 653-62). Liege and Austin: Université de Liège and University of Texas.

Bonanno, A. (1993). Tarxien and Tarxien Cemetery: break or continuity between Temple Period and Bronze Age in Malta? Mediterrâneo 2: 35-47.

Bonanno, A. (1999). Tarxien, Xaghra Circle and Tas-Silġ : occupation and re-use of temple sites in the Early Bronze Age. In A. Mifsud and C. Savona-Ventura (Eds.), Facets of Maltese Prehistory. (pp. 209-18). The Prehistoric Society of Malta.
Bonanno, A., Gouder, T., Malone, C. & Stoddart, S. (1990). Monuments in an Island Society: the Maltese Context. World Archaeology 22(2): 190-205.
Chen, J., Chen, Y., Liu, L., Ji, J., Balsam, W., Sun, Y., and Lu, H. (2006). Zr/Rb ratio in the Chinese loess sequences and its implication for changes in the East Asian winter monsoon strength. Geochimica et Cosmochimica Acta 70(6): 1471-1482.
Copat, V., Danesi, M., Recchia, G. (2010). Isolation and Interaction Cycles. Shima: The International Journal of Research into Island Cultures 4(2): 41-64.
Dixon, C.A. (1998). The End of Malta's Temple-building Culture. Journal of Prehistoric Religion 11-12: 37-59.
Evans, J.D. (1959). Malta: Ancient Peoples and Places Series. London: Thames and Hudson.
Evans, J.D. (1971). Prehistoric Antiquities of the Maltese Islands. London: Athlone Press.
Hunt, A. and Speakman, R. (2015). Portable XRF Analysis of Archaeological Sediments and Ceramics. Journal of Archaeological Science 53: 1-13.
Leighton, R. (1999). Sicily before History. An Archaeological Survey from the Palaeolithic to the Iron Age. London: Duckworth.
Malone, C., Stoddart, S., Bonanno, A., Gouder, T. and Trump, D. (1995). Mortuary Ritual of 4th Millennium BC Malta: the Zebbug Period Chambered Tomb from the Brochtorff Circle at Xaghra (Gozo). Proceedings of the Prehistoric Society 61: 303-345.
Malone, C., Stoddart, S., Bonanno, A., Trump, D., Gouder, T. and Pace, A. (2009). Mortuary Customs in Prehistoric Malta: Excavations at the Brochtorff Circle at Xaghra (1987-94). Cambridge: McDonald Institute for Archaeological Research.
Maniscalco, L. (2000). Osservazione sulla produzione metallurgica in Sicilia nell'Antica età del Bronzo. Sicilia. Archeologica 33: 159-66.
Molitor, M. (1988). Pots and Potters of Prehistoric Malta (Unpublished doctoral dissertation). University of California, Los Angeles.
Mommsen, H., Bonanno, A., Bonavita, K.C., Kakoulli, I., Musumect, M., Sagona, C., Schwedt, A., Vella, N.C. and Zacharias, N. (2006). Characterization of Maltese Pottery of the Late Neolithic, Bronze Age and Punic Period by Neutron Activation Analysis. In M. Maggetti and B. Messiga (Eds.), Geomaterials in Cultural Heritage. (pp. 81-89). London: The Geological Society of London.
Murray, Margaret A. (1923). Excavations in Malta I. B. Quaritch.
Murray, Margaret A. (1929). Excavations in Malta III. B. Quaritch.
Pace, A. (2004). The Maltese Bronze Age. In D. Cilia (Ed.), Malta before History. (pp. 211–27). Sliema: Miranda Publications.
Pedley, H.M., Hughes-Clarke, M., Galea, P. (2002). Limestone Isles in a Crystal Sea: The Geology of the Maltese Islands. Malta: Publishers Enterprises Group Ltd.
Pirone, F. (2017). Trade, Interaction and Change: Trace Elemental Characterization of Maltese Neolithic to Middle Bronze Age Ceramics Using a Portable X-ray Fluorescence Spectrometer (Unpublished doctoral dissertation). University of South Florida, Tampa, Florida.
Recchia, G. and Fiorentino, G. (2015). Archipelagos Adjacent to Sicily Around 2200 BC: Attractive environments or suitable geo-economic locations? In H. Meller, H.W. Arz, R. Jung and R. Risch (Eds.), 7th Archaeological Conference of Central Germany, 23-26 October 2014, Halle (Saale), Germany, pp. 305-319.
Raneri, S., Barone, G., Mazzoleni, P., Tanasi, D. and Costa, E. (2015). Mobility of Men Versus Mobility of Goods: Archaeometric Characterization of Middle Bronze Age Pottery in Malta and Sicily (15th-13th Century BC), Periodico di Mineralogia, 84(1): 23-44.
Robb, J. (2001). Island Identities: Ritual, Travel and the Creation of Difference in Neolithic Malta, European Journal of Archaeology 4(2): 175-202.
Sagona, C. (2011). Observations on the late Bronze Age and Phoenician-Punic Pottery in Malta. In C. Sagona (Ed.), Ceramics of the Phoenician-Punic World : Collected Essays. (pp. 397-432). Leuven: Peeters.
Skeates, R. (2002). Axe Aesthetics: Stone Axes and Visual Culture in Prehistoric Malta. Oxford Journal of Archaeology 21(1): 13-22.
Speakman, R., Little, N.C., Creel, D., Miller, M.R., AndIñañez, J.G. (2011). Sourcing ceramics with portable XRF spectrometers? A comparison with INAA using Mimbres pottery from the American Southwest. Journal of Archaeological Science 38: 3483-3496.
Speakman, R.J., and Schakley, M.S.(2013). Silo Science and Portable XRF in Archaeology: A Response to Frahm. Journal of Archaeological Science 40(2): 1435-1443.
Tanasi, D. (2009). Vasellame Metallico in Sicilia e Nell'Arcipelago Maltese Nella Seconda Metà del II Millennio a.C. Forme Egee per Pratiche Religiose Indigene, Orizzonti X: 11-28.
Tanasi, D. (2011). The Prehistoric Pottery. In D. Tanasi and N.C. Vella (Eds.), Site, Artifacts and Landscape – Prehistoric Borg in-Nadur, Malta. (pp. 71-158). Monza: Polimetrica.
Tanasi, D. (2015). The pottery from the excavation campaigns of David H. Trump (1959) at the settlement of Borġ in-Nadur. In D. Tanasi and N.C. Vella (Eds.), The Late Prehistory of Malta: Essays on Borġ in-Nadur and Other Sites. (pp. 35-98). Oxford: Archaeopress.

Tanasi, D. and N.C. Vella (2014). Islands and mobility: exploring Bronze Age connectivity in the south-central Mediterranean. In P. Van Dommelen and B. Knapp (Eds.), The Cambridge Prehistory of the Bronze and Iron Age Mediterranean. (pp. 184-201). Cambridge: Cambridge University Press.

Trump, D.H. (1961). The Later Prehistory of Malta. Proceedings of the Prehistoric Society 27: 253-62.

Trump, D.H. (1966). Skorba: Excavations carried out on behalf of the National Museum of Malta 1961-1963. London: Society of Antiquaries.

Tykot, R.H. (2004). Scientific Methods and Applications to Archaeological Provenance Studies. In M. Martini, M. Milazzo and M. Piacentini (Eds.), Physics Methods in Archaeometry. Proceedings of the International School of Physics "Enrico Fermi" Course CLIV. (pp. 407-432). Bologna: Società Italiana di Fisica.

Tykot, R.H. (2016). Using Non-Destructive Portable X-Ray Fluorescence Spectrometers on Stone, Ceramics, Metals, and Other Materials in Museums: Advantages and Limitations. Applied Spectroscopy 70(1): 42-56.

Tykot, R.H., White, N.M., Du Vernay, J.P., Freeman, J.S., Hays, C.T., Koppe, M., Hunt, C.N., Weinstein, R.A., & Woodward, D.S. (2013). Advantages and Disadvantages of pXRF for Archaeological Ceramic Analysis: Prehistoric Pottery Distribution and Trade in NW Florida. In Armitage, R.A. & Burton, J.H. (Eds.), Archaeological Chemistry VIII. (ACS Symposium Series). (pp. 233-244). Washington, D.C.: American Chemical Society.

Vella, C. (2016). Manipulated Connectivity in Island Isolation: Maltese Prehistoric Stone Tool Technology and Procurement Strategies Across the Fourth and Third Millennia. The Journal of Island and Coastal Archaeology 11: 344-363.