Architectural terracottas from Akragas : investigating monumental roofs from the Archaic and Classical period

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3 THEORY AND METHODOLOGY

The investigation of architectural terracottas as the product of diverse material and ideological conditions requires a research approach that incorporates a number of different areas including decorative style, production techniques, material composition and architectural function (section 2.3). Each of these topics is governed by different theoretical and methodological frameworks, which are thus considered separately in sections 3.2 to 3.5. It should be noted that the theory and methodology, which is applicable to each individual area of research, will be treated together. According to William Y. Adams and Ernest W. Adams; "theory and practice must be interrelated and inter-relevant."[1] In essence theory is grounded in the practical reality while any proposed methods should in turn be born from a thorough theoretical understanding. Due to the interrelated nature of theory and methodology, the two will thus be discussed together for each research area investigated in the following sections.

A number of scholars agree that the first step in the study of archaeological assemblages is organizing the material according to the various categories relevant to the particular research.[2] These categories can include the find location of objects as well as the functional form, to name but a few. The ordering of data creates a classification system, or typology. A typology can address both material and ideological material conditions. For example, the choice of material for a specific type of object can be governed by functional requirements, practical considerations and even ideological concepts regarding what is appropriate for a specific type of object.[3] The investigation of style, production and material composition is therefore also concerned with identifying objects which are similar in these terms. In this manner, the study of the different material and ideological conditions identified in section 2.3 includes the production of different typologies. These contain a stylistic typology (section 4.1) and a fabric typology, which is the combination of characteristics related to raw materials and production techniques (section 4.2). As described above (section 2.3), the production of a revised typology for the terracotta roofs from Akragas is one of the major goals of this thesis. This revised typology (section 5) aims to reflect the diverse conditions which affect architectural elements and as such is a synthesis of the various analytical typologies created in section 4. The creation of typologies is therefore both an important analytical tool as well as a research aim in this thesis. The theory and methodology which underlie the establishment of such classification systems will be considered in section 3.1.

3.1 TYPOLOGIES

In the introduction of this chapter the terms 'classification' and 'typology' were used together, but some scholars argue that these are separate concepts.[4] In essence a system of classification organizes objects into different groups based on specific characteristics, be it style or material or a wide range of other characteristics. A typology is a form of classification system which organized objects into types based on an underlying conceptual system related to the producers and users of the objects.[5] Adams and Adams define typology as follows: "A typology is a conceptual system made by partitioning a specified field of entities into a comprehensive set of mutually exclusive types, according to a set of common criteria dictated by the purpose of the typologist."[6] This definition introduces an important aspect of typologies, project specificity. Due to the large amount of criteria and the substantial differences between assemblages it is recognized that one

1 Adams & Adams 1991, p. 1.

2 Adams & Adams 1991, p. 9; Abramov et al. 2006, p. 256; Orton & Hughes 2013, p. 3; Winther-Jacobsen 2010, p. 49.

3 Read 2007.

4 Horejs et al. 2010, p. 10.

5 Read 2007.

6 Adams & Adams 1991, p. 91.

single typology will not necessarily be appropriate for all assemblages. Furthermore, as indicated by Read, the purpose of a typology is to identify the social and cultural context in which an object was produced.[7] The choice of characteristics used for organizing the data is therefore specifically chosen in order to investigate a specific research question, which introduces a level of subjectivity.[8]

Due to the nature of the objects in an assemblage, a typology is also required to account for a certain level of variability. For example, one of the attributes used for identifying fabric types is clay colour. Because of the manual production process and the variance of natural resources, even objects manufactured on the same day by the same person using the same material can be expected to vary slightly. It is therefore recognized that a typology must be able to account for a certain level of variability.[9] When considering this, it is important that the variation between objects within the same type must be smaller than the variation between objects from different types. In other words, the homogeneity inside a group is higher than the homogeneity between groups.[10] For example, while the dimensions of a particular profile element might vary with one or two millimetres between objects from the same sima, they may vary from objects from a different group of sima by centimetres. Due to this variability, the boundaries between different groups or types are rarely sharply defined. An object therefore occasionally falls within a fuzzy boundary and then the allocation of that object to a specific group becomes a judgement call. It is therefore of great importance that this process be as transparent as possible and that these boundary cases be clearly identified.[11]

The references used in the above description of typologies are all related to pottery studies and not architectural terracottas. Within archaeology the theory and methodology regarding the classification of objects is more defined and established in some disciplines compared to others. As was demonstrated in chapter 2, investigation of architectural terracottas only recently moved beyond classifying objects only according to style and chronology in order to include new areas of investigation such as methods of manufacture and material characteristics. In this regard pottery studies have the advantage. Clive Orton and Michael Hughes describe the research history of archaeological pottery as consisting of three phases. The first phase is primarily concerned with art-historical questions, the second with the creation of stylistic and chronological typologies and the last phase is characterized by a more complex contextual approach.[12] This contextual approach started in the 1960's and is characterized by a more systematic procedure in order to investigate the material based on raw materials, methods of production as well as well as wear and destruction. This allowed for the investigation of larger contextual concerns such as trade and exchange, use and abandonment.[13] Not only do pottery studies have a longer history of studying objects within a contextual approach, they also have a much more established theoretical and methodological research base. For example, there are a number of handbooks focused on methodology,[14] and the state of research is periodically reviewed and new methods explored.[15] For this reason, the theory and methods regarding typologies draw extensively on those developed within pottery studies.

The methodology for the creation of a typology can be divided into two steps; the first is the

7 Read 2007.

8 Adams & Adams 1991, pp. 2, 8; Horejs et al. 2010, p. 9; Read 2007; Winther-Jacobsen 2010, pp. 49-50.

9 Adams & Adams 1991; Read 2007; Winther-Jacobsen 2010, pp. 50-51.

10 Winther-Jacobsen 2010, p. 49.

11 Adams & Adams 1991, p. 46; Winther-Jacobsen 2010, pp. 49-50.

12 Orton & Hughes 2013, p. 4.

13 López Verala et al. 2002; Moody et al. 2003, pp. 38-39; Orton & Hughes 2013, p. 150; Rice 1996, p. 196.

14 Orton & Hughes 2013; Rye 1981.

15 Arnold 2000; Rice 1996; Gnesin, 2012.

identification and evaluation of attributes, the second step is combining different attributes into relevant groups or types.16 The first step is particularly important due to the potential for correlation between attributes. If one attribute has a direct influence on another, a typology based on these attributes will be distorted by the hidden dynamics between the two. In statistical terms, one attribute should be independent to another.17 The method by which attributes are combined into groups can be intuitive or rational, inductive or deductive, through attribute clustering or object clustering, or a combination of a number of methods.18 Read distinguishes between intuitive, objective and quantitative clustering, for example.19 Since the present investigation requires the formation of different typologies based on different types of attributes, the specific methods used will vary. The statistical analysis used for investigating the material composition of objects in section 4.3 is one example of quantitative clustering.

3.2 STYLISTIC TYPOLOGY

For both architectural terracottas as well as pottery the traditional attributes used for the formation of typologies were style and shape.[20] For this reason, the majority of published works on Western Greek architectural terracottas are in essence stylistic typologies.[21] While the discussion in section 2.2.2 demonstrates that the research focus applied to architectural terracottas is justifiable expanding beyond stylistic concerns, there is a number of valid reasons why such stylistic typologies are still an essential component to any investigation.

Earlier definitions saw style as a methodological approach by which art historians can classify and study objects.[22] But it is now recognized that style is a complex concept that carries meaning beyond its material form.[23] The influential work by Martin Wobst on the definition of style in archaeology emphasizes the role of style in exchanging information, and by extension in the integration or differentiation of social groups or individuals.[24] This view is reflected in the summary by Debra Schafter of the various ways in which style is being identified by previous researchers; style can function as an emblem, symbol, signifier and sign. All of these functions are connected to ideological concepts related to form, relationships, meaning and beauty that were held by the original makers and users of the objects.[25] For this reason, style is a valuable subject for investigation as it can reveal a vast amount of information regarding the production and usage circumstances of the objects. For example, style is used by various authors in order to identify patterns of influence or trade between the wider Mediterranean world.[26] The complex nature of style might be partly responsible for the variety of definitions of style itself proposed by the numerous scholars who have considered the subject.[27]

Since the majority of published architectural terracottas from Sicily and the wider Greek world is focused on style, any comparisons between the objects from Akragas and published material is thus often limited to stylistic elements. By finding attributes which are stable or those that are flexible over time or location, patterns of use appear which can be used for the identification of relationships between makers and users from different time

16 Adams & Adams 1991, pp. 182-183.

17 Adams & Adams 1991, p. 91; Winther-Jacobsen 2010, p. 59.

18 Adams & Adams 1991, p. 182.

19 Read 2007.

20 Abramov et al. 2006, p. 256; Alpers 1987, p. 138; De Miro 1965, p. 40; Wikander 1986, p. 10; Winter 1993, p. 4.

21 Danner 1996; Mertens-Horn 1988; Wikander 1986.

22 Alpers 1987, p. 138.

23 Van Eck et al. 1995, pp. 8-9.

24 Wobst 1977, pp. 8, 17; Wobst 1999, p 125.

25 Schafter 2003, p. 3.

26 Lulof 2007; Winter 1993.

27 Abramov et al. 2006, p. 256; Wobst 1977, 1-2; Wobst 1999, 122.

periods or locations.[28] In the published works mentioned above, regional and temporal aspects connected with style are key focus areas. As these two aspects are also of importance to this investigation they require a more detailed discussion.

Some of the earliest investigations regarding roof tiles already distinguished between different styles according to region. For instance, the Laconian and Corinthian roof systems are widely used in early publications.[29] In recent years, especially through the work of Winter and other scholars these categories have been expanded, but the new stylistic categories are still geographically bound to a large extend.[30] And while the regional character of sima and geison revetment objects are well documented,[31] additional elements have also been proven to be region bound; including the profiles of architectural elements[32] and antefixes.[33] Regional characteristics are used by scholars to identify the movement of objects, craftsmen or knowledge as well as relationships between various settlements or cultures. For example, Lucy T. Shoe uses the presence of specific profile elements to postulate that Selinus had the strongest influence on early architectural terracottas from Akragas,[34] while De Miro finds that Gela had the largest stylistic influence on the early objects based on decoration and profile.[35] The identification of stylistic elements that are indicators of regions are thus of key importance to this investigation.

Furthermore, a stylistic typology is instrumental to the study of architectural terracottas due to the challenges in dating these objects. One form of archaeological data with the potential to date a roof is the building itself, yet there are a number of complicating factors. Dating the collapse of a building only provides a terminus ante quem for the roof. The life span of terracotta roofs is not well understood but it is possible that the collapse of a roof took place a generation or two from when the roof was erected. Dating the foundation of a building can provide information on when the building was constructed, but it is difficult to determine if the roof associated with a building was part of the original building or a later refurbishment. An additional complication is the difficulty of dating Archaic building structures, the dates suggested by various scholars can vary by decades. For this reason, scholars still rely on dating objects based on stylistic comparisons with other objects. Attempts have been made to compare the decoration on roof and pottery examples, but this has been less successful. Therefore, most scholars agree that only comparisons with terracotta, and in later periods, stone roof elements are reliable.[36] Wikander found the stylistic development schema, as first suggested by Süsserott, a valid basis for dating Sicilian architectural terracottas.[37] This chronological development of the profile and decoration of Sicilian architectural terracottas has subsequently been expanded by Wikander, Winter and Lang and is summarized in chapter 2. To date there has not been any new developments which contradict this schema and as such it will form an important reference point in the dating of objects from Akragas.

As described in section 2.1, the stylistic typology for the Archaic architectural terracottas from Akragas was defined by De Miro in 1965. His typology consists of 15 friezes, and a small number of additional elements which he did not designate as being part of a defined frieze. These objects were grouped according to architectural type, such as

28 Ackerman 1962, p. 227.
29 Van Buren 1923, pp. xvii-xx.
30 Winter 1990, p. 13; Wikander 1990.
31 Wikander 1986.
32 Shoe 1952, p. 3.
33 Belson 1981, p. 89.
34 Shoe 1952, p. 25.
35 De Miro 1965, pp. 51, 59.
36 Conti 2012, pp. 23-24; Wikander 1986, pp. 11-12; Winter 1993, pp. 4-5.
37 Wikander 1986, p. 12.

ridge palmette group 3, for example.[38] To a large extent these groupings are retained by later scholars even if they use their own labelling system in their catalogues, and in the case of Lang, make some small revisions as well.[39] It is therefore evident that the friezes identified by De Miro are the established norm for the objects from Akragas. But the existing typology might not reflect the expanding terracotta assemblage from the colony or current knowledge based on newer finds and studies. It is therefore necessary to revisit De Miro's original typology to determine which of the original types are still valid in their entirety or if some amendments and additions are required. The first step in this process will be to revisit the original typology by analysing the original types according to their decoration and form. The identification of similar objects in the wider region is also an important step. Not only will this allow for the further identification of regional similarities and possible precedents it will also aid in the establishment of a chronology based on stylistic comparisons. This will be shown in section 4.1.

The stylistic typology is largely based on the profile and decoration of objects. A detailed description of these aspects is thus key, not only for finding similarities and discrepancies between objects, but also for comparison to other examples from Sicily for dating purposes. Previous scholars have used various methods for the systematic description of architectural terracottas. As already mentioned in chapter 2, the canonical sima consists of a number of different horizontal profile elements which can be complicated to describe. Van Buren wrote on each horizontal band in terms of its form, painted decoration and dimensions in a single sentence.[40] The work by Shoe demonstrates the benefit in a systematic approach to revetment profiles.[41] For this reason, subsequent works have included a more systematic description of the profile itself as well as an accurate drawing of the object in profile.[42] The publication by Wikander is such an example in which she describes the profile separately from the painted decoration.[43] Conti adopts this method but adds an additional layer of description for the profile dimensions as well. The placement of these different layers of description for the profile shape, dimension and decoration in a table is very clear and functional and allows for easy access to the data for reference and comparisons.[44] This method will therefore be used for the description of complex profiles. Some objects, including antefixes and ridge palmettes, are not composed of different decorative bands and as such a description in table form is redundant. For these elements the profile, painted decoration and dimensions will be provided in a general description.

3.3 FABRIC TYPOLOGY

While the investigation of raw materials and production techniques are gaining prominence within the field of architectural terracotta studies (section 2.2), the theory and methodology of such an investigation is not yet well developed. As with typologies in general (section 3.1) pottery studies have a long history of investigating these topics. The scientific methods and theoretical frameworks developed as part of such studies are often applied to the field of architectural terracottas. For example, the terminology and methods used for describing colour and inclusions, in most cases, are related to those in pottery studies.[45] This is not surprising, as terracotta objects and pottery are both made using natural clay and are then fired. Therefore, established methods from pottery investigations, such as the reliance on standardized charts for describing inclusion size, sorting, and percentages, for example, are relevant to this study as well.

38 De Miro 1965, p. 76.

39 Lang 2010 pp. 87-90; Wikander 1986, pp. 31-32.

40 Van Buren 1923.

41 Shoe 1952.

42 Edlund-Berry 1997, p. 73.

43 Wikander 1986.

44 Conti 2012, p. 90.

45 Conti 2012; Lulof 2007; Winter 2009.

Since the influential publication by Anna O. Shepard on the study of ceramics in archaeology, both the characteristics related to raw materials as well as the manufacturing process are used together in the classification of pottery.[46] While there is some variation, following scholars refer to the system of classification based on raw material and methods of production as a fabric typology.[47] From a methodological point of view it is appropriate to consider raw materials and methods of manufacture together. Both are directly related to decisions made by the producers of the original objects and some elements can potentially directly influence another. For example, the type of temper chosen can influence the firing of objects and the surface finish that is applied. For this reason, it can be problematic to consider the two as separate areas of investigation as important underlying connections could potentially be missed. Within pottery studies it is also practise to consider style and fabric as separate typologies.[48] In 1956 Shepard already noticed that methods of manufacture change slower than style, but this is a theory supported by more recent scholars as well.[49] For this reason, groups of objects identified as separate types in a stylistic analysis could be produced using the same raw materials and methods of manufacture. It is also possible that replacement pieces for a roof produced at a later period would be in the same style as the original roof, but manufactured using a different fabric. It is therefore a strong possibility that the assemblage will be organized differently in a fabric typology than in a stylistic one.

As discussed in section 3.1, typologies provide a conceptual system for the investigation of producers and users of objects. The use of a fabric typology for such a purpose has been one of the main aims of pottery studies since the 1960's when it has been used for the identification of imported objects and the study of cultural change.[50] At the root of this line of investigation is the practice of using non-decorative attributes in order to retrace the identity of the original producer.[51] At first, the focus was on identifying objects that were manufactured in a specific region in order to distinguish imports and to study how objects themselves travelled. But recently this line of investigation has been extended by a number of influential scholars who have postulated that the specific methods employed by a craftsman, workshop or region can form a 'technical style'.[52] A technical style is the culmination of all the various methods and decisions made by the producer during the entire manufacturing process. The concept was first formulated by Heather Lechtman in 1977, and from the beginning technical style was intrinsically linked to a social and cultural context.[53] While Lechtman is interested in the link between technical style and ideology, Pierre Lemonnier studies the various ways in which it reflects social groupings. For example, the social organization of a group during the application of a specific technical style.[54] Ethnographic and archaeological studies have demonstrated that craftsmen had a much wider range of available material and techniques and that the constraining influence of local resources are often over emphasized. The use of a particular method and material can therefore be seen as a choice which is governed by social, economic and ideological

46 Moody et al. 2003, p. 39; Orton & Hughes 2013, pp. 12,14; Rye 1981, p. 2; Shepard 1956, p. 306.

47 Moody et al. 2003, pp. 49, tab. 4; Winther-Jacobsen 2010, p. 51.

48 Horejs, et al. 2010, p. 10; Jung 2010, p. 148.

49 Rye 1981, p. 5; Shepard 1956, p. 314.

50 Moody et al. 2003, p. 39; Orton & Hughes 2013 p. 14; Shepard 1956, pp. 310-311, 314, 335-341.

51 Arnold 2000, p. 113.

52 Arnold 2000, p. 113; Lulof, 1994, p. 220; Rye, 1981, p. 5; Wikander, 1986, p. 26.

53 Hegmon 1998, 266; Lechtmann 1977.

54 Lemonnier 1986, p. 147; Hegmon 1998, p. 268.

factors.[55] In theory, a different producer would make different decisions, and thus the work of two producers would be identifiable due to different technical styles used. Technical style is therefore a way in which to identify different producers, but also a can provide insight into social groupings, boundaries and organization.

One manner in which these choices can be investigated is by considering each step which was taken in order to produce an object. The term, *chaîne opératoire* is used by some scholars in order to describe the series of operations by which raw material is transformed into a finished product.[56] The knowledge of materials, methods, and designs plays an integral part in this process. While new knowledge can be created through innovation, most knowledge is not. The term 'technological transfer' is used by some scholars to specify the process by which new production techniques are learned. This can be done through direct or indirect contact between the person learning and the one already in possession of the knowledge. The transfer of knowledge often involves adaptation or even reinterpretation by new users as it might be necessary to account for local conditions.[57]

The method of describing fabric attributes used in this work is based on the established methodology from pottery studies. A key component of ceramic descriptions is the use of standardized charts and descriptive terms that facilitate reuse and cross referencing.[58] The standardization of descriptions allows for a greater consistency to the data collected over a wider period of time and by different individuals. For example, the great variance in the perception and verbal description of colour by individuals has been well documented in relation to archaeological material.[59] Such inconsistencies are significantly reduced by using a standardized method of measuring and recording colour. The Munsell colour charts are the most common and widely accepted reference used for sorting archaeological material.[60] There are also charts developed by such institutions such as the Department of Urban Archaeology of the Museum of London which are recommended for use in pottery studies for the description of the shape of temper grains, the fabric break as well as the concentration of inclusions, to name but a few.[61]

Long-term exposure to the elements can change the surface appearance of terracotta objects. Burial conditions also affect the surface of objects by leaching or depositing salts and minerals. Since weathering and deposition causes discoloration and obscures details on exposed surfaces, the documentation of attributes requires a fresh break that allows a visual inspection of the original fabric of an object from the surface to the core.[62] The majority of material used in this thesis form part of museum collections which restricts the breaking of objects. Observations are therefore limited to the freshest visible breaks, generally caused during excavation and handling of objects in the past. For a number of fragments the available breaks were too small or degraded to allow for the recording of attributes. The suboptimal observation conditions might result in a higher margin of error, which leads to a higher degree of variance in the dataset. Analysis of attributes such as colour therefore requires the inclusion of broader categories which allows for a higher level of variance.

The first step in creating a fabric typology, which is specific to the research question and material of this thesis, is the identification and evaluation

55 Ingold 1988, 1990; Lemonnier 1986, 1992; van der Leeuw 1993; Nielsen 1995; Schiffer & Skibo 1987, 1997; Sillar & Tite 2000.

56 Cresswell 1976, p. 6; van der Leeuw 1993, p. 240.

57 Knappett & Kiriatzi, 2016, p. 8; Ownby, Giomi & Williams 2017, pp. 617, 623.

58 Orton & Hughes 2013, p. 155.

59 Goodwin 2000, pp. 29-33.

60 Abramov et al. 2006, p. 261; Goodwin 2000, p. 19; Orton & Hughes 2013, p. 73.

61 Overviews in Orton & Hughes 2013; Rye 1981.

62 Moody et al. 2003, p. 54; Orton & Hughes 2013, pp. 75-76, 155.

of different attributes. The majority of attributes evaluated during this process are the ones utilized for pottery studies, such as the size and sorting of inclusions.[63] A small number of attributes specific to of architectural terracottas have also been identified based on the existing research presented in section 2.1; such attributes include the finishing layers (e.g. slip or epidermis layer).[64]

There are different methods for identifying groups of objects with the same fabric attributes. Multivariate statistical methods are recommended by Read as being the most objective and accurate.[65] A number of precedents are available for such an analysis, including studies within the publication by Barbara Horejs.[66] Most of the handbooks on pottery and pottery classification still suggest a more manual process by which the researcher recognizes groups which correspond to the wider context of the dataset.[67] Multivariate analysis was explored but in the end it was found that compared to the traditional manual process, the statistical method is less effective. For the size of the assemblage, the type of data collected and the high degree of variability in the dataset, the traditional manual process of identifying fabric types is more appropriate.

3.4 COMPOSITIONAL ANALYSIS

The use of scientific methods for the study of the material composition of archaeological material is a relatively recent development which started in the middle of the 20th century. Studies undertaken in the 1950's such as the work by Shepard, are seen as instrumental to the establishment of archaeometric techniques for the study of archaeological ceramics.[68] Scientific standards for archaeometric study ideally require a combination of methods, especially for provenance testing. Every method has a limited range in terms of accuracy and the data it can produce. Comprehensive results therefore consist of a combined methodology; such as petrographic and chemical analysis, to produce data that can distinguish between occasionally overlapping material.[69] The approach taken in this research will make use of three methods; thin section petrography, wave-length dispersive X-ray fluorescence (WD-XRF) and handheld X-ray fluorescence (HH-XRF).

Thin section petrography is a widely used and established method for the study of ceramic material from Sicily and the wider Mediterranean world.[70] Thin sections were employed by William Nicol for the first time in the late 18th century but the method was only applied for the identification of minerals in rocks in the middle of the 19th century. While archaeological materials were already being investigated by the end of the 19th century, the method only came into widespread use for the study of archaeological ceramics around the middle of the 20th century. It is considered to be quick, relatively inexpensive, and a reliable means of investigating production techniques and comparing material with objects of known origin. The principle focus of petrography is the identification and classification of the mineral composition of ceramic and terracotta fabrics. Petrography rely on the use of thin sections which are investigated using a number of different methods including scanning electron microscopy (SEM), electron microprobe analysis (EMPA) and

63 Orton & Hughes 2013; Rye 1981.

64 Kenfield 1997; Lulof 1991.

65 Read 2007.

66 Horejs et al. 2010.

67 Adams & Adams 1991; Moody et al. 2003; Orton & Hughes 2013.

68 Degryse & Braekmans 2014, p. 191; Shepard 1956.

69 Degryse & Braekmans 2014, p. 193; Montana et al. 2011, p. 476.

70 Aquilia, Barone, Mazzoleni & Ingoglia 2012; Degryse & Braekmanss 2014, p. 193; Kamili & Ramage 1978, p. 12.

cathodoluminescence spectroscopy.[71] For this thesis, the petrographic analysis of thin sections made use of optical microscopy and was performed at the Laboratory for Ceramic Studies at the University of Leiden's Archaeology Faculty (NL) under the direction of Dennis Braekmans. Samples were prepared by grinding a material sample down to between 25 and 30 micrometres and then placing the thin section on a glass slide. The thickness of the sample means that it gains a translucent quality and thus, when viewed under a microscope with a polarized light source, the characteristic optical properties of minerals become visible. These characteristics include the distribution and shape of non-plastic inclusions, the colour of the clay matrix, and the shape and percentage of voids.[72] For this analysis photomicrographs were taken under crossed polarizers (XP).

There are a number of different methods that can be used to determine the chemical composition of ceramic and terracotta material. Neutron activation analysis (NAA) is a high-resolution method and therefore used quite frequently, as seen in the analysis of architectural terracottas from Gordion[73] and Olympia.[74] X-ray fluorescence (XRF) is a more accessible method which can be performed using a number of different instruments,[75] of which wave-length dispersive X-ray fluorescence (WD-XRF) is well established in the analysis of ceramic and terracotta objects from Sicily.[76] The extensive use of WD-XRF for Sicilian material makes this method attractive as it allows for the comparison between objects from Akragas and other colonies in Sicily. The WD-XRF analysis was performed at the Materials Science and Engineering Laboratory at Delft University of Technology (NL) using a Panalytical Axios Max WD-XRF spectrometer. The samples were prepared by grinding the material down to a fine, homogenous powder. 2 g of powder were mixed with 0.5 g of binding agent and then compressed into a pellet. The sum total of the elemental composition is normalized to 100 percent in order to calculate the weight percentage (wt%).

Both thin section petrography and WD-XRF are destructive methods. For each method samples require preparation before they can be analyzed in a laboratory environment. The majority of material under investigation form part of museum collections, and thus the collection of relatively large material samples are not desirable. For this reason, it was decided to experiment with the use of handheld X-ray fluorescence technology (HH-SRF). It was first developed for industrial application but has been adopted for the study of archaeological material. In theory HH-XRF allows for the quick, in-situ analysis of archaeological material, which makes it a non-destructive method that can also be used on objects on display in museums.[77] But this is a new method of analysis and as such has generated a lot of debate regarding appropriate application in the field of archaeology. One misconception among new users of archeometric technology is that non-destructive analysis can replace established laboratory based techniques.[78] A number of archeometric specialists instead only view HH-XRF technology as a first step process that helps to define the research hypothesis and sampling strategy for subsequent destructive analysis.[79] An example of this approach is the work by Erica Aquilia and Germana Barone on terracotta objects from Gela.[80] Ellery Frahm

71 Adams et al. 1984, p. i; Aquilia et al. 2012; Degryse & Braekmans 2014, p. 193; Kamili & Ramage 1978, p. 12; Peterson 2009, pp. 2-6.

72 Adams et al. 1984; Peterson 2009, pp. 1-2.

73 Henrickson & Blackman 1999, p. 318.

74 Lang 2010, pp. 68-69.

75 Bezur & Casadio 2012, p. 100.

76 Aguilia et al. 2011; Barone et al. 2005; Barone et al. 2011; Belfiore et al. 2010.

77 Frahm 2013, p. 1080; Hunt & Speakman 2015, p. 626; Shugar & Mass 2012, p. 17.

78 Frahm & Doonan, 2013, p. 1426.

79 Frahm & Doonan, 2013, p. 1428; Shackley 2010, p. 17.

80 Aguilia et al. 2011, p. 977.

believes that this approach might be too cautious. In his recent study of obsidian from the Near East he found that HH-XRF can be used for more analytical applications which extend beyond the first step phase.[81] Unfortunately, while HH-XRF might be particularly suited to the study of obsidian, there are a number of concerns regarding its use on ceramic and terracotta objects. It is therefore necessary to consider the use of HH-XRF technology for the study of terracotta objects in greater detail.

Truly portable, or handheld, XRF machines are a relatively new technology. While laboratory based XRF technology has been used in archaeological research for many decades with a standard methodology in place since the 1950's and in widespread use in archaeology since the 1960's,[82] handheld technology is only now being explored as an archeometric technology. The first handbook on the use of HH-XRF was only published in 2012.[83] It is therefore not surprising that the appearance of HH-XRF technology in archaeology is generating so much scholarly debate as a standard methodology and accepted application parameters have not been established yet. Recent publications by Frahm,[84] Robert J. Speakman,[85] and Michael S. Shackley[86] are representative of the controversy. A number of points have been raised which are of direct concern for this study and therefore require consideration.

The first point of contention centres around the perceived use of HH-XRF technology as a black box process. The relative low cost of handheld XRF instruments and the ease with which it can be used means this technology is accessible to a much wider range of users including museums and academic institutions which did not previously have archaeometric capabilities. The justifiable fear of established researchers with years of experience in XRF technology is that new researchers will treat the handheld technology as a black box process, with little scientific understanding of the processes taking place as well as the instrument functions. Some, including ambitious vendors, create the impression that the technology can be used with little training to produce quantifiable data. The truth is that without appropriate knowledge regarding basic chemistry, specifically X-ray spectrometry, as well as statistical data analysis and established XRF methodology, the user will not be able to avoid even the most basic of scientific errors nor would they be able to produce reliable and usable data.[87]

A second point of concern is the perceived lack of an established methodology. The absence of a comprehensive, widely accepted methodological framework limits researchers in how the technology is applied but also in the ability to produce scientifically reliable results. In recent publications scholars have proposed a number of methods which improve accuracy; these include polishing surfaces before testing, minimizing background interference, establishing sample error and periodic instrument stability tests.[88] But to date, without an established methodology, it is hardly surprising that researchers are relying strongly on the established methods for laboratory based XRF applications as a reference in regards to guidelines for the selection of material, calibration and data analysis.

A third point of concern centres around the reproduction of results. Established laboratory XRF methods require grinding down samples to a homogeneous powder. Since archaeological

81 Frahm 2013.

82 Frahm & Doonan 2013, p. 1426; Hein et al. 2002, p. 542; Kempe & Templeman 1983, p. 43; Shugar & Mass 2012, p. 31.

83 Shugar & Mass 2012

84 Frahm & Doonan 2013.

85 Speakman & Shackley 2013.

86 Shackley 2010.

87 Shackley 2010, p. 18; Shugar & Mass 2012, pp. 17-18; Speakman & Shackley 2013, p. 1435.

88 Shugar & Mass 2012, p. 19; Speakman & Shackley 2013, p. 1436.

objects are rarely homogeneous and XRF only measures a very small area this is the best practice for producing reliable data. Unfortunately, the same method cannot be used with the HH-XRF when testing objects in-situ. For this reason, reproducible measurements are might not be achievable.[89] To put it simply; a single measurement is dependent on the particular components in a specific 5 mm spot on an object. Measurements from different spots on the same object composed of a mixture of material would potentially produce different results based on the specific composition of each spot and thus reproducing data becomes problematic. This is a serious concern since established scientific practice relies on the use of data that can be compared to previous tests or verified by subsequent tests. Some authors, including manufacturers, try to downplay this point by stating that internally consistent results are enough in regional scale studies and targeted research.[90] But this view is not supported by all researchers. In a review on the Frahm article,[91] Speakman and Shackley express concern over the acceptance of 'internally consistent' results; the authors fear this will create a 'silo science' in which each individual researcher's data is self-contained and independent with no independent external verification possible. [92] "If the results of any experiment cannot be compared and evaluated by a subsequent experiment outside the original experiment, then it is unreliable even though it is internally consistent."[93]

Within the current debate on the use of HH-XRF in archaeology, calibration is seen by many scholars as one of the most important concerns regarding the technology's application. Since each instrument model and analytical method has a specific instrument error, the established method uses international geological reference materials (CRM) to calibrate results in order to compare data from different laboratories, instrument models and analytical methods.[94] When it comes to the HH-XRF one point of current debate is that the instruments and most specifically, the calibration files, were developed for use in metal recycling industry and archaeologist are thus treated as minor or novel users. Manufacture calibration files for specific materials are therefore often unsuitable to historic artefacts.[95] One exception is the 'green filter' calibration developed by Shackley for the Bruker HH-XRF instrument for the analysis of obsidian objects.[96] Most off the shelf settings are rarely sufficient and are typically only instructional. Many researchers see the need for empirical, user specific, calibrations as the single most important concern when it comes to the use of HH-XRF in archaeological research.[97] The recent study performed by Alice M. W. Hunt and Robert J. Speakman in 2015 tested the accuracy of HH-XRF data calibrated according to the recommended manufactures mudrock calibration files against the data obtained through laboratory based ED-XRF analysis. The authors found the mudrock calibration to be rather unreliable for ceramic investigations but that custom calibration using matrix matched certified reference materials produces systematically better results.[98]

The study by Hunt and Speakman is an important reference regarding the use of HH-XRF for ceramic objects as it identifies limitations not previously known. This includes the overlapping of spectrum peaks for elements which means that HH-XRF cannot accurately measure sodium (Na), phosphorus (P), vanadium (V), chromium (Cr), cobalt (Co), nickel (Ni), and the L-lines of barium

89 Shugar & Mass 2012, p. 28.

90 Frahm 2013, p. 1087.

91 Frahm 2013.

92 Speakman & Shackley, 2013, p. 1435.

93 Speakman & Shackley 2013, p. 1436.

94 Hein et al. 2002, pp. 543-545.

95 Shugar & Mass 2012, pp. 24-25.

96 Speakman & Shackley 2013, p. 1437.

97 Shugar & Mass 2012, pp. 19-28; Speakman & Shackley 2013, p. 1437.

98 Hunt & Speakman 2015.

(Ba). Within their study they also prepared samples by grinding material down to a fine homogenous powder and using a Helium vacuum for the measurement of low-Z elements, or elements with a low atomic number. The authors conclude that under these conditions HH-XRF can match the performance of conventional laboratory based XRF methods, for a limited range of elements.[99] These results support that of Speakman and Shackley. According to their recently published article, HH-XRF machine capabilities are on par with laboratory based instruments of 5-10 years ago which are still in use in many laboratories today, and therefore make the handheld capabilities comparable to those of many laboratories.[100] Tests performed using international standard obsidian samples and the Bruker calibration for obsidian produced results with a relative standard deviation (RSD) of less than 2 percent, which is comparable to laboratory results. Instrument drift was also proved to be negligible which leads Speakman and Shackley to conclude that the challenge in producing scientific relevant data using HH-XRF technology depends on the expertise and the experience of the user in order to produce reliable quantifiable data that is reproducible.[101]

The conclusion drawn from the current debate on the application of HH-XRF technology in archaeology is that the concerns of the research community are not based on instrument performance but on the calibration of data and the establishment of a scientific methodology appropriate to the material under investigation. The methodology used for the HH-XRF analysis applied in this thesis therefore attempts to address the most pressing of these concerns.

The HH-XRF analysis was performed using a Bruker Tracer HH-XRF instrument. Measurements were taken with the Ti-Al (or yellow) filter for 300 seconds per reading at 40 kV. For all measurements spots were chosen on the most suitable fracture of an object that is as flat and as clean as possible in order to avoid contaminating the sample with surface encrustation.[102] As pointed out above, terracotta fabric is non-homogenous, with large inclusions and uneven distributions. Hence, taking a measurement on non-homogenous material is problematic, as only a small area is sampled, close to 5 mm in size and 1 mm deep. Large inclusions can therefore easily skew the final result.[103] For this reason, three measurements were taken per object in different positions on a clean break and large visible inclusions were avoided. In order to measure low-Z elements a vacuum is required and essential. Due to the uneven surface of the terracotta objects a sufficient vacuum could not be established. Therefore, only the heavy (or mid- to high-Z) elements were measured since these do not require a vacuum. The spectrum data obtained using this method was calibrated using six sediment and clay CRM that are as close as possible to terracotta material in terms of the fabric matrix. The six CRMs used for the calibration are BCR-667(estuarine sediment), BIR-1a (Icelandic basalt), GSP-2 (granodiorite, silver plume, Colorado), NIST-98b (plastic clay sediment), NIST-2710a (Montana soil) and SGR-1b (oil shale, Wyoming). The calibration is based on calculating the relationship between measured HH-XRF values (in counts per second) and the known quantified values (in weight percentage). This relationship is expressed as a regression equation that can then be used to calculate the quantified values for HH-XRF values measured in the field. This is the method that was also used by Hunt and Speakman for creating custom calibrations for HH-XRF data.[104]

As discussed in the beginning of this section, the accuracy of quantified HH-XRF data has been questioned. The calibrated data obtained through

99 Hunt & Speakman 2015.

100 Speakman & Shackley 2013, p. 1436.

101 Speakman & Shackley 2013, pp. 1438-1439.

102 Shugar & Mass 2012, p. 29.

103 Shugar & Mass 2012, p. 28

104 Hunt & Speakman 2015.

the custom calibration detailed above is therefore first evaluated using a control group. 15 roof tile samples were obtained from the extra-urban sanctuary at S. Anna. These objects were analysed using petrography, WD-XRF, and HH-XRF. The WD-XRF data for this group of objects forms a benchmark by which the calibrated HH-XRF data that can be evaluated. The control group is also used for identifying elements susceptible to local weathering conditions by considering the degree of variance for known groups of objects. It is clear that weathering and centuries of burial have an impact on the chemical composition of objects. For example, zirconium (Zr) tends to accumulate in weathered profiles, but the exact nature of the transportation and accumulation of the element is yet unknown.[105] Local weathering conditions produce site specific weathering. One method, which is also applied by Speakman and Shackley, is the use of standard deviation, as high variance can be an indication of weathering.[106]

Archaeometric studies are closely tied to the question of provenance.[107] The large number of studies using WD-XRF to investigate ceramic and terracotta material from Sicily is in essence concerned with the identification of imported and locally produced material.[108] Provenance is a key characteristic in the investigation of a wide range of research topics including economies, trade, cultural interactions as well as Greek colonization. Contemporary provenance studies are based on the 'provenance postulate' as formulated by Wiegand et al.l in 1977. The postulate assumes that the chemical variance within a natural source is less than in the object being tested.[109] This assumption leads to a further assumption that the variance inside a population group is smaller than the variance between two population groups.[110] Furthermore, discreet population groups are thought to relate to geographically restricted sources or 'source zones'. As a result, provenance testing often revolves on matching population groups with raw sources.[111] However, caution is required since specific raw source material and finished objects rarely match up completely. Manufacture can significantly alter the composition of the finished object with the addition of temper, the removal of coarse grained objects through levigation and the mixing of different clays.[112] Hence, the use of 'source zones' which aims to establish the compositional characteristics for the raw material from discreet geographical zones. The study by Giuseppe Montana et al. on clayey sources in Sicily is such an example where numerous samples from within a specific zone are analysed in order to establish the characteristics of the overall zone.[113]

Thus, use of HH-XRF data to establish provenance has not yet been established. Frahm proposes that even in suboptimum conditions the results do not contradict the 'provenance postulate', and he supports the possibility of using HH-XRF technology in provenance testing for obsidian objects.[114] Hunt and Speakman consider the identification of provenance in ceramic material to be much more complicated than for obsidian. They point out the limited range of elements which can be reliable calibrated for HH-XRF data as a prohibitive factor.[115] Aaron N. Shugar and Jennifer L. Mass identify provenance testing as the most problematic aspect of HH-XRF application which can only be successfully achieved by making use of samples from raw sources and custom

105 Degryse & Braekmans 2014, p. 194.

106 Speakman & Shackley 2013, pp. 1438-1439.

107 Degryse & Braekmans 2014, p. 191.

108 Barone et al. 2003; Belfiore et al. 2010; Montana et al. 2009.

109 Weigand et al. 1977.

110 Degryse & Braekmans 2014, p. 191; Hein et al. 2002, p. 542.

111 Degryse & Braekmans 2014, p. 195.

112 Bezur & Casadio 2012, pp. 262-263; Degryse & Braekmans 2014, p. 195.

113 Montana et al. 2011.

114 Frahm 2013, p. 1091.

115 Hunt & Speakman 2015, p. 638.

calibration.[116] The HH-XRF data will therefore not be used for establishing provenance in this thesis.

Provenance testing relies on the formation of compositional groups. Based on a number of major and minor focus elements such as SiO_2, CaO, Na_2O, Ti, Zr, Sr, and Rb, the compositional characteristics of specific groups can be determined and subgroups can be identified or the coherence of a particular group can be evaluated. The statistical method used to establish and evaluate compositional groups is the principal component analysis and has been in use in archaeology for a number of decades.[117] For example, based on studies by Richard Jones and Marie Farnsworth in the 1970's and 1980's, scholars investigating Sicilian ware can reliably distinguish between local manufacture and Greek imports based on the higher levels of Co, Cr, and Ni in Greek objects.[118] The choice of which focus elements to use is related to the instruments used since each instrument provides reliable readings for only a specific range of elements. For this analysis the elements are determined by the precedent set by a number of provenance studies on Sicilian material which used the same instrument.

Before the principle component analysis can be performed the data is first transformed in order to avoid the constant sum problem of compositional data. This transformation is done by means of a log normalization.[119] For this study the central log-ratio (clr) was used as it has a developed theoretical background and has been used for pottery studies by a number of scholars.[120] Statistical analysis was performed using the program R. The clr normalization used can be found in the hotelling package and all diagrams were created using ggplot packages for biplots and dendrograms.

3.5 RECONSTRUCTING ROOF SYSTEMS

As discussed in chapter 2, architectural terracottas are increasingly studied as complete roof systems which include both decorated and undecorated terracotta elements.[121] Unfortunately, the archaeological remains are very fragmentary and it is exceedingly rare to find the various elements that constituted a roof in a single, undisturbed context. For instance, in the objects from Akragas it is clear that fragments that belonged to the lateral sima of a single roof were found distributed in various mixed contexts in an area with an estimated 90 m radius (section 4.1, frieze F). It is therefore necessary to consider the collection of objects as a whole in order to identify objects that belonged to the same roof. The criteria used for organizing fragments is governed by two main theoretical principles

The first principle centres on the manner in which the roof is manufactured. The general theory states that the entire roof was made by a single workshop during the same period of time. This would result in objects that are manufactured using the same techniques and raw materials and, therefore, there will be consistency in the fabric, decoration, form and technical execution between the various elements. An example of this principle being used for identifying roofs is the work by Conti on the architectural terracottas from Selinus. Both Conti and Winter do identify a number of limitations to the application of this principle.[122] For instance, it is thought that especially in later periods a workshop could have produced a number of different roofs which would result in fragments with similar fabric and technical characteristics. Conti notes that in these cases the dimensions of the elements and the form of the objects can be

116 Shugar & Mass 2012, p. 27.

117 Braekmans et al. 2017, p. 478; Degryse & Braekmans 2014, p. 195; Hein et al. 2002, p. 542; Kempe & Templeman 1983, p. 48.

118 Farnsworth et al., 1977; Jones, 1986.

119 Braekmans et al., 2017, p. 483; Baronne et al., 2011, p. 3064.

120 Aitchison 1986; Aitchison & Greenacre 2002; Aquila et al., 2015, p. 5; Baronne et al., 2011, p. 3064.

121 Lulof 2007, p. 41; Strazzulla 1997, p. 701; Winter 1993, pp. 202-203.

122 Conti 2012, p. 22; Winter 1993, p. 3.

used for separating the fragments into respective roofs. Another limitation to the application of this principle concerns the maintenance of a terracotta roof. Over time an individual piece might be damaged or fail completely. It is acknowledged that replacement pieces can be manufactured using different raw materials and techniques but retaining roughly the same decorative scheme, dimensions and form of the original elements. In his work on the Archaic architectural terracottas from Morgantina, Kenfield notices that objects associated with the same roof are manufactured using different techniques. While the reasons for this are unclear, Kenfield suggests that the depth of relief of objects or workshops employing craftsmen of different cultural traditions might play a role.[123] Since methods of manufacture are not traditionally considered in the study of Sicilian architectural terracottas it is not certain if the situation at Morgantina is an isolated case or if it is a more widespread occurrence. For the roofs of Selinus, at least, the methods of manufacture do not appear to be mixed on individual roofs.[124]

A second theoretical principle used by scholars for identifying elements from the same roof is that of modular design. In order for all elements including pan and cover tiles as well as sima and ridge tiles to fit together on the roof without excessive overlap or large gaps the objects need to be sized according to a number of key dimensions.[125] For example, the sima, geison revetment, and pan tiles should all have the same width. Examples of such modular systems are known from Sicily and mainland Greece. These include roof 3 from Selinus,[126] and the temple of Apollo at Halieis.[127] The two roof phases associated with a building from Naxos erected during the 5th century use the same module.[128] But not only should the roof elements be sized according to each other, they should also be sized according to the building. Therefore, roof elements from the Archaic period are thought to be sized according to a module specific to each building.[129] Starting at the end of the 6th century BC, however, greater standardization can be seen in the dimensions of building elements.[130] Thus, a single workshop could produce such objects that could be used for a number of different roofs; as was the case with some Laconian workshops which had a stock pile of tiles of standardized size.[131] According to Conti the greater standardization seen in the 5th century BC means that in some cases it is no longer possible to identify a single roof but rather a roof type.[132]

In the discussion above it becomes apparent that there is not a single characteristic which by itself reliably identify fragments from the same roof in all circumstances. Instead, a combination of characteristics including the raw materials, the production techniques, decoration, and profile dimensions should be taking into account. The method employed by Conti for the objects from Selinus focuses on fabric, structural elements, profile dimensions, technical execution and decoration.[133] Style, fabric, chemical composition and architectural context are already separate areas of research in this thesis. The identification of roofs will therefore rely on a synthesis of the

123 Kenfield 1997, pp. 110-111.

124 Conti 2012.

125 Sapirstein 2009, p. 223.

126 Conti 2012, p. 58. Roof 3 has the same width for the sima, geison, and roof tiles with 1 or 2 cm variations.

127 Cooper 1990, p. 72. According to Nancy K. Cooper the temple and the roof tiles all use the same basic dimension as a module, this dimension is known as the Halieis foot

128 Lentini et al. 2008, pp. 323, 337, 347, 360. The ship sheds at Naxos had two different roofs, one from the start of the 5th and one from the second half of the 5th century BC. Both have roughly the same module as can be seen in the geison fragment having roughly the same width as the pan tiles. The cover and pan tiles of the two roofs also follow the same modules.

129 Sapirstein 2009, p. 223; Winter 1993, pp. 3-4.

130 Wikander 1986, p. 30.

131 Winter 1993, p. 3.

132 Conti 2012, p. 23.

133 Conti 2012, p. 22.

results from each of these different analyses. The methodology applied to this thesis is based on the work by Conti. One important element of the proposed methodology is the emphasis on direct observation. As Conti notes, published records use different methods of observation and recording, the level of information regarding the fabric, manufacture, profile and decoration is also not consistently documented.[134] For this reason, only objects that were observed and documented in person (either the author or students working under direct supervision by the author) are included in the analysis.

While known profile dimensions are provided in section 4.1, additional dimensions can be proposed by graphically reconstructing the roofs. The availability of dimensions for the various elements that constitute the roof allows for a more comprehensive comparison with known roofs from Sicily as well as forming an integral part in the discussion of the roofs within an architectural context (chapter 6). Apart from frieze A, D and G from De Miro's typology, none of the revetments from Akragas have been reconstructed either physically or graphically. Graphically reconstructing the fragments identified by fabric, methods of manufacture and decoration as being part of a single roof serves a dual purpose. As already mentioned this provides information crucial to the subsequent study of the architectural context. But Conti also mentions that by graphically combining fragments it is possible to determine if fragments can realistically be considered to be part of the same roof. She found that for a number of fragments there were a number of discrepancies in the observed profile of objects which raised questions regarding the attribution of individual fragments.[135] As such the graphical reconstruction process provides additional answers. For this reason, a large number of object drawings were produced that document both the front, back, and profile of individual fragments. These drawings are then employed for reconstructing roofs graphically by using the AutoCAD program, which was found to allow for the highest level of accuracy and technical capability as opposed to purely graphical platforms. As a scientific method, graphic reconstructions in archaeology and heritage studies have been criticized for a lack of scientific rigour.[136] When only the complete reconstruction is presented the decision making process becomes opaque and it makes the determination of reliability problematic. For this reason, the reconstruction drawings make a distinction between known fragments and the hypothetical reconstruction of connecting space.

Roofs that had already been identified and reconstructed by previous scholars play an important role in the reconstruction process. Conti uses established roofs as a means of verifying known fragments and to attribute unknown fragments to existing groups.[137] Not only are those roofs used for comparison, they also provide a benchmark for the amount of variation that can be found in the dimensions and decoration of objects belonging to the same roof. As will be discussed in greater detail in section 4.2 and chapter 5, the production process utilized for Archaic terracotta objects in the Greek period is a manual process. In principle small variations can therefore be expected for objects from the same roof, but when the variations in size are too large these elements can no longer constitute a functional roof. The allowable tolerance is difficult to determine and can vary depending on the type of object and the time period in which it was manufactured. Established roofs therefore offer a valuable indication of the level of variation that can be expected for various objects.

134 Conti 2012, p. 23.

135 Conti 2012, p. 23.

136 Vico & Vassallo 2013, p. 63.

137 Conti 2012, p. 23.