The Role of Ochre in the Development of Modern Human Behavior: A Case Study from South Africa

by

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ABSTRACT

In recent years, southern Africa has figured prominently in the modern human origins debate due to increasing evidence for precocious behaviors considered to be unique to our species. These significant findings have included bone tools, shell beads, engraved ostrich eggshell, and heavily ground and engraved ochre fragments. The presence of ochre in Middle Stone Age (MSA, ~250-40kya) archaeological sites in southern Africa is often proposed as indirect evidence for the emergence of symbolic or artistic behavior, a uniquely modern human trait. However, there is no remaining artwork from this period and there is significant debate about what the ochre may have been used for. With a few exceptions, ochre has gone largely unstudied. This project tested competing models for ochre use within the Pinnacle Point (PP), South Africa research area. Combined results from characterization and sourcing analyses, color classification, heat treatment analysis, and hafting experiments suggest MSA ochre is tied to early symbolic or ritual behavior.

To my husband Ian, for regularly asking what was taking so long.

To my son Kieran, for giving me the motivation to finish.

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CHAPTER 1: PROJECT INTRODUCTION

Introduction

Africa plays a significant role in the modern human origins debate due to the presence of the earliest dated human fossils widely considered anatomically modern (Grine *et al.* 1998; White *et al.* 2003; McDougall *et al.* 2005), increasing genetic evidence pointing to an African origin (Jorde *et al.* 2000; Ingman *et al.* 2000; Teschler-Nicola *et al.* 2004; Campbell and Tishkoff 2008) and a growing body of evidence suggesting the appearance of early modern behavior (McBrearty and Brooks 2000; Henshilwood *et al.* 2002; 2004; Marean *et al.* 2007; Brown *et al.* 2009). While anatomy and behavior may be related, the search for the origin of behavioral modernity has become a prominent research topic in its own right. Whether modern behavioral patterns appeared simultaneously with modern morphology in the Middle Stone Age (MSA ~250-40kya), or later with the emergence of Later Stone Age (LSA) and Upper Paleolithic technologies is an important question in modern human origins research (Klein 2000; McBrearty and Brooks 2000; Henshilwood and Marean 2003). One commonly cited trait of the modern behavioral package, symbolic or artistic expression, has been much discussed but rigorous research focusing on developing hypotheses and test implications for the archaeological record has been lacking.

Several archaeological markers, including potential pigment, have been suggested for identifying symbolic behavior (McBrearty and Brooks 2000). Ethnographically, ochre is widely used as symbolic pigment (Spencer and Gillen

1899; 1904; 1927; Kaufmann 1910; Bleek and Lloyd 1911; Fischer 1913; Basedow 1925; Dornan 1925; Fourie 1928; Chewings 1936; Strehlow 1947; Simpson 1951; Willcox 1956; Viegas Guerreiro 1968; How 1970; Kohler 1973; Lewis-Williams and Biesele 1978; Rudner and Rudner I. 1978; Sagona 1994; Watts 1999). As a result, the presence of ground ochre in archaeological sites has been viewed as early evidence for symbolic behavior (Watts 1998; 1999; 2002). These claims have proven difficult to substantiate and test directly. As a result, several alternative explanations have been proposed including use of ochre in hide preparation, in the hafting of stone tools, and for medicinal purposes (Velo 1984; 1986; Allain and Rigaud 1986; Klein 1995; Wadley 1993; 2001b; 2005; Mithen 1999; Wadley *et al.* 2004; Lombard 2005). This research addresses the following major **research question:** Within MSA sites at Pinnacle Point (PP), South Africa, was ochre used as a pigment for symbolic activities or was it used for more utilitarian activities?

This question was investigated using data from two sites (PP13B and PP5-6) in the PP research area near Mossel Bay, South Africa (Fig. 1.1). The PP research area has been and is currently being studied through the SACP4 project. This research initiative is aimed at investigating early modern human behavior with an added focus on reconstructing MSA environments and understanding their role in human evolution. This project has brought together a large team of senior researchers from various fields inside and outside of anthropology.

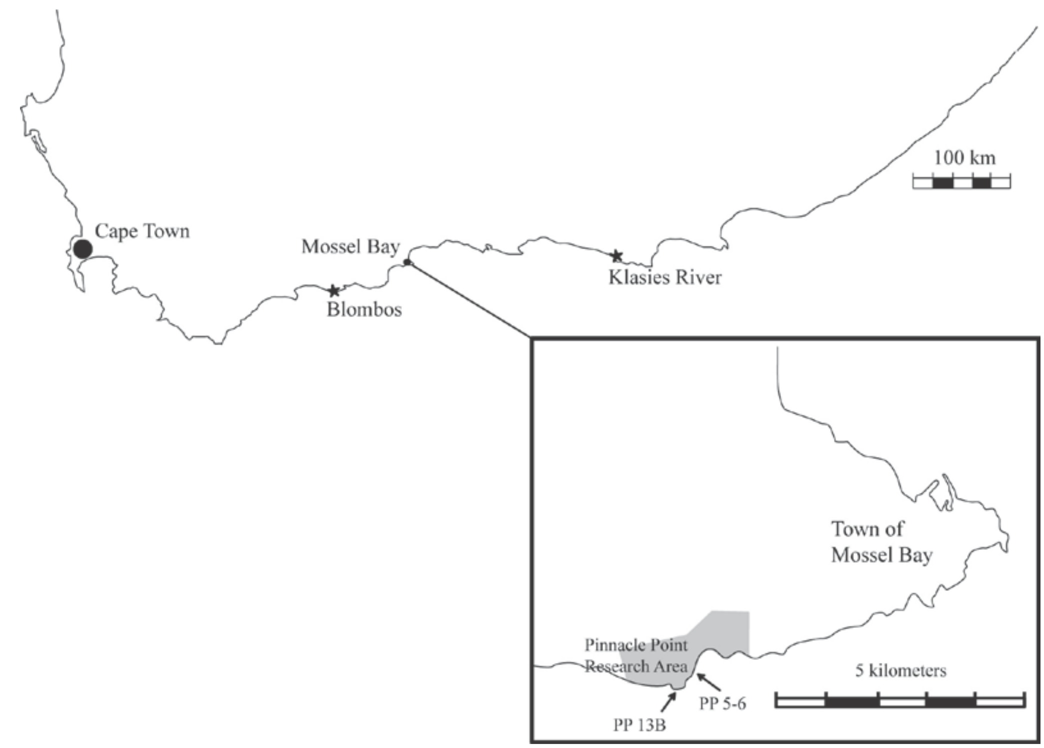

Fig. 1.1. Location of the PP research area

Hypotheses and test implications

Direct testing of the ochre record provides insights into the development of modern behavior. However, work of this kind has rarely been done. Several connected research questions were addressed in this project in an attempt to further knowledge about the ochre record.

1) Does a symbolic hypothesis or a hafting hypothesis better fit the data at these sites, or were there a combination of activities taking place?
2) Where is the ochre being procured from?
3) Are geological properties of the ochre guiding source selection, and if so what are they?

4) Are there distinct color preferences being procured or are materials being heat treated to achieve desired redness?
5) How does ochre use change overtime?

It was possible to construct several test implications for different activities involving ochre. For this study, a symbolic or artistic interpretation and a hafting agent interpretation were tested for the ochre at PP.

Hypothesis 1: Ochre is used as a pigment in symbolic activities.

Symbolic activity is difficult to test in MSA sites where only ochre fragments and powder remain. It is presumed that if symbolic activities were taking place it involved body painting and perhaps artistic expression on cave walls or other organic surfaces that, because of local conditions, would not be expected to survive in the record. There are, however, some testable implications for symbolic activity. Some test implications provide stronger evidence than others for symbolic behavior. It is necessary to consider various types of data in order to begin to understand the role ochre played in the MSA.

<u>Test Implication 1a: Exploitation patterns</u> Exploitation patterns may provide information on ochre use. The acquisition of ochre is typically a highly ritualized activity for recent hunter-gatherer groups when compared to the exploitation of other non-symbolically loaded raw materials (such as stone). Often large distances are covered to extract socially valuable ochre even in cases where high quality ochre deposits are available locally that should be adequate for utilitarian purposes (Bleek and Lloyd 1911; Basedow 1925; Jones 1984a; 1984b; McCarthy

1939a; 1939b; Robson and Plomley 1982). This research endeavor begins with archaeometric analysis and sourcing of ochre from the PP area to assess the ochre exploitation patterns for this time period. An exploitation pattern focusing primarily on distant sources rather than closer sources or a pattern focused on a few deposits when many are available may be suggestive of some symbolic meaning. Alone such patterns would not overtly demonstrate symbolism but in the presence of other test implications described below they would lend solid support.

Test Implication 1b: Color preferences The second test implication involves the color distribution of ochre found in these sites. Many colors of ochre are available on the landscape and color should not necessarily dictate the usefulness of material for utilitarian purposes. If there is a skewed color representation in the PP sites as compared to the distribution of ochre colors on the landscape this would be a strong indication of symbolic overtones.

Test Implication 1c: Heat treatment It has been shown that the MSA inhabitants of the PP area in South Africa heat treated silcrete to enhance the quality of the raw material for knapping (Brown *et al.* 2009). It has also been suggested that early humans may have heated yellow ochres (goethite bearing) to transform the material to red ochre (hematite bearing). The thermal transformation of goethite to hematite is well known and can be achieved by heating goethite to temperatures approaching 300°C (Wreschner 1983; Weinstein-Evron and Ilani 1994; Pomiès *et al.* 1999; Godfrey-Smith and Ilani 2004; Béarat and Pradell 1997; Béarat 1996). It has been argued that red ochre is more common in archaeological sites despite the availability of yellows on the landscape (Watts 1998; 1999; 2002; 2009; 2010). However, there is no evidence to suggest that red ochre is more functional than yellow for the utilitarian tasks that have been presented in the literature. Therefore, if it can be demonstrated that ochre is being heat treated in MSA sites to redden the material, it would also lend strong support to symbolic and artistic interpretations of use.

Hypothesis 2: Ochre is used in utilitarian activities, namely hafting of stone tools.

Two main test implications would indicate use of ochre in a primarily utilitarian context to enhance the quality of stone tool hafts.

Test Implication 2: Strength of hafts with ochre Replication testing must show that the ochre found in the sites is actually beneficial as a hafting agent. Ochre is highly variable, and it is likely that some material is better for different activities. Experimental tests must show that the inclusion of ochre increases the longevity of the haft. If geological ochre that matches ochre from the sites does not improve the durability of hafts, it would seriously weaken a strictly utilitarian argument.

Alternative Outcome: A variety of activities can be identified.

It is, of course, likely that multiple activities were taking place in the MSA that involved the use of ochre. This is the case ethnographically, although there are often symbolic connotations even when the use has utilitarian benefits. It is also possible that other ochre activities not directly investigated here were carried out. If the data do not fit well with either symbolic practices or use as a hafting agent, future work should address its use in hide tanning, medicinal uses or other uses not yet proposed.

Chapter overview

Chapter 2 provides the background research that lays the foundation for this project. Ochre is defined, its formation is explained, and its most common mineral components are discussed. The ethnographic record of ochre use is reviewed for southern Africa as well as for Australia, where the ochre record is particularly rich. The archaeological record of ochre use is then presented beginning with a brief description of the earliest occurrences and then focusing on finds from the MSA of southern Africa. Based on the ethnographic and archaeological records the various proposed uses of ochre in the MSA are then presented. Finally, the body of research dealing with archaeological and geological ochre around the world is discussed.

Chapter 3 presents the study area, PP, South Africa. It describes the location and nature of the two focal sites, PP13B and PP5-6. Excavation methodology is briefly outlined and stratigraphy and dating for both sites are presented.

Chapter 4 presents the archaeological ochre assemblages from PP13B and PP5-6. The coding and descriptive methodology is laid out. All ochre finds from both sites are then discussed in order to demonstrate that the ochre has been both transported to the site intentionally and modified for use.

The next few chapters assess each of the test implications laid out above. Chapter 5 deals with Test Implication 1a by discussing the geological survey and characterization analyses of the potential sources identified on the landscape. The survey methodology is first presented. Then each identified ochre source is described and the characterization results for samples collected from these sources are presented. This chapter provides the ochre landscape to which archaeological samples must be matched.

Chapter 6 continues to address Test Implication 1a by discussing the characterization results for archaeological ochre samples taken from PP13B and PP5-6. These samples are matched to their most likely origin points on the landscape and the exploitation patterns of ochre are discussed.

Chapter 7 addresses Test Implication 1b, color preferences. The distribution of color is described using two methods and results for both are described. The distribution of geological ochre color is compared to the distribution of ochre colors in each of the sites to determine if there are differences between what is available and what is collected and transported.

Chapter 8 deals with Test Implication 1c, the identification of potential heat treatment. The XRD results are reviewed for evidence of archaeological samples being exposed to heat. These results are compared to the distribution of heat sediments in the sites in order to determine if any heating was likely intentional or post depositional.

Chapter 9 focuses on Test Implication 2a, the testing of the ochre and resin hypothesis. The results of the actualistic hafting experiments are presented along with the results of mechanical testing of resins with different ochre and non ochre additives. The functionality of using ochre to produce more durable hafts is assessed.

Chapter 10 concludes this dissertation by considering the results of each test implication together to attempt to draw a picture of ochre use at PP in the MSA. Ochre usage over time is discussed and is tied into other trends at the site and into the environmental context as presently understood by the SACP4 research team. Future directions for ochre research in this region and time period are discussed.

Conclusion

This dissertation addresses the use of ochre in MSA archaeological sites at PP, South Africa. Ochre assemblages from two sites are fully described and a sub-sample is sourced. Use wear modifications are identified, color preferences are assessed, heat treatment is investigated, and the alternative use hypothesis of hafting is directly tested. Using these data, it will be possible to address the larger research question of interest: Within these MSA sites, was ochre used as a pigment for symbolic activities or was it used for more utilitarian activities? While it will be difficult to conclusively say that ochre was used in symbolic contexts in the MSA, the investigation of numerous factors such as color preferences, heat treatment and preferential exploitation should contribute significantly to the research problem. It should, however, be possible to determine if ochre was being used in hafting in a strictly utilitarian way. It is also possible that this research will point to a complex set of utilitarian and symbolic activities taking place at PP.

Symbolic behavior is a defining characteristic of modern humans (Henshilwood and Marean 2003; McBrearty and Brooks 2000). Understanding when it becomes archaeologically visible is crucial to resolving debates about the origins of modern human behavior. Potential indicators of modern behavior must be studied in depth before being interpreted as such. To date, the ochre record has not been analyzed in sufficient detail, and this project addresses this gap in archaeological knowledge. While a few studies have been conducted using ochre from this region (Watts 1998; Wadley 2005), as pioneering studies they were necessarily limited in some aspects. This work has collected multiple types of data to help address the nature of ochre use in the MSA and is unique in this regard. PP offers several sites with ochre occurrences that may be among the earliest in the region and so is ideal for this study.

CHAPTER 2: BACKGROUND TO OCHRE RESEARCH

Introduction

Pigment use in prehistory has involved many types of materials including charcoal, graphite, manganese oxide, and kaolin (Valladas *et al.* 1992; Clottes 1993; Chauvet *et al.* 1996). However, it is the iron oxides in the form of red and yellow ochre that are by far the most common potential coloring materials found in prehistoric archaeological sites (Knight *et al.* 1995; Watts 1999; McBrearty and Brooks 2000). The use of red ochre in particular is well documented ethnographically around the world, and in recent societies is frequently applied to the body and/or artifacts during ritual or general symbolic practices. As a result, the presence of ground ochre and ochre fragments in Middle Stone Age (MSA) archaeological sites is often cited as early evidence for symbolic behavior in southern Africa (Watts 1999; Watts 2002). Ochre is then further interpreted as some of the earliest evidence for modern human behavior. However, several alternative explanations for ochre use have also been proposed including use of ochre in hide preparation, in the hafting of stone tools, and for medicinal purposes. Various studies have been undertaken in an attempt to better understand ochre use in the past. However, these studies are relatively few in number, and a large scale study of a single ochre assemblage addressing various possible uses has not been undertaken. Studies that have been done tend to focus on only one aspect of these assemblages. Some studies, such as Watts 1998, have carefully described ochre assemblages. Other studies, such as Wadley *et al.* 2004a and

Wadley 2005b, have investigated the use of ochre in hafting of stone tools. Others, such as Audouin and Plisson 1982, have studied the use of ochre for tanning hides. A further body of work focuses on the mineralogical characteristics of archaeological and geological ochre with an aim on sourcing (Jercher *et al.* 1998; Hughes and Solomon 2000; Popelka-Filcoff *et al.* 2008).

Because archaeological sites from the MSA preserve only a limited number of artifact classes, the lack of focused research on the ochre record needs to be addressed. The possible role of ochre as an indicator of symbolic “modern” behavior increases the need for this work. A study addressing the debated possible uses of ochre in the MSA requires an understanding of the potential mineralogical make-up of ochre, the ethnographic record of ochre use, the archaeological ochre record, the competing explanations of ochre use in the past, and the history of research already completed on the subject. This review attempts to cover all these aspects with a focus on research most applicable to ochre use in southern Africa. This review was used to develop a platform from which to construct the research protocol for this dissertation.

Ochre

Definitions

Archaeologically the term ochre is applied to a wide range of materials. In this context, ochre is a general category encompassing any ferruginous earth, clay, mineral or rock containing sufficient hematite, goethite, or other mineral to produce a colored streak (Jercher *et al.* 1998). Archaeological material labeled as ochre may not be ochre in a geological sense but is included in the category because it is thought to have been used for the same activities, namely producing pigment. Within geology, the term ochre is more restricted but still encompasses a variety of materials and minerals. Geological ochre can vary from pure oxide (iron or manganese) to a mixture of oxide with clays, silicates, and other minerals and may range in color from purple to yellow, although red is most common (Robertson 1976; Jercher *et al.* 1998; Popelka-Filcoff *et al.* 2007b). Red ochre (hematite bearing) is typically defined as being 70 weight percent Fe, and yellow ochre (goethite or limonite bearing) as at least 63 weight percent Fe (Mortimore *et al.* 2004).

Formation processes

Ochre can form in association with sedimentary, igneous, and metamorphic rocks, or as a weathering product, or in soils or unlithified sediments (Ellis *et al.* 1997; Jercher *et al.* 1998). Ochre most commonly forms in situations where chemical weathering occurs in association with iron concentrations and oxidation. This process sometimes includes hydration resulting in different mineral formations. Depending on the parent rock, hydrolysis of aluminosilicates or dissolution of carbonates can also occur. As a result, ochres typically contain accessory minerals such as clay minerals and quartz (Jercher *et al.* 1998). Ochre can take a variety of crystal forms. Some formations have porous structures, others flat plates that form uniform flat surfaces, and others have tabular particles (Hughes and Solomon 2000; Hodgskiss 2006).

Mineralogical components

Ochres are often mixtures of several different minerals, and the mineralogical make-up of ochres can vary considerably due to the varied conditions under which they form. However, they must contain some pigmenting agent usually an iron oxide (manganese oxides are also common). Colors of ochre will vary depending on the nature and amount of coloring agent, the particle size, the crystal structure, the degree of cementation, and the amount of cation substitution (Schwertmann and Cornell 1991; Schwertmann 1993). The most common color bearing minerals found in ochres are hematite, goethite, and limonite. Common accessory minerals include kaolinite, micas, quartz, gympsum, maghemite, calcite, and feldspars.

Hematite (α-Fe_2O_3) is an iron oxide that crystallizes in the hexagonal system with hardness of 5-6. It varies in color from red to black and has a rich red-brown streak. Hematite commonly forms in weathering contexts or through hydrothermal alterations of iron-bearing minerals under arid oxidizing conditions and can be a major component of both sedimentary and metamorphic formations (Blake *et al.* 1966; Anthony *et al.* 1997).

Goethite (α-FeO(OH)) is an iron oxide hydroxide that crystallizes in the orthorhombic system with hardness of 5-5.5. Goethite is typically brown to yellow in color with a similar colored streak. It also can form through the alteration and/or weathering of other iron bearing minerals under wet oxidizing conditions and can be found in sedimentary formations (Anthony *et al.* 1997).

Goethite lacking a crystal structure is commonly referred to as limonite ($2Fe_2O_3 \cdot 3H_2O$). Limonite is technically a rock that consists of mainly cryptocrystalline goethite or lepidocrocite and water (Deer *et al.* 1992). This form can also be used as pigment. Goethite and limonite have lower iron contents than hematite. When goethite is heated to between 80-800˚C it dehydrates and transforms to hematite (Schwertmann and Cornell 1991; Pomiès *et al.* 1999). Based on experiments, goethite transforms to disordered hematite around 200-250 ˚C, and a sample must be heated to at least 700˚C before normal, well-crystallized hematite is obtained (Béarat 1996). Therefore, hematite that has formed as a result of the dehydration of goethite at temperatures ranging from 200-700˚C can be recognized by a non-uniform broadening of X-ray diffraction patterns and a porous nanostructure (Pomiès *et al.* 1999).

Kaolinite ($Al_2Si_2O_5(OH)_4$) is a clay mineral that crystallizes in the triclinic system with a hardness of 2-2.5. Kaolinite is typically white to tan in color with a white streak. It can form from weathering, soil formation, diagenesis, and hydrothermal alteration by replacing other aluminosilicate minerals (Brindley and Robinson 1945; Goodyear and Duffin 1961; Anthony *et al.* 1995; Young and Hewat 1998).

Mica minerals such as muscovite ($KAl_2(Si_3Al)O_{10}(OH,F)_2$) or biotite ($K(Fe,Mg)_3AlSi_3O_{10}(OH)_2$) are commonly found in ochres although it can be difficult to determine which mica mineral is present. These minerals crystallize in the monoclinic system with hardness ranging between 2 and 4 (Robertson 1976;

Nesse 2000). Mica minerals range in color from colorless (typically muscovite) to dark brown, green or black (typically biotite). Micas are common minerals in rocks and form from other minerals through hydrothermal alteration (Yoder and Eugster 1955; Anthony *et al.* 1995).

Quartz (SiO_2) is a tectosilicate that crystallizes in the hexagonal system (trigonal division) with a hardness of 7. Quartz can be a variety of colors including white, gray, red, yellow, green blue, brown and black as well as colorless with a white streak. Quartz is extremely common and can be found in most types of environments. Quartz is stable in weathering conditions and so is typically found in sedimentary rocks (Le Page and Donnay 1976; Anthony *et al.* 1995).

Gypsum is a common sulfate mineral that crystallizes in the monoclinic system with hardness of 1.5-2. Pure gypsum is typically colorless or white with a white streak. Other colors are possible with trace impurities. Gypsum is common in sedimentary rocks and can form when sulfuric acid and carbonate rock react or when sulfurous volcanic gases react with calcium rich rocks (Pedersen and Semmingsen 1982; Anthony *et al.* 2003).

Maghemite (γ-Fe_2O_3) is an iron oxide that typically crystallizes in the cubic system with hardness of 5. It is usually brown to black in color with a brown streak and is strongly magnetic. Maghemite forms through the weathering or oxidation of spinels with ferrous iron such as magnetite. It often occurs as a red pigment in sediments, rocks and soils in association with hematite (McLeod 1970;

Collyer *et al.* 1988; Schulz and McCarthy 1988; Fabris *et al.* 1995; Anthony *et al.* 1997). Maghemite can also form through heat treatment of lepidocrocite ($\gamma FeO \cdot O$) under arid oxidizing conditions (Morris *et al.* 1998; Dinesen *et al.* 2001)

Calcite ($CaCO_3$) is a carbonate mineral that crystallizes in the hexagonal system with hardness of 3. Calcite is commonly colorless or white with a white streak but any color is possible depending on impurities. Calcite is a common rock forming mineral and can be found in sedimentary contexts, in hydrothermal veins, in igneous rocks, and as cave speleothems (Effenberger *et al.* 1981; Anthony *et al.* 2003).

Feldspars are the most common minerals on earth and so are often found incorporated in ochres. Plagioclase crystallizes in the triclinic system with hardness ranging from 6 to 6.5. White and gray are the most common colors although blue, green, yellow, and red tints are also found. K-feldspars crystallize in the monoclinic and triclinic systems depending on the variety and hardness also ranges from 6 to 6.5. Plagioclase can be distinguished from K-feldspar by the presence of parallel striae on cleavage surfaces. In rocks that contain both plagioclase and k-feldspars the plagioclase is commonly grayish while the k-feldspars are pinkish (Nesse 2000).

Ethnographic ochre use

Distinguishing utilitarian uses from symbolic uses of ochre in the archeological record is crucial to identifying the origins of modern symbolic behavior. In order to accomplish this, it is necessary to determine what the possible range of ochre uses are and how these may be archaeologically manifested. Different ochre uses may be expected to leave different signatures and require different exploitation strategies. As Hovers *et al.* have argued, the ethnographic record can be used for constructing models of ochre use in the past as long as it is not also applied as a test of that model (Hovers *et al.* 2003). The ethnographic record is best used to outline the potential uses of ochre and to generate test implications to be applied to the archaeological record.

It would be desirable to build archaeological expectations for the Cape from hunter-gatherer ethnography of that region. Unfortunately, the resident hunter-gatherers present at the time of European contact, the Cape Khoi, were rapidly exterminated and/or assimilated. Ethnographic information on the Cape Khoi is limited as a result. It is necessary to look at the ethnography of other groups in the region. One valuable published source (Bleek and Lloyd 1911) as well as unpublished documents and notebooks written by Bleek and Lloyd do exist for the \Xam people from the Karoo (some documents available online at http://www.lloydbleekcollection.uct.ac.za/index.jsp). Bleek was not a cultural anthropologist but a linguist interested in studying this language before it went extinct. Bleek found several subjects to study at a convict station close to Cape Town, and these men afterwards returned to their homes and brought their families back to Bleek's land. After Bleek's death in 1875 his work was carried on by his sister in law, Lucy Lloyd and eventually published in 1911 (Bleek and Lloyd 1911)

Although this work provides valuable insights, alone it may not provide a full representation of possible ochre use and exploitation patterns in the past. It was therefore necessary to expand the ethnographic case study to other hunter-gatherer groups. The ethnography of other African hunter-gatherers namely Khoisan groups from further north in southern Africa are included here. All groups mentioned are of the San language group. This large and diverse group of peoples speaks or spoke languages containing clicks and has been described as hunter-gatherers. Their relationship to groups that would have been living along the southern coast in the MSA is not certain. However, the body of genetic data conclusively demonstrates that the Khoisan lineage is one of the oldest in the world (Behar *et al.* 2008; Campbell and Tishkoff 2008; Ramachandran *et al.* 2005). They are included here simply to get a grasp on possible uses of ochre to be tested for in the archaeological record. They are not meant to be a direct example of MSA groups. The ethnography on Australian hunter-gatherers is also included here. Ochre is known to have played an important role in the lives of Australian aborigines, and the ethnographic record from this region is quite rich in references to ochre particularly in comparison to southern African ethnography. This helps to further develop the list of possible uses to look for in the archaeological record.

Ochre and the Khoisan of southern Africa

Mention of ochre is not common in Khoisan ethnography. The use of ochre had largely been lost by the time ethnographic description began. Also, far more work taking a multidisciplinary, ecological approach has been done rather than work focusing on symbolic aspects of Khoisan life. There are, however, some revealing descriptions in the available literature. Red pigments were among the most valuable to the Khoisan and were a common element in ritual and ceremony (How 1970; Lewis-Williams and Biesele 1978; Watts 1999). Its use is known in rites of transition, healing, rain making magic, hunting magic and ritual rock painting (Kaufmann 1910; Bleek and Lloyd 1911; Viegas Guerreiro 1968; How 1970; Kohler 1973). Purely utilitarian uses of ochre were not found in the available ethnographic literature.

<u>General ritual use</u> According to Biesele (Biesele 1993), in stories of ritual, women are always by the fire grinding ochre to prepare for the ceremony. The sound of red ochre being pounded is a metaphor in Zu/'hoasi oral narratives for impending ritual action.

<u>Menarcheal ritual</u> According to Watts, red ochre is almost always involved in menarcheal rituals for Khoisan girls (Watts 1998; Watts 1999; Watts 2002). Fischer (Fischer 1913) comments on this for the Khoisan of Namibia. At the time Fischer studied the Khoisan, there were few who still painted themselves with ochre. However, those who did paint themselves did so during menstruation. Other examples are known for the \Xam of the Cape and the !Kung of the

Kalahari. Among the \Xam, when a young woman emerged from seclusion following her first menses, she used powdered hematite to appease the rain animal and protect the water supply from running out (Watts 1999). Also the “new maiden” was required to give red ochre to the women in her band for decorating their cloaks and faces (Knight *et al.* 1995). Among the !Kung a “new maiden” had a design painted on her forehead and cheeks in red ochre (Marshall 1959). Both !Kung and \Xam “new maidens” gave adolescent boys red ochre to protect them from hunting accidents (Lewis-Williams 1981).

<u>Artistic expression</u> The Khoisan are thought to be responsible for much of the rock art in the region (Lewis-Williams 1983). A missionary S. S. Dornan reported that he saw a “half-bred bushman” painting a granite boulder. According to Dornan’s report, the artist smoothed the rock surface with a pebble and used a crayon and warm liquid paint to create a zebra. The artist, however, was paid to paint the image (Dornan 1925).

Other indirect accounts are also known. A geologist G. W. Stow in 1866 described a man shot for stealing stock who had ten small horn pots hanging from his belt. Each pot contained a different color pigment (Rudner and Rudner I. 1978). A. R. Willcox (Willcox 1956) quotes a black man who lived among the “bushmen” in the Drakensberg around 1850. The man said they painted well and used brushes of wildebeest hair and earth colors (Willcox 1956; Rudner and Rudner I. 1978). Another missionary, V. Ellenberger told of an old Sotho woman, born about 1856. When young, the woman visited a Bushmen headman in a large cave and saw three men painting in the corners. In 1752, an expedition to the eastern Cape attributed rock art near the Kei River to the “Little Chinese” or Khoisan people. In 1797 and 1798 Sir John Barrow described rock paintings near “Waay Hoek” in the eastern Cape:

> On the smooth sides of the cavern were drawings of several animals that had been made from time to time by these savages. Some of the drawings were recognized to be of recent execution; but many of them were remembered to exist from the first settlement of this part of the colony. (Quote in Rudner and Rudner 1978: 58)

Personal adornment In Bleek and Lloyd (Bleek and Lloyd 1911), ochre seems to be referred to both as ||ka and tto. They describe the smearing of ochre along with another black pigment called ||*hara* on the body:

> ||*hara* [A certain stone which is said to be both hard and soft] is black; the people [having mixed it with fat] anoint their heads with it; while *tto* is red, and the people rub their bodies with it, when they have pounded it; they pound it, pound it, pound it, they rub their bodies with it. They pound ||*hara*, they anoint their heads, when they have first pounded the *tto*; they first rub their bodies with *tto*. And they pound ||*hara*, they anoint their heads. They anoint their heads very nicely, while they wish that their head's hair may descend (ie., grow long). And it becomes abundant on account of it; because they have anointed their heads, wishing that the hair may grow downwards, that their heads may become black with blackness, while their heads are not a little black. (375)

Hunting Bleek and Lloyd (Bleek and Lloyd 1911) make mention of the use of ochre in hunting technology. The implications of its use, symbolic or utilitarian (or both) are not further discussed. Feather brushes used in hunting springbok were also covered with ochre.

> They roll the feather brushes, binding the ostrich feathers (the body feathers) upon the "Driedoorn" stick. They become numerous; and they (the Bushmen) pound red stones,[The red stones here meant, are ||ka; not tto] they paint [Paint them red.], the feather brush sticks. (359)

According to an observation made by a Doctor Atherstone in 1854, the San from Namaqualand also attached feathers to arrows using “euphorbid milk and red clay” as cement (Webley 1994).

Bleek and Lloyd also describe the use of red pigment in marking arrows so they can be identified to hunter. “|*kwae* is that which they make the marks. They put *tto* into it and they pound the *tto* together with the |*kwae*; and the |*kwae* becomes red on account of it; then, they mark the arrows with it” (Bleek and Lloyd 1911: 363).

<u>Exploitation and trade</u> One of the most interesting passages from Bleek and Lloyd (Bleek and Lloyd 1911) is one describing how *tto* is obtained. This passage clearly indicates the importance and symbolic power of the substance:

> *Tto* is in the mountain, the *tto* mine; the people say that the *tto* mine is on the side of the mountain, the people say '*tto* mine' to it. The people are afraid of it [that is, of the sorcerers who live by the mine], because the people are aware that people are there (sorcerers). They (the sorcerers) make a house [The narrator thinks that their houses are small holes, like mouse-holes.] there. Therefore, the people who intend to pound *tto,* rub themselves when they (go to) collect *tto*. And when they go to the *tto*, they throw stones at the *tto* mine, when they wish the sorcerers to bide themselves, that they may go undisturbed to work at the *tto*, while they feel that the sorcerers dwell at the *tto* mine. Therefore, they take up stones, they throw stones at the *tto* mine, when they wish the sorcerers to hide themselves, that they may go in peace [For, they would be ill, if the sorcerers saw them.] to work at the *tto*. And they go to work at the *tto*, *tto*, *tto*. They also get ||*hara*; [The ||*hara* mine [literally, "mouth" or "opening "] is in a different place; the *tto* mine is also in a different place.] they put away the ||*hara* and the *tto*, and they return home. (379)

This passage describes direct acquisition of ochre, but Fourie (Fourie 1928) does briefly mention trading of ochre. In his report he names red ochre, along with arrow poison, as one of the most traded items among northern Khoisan groups.

Ochre and the Australian/Tazmanian Aborigines

The ethnographic literature on Australian aborigines describes red ochre being used for many purposes. It is used as pigment to decorate the human body, to coat ritual objects, tools and weapons such as clubs and boomerangs and to paint rock shelters and bark (Spencer and Gillen 1899; Spencer and Gillen 1904; Basedow 1925; Spencer and Gillen 1927; Chewings 1936; Simpson 1951; Sagona 1994). The use of ochre is nearly always symbolic or ritual in nature. Although utilitarian functions have been reported, they are often confounded by symbolic overtones. The literature on ochre use is far more extensive for Australian groups than African groups. Basedow's ethnography (Basedow 1925) is particularly rich with ochre references, and Spencer and Gillen (Spencer and Gillen 1899; Spencer and Gillen 1904; Spencer and Gillen 1927) often mention ochre as well. Presented here are examples of the most common patterns recorded throughout Australia.

<u>Initiation ceremonies</u> Ochre played a prominent role in both male and female initiation ceremonies in aboriginal Australia and is often smeared on novices (Basedow 1925; Chewings 1936; Sagona 1994). For circumcision and female mutilation ceremonies, special messengers with their bodies covered in red ochre visit neighboring groups to invite novices to partake in the ceremony. At the celebrating camp nightly, corroborees are held and the novices are smeared with

emu fat and red ochre (Basedow 1925). Among the Wiradjuri, initiates were taken into the bush and covered with red ochre (Sagona 1994). According to Spencer and Gillen, among the Arunta the final stage of an initiation ceremony involved covering the initiate with red ochre (Spencer and Gillen 1899; Spencer and Gillen 1904; Spencer and Gillen 1927).

Ochre is also involved in the tooth rapping male initiation ceremony in some parts of Australia. Several old men decorate themselves with vegetable down and red ochre. The young boys to be initiated are covered with red ochre and symmetrical designs are drawn on top of the red base. The older men hold the heads of the boys while an undecorated man repeatedly raps one tooth with a stick until it falls out. After this ceremony the boys are considered men (Basedow 1925).

Ochre also plays a role in menstrual rituals of females. Among the coastal tribes in the north, females are segregated for three days during their first menstruation. During this time, they are taught the taboos associated with womanhood. After this period, they are smeared with ochre, given a ritual bath, and return to camp richly decorated. In eastern Arnhem Land, menstruating women are allowed to remain in camp but are covered in ochre to warn the others of their condition. In the Lake Eyre district, women smeared ochre on themselves at the end of their cycle and also during periods of mourning (Sagona 1994).

<u>Healing ritual</u> When someone feels sick, red ochre is immediately rubbed over the entire body. If the illness is serious, the women will charm a mixture of fat and

red ochre by singing to it and then rub it on the sick person. If the man recovers, he cannot speak to these women until he has made them an offering of meat. When the offering has been made, the women rub him with red ochre again to remove the silence ban (Spencer and Gillen 1927). Ochre was also mixed with fat and applied to wounds, burns, and swellings. At times it was chewed in the mouth and sprayed on the infected area. Ochre was also applied to the skin after scarring operations (Sagona 1994).

<u>Mortuary rituals</u> Basedow also described the use of ochre in various mortuary practices (Basedow 1925). Along the mouth of the Murray River mummification is achieved by placing the body on a platform and smoking it over a fire. The body is then covered with ochre and grease. The Larrekiya, Wogait, and other northern tribes smear red ochre over the corpse and then place it in a tree to decompose (Basedow 1925). Some groups cover the bones of dead relatives in grease and ochre and wrap them in kangaroo sinew. This charm is used to relieve pain (Sagona 1994).

<u>Sacred objects</u> Ochre was also often applied to ritual objects. Spencer and Gillen describe the use of ochre in decorating Churinga. Churinga are sacred objects never allowed to be seen by women. Generally these are round, oval, or elongated flattened slabs of stone or wood. When these objects are examined by the older men they are carefully rubbed with powdered dry red ochre (Spencer and Gillen 1899). Red ochre was applied to numerous other objects as well. Designs were

painted on pipes, stone axes, spears, adzes, wooden hafts of knives, pitchis, and boomerangs (Spencer and Gillen 1904).

Artistic expression Ochre is frequently ground to be used as a pigment for rock art (Spencer and Gillen 1899; Spencer and Gillen 1904; Basedow 1925; Spencer and Gillen 1927; Mountford 1956). Basedow (Basedow 1925) describes the process. A measured amount of ochre was placed on a level surface of rock and ground with a medium sized pebble. Portable slabs were also used when no natural surface was suitable. The powder was then mixed with water or fat on a piece of bark to make a thick paste. Among the Bathurst Islanders, large concave shells (Cyrena) were also used for mixing pigments. If paint was being applied to a large surface often the fingers would be used. Short sticks were used for applying finer details. Bathurst Islanders are known to have cut green shoots of lawyer-cane and chew the end to produce a paint brush (Basedow 1925).

Among aboriginal art, hand shadows are common. Basedow describes their creation (1925). A small handful of ochre was placed in the artist's mouth with water and mixed. One hand was placed on a flat surface, and the pigment was sprayed from his mouth, leaving an impression of the hand. Sometimes the negative print was then filled in with another color. The Arunda refer to this practice as "ilja imbadja". Negative imprints are most commonly hands but examples exist of feet and personal objects such as stone tomahawks. More rarely the hand would be smeared with ochre to create a positive hand print on a surface (Basedow 1925).

Personal adornment Ochre is most often described as a substance applied to the body. Red ochre is worn by both women and men. Often the hair is coated with red ochre and grease (Spencer and Gillen 1899; Spencer and Gillen 1904; Basedow 1925; Spencer and Gillen 1927; Chewings 1936; Simpson 1951). Chewings (Chewings 1936) describes women wearing a cord of wallaby hairs covered with grease and red ochre and wrapped around the head. He also reports men wearing long hair cords colored with ochre wrapped around their heads. According to Strehlow (1947), the pigment colors used for bodily adornment at specific times are dictated by tradition. Red is described as the color of joy and the favorite of the people (Strehlow 1947).

Creation myths Much of the Australian ethnography dealing with ochre emphasizes its strong association with blood. This is evident in the various myths surrounding the creation of major ochre deposits. In several myths, the blood is vaginal. One myth involves dancing women, called Unthippa. These women came from the west and danced all the way to the lands of the Arunta. “Upon arrival at a place called Wankima, about a hundred miles further to the east, their sexual organs dropped out from sheer exhaustion, caused by their uninterrupted dancing, and it was these which gave rise to well-known deposits of red ochre” (Spencer and Gillen 1899; Spencer and Gillen 1904; Spencer and Gillen 1927).

A second myth was reported by Spencer and Gillen (Spencer and Gillen 1927):

> Near to Stuart's Hole, on the Finke River, there is a red ochre pit which has evidently been used for a long time; and tradition says that in the Alcera two kangaroo women came from Ilpilla, and at this spot caused blood to flow from the vulva in large quantities, and so formed the deposit of red ochre. Traveling away westward they did the same thing in other places. (484).

The third prominent myth does not involve vaginal blood but rather the blood of an emu. The owners of the Parachilna ochre mine in the Flinders Range tell a myth of an emu being chased by a pack of wild dogs. The emu was caught and killed at Parachilna and the blood become ochre (Basedow 1925).

Exploitation and trade The exploitation of ochre in Australia was highly ritualized. It is also clear from the ethnographic record that certain ochre deposits were preferred over others. Aborigines in Wilunal cited deep red color, high covering power (opacity), and fine powdery texture as important qualities of preferred ochre. They named Wilgie Mia, an ochre source 300km to the north east as the best known ochre source (Clarke 1976). Often local sources were held to be inferior and went unused (Sagona 1994). Prior permission to exploit the mines was obtained from the owners before the expedition set out. To reach the mines, expeditions often followed mythical routes that traced the creation stories of the ochre deposits.

Basedow (Basedow 1925) describes such an expedition undertaken by the "Salt Water Tribe" who sent men across Queensland to collect ochre. The expedition was controlled by an old man who led a group of younger men who had recently been initiated. The expedition was viewed as a test of strength and endurance for the young men involved. When the expedition came close to the mine they dropped their belongings and ran. As they ran they threw stones at rocks thought to be the petrified remains of the dogs that killed the sacred emu whose blood created the ochre deposit. The young men then stopped at a stone platform, the place the emu died, while the old man went into the mine. He returned with ochre and covered the bodies of the young men. At this point the young men cut off their beards and offered them to the emu as feathers. Entering the mine, each man fills his bag with ochre and then runs away from the mine back to his belongings. While leaving the mine he is forbidden to look back, and if a bag is dropped it is left behind where it falls (Basedow 1925).

Numerous other ethnographic accounts of ochre expeditions exist recording the great distances men were willing to travel to obtain high quality ochre. Distances traveled to the Flinders Range deposits are particularly impressive. There are accounts of parties of 70-80 fighting men traveling up to 450km to the Flinders Range and carrying back up to 170kg of red ochre (Jones 1984a; Jones 1984b). McCarthy cites travel of over 300km to obtain high quality ochre (McCarthy 1939a; McCarthy 1939b). The Yantruwunta traveled 482km (300 miles) to obtain ochre from the western side of the Flinders Range. The Dieri traveled approximately 500km to Bookartoo on ochre expeditions each year (Mulvaney and Kamminga 1999). In an extreme case, it is reported that aborigines traveled 1448km (900 miles) from south-west Queensland to obtain ochre at Flinders. In addition, the Wonkonguru and Dieri people also traveled to Beltana for ochre despite the fact that closer ochre sources existed (McCarthy 1939a; McCarthy 1939b). Long distances were also traveled in Tasmania to achieve ochre even when alternative sources were nearby (Robson and Plomley 1982).

According to Basedow, the Australian aborigines were never without ochre. If they were in danger of running out they would trade for it from neighboring tribes (Basedow 1925). McCarthy (McCarthy 1939a; McCarthy 1939b) cites ochre as one of several widely distributed items in Australia. Wilgie Mia ochre was extensively traded and may have moved as far as Queensland. The Flinders Range was also the center of a highly organized network of ochre mining and trade. Jones has published a letter written by Dr. P.F. Shanahan which details an ochre expedition he accompanied in 1904 (Jones 1984a; Jones 1984b). Shanahan writes that Flinders ochre was distributed Australia-wide. While this may seem unlikely, its distribution was considerable. Ochre from the numerous Flinders mines is believed to have reached Boulia to the north and Cloncurry in western Queensland by a path referred to as the “red ochre trade route”. To the east, Flinders ochre is known to have reached the Darling River Region and may have gone as far as Charleville in southern Queensland. Ochre also reached the Mulligan River District to the west (Sagona and Webb 1994). In some cases this requires the ochre to have traveled several thousand kilometers.

Utilitarian Uses More utilitarian uses of ochre are also mentioned in the literature but are given far less attention. According to historical records, ochre was mixed with vegetal fiber and resin to form adhesive (Rots 2002). Hunters often smeared red ochre on their bodies while hunting in the desert for camouflage (Sagona 1994). There is one report of the use of red ochre as a food preservative. Along the northern coast, wild plums were dried in the sun, rubbed with ochre, and dried again. After this process the fruit would last for several weeks (Thomson 1949). The Aluridja were recorded to smear ochre over infants as a protection from hot sun and flies. This was also reported for some southeastern tribes (Basedow 1925). It was similarly smeared on the body as a protection from the cold in some areas (Sagona 1994). Spencer and Gillen (Spencer and Gillen 1899) report the use of ochre to protect against insects like the white ant.

Ochre use among other groups

There are numerous other ethnographic uses of ochre recorded in the HRAF files. In 1907, Schultze observed Hottentots in Nambia using ochre and clay as make-up (Schultze 1907). Baganda in Uganda used ochre for canoe paint and for dying cordage (Roscoe 1911). In West Africa, the Mali use ochre for coloring ritual masks (Palau Marti 1957). The Katab of Nigeria stain women's headboards with red ochre (Gunn 1956). Yapese of Micronesia make all purpose dye from red ochre (Senfft 1903), and the Woleaians used ochre to paint their canoes (Damn 1938). Kurtatchi of the Solomon Islands use ochre for general dye and for body paint (Blackwood 1935). Kapauku of New Guinea paint their faces with red ochre for ritual pig feasts (Pospisil 1959). The Maasai of East Africa use red ochre for ritual confrontations (Spencer 1988). It seems wherever these materials are available groups of varying social structure have identified and exploited them for various often ritual purposes.

Discussion

The ethnographically known uses of ochre overwhelmingly occur in ritual contexts. Even in contexts where it serves a utilitarian function, symbolic power is still invoked in its use. This makes the two aspects difficult or impossible to disentangle among modern groups. Neither utilitarian nor symbolic uses in the archaeological record can be ruled out based on the ethnographic evidence.

Ethnographically, the use of ochre in arrow technology was reported in southern Africa (Bleek and Lloyd 1911; Webley 1994). However, its function is sometimes described as marking the arrows and so is overtly symbolic in nature. While ochre may prove to be functionally useful in hafting the use of red symbolism in hunting practices is certainly common.

The most striking similarities cross-culturally have to do with ochre exploitation. The ethnographic record from both southern Africa and Australia suggest highly ritualized ochre exploitation. In Australia, specific ochre sources are valued while others on the landscape are ignored. Ochre is not exploited casually as part of regular rounds. Rather it is important enough to warrant special expeditions which are often viewed as dangerous. Large distances are covered to extract socially valuable ochre despite the proximity of other arguably high quality ochre deposits. The strong focus on red ochre is also evident although in both study areas other pigments exist and are used in lower frequencies. One can argue that such exploitation patterns of preferential use and long distance movement of material either through trade or direct procurement would be strong evidence for symbolic importance of the ochre.

A group of people using ochre in strictly utilitarian purposes would be expected to use material closest to them, assuming it is of sufficient quality for the task. Its exploitation would likely conform to general patterns of lithic raw material exploitation with local materials dominating assemblages and non-local material being more common as mobility increases and more sources are encountered (Ambrose and Lorenz 1990). This could be addressed archaeologically with geochemical analysis and sourcing of archaeological ochre. If ochre is coming from primarily distant sources rather than closer sources or exploitation is focused on a few deposits when many are available it may be suggestive of more symbolic uses. Exploitation patterns could also be compared to the exploitation patterns of other raw material types, namely stone, that are thought to be used for utilitarian activities.

The archaeological ochre record

Claims for early ochre use

The earliest evidence for ochre use is controversial. Early ochre occurrences have been reported in an Acheulian assemblage at Olduvai Gorge dating to approximately 500,000 BP (Leakey 1958; Wreschner *et al.* 1980), and in the European Late Acheulian sites of Ambrona, Terra Amata, and Becov (Howell 1966; de Lumley 1969; Marshack 1979). The anthropogenic origin of these ochre fragments has, however, been disputed (Wreschner *et al.* 1980; Wreschner 1985). Around a dozen Middle Paleolithic sites in Europe have pigment occurrences in the form of iron and manganese oxides and calcareous earth (Bordes 1952; Kraybill 1977; Marshack 1981; Combier 1989; Demars 1992; de Beaune 1993; Mellars 1996; McBrearty and Brooks 2000)

. In the Kapthurin Formation, Baringo, Kenya, ochre has been discovered in context with stone artifacts, fragmentary bone and ostrich eggshell fragments on a paleosol sealed by several meters of volcanic tephra. Pyroclastic material above the site has been K/Ar dated to greater than 240 ka (Tallon 1978; McBrearty *et al.* 1996). The fragments are too friable to preserve evidence of grinding but the material is widespread at the site (McBrearty 1999). The original sample consisted of 74 items weighing a total of 5kg. Further excavations in 1997 added to the sample and included the discovery of ochre stained grindstones (McBrearty and Brooks 2000; Tryon *et al.* 2005). This material, unfortunately, has not been fully published and described. It is unclear how closely related the ochre fragments are with the rest of the archaeological deposit.

There have also been claims for early ochre use at the site of Twin Rivers in Zambia. Many ochre fragments were discovered in an artifact and bone-bearing breccia with two U-series dates associated (230,000 ± 35,000 or 28,000 B.P. and 195,000 ± 19000 B.P.). These dates come from an overlaying speleothem

(Barham and Smart 1996; Barham 1998; Barham 2000; Barham 2002). Another set of U-series dates range from 225,000 to 160,000 B.P. (Gilmour *et al.* 2000; Barham 2002). The validity of these dates and their association with the ochre is unclear.

The most reliable evidence for early ochre use comes from PP13B near Mossel Bay, South Africa. Ochre has been found throughout the MSA deposits at the site including in the oldest excavated deposits which have a weighted mean optically stimulated luminescence (OSL) age of 164 ± 12 ka (Marean *et al.* 2007). These deposits have been carefully excavated (Marean *et al.* 2004), and the OSL ages from which the weighted mean is calculated are clearly associated with the ochre recovered.

MSA ochre assemblages in southern Africa

The presence of ochre becomes common in MSA sites of southern Africa particularly after 120,000 years ago (Watts 2002). For example, in a sample of MSA sites generated by Watts (Watts 1998; Watts 1999), 43 out of 53 rockshelters and 7 out of 21 open-air sites contained ochre. Typical ochre remains include unutilized material, ground tablets, powder, and stained artifacts. This usage pattern differs somewhat from patterns elsewhere in the world. In Europe ochre is found in Middle Paleolithic contexts, but it is rare by comparison. According to McBrearty and Brooks (McBrearty and Brooks 2000), only about a dozen Middle Paleolithic sites in Europe have pigment (iron and manganese oxides). Ochre is also found in the Levant in association with early modern humans (Hovers *et al.* 2003; Bar-Yosef Mayer *et al.* 2009).

Blombos Cave Ochre fragments are abundant at Blombos Cave. In the 1998/99 excavations alone, 8,224 pieces of ochre were excavated, and 7,914 of these have been classified as pigments. Non-pigment pieces may have been brought to the site unintentionally with shellfish or seaweed. Most of the ochre, both by number and by mass, comes from BBC3, the lowest stratigraphic unit at the site. These layers contain three times more ochre than any other MSA or LSA site in the area. However, a higher percentage of pieces are utilized in later layers. The large quantities brought to the site in BBC3 suggest a nearby source perhaps now submerged by rising sea levels. Because the source was close, more material may have been brought to the site than needed. During later occupations, ochre may have been retrieved from further sources resulting in smaller quantities at the site and a higher percentage of use (Henshilwood *et al.* 2001).

Many of the ochre pieces show distinctive striae from grinding and scraping. These pieces are classified as scraped tablets and ground crayons. Crayons are defined as pieces with three or more ground facets. Twelve definite crayons have been identified along with twelve more probable ones. Crayons are better represented in BBC1, the youngest MSA units. Also, there seems to have been some selection for specific ochre colors at the site. In general, saturated reddish-browns are preferred and similarly red but less saturated material often went unused (Henshilwood *et al.* 2001).

Two pieces of engraved ochre are also known from Blombos Cave. These were recovered from Layers CC and CD (BBC 1). Piece 8937 has one edge with two ground facets. The larger of the facets has been engraved with a crosshatched design made up of two sets of six and eight lines intersected by a longer line. Piece 8938 has a row of cross-hatchings bounded by parallel lines on the top and bottom and another line through the middle to create triangles. Analysis has shown that the hatchings were created by engraving all the lines in one direction first then engraving the others, rather than engraving each crosshatch individually. The engravings are dated by association with burnt lithic pieces and OSL to 77,000 years ago (Henshilwood *et al.* 2002; Jacobs *et al.* 2003a; Jacobs *et al.* 2003b).

An ochre preparation "tool kit" has also been described for Blombos Cave. This kit includes two Haliotis midea (abalone) shells with the remnants of an ochre mixture on the interior surfaces as well as fragments of ochre, bone, and charcoal in association with ochre stained grindstones and hammerstones. The finds are thought to data to approximately 100,000 years ago (Henshilwood *et al.* 2011).

<u>Hollow Rock Shelter</u> At Hollow Rock Shelter in the northern Cederberg, South Africa, nodules of pigment are surprisingly abundant. There are ground pieces of various sizes including a large piece with striations. Two notched pieces were also discovered (Evans 1994).

Twin Rivers At the site of Twin Rivers in central Zambia, 180 pieces of hematite, specularite, limonite, ferruginous sandstone, and manganese dioxide were recovered from A Block. Specularite is the most common coloring material, making up 61.1% of the assemblage while hematite is the next most common making up 26.7% of the assemblage. F Block yielded 122 pieces of hematite, specularite, sandstone, limonite and manganese dioxide. Several pieces from both assemblages show signs of rubbing (Barham 1998; Barham 2002).

A quartzite cobble shows heavy pockmarking from use on both ends and all surfaces are stained yellow or have traces of yellow sediment trapped in the pores between quartz grains. Similar yellow staining was identified on several artifacts. While yellow staining can occur naturally in cave clays, trace element analysis of the breccia in which the artifact was found did not suggest the presence of iron oxide. Further, the trace elemental signature of the staining most closely matched the trace elemental signatures of specularite fragments found in the excavations (Young 2000b; Barham 2002).

A flowstone near the top of Block F has been dated to 195,000 ± 19,000 B.P. using mass spectrometric uranium-series and 230,000 ± 35,000 or 28,000 B.P using conventional uranium-series (Barham and Smart 1996; Barham 1998). Various dates for A Block range from 225,000 to 160,000 B.P. (Barham 1998; Barham 2002).

Klasies River Mouth A total of 180 pieces of red ochre were reported from Klasies River (Singer and Wymer 1982). A few pieces of soft yellow sandstone were also found throughout the Klasies sequence. Many have been smoothed and several could be described as crayons. Some flat pieces also show cross-hatchings of thin lines as seen on LSA palettes. One broken crayon has three circular shallow depressions on one side (two are .7cm and the other is .4cm). The smoothness of the marks suggests they were made with a wood or bone drill. In the material from the Singer Wymer excavations, there is a significant increase in ochre fragments in the Howiesons Poort levels. Also found in these levels were four tabular quartzite pieces (10-20cm). They were found close together in the same square, and one has a battered edge perhaps to make the pieces more regular. This piece also has faint traces of red ochre (Singer and Wymer 1982).

One piece of potentially engraved ochre has recently been reported from Klasies thought to date between 100,000 and 85,000 years ago. Microscopic investigation of the ochreous pebble fragment revealed that it had been ground smooth prior to the engraving of a series of sub-parallel lines. Based on X-ray fluorescence and color based analysis the argument has been made that this piece differs in composition from other raw material found in the same level (d'Errico *et al.* 2012).

Rose Cottage Cave Colored materials were found in all levels at Rose Cottage Cave. Several particularly large pieces of red ochre (mostly hematite) were recovered, some of which are ground. Two pieces have been described as crayons (Wadley and Harper 1989; Wadley 2001b).

Sibudu Cave Ongoing excavations at Sibudu Cave have recovered considerable amounts of modified and unmodified ochre. Some pieces can be described as "crayons" and several ochre stained grindstones have also been reported (Wadley 2001a). Although much experimental work has come out of the Sibudu project in regards to ochre use, the ochre assemblage has yet to be fully described in publication. One interesting feature at Sibudu is the presence of several cemented ash patches with ochre residue. The research group argues that these surfaces were being used as an ochre preparation area (with grindstones) or to store powdered ochre (Wadley 2010a; Wadley in press).

Die Kelders Cave Ochre is also present at Die Kelders in Layers 4/5, 6, 8, 9, 10, 9/10/11, 11, 12, and 14. The majority is small nodules, chips, and crumpled debris. Several large pieces show ground surfaces and striations. A small platform piece with rounded edges comes from Layer 10, and two similar pieces were excavated from Layer 14. Also in Layer 10 was an ochre flake with a faceted platform. Two crayons come from 12 and 14. There are also a few ochre stained flakes known at the site and two ochre stained upper grindstones from Layer 4/5 (Grine *et al.* 1991; Avery *et al.* 1997; Thackeray 2000).

Nelson Bay Cave Inskeep reports the occurrence of ochre in thirty-seven out of one hundred twenty-two excavation units (excavated in 1964, 1965/66, 1970/71 and 1979). Twenty-four ochre pencils were recovered from these excavations, and all but one are various shades of red. The last is described as black with pockets of creamy white and was found in association with Burial 5 at the site. Twenty-one artifacts with ochre staining were also recovered including rubbing stones, grinding stone fragments, and flakes (Inskeep 1987).

A total of 707 ochre fragments were counted in Klein's LSA collections from NBC (Bernatchez 2008). The MSA collections include 99 ochre fragments, 58 from the Howiesons Poort levels and 41 from the early MSA (Volman 1981). The LSA and MSA collections both contain ochre fragments of various shades of brown, yellow, and red.

PP13B Three major areas have been excavated within PP13B near Mossel Bay, South Africa, and ochre has been recovered from all areas. The LC-MSA area yielded 57 pigment pieces (93.4g). All the fragments can be classified as red ochre and 10 showed evidence of definite use. Another two showed evidence of likely use. Most of these utilized fragments are moderately to intensively ground on one surface. It has been suggested that the used pieces are the reddest fragments in the collection (Marean *et al.* 2007). The Western excavation area yielded 166 fragments (503g). Of these 14.5% are definitely utilized and 4.8% are possibly utilized. The Eastern area had 163 pigment pieces described (410g). 9.2% of these fragments were definitely utilized, and another 6.2% were possibly utilized. Watts argues there is evidence for the reddest pieces being the most utilized (Watts 2010).

Border Cave Red hematite crayons were found throughout the entire Border Cave sequence, the base of which was thought to date to at least 200 ka (Beaumont *et al.* 1978; Beaumont 1980). More recent ESR dating on enamel from the Border 5 hominid yielded at date of 74 ± 5 ka. This hominid was recovered from Layer 3 WA near the middle of the sequence (Grün *et al.* 2003). Fibrous material interpreted as bedding was also recovered stained with iron oxide (Volman 1984). The BC3 infant burial was also found to be stained with hematite (de Villiers 1973).

Apollo 11 A painted stone slab has been reported from Apollo 11 cave in Namibia (Wendt 1975; Wendt 1976; Vogelsang 1996; Vogelsang 1998). The slab comes from MSA layers stratified directly above a Howiesons Poort occupation. Wendt (Wendt 1975; Wendt 1976) has argued that the piece is a portable art object, but it could also be exfoliated from the cave ceiling or walls. The MSA levels at the site also produced several ochre "crayons" (Wendt 1976).

Other occurrences The presence of ochre is mentioned briefly in the literature for numerous other MSA sites. These sites include Boomplaas, Umhlatuzana, Bushman Rockshelter, Mwulu's Cave, and Olieboompoort (Watts 1998). Grindstones with ochre residues have also been recovered from MSA levels at Pomongwe in Zimbabwe and ≠Gi in Botswana (Walker 1987; McBrearty and Brooks 2000). At Porc Épic in Ethiopia, 298 ochre fragments, 40 with evidence of grinding, have been reported. These are thought to date to at least 77 ka (Clark *et al.* 1984; Clark 1988). One fragment of potentially engraved ochre has also been reported among collections from Klein Kliphuis. The piece was found amongst the stone artifacts in the museum collections (Mackay and Welz 2008).

Ochre mining

Evidence for the mining of ochre is abundant in later periods in southern Africa (Beaumont and Boshier 1974). Since 1991, numerous specular hematite mines have been identified in the Tsodilo Hills of the Kalahari. These mines are dated by radiocarbon to within the last 1200 years (Robbins *et al.* 1993; Robbins *et al.* 1998). Boshier and Beaumont cite 15 other unexplored hematite mines in Zimbabwe, Swaziland, Lesotho, northern, central, and eastern Transvaal, the Orange Free State, and the south-western and northern Cape (Boshier and Beaumont 1972). Numerous accounts of ochre mining are also cited in the ethnographic literature (Beaumont 1973).

Possibly the oldest ochre mines in the world are located on the Bomvu (red in Zulu) Ridge (Sagona and Webb 1994). Archaeological investigations of the mines were undertaken following modern exploitation by the Swaziland Iron Ore Development Company. These outcrops cover a length of 2000m including the peaks Lion, Castle, and, Stag, and ten quarries were initially identified. Extensive excavations were carried out at three sites, Castle Quarry 2, Castle Cavern, and Lion Cavern (Dart 1967; Dart and Beaumont 1969; Boshier and Beaumont 1972). The Lion Cavern excavations produced tens of thousands of MSA lithics, and the oldest radiocarbon date at the site is >43,000 B.P. (Dart and Beaumont 1969; Dart and Beaumont 1971; Boshier and Beaumont 1972; Beaumont 1973). It has been estimated that 140 tons of iron ore, 50 tons of it containing hematite rich in specularite, were mined to create the artificial cavern.

Nearly two-thirds of this material may have been removed during the MSA (Sagona and Webb 1994). Also, in the Tsodilo Hills, Rhino Cave has evidence of MSA mining. This is based on the presence of hematite crystals, hammerstones, and grindstones in MSA layers (Robbins *et al.* 1998).

Discussion

Unlike other artifact classes, full scale descriptions of ochre assemblages are rare in southern Africa. In most cases, the presence of ochre is only briefly mentioned if at all. This is surprising given that most MSA sites do have ochre recovered (Watts 1998; Watts 1999; Watts 2002). Papers reporting and describing ochre recovered at excavated sites should be common practice as is the case with all other artifact classes. Information such as frequency and size of ochre fragments, color distribution, and use-wear modification will be crucial for determining the role ochre played at various sites. Color distribution could prove particularly important. Many colors of ochre are available on the landscape and color should not necessarily dictate the usefulness of material for utilitarian purposes. Yet arguments have been made that red is more prevalent archaeologically (Watts 1998; 1999; 2002). A skewed color representation in a site compared to the distribution of ochre colors on the landscape would be strong evidence that the ochre plays more than a strictly utilitarian role. If this pattern can be documented repeatedly at sites, the argument for symbolic use of ochre would be strengthened.

There are also problems with existing ochre collections that make it difficult to go back and study them. Many sites where ochre has been excavated it has not been properly curated. In these cases, ochre fragments are likely to have lost potential evidence of use wear in the form of striations as well as potential engravings. Also, very few sites have ochre that has been piece plotted in three dimensions. Having this spatial information could prove useful when trying to identify various types of ochre use in the archaeological record.

Hypotheses for ochre use in the past

Symbolism

Those who argue for a symbolic interpretation of MSA ochre assemblages rely heavily on the ethnographic record, evidence for color selection, and the crayon-like morphology of some ochre pieces (Watts 2002). These lines of evidence have led some to argue for Khoisan-like symbolic uses of ochre in the MSA.

Watts has argued, convincingly, that the MSA ochre assemblages show a strong preference for redness and brilliance, and these preferences are inconsistent with more utilitarian hypotheses about ochre use. Watts has recorded streak values for over 4000 pieces of ochre from seventeen sites (Watts 1998; Watts 1999). His streak data show a definite preoccupation with redness in the MSA. Watts also attempted to identify brilliance. Pieces described as brilliant met the following criteria: 1) close to focal yellow or red, 2) streaks described as rich or bright, 3) pieces described as metallic, sub-metallic or lustrous in appearance, and

4) high mica content. Based on these criteria, Watts identified a concern with brilliance in the MSA. Watts sees the selection of the reddest and most brilliant ochre as evidence against utilitarian hypotheses (Watts 1999).

Hide Preservation

Use of ochre as a hide preservative is one commonly proposed utilitarian explanation for the presence of ochre in archaeological sites (Wadley 1993; Klein 1995; Mithen 1999; Wadley 2001b). This hypothesis is based largely on laboratory experiments carried out by Mandl (1961). These experiments have shown that metal ions inhibit the breakdown of collagen. This hypothesis is further supported by evidence for ochre staining on some scrapers and blades which may have been used in the hide working process. However, this hypothesis has been investigated mainly in regards to the Upper Paleolithic and Mesolithic records of Europe and the Levant. It is applied to southern Africa without experimentation or close examination of the record (Watts 2002).

Watts and others (Knight *et al.* 1995; Watts 1998; Watts 1999; Watts 2002) have raised several issues with the hide preservation hypothesis. First, although lab experiments indicate that metal ions inhibit the breakdown of collagen, field experiments do not generate the same results. Taxidermists have also questioned the utility of ochre in hide preservation. Second, the use of ochre for hide preservation should have no implications for color choice. Iron hydroxides should work equally as well as oxides. Black minerals like manganese and magnetite should also be suitable. This is not consistent with the pattern seen in the archaeological record. Third, ethnographic sources from a variety of environments show that threat of decay is less significant than often assumed. High rates of decay would be necessary to surpass the normal use life of hides. Fourth, evidence for use of ochre in hide preparation comes late in the archaeological record during the Upper Paleolithic and Epipaleolithic. Lastly, ethnographic uses of ochre in hide-working are almost always for decoration.

Use in hafting

The use of ochre for hafting stone tools has also been proposed. Pigment may have been incorporated in the mastic or binding material. This has been suggested for Sibudu Cave and Rose Cottage Cave in South Africa, because the butts of some MSA points and blades from the site have ochre residue (Tomlinson 2001; Wadley 2001b; Lombard 2004; Wadley *et al.* 2004a; Lombard 2005; Wadley 2005b; Lombard 2007). Hafts with ochre have also been suggested for European artifacts (Allain and Rigaud 1986). It is possible that incorporating ochre in the binding makes it less brittle and less susceptible to breakage.

Medicinal uses

The use of ochre as medicine has also been offered as an explanation for archaeological ochres. According to Velo (Velo 1984; Velo 1986), ochres do have healing properties. They act as powerful astringents, tend to arrest hemorrhage, and have antiseptic and deodorizing properties. Wilcox (Wilcox 1911) has also noted that iron salts found in ochre tend to have these properties. The medicinal use of ochre has been reported among the Gugadja of eastern Kimberley Range in

Australia. The group uses both yellow and red ochre as medicine, although red is said to be preferred (Peile 1979; Velo 1984; Velo 1986). However, confusing the issue is the consistent use of ritual in healing involving ochre. The use of ochre as insect repellant, sun protection, or for insulation from the cold can also be included in this category (Wadley 1993; Wadley 2001b).

Previous ochre research

Characterization and sourcing

A variety of techniques for characterizing and sourcing ochres are available. These include energy dispersive x-ray analysis coupled with a scanning electron microscope (SEM/EDXA), proton-induced x-ray and gamma-ray emission (PIXE/PIGME), neutron activation analysis (NAA), Fourier transform infra-red photo acoustic spectroscopy (FTIR-PAS), x-ray diffraction (XRD), x-ray fluorescence (XRF), inductively coupled plasma spectroscopy with mass spectrometry (ICP/MS), thermal methods, Mössbauer spectroscopy, analysis of stable oxygen isotopes, and magnetic parameters. Studies using trace element chemistry combined with structural mineralogy have been the most successful to date. Unfortunately these techniques often require grinding or dissolving the sample, and experimentation with other less destructive techniques continues. Work of this type has been rare in southern Africa and so this section describes studies carried out on ochre from all regions of the world. The majority of research has been done in Australia with a handful of studies carried out in the Americas, Europe, the Middle East, and Africa.

Australia The earliest study to look at ochre composition from an archaeological perspective was done by Clarke (Clarke 1976). Clarke collected several naturally occurring pigments used for rock paintings in Western Australia. These included red pigment from the Wilgie Mia ochre mine. This mine was exploited until the 1930s when Aborigines were displaced by European mining operations. Samples were taken from the cavern floor in an area not mined by Europeans. Elemental compositions of the red ochre were determined using a qualitative spectrographic analysis. Based on this, as well as determination of particle size and shape and color the red pigment was determined to be hematite. Clarke also collected samples from rock paintings at Walga Rock that were thought to have used these same pigments. This site is 60km south of Wilgie Mia and is the closest known rock painting site to the mine. The red pigment was determined to be similar to that from Wilgie Mia. Samples were also taken from a snake painting at Mount Methwin, 380 km east of Wilgie Mia. This pigment was also determined to be hematite. A white pigment from northern Kimberly was also included in the study. The material occurs as nodules in a creek bank. The chemical composition was determined to be magnesium calcium carbonate and XRD patterns conform to those of the rare mineral huntite. The use of this material in paintings was confirmed by studying samples from 10 sites in Northern Kimberley over an area of 44,000 square kilometers (Clarke 1976).

David *et al.* (David *et al.* 1993) had some success differentiating ochre sources from different geological settings using PIXE/PIGME. However, differentiating sources within the same geological formation requires use of an additional technique (David *et al.* 1993; David *et al.* 1995). PIXE has been combined with FTIR-PAS to characterize and source ochres from Fern Cave in Queensland. Thirty-four fragments were sampled from the archaeological material and 62 samples were taken from sources in the area. The archaeological samples were placed into three main groups based on their FTIR-PAS spectra. Comparison with the source samples has yet to be published, but preliminary results are promising (Goodall *et al.* 1995).

Smith and Pell (Smith and Pell 1997) attempted to source ochre using oxygen isotopes of fine-grained quartz extracted from the samples. This study is based on the assumption that the stable O-isotope ratio (18O/16O) in quartz grains found in ochre will match the ratio found in the parent rock. A small series of red ochres from central Australia were included in the study. The sample includes ochre from two ethnographically known ochre mines (Karrku and Ulpunyali), an archaeological specimen from Puritjarra rock shelter and two more ochre samples from Paterson X and Bookartoo in different geological provinces. The study shows that ochre from different geological provinces can be distinguished based on this technique, but sourcing would be most successful with a combination of techniques. Because ochres within geographic regions are likely to have similar isotope ratios, the authors argue that the technique would be most useful for quickly identifying ochres that come from some distance away from the site in which they are found.

Geochemical sourcing methods have also been applied to an ochre assemblage from Puritjarra rock shelter in western central Australia. The sourcing study shows changes overtime in ochre acquisition. Using SEM/EDX, XRD, and ICP/MS the ochre from the site was divided into three major groups. Group 1 ochres were most common and cluster with ochre samples from the Karrku mine (Smith *et al.* 1998). This deposit is located in central Australia, 150km north-west of Puritjarra, and is still mined by local Walpiri people (Peterson and Lampert 1985). Ochre from Karrku is most abundant at Puritjarra in levels dating from 32,000 to 13,000 BP. Based on the presence of this ochre type at Puritjarra, it appears the deposit has been mined for at least 32,000 years (Smith *et al.* 1998). Karrku is not, however, the closest ochre source to the site. The Ulpunyali mine is closer (65 km south of the site), and ochres of Group 2 originate from there. This ochre is less common in the site overall but appears in significant quantities after 13,000 BP. This period, especially after 7500 BP, also sees a decline in Karrku ochre and the addition of several other inferior quality local ochre materials. After 1000 BP, Karrku ochre again becomes the most common at the site (Smith *et al.* 1998).

The combined use of XRD and XRF is also useful for sourcing ochres. Materials from six major Australian sources were studied in an attempt to determine the reliability of these methods. Samples came from Bookartoo, Moana, Port Noarlunga, Lyndhurst, Wilgie Mia, and Mount Howden. Using these techniques, the sources were distinguishable, suggesting it would be possible to match archaeological materials to them (Jercher *et al.* 1998).

Mooney *et al.* (Mooney *et al.* 2003) have had success using magnetic parameters to distinguish between Australian ochre sources. The study included samples from numerous ochre sources including Ulpunyali, Bookartoo, Karrku, Gunoydbe djadjam, Djibitgun, Wilgie Mia, and the Glen Helen ochre pits. Samples from the site of Puritjarra were also included in the analysis as well as an ochre sample obtained from an aboriginal woman at Uluru. The sample is referred to as Paterson X. Magnetic susceptibility, isothermal remnant magnetization, anhysteretic remnant magnetization, and hysteria loops were measured for all samples. On the basis of these parameters, it was possible to distinguish ochres. Mooney *et al.* argue that simple parameters (magnetic susceptibility and isothermal romance) are sufficient for distinguishing between sources, but more complex parameters are necessary for identifying the sources of archaeological samples (Mooney *et al.* 2003).

Recently, Thomas *et al.* (2011) have experimented with the potential of thermal methods for characterizing ochre paints on aboriginal bark paintings. Thermogravimetric analysis (TG) was combined with differential scanning calorimetry (DSC) and mass spectrometry to identify and quantify paint components. The presence of kaolinite, quartz, and charcoal were detected. These results were supplemented with XRD and FTIR data which confirmed the presence of these components as well as hematite. The authors argue for the use of thermal methods in characterizing ochres based on this study, particularly because only milligrams of paint need to be removed from a given specimen (Thomas *et al.* 2011).

The Americas Tankersley *et al.* (1995) used three techniques to describe Sunrise red ochre from the Powars II site, Platte County, Wyoming: 1) macroscopic identification of the general physical characteristics, 2) high-magnification microscopy of mineral fabrics and bioinclusions and 3) XRD to determine mineralogical composition. These analyses determined that Sunrise red ochre has a distinctive fabric, mineralogy, chemical composition and suite of bioinclusions that should make it possible to recognize at archaeological sites. This theory was tested by investigating ochre from the Hell Gap archaeological site located 10km northeast of the Powars II location. One ochre fragment and ochre powder adhering to a bone were studied and found to be identical to the Sunrise red ochre material.

Ochre from two neighboring sites, 41MK8 and 41MK9, in McCulloch County, Texas have also been characterized (Ellis *et al.* 1997). Ochre samples from these sites were compared to samples from two existing outcrops in McCulloch Country, a possible ochre mine (41TA114) in Taylor County, and an archaeological site in Taylor Country close to the mine. The basic sedimentology and mineralogy of all samples were first described using a 10X hand lens and a low powered binocular microscope. Two pilot studies were then conducted with the various samples. In Pilot Study A, a variety of element concentrations were determined using ICP-OES and some samples were also studied using XRD. Pilot Study B used NAA to determine more detailed elemental concentrations. The authors argue that both techniques provided useful information, but they had insufficient background data to be able to successfully identify any of the archaeological samples to geological sources.

Erlandson *et al.* (Erlandson *et al.* 1999) reported results from a geochemical study on ochre sources from Western North America. The study was designed to test the feasibility of geochemically sourcing red ochre in this region. Samples were collected from eight red ochre sources, three in California, three in Oregon, one in Wyoming, and one in Alaska. The sources come from a variety of geological formations including hot spring deposits, baked volcanic soil, filled solution cavities in karstic limestone bedrock and a massive oxidized iron deposit. Geochemical data were obtained using PIXE. These data were explored using PCA on 12 of the elements detected. The first four components accounted for 91% of the variation. Each ochre source was effectively isolated and samples from the same source cluster together. The authors conclude that sourcing of ochre is possible with this technique as the samples vary significantly between major sources. This material was traded and used among Native Americans and could expand the range of materials used to reconstruct exchange systems in the past.

Sixty-five ochre samples have been characterized from the Terminal Archaic-Early Formative site of Jiskairumoko, Peru (Popelka-Filcoff *et al.*

2007a). Ochre is quite common in this site and samples from varying archaeological contexts were analyzed to investigate the degree of heterogenity within the assemblage. This was viewed as a preliminary way of demonstrating whether or not different sources were being exploited for different purposes. Elemental concentrations were derived using INAA. These data were analyzed using principal components analysis and canonical discriminant analysis, and several statistically significant groups that could correspond to sources were identified. However, it was not possible to tie any one chemical group to a specific context suggesting that specific sources were not exploited for specific tasks at the site (Popelka-Filcoff *et al.* 2007a).

In an attempt to better understand the variability within and between ochre sources, Popelka-Filcoff *et al.* (Popelka-Filcoff *et al.* 2007b) investigated the major, minor and trace element patterns of ochre from various sources in southwestern Missouri. Samples were studied with INAA and XRF spectroscopy. Data were analyzed using Pearson's linear correlation and multivariate analysis. The study was undertaken to determine if ochres in this region meet the provenance postulate. This postulate states that the inter-source variation must be greater than the intra-source variation to be able to match archaeological materials to their geological origins on the landscape (Weigand *et al.* 1977). It was determined that the ochre sources included in the study meet the postulate and that it would be possible to source archaeological materials deriving from these sources.

Popelka *et al.* (Popelka-Filcoff *et al.* 2008) investigated potential geological sources of ochre in the Tucson basin of Arizona using INAA. The study began with several goals: first to characterize geological trends within and between ochre sources in the region, second, to identify important elements for geochemically characterizing ochres, and third, to establish a database for use in future ochre studies. A total of 110 samples were collected from multiple locations at three major sources. Compositional data were analyzed with PCA to identify the elements driving the variance in the sample. These elements were then used to view the data in a series of bivariate plots. These elements tended to be members of the transition metals and rare earth element groups. Ratios such as As/Fe and Sb/Fe were particularly useful for identifying groups in the bivariate plots. Arsenic helped provide further separation. Based on this work, the researchers concluded that inter- and intra-source variations can be distinguished in the Tucson basin. This study laid the ground work for future research which will match artifacts to sources helping to understand ancient ochre exploitation patterns in this area.

<u>Europe</u> Two ochre samples possibly associated with the "Red Lady" burial at Paviland Cave were studied by Young (Young 2000a) along with a series of iron ore samples and one manganese sample. Various samples were studied with XRF, ICP-MS, and SEM. One ochre sample (PAV7) was a fine-grained powder adhering to a bone fragment with a pinkish color. The other sample (PAV1) was a lump of brown ochre. These samples were too small to be analyzed with the XRF

technique used for the other iron ores in the study. Using ICP-MS it was determined that the ochre samples were rather similar in terms of their trace element distributions. PAV7, however, was more clay rich. Young argues that the ochres may represent a dilute mixture of iron ore with the cave sediments. However, no sediment was preserved from the excavations so this hypothesis could not be directly tested. Young further suggests that the red-brown coating on the bones of the burial was produced through the precipitation of phosphate minerals during diagenesis (Young 2000a).

Red and yellow archaeological ochre samples from Catalhoyuk and geological ochre samples from Clearwell Caves were studied using infrared spectroscopy, Raman spectroscopy, scanning electron microscopy (with energy-dispersive X-rays (EDX) analysis), powder X-ray diffraction, diffuse reflection UV-Vis and atomic absorption spectroscopies (Mortimore *et al.* 2004). The goal of this study was to relate the color of ochre samples to their chemical composition and particle size distribution. The color of the Clearwell Cave's samples was found to relate to the chromophore present and not to particle size. The darker red ochres contained mainly hematite while the lighter ones had mainly goethite. The four samples from Catalhoyuk had a much lower iron concentration (about one-twentieth). All samples had hematite as well as minerals suggestive of soft lime plaster. It is likely the ochre was painted onto a plaster surface or mixed with the plaster before applying. This study demonstrated the usefulness of infrared spectroscopy for ochre analysis. These techniques are more informative, however, when combined with other techniques including XRD, SEM, and EDX. According to the authors, this study will contribute to future work on pigment color, chemical composition, and preparation techniques as well as the study of ochre sources and ancient uses (Mortimore *et al.* 2004).

Further analyses of Clearwell Cave ochres were reported by Marshall *et al.* (2005). Three samples, one orange-red, one red, and one purple, were subjected to IR and diffuse reflectance UV-visible-NIR spectroscopy, X-ray diffraction, elemental analysis by ICP-AES and particle size analysis. Although the purple ochre sample gave a spectrum with much lower reflectance all three samples were found to have hematite as the primary choromophore. Based on this work and previous work on Clearwell Cave ochres (Mortimore *et al.* 2004), the authors propose a number of factors which influence the colors of ochres. First, pale yellow ochres get their color from the presence of goethite while darker red ochres have hematite. Second, slight differences in red ochre colors may result from differences in mineralogy such as the presence of carbonate minerals. Third, particle size can affect color and this was the case for the purple sample. When this sample was ground it had a color indistinguishable from the other samples. In general it seems that with darker ochres particle size is a crucial factor for determining color while for lighter colored ochres the presence of hematite versus goethite is more important (Marshall *et al.* 2005).

Ochre samples from outcrops in Tito Bustillo Cave and Monte Castillo Cave in Northern Spain have been characterized using petrography, XRD, SEM-

EDS and ICP-MS (Iriarte *et al.* 2009). The goal of the study was to identify trends within and between sources in order to establish a database for further sourcing studies. It was concluded that it was possible to distinguish ochres from the two caves based on several indicators including Si/Al and Si/Al/Fe ratios, rare earth elements, and iron oxide crystal habits. It may be possible now to match Upper Paleolithic rock art paint samples to these ochre sources.

<u>The Middle East</u> Various ochre fragments were recovered from the Natufian layers of El Wad Cave at Mount Carmel (Weinstein-Evron and Ilani 1994). The mineralogy and geochemistry of eighty-two fragments were studied along with five pebbles and six basalt pestles stained with ochre. Most of the ochre pieces were composed of hematite (36.5%), followed by goethite (15%) and jasperoid (8.5%). Twenty-two percent of the samples were burnt clays, and about 18% were reddish colored chert. Geological samples were also collected from iron mineralization occurring as veins at Mount Carmel. The mineralogy of these fragments was studied using XRD. Three main types were identified. Samples that were yellow to brown were composed of goethite with calcite or dolomite. Samples that were red to dark brown and yellow were found to have hematite, goethite and calcite or dolomite. Lastly, red or orange and brown samples proved to be a jasperoid rock composed of silica and iron in varying proportions with some calcite. The study shows that in general the archaeological ochre samples analyzed are similar to material found locally. Due to the similarity in ochre within the region it was not possible to determine which sources may have been

used. It was also noted that goethite is far more common in the area raising the possibility that inhabitants were heating yellow goethite to create red hematite. However, this was not directly tested. The authors argue that the only way to confirm this hypothesis would be by finding hearths containing both hematite and goethite fragments.

Africa Hughes and Solomon (Hughes and Solomon 2000) reported on a preliminary study characterizing a range of ochres and pigments from Kwa-Zulu Natal in South Africa. The samples come from a large area and some are from well-known archaeological sites ranging in time from 1700 AD to 9180 BP. Archaeological sites sampled include Mabhija, Maqonqo, Umhlatuzana, KwaThwaleyakhe, and Inanda Dam. A variety of techniques were used to study the samples. Samples were physically characterized by bulk specimen color, crushed dry color, hardness, and streak color. Organic carbon was measured, extractable iron, aluminum and manganese in crystalline oxides were determined by the dithionite/citrate, bicarbonate (DCB) method, and amorphous oxides were determined with the ammonium oxalate technique. Major and trace elemental analysis was conducted with X-ray fluorescence spectrometry. Some samples were also examined with scanning electron microscopy (SEM) and transmission electron microscopy (TEM). XRD was also carried out on powdered samples. All samples were similar in color with a reddish brown streak and color tended to be redder when samples were crushed. All samples had very low amounts of organic carbon. The samples, however, were all distinctive from each other based on these techniques. The authors conclude that it may be possible to match ochres/pigments to the paints used by the San at various archaeological sites.

Kiehn *et al.* (Kiehn *et al.* 2007) examined specular hematite from seven historical mines in Botswana in order to test the possibility of later sourcing artifacts. The study was designed to determine if specularite sources could be distinguished and at what scale (mine, local, regional). Five mines were sampled at the well-known location of Tsodilo Hills. These mines are all within a few kilometers of each other. The fourth and fifth mines were at Dikgatlampi and Sebilong near Gaborone. These mines are hundreds of kilometers from Tsodilo Hills. This study also aimed to determine which elements would be most reliable for sourcing specularite. The heavy mineral fractions of 73 samples from these mines were subjected to INAA. Discriminant function analysis was performed on the elemental data, and it was determined that specularite can be fingerprinted to specific mines or groups of mines that are separated by tens to hundreds of kilometers. Mines located in closer proximity were more difficult to distinguish. Transition metals were most useful when identifying groups and rare earth elements provided addition information in some cases. The authors argue that specular hematite is similar to other pigments, namely red and yellow ochre, so similar analytical techniques could be used for these materials. This would allow valuable studies of past trade routes and exploitation patterns.

Bernatchez (Bernatchez 2008) examined the utility of ochre sourcing using a Middle to Later Stone Age ochre assemblage from Nelson Bay Cave on the Robberg Peninsula, South Africa. Archaeological ochre samples were subjected to both powder XRD and PIXE in order to determine chemical and mineralogical composition. Using these techniques, several probable source groups were identified within the assemblage. This study suggests that it may be possible to match archaeological ochre fragments to geological deposits on the landscape.

Wadley (2010a) has recently characterized the ochre powders found in association with cemented ash layers at Sibudu Cave. Using XRF, Wadley identifies concentrations of Si, Fe, and Al. This is to be expected in any ochre sample. XRD results are also presented. Wadley argues for high maghemite and quartz peaks in all samples. She also cites a mixture of goethite and hematite peaks with one or the other predominating based on color of the sample. Her results are difficult to assess as her XRD graphs are presented on far too large a scale. As is almost always the case with ochre XRD patterns, the intensity of the quartz signature diminishes other minerals peaks. However, it appears unlikely that maghemite is present in many of her samples especially those that are yellow. Wadley also argues that none of the samples show evidence of heating which is at odds with an argument for maghemite. It is also impossible on this scale to assess her argument that none of these samples show evidence of heating.

Discussion

A drawback to the body of research on characterization and sourcing of ochre is the fact that the vast majority of it has been done outside of Africa. Only three studies (Hughes and Solomon 2000; Kiehn *et al.* 2007; Bernatchez 2008) have focused on characterizing ochre/hematite sources within Africa. Research carried out in other regions has helped to define what methodologies are likely to be successful. Characterization and grouping of similar ochre samples will be more successful if several types of data are assessed. It is beneficial to analyze the elemental and mineralogical composition of the material as well as deviations in its crystalline structure. Based on previous work, these data are effectively attained through X-Ray Diffraction (XRD) and Particle Induced X-Ray Emission (PIXE). XRD has been used widely in materials research. It has been used successfully on prehistoric archaeological and geological ochre samples in Europe, Australia, North America, and Africa (Clarke 1976; David *et al.* 1993; Weinstein-Evron and Ilani 1994; Tankersley *et al.* 1995; Tankersley 1996; Ellis *et al.* 1997; Jercher *et al.* 1998; Smith *et al.* 1998; Hughes and Solomon 2000; Mortimore *et al.* 2004; Marshall *et al.* 2005; Bernatchez 2008). Particle Induced X-Ray Emission (PIXE) is a well-developed method that has been used to identify the elemental composition of various artifacts. PIXE has several advantages: small samples can be used, there is minimal sample preparation, and there is a short analysis time (~15 minutes per sample). The technique has been used on Australian, North American, and African ochres and preliminary work suggests it can be used to identify the geological source of archaeological ochre fragments (David *et al.* 1993; David *et al.* 1995; Goodall *et al.* 1995; Erlandson *et al.* 1999; Bernatchez 2008). Both XRD and PIXE are widely available and are likely to make sourcing of samples possible. However, because ochre is heterogeneous in nature, regional work in Africa will have to be done to determine if these techniques are really most suitable. It may be necessary to add other techniques to adequately sourcing a given ochre assemblage such as XRF (Jercher *et al.* 1998), magnetic parameters (Mooney *et al.* 2003), ICP-MS (Smith *et al.* 1998; Hovers *et al.* 2003), SEM (Young 2000a; Mortimore *et al.* 2004), and thermoluminesence (Godfrey-Smith and Ilani 2004).

Also, although characterization work has been done, there has not yet been a full scale sourcing project including identification of all possible sources on the landscape surrounding a given site. Without this it is not possible to begin attempting to match archaeological specimens to their geological sources. Ochre sourcing studies could provide significant insight to ochre use in the past. The ethnographic record suggests that ochre used for symbolic purposes will have a different exploitation pattern from that used for utilitarian purposes. It is necessary to first identify available ochre sources in a given study area. These areas need to be recorded and described in terms of color, extent, and accessibility during various time periods. This will provide an understanding of the availability of ochre sources on the landscape. By sourcing archaeological fragments to their geological sources it is then possible to determine if exploitation follows the pattern expected for symbolic or utilitarian practices. If specific sources are being exploited more heavily than others or are being exploited from long distances this may indicate symbolic importance. If sources are being utilized according to their landscape distribution and degree of accessibility, utilitarian uses may be a more likely explanation.

Heat Treatment

Heating of ochre as part of its preparation for use is often mentioned as a possibility in the Paleolithic. However, only a few studies have been conducted to study this process. The earliest work was done by Wreschner (1983). Wreschner carried out a series of experiments heating natural clays enriched in iron oxide. These experiments showed that heating goethite to between 260-280ºC depleted the hydroxides and formed red iron oxide.

At el-Wad twenty-two percent of the ochre pieces recovered are likely fragments of burnt clay (Weinstein-Evron and Ilani 1994). In order to establish that local goethite could be burned to produce red hematite, Weinstein-Evron and Ilani (Weinstein-Evron and Ilani 1994) conducted a series of heating experiments on various ochre samples from the iron oxide occurrences in Mount Carmel. These experiments showed that heating goethite to 300 ºC for two hours transforms most of the yellow goethite to red hematite. The authors argue that heating to 500 ºC produced a less red color because some of the hematite begins the transition to black magnetite. This interpretation, however, is likely to be incorrect. Other experiments have shown that red coloring increases up to 700 ºC (Béarat 1996). Because the authors do not present their XRD diffraction patterns, it is difficult to assess what might actually be causing this observation. The authors suggest that to avoid overheating, people may have heated material at the edges of hearths or by placing material on stones placed on hot ashes. There is evidence that fire was used in the cave but no direct evidence for burning of ochre was found (Weinstein-Evron and Ilani 1994).

Pomiès *et al.* (Pomiès *et al.* 1999) presented a method using XRD and transmission electron microscopy to distinguish heated goethite that has dehydrated to hematite from naturally formed hematite. Synthetic pure goethite samples were heated for 18 hours at temperatures ranging from 200 to 1000 ºC and then analyzed with XRD and TEM. The researchers determined that selective broadening of diffraction reflections and porous nanostructure are identifiable in heated samples. This technique was then applied to twelve hematite samples from the Paleolithic site of Troubat in France. Five samples (group 1) showed non-uniform broadening. Four of these also were associated with maghemite. This iron oxide forms in surface soils when goethite is heated with organic matter. TEM results for these samples were argued to support goethite burning. The remaining samples (group 2) showed no broadening and no pores in their structure. Further, these hematite samples were associated with goethite. If these had been heated, goethite would not be present.

Godfrey-Smith and Ilani (Godfrey-Smith and Ilani 2004) present potential evidence for the heating of ochre as early as 100 ka at Qafzeh Cave, Israel. The study reports on the thermal activation properties of three ochre fragments from archaeological levels and one geological ochre fragment from a source near

Qiryat Shemona, Israel. It is suspected that red ochre fragments found in archaeological sites may have been heat treated to achieve a desired red color. Learning the past thermal history of ochres is one way to test this hypothesis. Most ochre samples contain grains of quartz which can act as natural dosimeters. The thermal history of quartz can sometimes be determined by the thermal activation characteristic (TAC) of its 110 ºC thermoluminescence (TL) peak. Measuring the TAC can give an estimate of the highest temperature the quartz has last been exposed to. Measuring the TAC involves the observation of the prompt response of the 110 ºC TL peak to a fixed small radiation dose in the laboratory. When quartz remains unheated between cycles of test dose and TL, the intensity of the 110 ºC peak remains unchanged. If the quartz has been heated to a temperature above 300 ºC, the response of the peak will change (Godfrey-Smith and Ilani 2004). Therefore, a TAC curve can give information on past heating of quartz in an ochre sample. A sample which has not been heated will show a TAC in which sensitivity increases at a relatively low temperature while samples that have been heated will have an increase in sensitivity at higher temperatures. Two of the tested archaeological ochre fragments were red and one was yellow. Both red samples showed that they had been heated to higher temperatures than the yellow archaeological and the geological fragments (Godfrey-Smith and Ilani 2004).

Wadley (2010b) has argued that much of the predominance of red pigments in archaeological sites may actually be due to post-depositional heating of pigments. Based on experimentation, they conclude that color change can be achieved up to 10cm beneath an active camp fire. The post-depositional heating of pigments is an important factor to consider when analyzing archaeological ochre assemblages. However, that the predominance of red can be explained in this way is an untested hypothesis. The study does not present any data on the location of red ochre finds in relation to burning features, nor does it present any XRD data on archaeological samples that show evidence of exposure to heat.

Discussion Heat treatment research on ochre has been limited (Wreschner 1983; Weinstein-Evron and Ilani 1994; Pomiès *et al.* 1999; Godfrey-Smith and Ilani 2004). More experimentation with geological samples is necessary so we can identify this practice in the archaeological record and better understand what heat treated ochre was used for. It has been suggested that early humans may have heat treated yellow ochres (goethite bearing) to transform the material to red ochre (hematite bearing). It has been argued that red ochre is more common in archaeological sites despite the availability of yellows on the landscape (Watts 1998; Watts 1999; Watts 2002; Watts 2009). There is no evidence to suggest that red ochre is more functional than yellow for the utilitarian tasks that have been presented in the literature. However, experimental testing of heated and unheated ochres in various tasks is necessary to confirm this. If this assumption is upheld and it can be demonstrated that ochre is being heat treated in MSA sites, it lends support to symbolic and artistic interpretations of use.

Residue Analysis

The study of ochre residues on MSA stone tools in South Africa has stemmed from the observation of ochre staining on many stone tools at Rose Cottage Cave (Wadley 2005b). Since that time, numerous residue studies have looked at the distributions of ochre and other substances on stone tools. These studies are all associated with Lyn Wadley and her research group and have all identified a prevalence of ochre staining on the hafted portions of stone tools at several sites (Williamson 1996; Williamson 1997; Williamson 2000; Tomlinson 2001; Lombard 2004; Williamson 2004; Gibson *et al.* 2004; Wadley *et al.* 2004a; Lombard 2005; Lombard 2007). Blind tests have also been published by this research group. They argue that under the right conditions they do achieve a high level of accuracy when identifying residues (Wadley *et al.* 2004b; Wadley and Lombard 2007; Lombard and Wadley 2007). The early blind tests have been disputed, however. The most substantial criticism of these blind tests was that there was a lack of documentation of residues prior to blind testing and there was also contamination of the samples (Crowther and Haslam 2007). However, this critique focuses mainly on identification of plant and animal residues. Ochre residues are arguably the easiest to identify and are often visible macroscopically. It seems likely that the general patterns of ochre residues described below are correct.

Williamson reported on a residue study of 167 artifacts excavated from Rose Cottage Cave. Most artifacts came from the same square (P5) while a few came from other squares (Q5, O5, and N5) dating to the Later Stone Age (5970±70BP). Eight percent of the stone tools were reported as having ochre residue on them. The locations of ochre residues are not reported but Williamson notes that ochre residues do not occur with animal residues (Williamson 1996). This study was followed by an examination of stone tools from the Robberg and Oakhurst levels at Rose Cottage Cave. Ochre residues were also reported as identified but patterned locations on the tools were not discussed (Williamson 1997).

Based on successes with earlier work looking at LSA tools, Gibson *et al.* (2004) studied the residues on segments and backed and obliquely backed blades from the Howiesons Poort at Rose Cottage Cave. The study was aimed at determining how the tools were used and also whether they were likely to have been hafted with mastic. Forty-eight tools were examined using an Olympus BHS 2UMA stereo-binocular microscope with an internal (reflected) light source under various magnifications ranging from 50x to 800x. Gibson *et al.* determined that even at magnifications as low as 50-100x ochre residues were often visible and appeared smeared on the stone tool surface. The study divides the residue positions on the tools into three main areas: the backed edge, the shaft, and the working edge, and the locations of specific types of residue were marked on sketches of each tool sample. In general, Gibson *et al.* argue that residues are least dense on the shaft, and ochre residues are rare on the working edges of tools. However, there appeared to be high concentrations of ochre and plant residues near the backed edges. Using a Chi-squared test the spatial distributions of ochre, plant fiber, plant tissue and white starchy deposit were tested for randomness. The chi-squared value for ochre was 10.2, for plant fiber 11.3, for plant tissue 19.8, and for white starchy deposit 10.3. All are reported as having two degrees of freedom. The results showed a less than 1% chance that the ochre, plant fiber and white starchy deposit were distributed by chance. There was a less than 0.1% chance that the plant tissue was distributed by chance. Based on these data Gibson *et al.* (2004) argue that the identification of ochre on the backed edge and/or shafts suggests ochre was used in the hafting process.

Williamson (2004) conducted microscopic residue analysis on 412 stone tools from Sibudu Cave to investigate possible uses of different tool types at the site. Identified residues included animal tissues (blood, hair, collagen tissue, and bone fragments), plant tissues (cellulosic fibers, resins and exudates, starch grains, and starchy residues) and mineral deposits such as ochre. Use-related ochre was found to be more common on points and other retouched pieces than other tool categories.

Wadley *et al.* (Wadley *et al.* 2004a) further demonstrated that ochre may have been used in the MSA as an ingredient in mastic for hafting. Tools from the MSA at Sibudu Cave (26000BP to 60000BP) were chosen and examined using the same methodology as Gibson *et al.* (2004). Two microscopy studies were undertaken. The first study recorded the presence of residues within a grid that divided tools into 6 regions, the proximal, medial and distal portions for both the dorsal and ventral surfaces (Wadley *et al.* 2004a). Ochre residue was identified on 29 of 104 points, 30 of 83 scrapers, 23 of 77 other retouched pieces, and 26 of 113 flakes. It was concluded that ochre residues were likely to be found on the medial and proximal portions of flaked tools. Flakes had higher proportions of ochre residues on their working edges. In the second study 24 whole points were studied. The tools were divided into $5mm^2$ blocks and were examined for macro-fractures as well as residues. The highest proportions of ochre were found on the medial portions of whole points. Based on a Chi-squared test (chi-squared values were not reported), at one degree of freedom, there is a less than 1% likelihood that the distribution on proximal and medial portions is purely by chance and less than 0.1% chance the distribution on distal portions is only by chance. Ochre is also often associated with damage where handles or shafts could have been attached. This is taken as evidence that tools were hafted with ochre included in the mastic. The study also reports, however, that more plant tissue and starch residues were found on tools with ochre, and there was a tendency for more resin to occur on tools with no ochre. This contradiction is not explained. Overall, the authors suggest that the study demonstrates that the MSA tools with ochre residue result from at least two activities. First, some stone tools were used to process ochre and second, some tools had ochre incorporated into their hafts (Wadley *et al.* 2004a).

Lombard (2005) further examined points and point fragments from the MSA layers (50,000 to 60,000 years ago) from Sibudu Cave to determine if they were used as hafted spearheads for hunting. Fifty bifacial and unifacial points and point fragments from the post-Howiesons Poort layers were used for the study. None of the tools were washed after excavation and each was bagged separately. Tools were divided into proximal, medial, and distal portions and locations and types of microfractures, use-wear traces, and residues were recorded. Lombard identified bending fractures along lateral edges indicative of hafting for at least 52% of the tools. Another 48% had evidence of proximal crushing and removals from the proximal dorsal ridges. Points with multiple microfracture lines of evidence made up 38% of the sample. Lombard argues that the distribution of edge-rounding, edge-damage, polish and striations from the use-wear investigation further support hafting. The residue analysis lends further support. Plant tissue occurs more commonly on the proximal and medial portions of the tools. Ochre was also found on the proximal (63%) and medial (77%) surfaces of tools often in conjunction with plant residues likely used for hafting. The Chi-squared value for the distribution of ochre on proximal and medial portions of whole points (n=24) was 8.2 and for distal portions it was 13.56. Degrees of freedom were not reported. However, p values of .001 are reported suggesting the distribution of residues on the points is unlikely to be random. This result is interpreted as evidence for the use of ochre along with plant materials for hafting stone points (Lombard 2005).

Lombard followed this study by examining 24 post-Howiesons Poort points and 53 Howiesons Poort segments (Lombard 2006). Like the earlier study, most of the tools were not handled, washed, or marked following excavation. Similar patterns were identified with this study. Of the post-Howiesons Poort points, 80.5% of all identified ochre residues were found on the proximal and medial portions. 87% of all identified resin residues also occur in these areas. The distributions of the 807 residue occurrences are not likely to be due to chance based on Chi-squared results previously reported for these tools (Lombard 2005). The examined segments also tend to have ochre and resin residue concentrated on their backed portions. 502 ochre occurrences and 585 resin occurrences were documented on these tools. 80% of the ochre residues were located on the backed portion and 87% of the resin residues were located on the backed portion. This is argued to support the use of ochre in hafting of Howiesons Poort segments. No statistical analyses were reported for the Howiesons Poort segments.

Lombard (Lombard 2007) provided further evidence for the use of ochre in adhesive recipes. For this study, stone tools from two sites in KwaZulu Natal were analyzed for ochre and resin residues. Residues are associated with portions of tools that would have been in the haft. This study also suggests that there may have been different recipes for different raw materials. Two samples from Sibudu Cave were included. Sample A was made up of 53 Howiesons Poort segments with controlled curation (not washed and not handled prior to residue analyses) and Sample B was made up of 14 segments with uncontrolled curation (lightly rinsed and handled prior to residue analyses). Sample B served as a control group to investigate the effect of post-excavation handling on residue distributions.

Sample C was made up of 30 non-quartz segments from Umhlatuzana Rock Shelter and Sample D was made up of 25 quartz and crystal-quartz segments from the same site. The sampled tools from Umhlatuzana were not washed but may have been brushed. The methodology for this study was similar to previous work by Lombard (Lombard 2006; Lombard 2007). Segments were divided into six portions each with a ventral and dorsal side. The portions were upper blade, medial blade, lower blade, lower back, medial back, and upper back. The backed portions of the segments were expected to have ochre and resin residue if they were in fact hafted. For Sample A, this assumption was upheld. 80% of ochre residues and 87% of resin residues were located on the backed portions. This result is statistically significant using a Chi-squared test (ochre on backed portions $p=.01$ and resin on back portions $p=.001$). Actual Chi-squared values were not reported. Results for Sample B are similar with 92.5% of ochre and 97.5% of resin occurrences located on the backed portions. This is significant at the 0.05 level using a Chi-squared test (ochre on back portions $p=.05$, resin on backed portions $p=.01$). Sample C is also statistically significant and had 83% of ochre and 85.5% of resin located on the back portions (ochre on back portions $p=.01$, resin on backed portions $p=.01$). The results from Sample D were quite different. Ochre residue was much less common with only 43 occurrences noted on the 25 tools, but 269 resin occurrences were noted. Distribution patterns were still similar, however, with 81.5% of ochre and 83% of resin occurring on the backed portions. Again Chi-squared results suggest this is not due to chance (ochre on back portions p=.05, resin on backed portions p=.01). Lombard speculates that the less common use of ochre in these hafts may have to do with different requirements of the stone raw material. 68% of the quartz/crystal-quartz segments have evidence of resin but not ochre.

Lombard (Lombard 2008) further investigated the unwashed Howiesons Poort segments from Sibudu Cave for evidence of hafting. This study demonstrated that animal residues were concentrated on the blade portions of tools supporting the hypothesis that the backed ends were protected from these residues by their hafts. Use-wear and microfracture evidence suggested that 63.5% of the segments for the younger HP layers were inserts in hunting weapons, and 90% of the tools from older HP layers are also argued to have been used to process animal material. This evidence supports the hypothesis that the occurrences of ochre on the backed portions of segments are a result of the ochre being incorporated into the hafting process.

Soriano *et al.* (2009) identified ochre residue on the platforms of 20 flakes thought to be debris from biface production. Based on their analysis of these flakes, they conclude that ochre nodules were used as abraders and hammers during the production of Still Bay bifaces. If this is the case, the technique was only rarely used as the majority of debris does not have ochre staining.

Discussion The residue analyses that have been carried out at Rose Cottage Cave and Sibudu Cave have been significant in developing the ochre hafting hypothesis. There has been some debate about the accuracy of residue studies in southern Africa due to the poor design of early blind tests and the fact that the majority of research is being conducted by one researcher (Crowther and Haslam 2007). However, criticisms focus mainly on non-ochre residues. Ochre residues are arguably the easiest to identify and in many cases are visible without magnification.

Chi-squared results are used to statistically support conclusions about the distributions of ochre and other types of residues. However, results are inconsistently reported. In some cases only a p-value is reported and Chi-squared values and degrees of freedom are not. Also, all observed and expected values are not consistently reported making it difficult to evaluate whether underlying assumptions for Chi-squared tests are being met. Further, none of these studies include any type of measure of the strength of associations. Although the distribution patterns of ochre residues presented seems convincing, it is not possible to properly evaluate the statistical results of this group of papers.

Residue studies have not been common practice for MSA collections. This is slowly changing as other residue analysts take an interest in this area of the world. Hopefully in the future more of this work will be done resulting in a better understanding of the distribution of ochre and its relation to other types of residues on stone tools. The incorporation of more residue specialists will also allow for more robust interpretations as cross checking of results will become possible.

A growth in this area of research will require proper excavation and curation of stone tools. Many sites that have already been excavated are not suitable for residue analysis as collections were excavated with tools with would have contaminated artifacts. Most collections have also been washed which can both contaminate and remove residues. Piece plotting of artifacts and soil analysis are two components of excavation protocol that are also crucial for successful residue analysis. It is necessary to understand the depositional environment of a tool with residues before interpreting its use.

Actualistic Experiments

Numerous studies have been conducted by Wadley and colleagues beginning to test various uses of ochre with experimental archaeology. Wadley (Wadley 2005a) compared ochre "crayons" from Sibudu Cave to experimentally ground fragments that were created while grinding ochre to use in hafting experiments. Ochre crayons have been defined in the literature as "piece with three or more facets converging to a point" (Henshilwood *et al.* 2001). Pieces defined as crayons are uncommon in the record but appear in small frequencies from the earliest MSA. Wadley notes that crayons have been assumed to be used as such, and Watts (Watts 1998) suggested that these were applied directly to draw patterns based on the small size of some facets. This study by Wadley is the first to test this hypothesis. Wadley looked at crayons from Sibudu cave under incident light using an Olympus binocular microscope at magnifications ranging from 50x to 500x. Polish and striations were clearly visible even as low as 50x magnification. Wadley argues that the polish and striations on the tips of crayons are impossible to distinguish from those on the lateral facets and that the modifications on the archaeological crayons were identical to those on the experimentally produced crayons. None of the Sibudu crayons had wear on the tips that might suggest writing use like that argued for by Watts (Watts 1998). Wadley further compared the crayons to artists' pastels which were used for drawing. These showed a pattern of use wear inconsistent with that seen on ochre crayons. Wadley suggests that so called ochre crayons be carefully examined for use wear and residue as it is possible that they are simply a waste product of grinding for other purposes (Wadley 2005a).

In numerous instances, ochre staining on stone tools has been noted. Many French Paleolithic tools have evidence of ochre staining (Beyries and Inizan 1982; Audouin and Plisson 1982). At the Magdalenian site of Gouy in northern France a backed blade was found with ochre residue on the backed edge. At la Garenne, another Magdalenian site, ochre was found on the base of a bone point (Allain and Rigaud 1986). Adhesive containing red ochre was also noted on backed bladelets at Lascaux (Audouin and Plisson 1982). Allain and Rigaud (1986) note the presence of ochre on stone tools from another eight French sites but do not describe the positioning of the residue. Based on these observations Allain and Rigaud (Allain and Rigaud 1986) carried out a series of experiments to determine the usefulness of ochre as an additive in adhesives. They concluded that the most successful adhesive recipe contained four parts plant resin, one part ochre, and one part beeswax. This mixture was easier to work, more homogenous, and had few cracks when dried. The ochre powder acts as an emulsifier to help the resin and wax mix and it also seems to encourage hardening of the mastic. The mixture was heated during mixing and temperatures were sufficient to convert yellow goethite to red hematite (Allain and Rigaud 1986).

In Africa, similar patterns have been noted. In Kenya, at Enkapune Ya Muto, backed blades were recovered with red ochre residue on their backed portions. These are thought to date to between 50,000 and 40,000 years ago (Ambrose 1998). It was also noted in residue studies that stone points from Rose Cottage Cave and Sibudu Cave often have ochre residue on their proximal and medial portions (Williamson 1997; Tomlinson 2001; Williamson 2004; Gibson *et al.* 2004; Lombard 2006; Lombard 2007). This led to the hypothesis that these tools were hafted and that ochre was part of the binder used to haft the tools (Wadley *et al.* 2004a). Wadley conducted a series of experiments to test the usefulness of ochre in adhesive recipes. She argues that heating of ochre and plant resin paste can be used to set stone tools into wooden shafts. The inclusion of red ochre is argued to strengthen the haft and make it more durable.

Further experiments suggest that MSA people could have used several different adhesive recipes for hafting stone tools (Wadley 2005b). Thirty-eight flakes of various stone types were hafted with replicated adhesive recipes. Raw materials for the experiments were collected from the Wildlife Sanctuary in Moletadikgwa, South Africa. Materials included nodules of hematite and coarse sandstone slabs as well as resin from *Acacia karoo* trees, branches from *Grewia flava* shrubs, and fibrous leaves from *Hypoxis rigidula* plants. Wooden shafts were prepared in two ways, by splitting the haft and by cutting an L-shaped platform (12mm wide by 18mm high). Hematite powder was generated by grinding nodules on the sandstone slabs. Four types of adhesive were then mixed: 1 *Acacia karoo* resin (5ml per haft) 2 *Acacia karoo* resin (2.5ml) with red ochre powder (2.5ml) 3 *Acacia karoo* resin with equal parts of red ochre powder and beeswax and 4 *Acacia karoo* resin mixed with equal quantities of red ochre power and a few drops of water. The processing and hafting techniques varied for each point. Wadley (Wadley 2005b) describes seven ways in which materials were processed with various ways of mixing, heating, drying, and binding the hafts. All replicated hafts were then used to chop bark from branches for six minutes and surfaces of the hafts were examined under magnification ranging from 50-500X. Five tools were mounted using recipe one. Four of these tools were successful for five to six minutes of chopping (80%). Fifteen out of eighteen tools (83%) using recipe 2 with L-hafts (split hafts were removed from the experiment). Only three tools were made with recipe 3 and all were deemed successful. Two tools were also hafted with yellow ochre and neither was successful (Wadley 2005b).

Hodgskiss (Hodgskiss 2006) completed a master's thesis further testing the ochre hafting hypothesis. Two sets of hafting experiments were carried out. The experiments included 97 hafted tools. Each was hafted with resin with various additives and heated for varying times. Additives included red ochre, yellow ochre, commercial ferric oxide, sand, kaolinite, ash, ground bone, gypsum, and wood shavings. Like the Wadley (2005b) experiments, the various tools were then tested by using them for chopping and sawing activities. Hodgskiss argues that the first set of experiments had too many variables, making it difficult to determine what variables (resin species, ochre content, heating time etc.) were responsible for successful or unsuccessful hafts. A second set of experiments were carried out with fewer variables. ICP-OES, SEM, EDS and hardness tests were also performed on select ochre samples and hafts. Results of these experiments were somewhat inconclusive as sample numbers for each combination of variables were low. However, Hodgskiss does point out that plain resin is a successful adhesive but can be difficult to work with. Adhesives with red ochre did not have as high a success rate as Wadley's experiments but were among the more successful adhesives experimented with. Based on ICP-OES analysis, iron content did not seem to play a major role in determining the success of hafts. Rather, particle size of the additive seemed to be more important (Hodgskiss 2006).

Further results on replicated ochre resins were reported by Wadley et al (2009). Three recipes were tested, *Acacia* gum alone, *Acacia* gum with red ochre, and *Acacia* gum with ochre and beeswax. Each tool was mounted and dried by a fire and then used for 5 minutes (2 strokes per second) to chop branches. The study concluded that resins with beeswax were most successful. The study also reported on various properties of the resins including hardness, iron and silica content, particle size, pH, and zeta potential. Hardness, iron content, pH, and zeta potential did not predict haft success. The authors argue for some connection between particle size and perhaps silica content.

Audouin and Plisson (Audouin and Plisson 1982) conducted a series of experiments to test the hypothesis that ochre can be used as a tanning agent to slow or reverse the process of decay. In one experiment, a three day old moose skin that was beginning to putrefy was scraped with stone flakes and ochre power was applied. The skin is reported to have dried rapidly and become thinner and softer. Portions of the same skin that were not treated became green and malodorous. Another experiment took two pieces of the same hide and treated one with red ochre and one with yellow ochre. According to Audouin and Plisson (Audouin and Plisson 1982), the yellow ochre treatment resulted in a skin that was stiff, thick, and rough while the red treated skin dried rapidly, was 1mm thinner and started to get soft. From this the authors concluded that ochre is useful for stopping hides from rotting and for helping them to dry quickly. Further, they argued that the higher iron content of red ochre produces better results than yellow ochre (Audouin and Plisson 1982).

Hodgskiss (2010) conducted a series of experiments on ochre modification. Ochre samples from a shale and mudstone quarry were subjected to various grinding, scoring, and rubbing activities and the use wear patterns were described. Grinding produces a plane with parallel striations with unfrayed edges. When a piece is scraped or engraved, grooves do not regularly reach the end of the piece and edges tend to be frayed. Rubbing produced smoothing, edge rounding and polish.

Discussion Actualistic studies using ochre have just begun and more work is needed. Lessons learnt in previous hafting experiments (Wadley 2005b; Hodgskiss 2006) can be used to construct better experiments that will hopefully begin to yield more conclusive results. It is necessary to control for as many variables as possible. Many of these studies are based on subjective characterization of the impact of ochre as an additive. It would be beneficial to find more objective and quantifiable criteria. Rather than using tools manually, they could be used mechanically with a stress gauge, or with a calibrated cross bow as has been done for other hafting experiments (Shea *et al.* 2001; Shea *et al.* 2002) so that force is measurable. While there is merit in replicating and using tools to test resin hypotheses, much could also be learned by directly testing the resin mechanically. Also, sample sizes need to be increased so that quantified results can be evaluated statistically. Further, it would be useful to first identify what ochre sources are being utilized at a site and then use ochre from those sources in experiments since the mineralogical properties vary between sources and this may impact an ochre's effectiveness as an additive.

Little work has been done directly testing the hide working hypothesis (Audouin and Plisson 1982). Studies are needed that both produce stone tools used with ochre for hide preparation and test the effects of ochre on the hide decay process in different conditions. It may also be beneficial to incorporate use-wear analyses with residue analyses on experimental tools to identify an ochre/hide working signature that can be identified on archaeological tools.

More research investigating ochre grinding would also be beneficial. Only one in depth study has been reported (Hodgskiss 2010). It is useful to generate comparative collections of ochre fragments ground and used in different ways to compare to utilized archaeological specimens. It would be ideal to use ochre from the same sources as the archaeological specimens since the material can vary considerably from one region to another. Patterns of wear can be affected greatly by particle size which varies between sources.

Because heat treatment of ochre is a possibility in MSA sites it would also be beneficial to compare the use of heated and unheated ochre in various utilitarian tasks. It is possible that heat treating ochre somehow improves its performance as an additive. This possibility has not been tested. This is necessary to demonstrate that the heating of ochre is not utilitarian but rather a step taken to produce symbolically loaded red pigments.

Conclusion

The ethnographic record lays out several hypotheses for ochre use in the past. These include but are certainly not limited to various symbolic uses (body painting, rock painting, and decorating sacred objects), use in hafting, use in hide working, and use as medicine or body protection. These various possibilities are testable in the archaeological record of southern Africa. In general, the previous research on ochre has laid a solid groundwork for more in depth studies.

However, there are various criticisms of the body of characterization research, heat treatment research, residue analysis, and actualistic experiments. Each area of research raises its own problems that need to be studied further. Studies that apply multiple lines of research to the ochre record of a site or a region are necessary to begin to understand the role of ochre in the MSA and in the modern human origins debate.

Such a study should begin with a general description of the archaeological ochre similar to work done by Watts (Watts 1998; Watts 1999; Watts 2002). This would provide data describing the amount and quality of the ochre as well as color preferences and use wear modifications. Several of the utilitarian hypotheses put forth require large quantities of ochre and would leave evidence of extensive grinding. Others do not require ochre of a specific color and so identifying distinct color preferences would have relevant implications.

Second, use wear could be studied in more detail via experimental use wear analyses using geological ochre from the same sources as the archaeological material. Much of the ochre at MSA sites preserves evidence of use wear. However, comparative examples are limited for identifying how the ochre has been modified. These comparative collections should be region specific as ochre can be quite heterogeneous. Conducting these experiments should allow for more accurate assessments of use wear and discussion about possible activities that would result in these patterns.

Third, a study should attempt to match archaeological material to geological sources using geochemical characterization analysis. Ethnographic studies have indicated that the exploitation of ochre sources on the landscape could contribute to symbolic versus utilitarian arguments as patterns of ochre exploitation differ considerably from exploitation of raw materials without symbolic importance (Bleek and Lloyd 1911; Basedow 1925; McCarthy 1939a; McCarthy 1939b; Robson and Plomley 1982; Jones 1984a; Jones 1984b). Geochemical analysis should also be used to determine if archaeological ochre fragments have been subjected to heat treatment to alter their color.

Fourth, the most common utilitarian use of ochre put forth, as a binding agent in hafting, should be experimentally tested using replication of stone tools with various hafting techniques and mastic mixtures. Replicas can be tested using a calibrated crossbow to ascertain the usefulness of ochre for increasing the strength of hafts (Shea *et al.* 2001; Shea *et al.* 2002). Direct mechanical testing of resins would also be appropriate to determine what characteristics of the resin are altered when different additives are included.

Focused ochre study incorporating combinations of these types of research at various sites will aid in determining what uses of ochre existed in the MSA. This important aspect of the MSA archaeological record should no longer be held up as critical evidence in the modern human origins debate until it has been properly studied.

CHAPTER 3: THE PP RESEARCH AREA

Introduction

The PP area is a stretch of coastline that was extensively surveyed in 1997 to assess potential damage that may result from the construction of a large golf resort above the coastal cliffs (Kaplan 1997). Twenty-one MSA sites were identified in a 2 km (along the coast) by 1 km (inland) area and fifteen of these sites are caves/rockshelters with excellent bone and shell preservation. Two sites from the region are included in this study. Extensive excavation has been completed at PP13B and work is ongoing at PP5-6.

This research area was appropriate for this study's research questions for several reasons. First, the sites in the area cover the time range, marine isotope stage (MIS) 11 (starting 427 ka) to MIS 3 (starting 60 ka), when modern human behavior is thought to be developing (Klein 2000; McBrearty and Brooks 2000; Henshilwood and Marean 2003). Second, these sites have evidence of ochre use, and geological exposures with ochre formation have also been identified. Third, these excavations provided high quality data due to high resolution excavation procedures (Marean *et al.* 2004). Fourth, the larger project's multi-proxy study of environment and behavior provided excellent contextual information for the study (Herries *et al.* 2007; Jacobs and Marean 2007; Marean *et al.* 2007; Roberts *et al.* 2007; Bar-Matthews *et al.* 2008; Bernatchez *et al.* 2008; Herries *et al.* 2008; Jerardino and Marean 2008; Marean *et al.* 2008; Brown *et al.* 2009; Matthews *et al.* 2009; Bernatchez 2010; Fisher *et al.* 2010; Herries and Fisher 2010; Jacobs 2010; Jerardino and Marean 2010; Karkanas and Goldberg 2010; Marean 2010; Marean *et al.*

2010; Rector and Reed 2010; Schoville 2010; Thompson 2010; Thompson *et al.* 2010; Watts 2010; Matthews *et al.* 2011). Lastly, the ongoing SACP4 project provided many resources, including access to specialists, particularly geologists and archaeometrists, and to lab and storage facilities in the field.

Local geology

The coastal caves and rockshelters at PP are eroded zones of faulted breccia within folded and faulted exposures of the Skurweberg Formation of the Paleozoic Table Mountain Group (Marean *et al.* 2010). The Table Mountain Group is one of three groups belonging to the Cape Supergroup (Table Mountain Group, the Bokkeveld, and the Witteberg Group). The supergroup represents 170 million years of earth history from the Early Ordovician (~500 Ma) to the Early Carboniferous (~330 Ma). The three groups were deformed during the Cape Orogeny but have remained distinctive with lateral continuity throughout the region (Thamm and Johnson 2006). The Table Mountain Sandstone at PP is coarse grained and light gray. It is capped along the cliffs by unlithified dunes, aeolianites, calcarenites, and calcretes (Marean *et al.* 2010).

Approximately 5 km north of PP there is a 1 km wide syncline outgroup of Bokkeveld shale within the Table Mountain Sandstone. The Bokkeveld group is an alternation of fine-grained sandstone and mudrock units (Thamm and Johnson 2006). A deep valley has been cut into the outcrop due to active stream erosion (Watts 2010). This weathered Bokkeveld exposure and others further away are prime candidates for ochre formation.

The edge of the coastal platform is approximately 120 km offshore. The platform declines gradually and lower sea levels would have exposed a vast coastal landscape (Fisher *et al.* 2010; Marean *et al.* 2010). It is possible ochre sources could exist as a part of this submerged landscape. However, these coastal profiles tend to be poorly developed and ochre is more likely to occur in more heavily weathered deposits more than 200 meters above present sea level (Watts 2010).

Excavation procedures

All excavations were conducted using MAP/SACP4 protocols, which are detailed in Marean *et al.* (2004; 2007), and Bernatchez and Marean (2011). These are briefly summarized here.

The excavations at PP are conducted within small stratigraphic lenses and features, collectively titled StratUnits. Within a StratUnit, lot numbers are assigned. A lot number is a unique ascending interger that designates a StratUnit in a specific square and quad. If a StratUnit covers more than one quad of a square, it will have a new lot number assigned for each quad. The volume of a StratUnit is typically less than one bucket of sediment making them too small for meaningful statistical analysis of their contents. These StratUnits are then grouped into larger Stratigraphic Aggregates (StratAgg, what many archaeologists may call layers) based on more general geogenic and anthropogenic characteristics. Each StratAgg reflects a homogeneous set of formation processes recognized by field observations. These groupings are often fine-tuned using micromorphological data, detailed section photography, and GIS-based 3D representations of artifact distributions and orientations after excavation.

At PP5-6 all archaeological finds were plotted in true South African National Grid x-y-z coordinates by total station directly to a hand-held computer. At PP13B all finds were also plotted using a total station but this was done in an arbitrary grid referred to as the MAP Grid, eventually replaced by the National Grid. At both sites each find was assigned an individual "plotted find number" that links the find to its coordinates. These numbers are bar-code scanned into the handheld computer to minimize or eliminate transcription error. Each find is also associated in the computer with its lot number. This system guarantees that as soon as a find leaves the sediment its precise location and stratigraphic assignment has been automatically recorded.

PP13B

PP13B is a cave approximately 30m long by 8m wide and is oriented in an east/west direction (Fig. 3.1). Test excavations in PP13B were completed in 2000 and multiple full seasons were undertaken between 2003 and 2009. Three excavation areas were opened in PP13B, the Eastern Area, the Western Area, and the North-Eastern Area (Lightly Cemented MSA Facies = LC-MSA). The stratigraphy and dating of this site is summarized below but is discussed in more detail in Marean *et al.* (2010), Karkanas and Goldberg (2010) and Jacobs (2010). Excavations at PP13B have produced a large ochre assemblage of 653 pieces including plotted finds and material recovered from the 10mm and 3mm sieves.

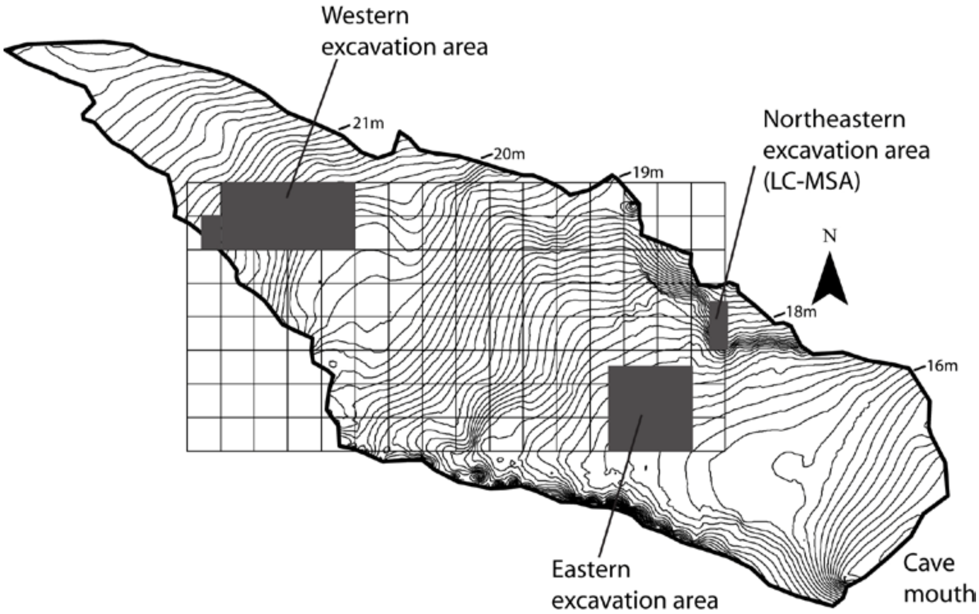

Fig. 3.1. Layout of PP13B with excavated squares

North-Eastern Area (LC-MSA)

The LC-MSA deposits occur as cemented remnants clinging to the north and south walls of the cave. The north deposits are more extensive and excavations were placed in this area. The LC-MSA deposits consist of three excavated StratAggs, the LC-MSA Lower, Middle, and Upper.

LC-MSA Lower The LC-MSA Lower is at the bottom of the LC-MSA sequence, sitting just above bedrock where it has been fully excavated. There are 3 OSL ages from this aggregate with a weighted mean age of 162 ± 5 ka coinciding with a short event of high sea level that brought the coast within 5km of the cave during MIS 6 (Fisher *et al.* 2010). This aggregate is the least cemented in the LC-MSA and also has the highest density of lithic finds. Shellfish density is moderate and increases horizontally to the north towards the cave wall. Multiple burnt lenses were identified corresponding to relatively high mean magnetic susceptibility (MS) values for the sediments.

Micromorphology demonstrated that some of these burnt features are *in situ* while others have been trampled. There is truncation at the contact of the LC-MSA Lower and the LC-MSA Middle which would explain the age gap between the two (Herries and Fisher 2010; Jacobs 2010; Karkanas and Goldberg 2010; Marean *et al.* 2010; Marean *et al.* 2007).

LC-MSA Middle The LC-MSA Middle overlies the LC-MSA Lower. It has an OSL age of 125 ± 5 ka, around the MIS 6 to 5e transition. MS values and lithic density are moderate while shell density is high following a similar horizontal distribution as the LC-MSA Lower. This aggregate includes multiple dark organic horizons with charcoal, a lot of ash, and *in situ* hearths, according to micromorphology samples. There are also distinctive white pipes reaching through the aggregate. These have been identified as the remnants of ancient roots which have been replaced with calcite (Herries and Fisher 2010; Jacobs 2010; Karkanas and Goldberg 2010; Marean *et al.* 2010; Marean *et al.* 2007).

LC-MSA Upper The LC-MSA lower is a heavily cemented zone with multiple layers that caps the LC-MSA deposits. At the base of the StratAgg there is a hard sandy silty layer. Above this is a sandy horizon with a series of black and dark brown organic lenses and shellfish lenses. This layer has a mean OSL age of 126 ± 4 ka. This is capped by a dune (OSL 93 ± 4 ka) that subsequently sealed the cave. Occupation intensity is argued to be low during this period based on decreasing lithic density and decreasing MS values (Herries and Fisher 2010; Jacobs 2010; Karkanas and Goldberg 2010; Marean *et al.* 2010; Marean *et al.* 2007).

LC-MSA Flowstone The LC-MSA flowstone grew by dripping from the cave wall and over the sequence. It began to accumulate after the closure of the cave. It has been U-Th dated from 92 ka to 30 ka (Marean *et al.* 2010; Marean *et al.* 2007).

Western Area

The Western excavation area sits near the back of the cave. Field observations suggested that this area was a midden or dump but micromorphological study identified *in situ* combustion features. There are areas in the Western excavations with substantial geogenic disturbances such as faulting, slippage and subsidence. There is also evidence of MSA cutting and pit digging, and at least one instance of modern disturbance. All these factors make the stratigraphy in the Western area more complex than in the LC-MSA or Eastern areas (Karkanas and Goldberg 2010; Marean *et al.* 2010).

Boulder Facies This aggregate consists of a set of large boulders and a thin rind of silty loam and clay between and around the boulders. The layer sits at the base of the unconsolidated sediments in the back of the cave as currently sampled. This aggregate is sterile and has been interpreted as a cobble beach formed by high sea levels (Karkanas and Goldberg 2010; Marean *et al.* 2010).

Laminated Facies The Laminated Facies overlies the Boulder Facies and is at the base of the archaeological sediments in this area of the cave. This aggregate has a TT-OSL weighted mean age of 385 ± 15 ka. This Facies is made up of grayish-brown sediment with thin laminae of sand and silt intercalated with yellow-brown spots and stringers from guano. It is mainly sterile but some micromammal bone was identified from the mircromorphology (Jacobs 2010; Karkanas and Goldberg 2010; Marean *et al.* 2010).

Light Brown Silt Facies The Light Brown Silt Facies is a poorly sorted silty sand with significant apatite input from guano. Most of the aggregate is referred to as the LB Silt, while a small gulley area is referred to as LB Silt-G. An OSL sample taken from the base of the aggregate was saturated and a sample from the top has an age of 157 ± 8 ka. Lithic density and MS values are low. Organic input increases nearing the top of the aggregate approaching the main archaeological layers (Herries and Fisher 2010; Jacobs 2010; Karkanas and Goldberg 2010; Marean *et al.* 2010).

Dark Brown Sand Facies The Dark Brown Sand Facies is actually a series of horizons of dark greasy brown sand that have layers of lighter brown to gray sandy horizons between them. This facies has been divided into the DB Sand 4, 3, and 2. The sediments have strong aeolian and guano input with low to moderate densities of lithics and fauna. MS values support that these deposits are burnt. The DB Sand 4 is stratified within the LBG Sands (see below) and has a slight increase in lithic and faunal density compared to layers below. The DB Sand 4 has an OSL age of 159 ± 7 ka. The DB Sands 3 and 2 are above the LBG Sands and within the LB Sand 1 (see below). DB Sand 3 is one of the most prominent and laterally extensive aggregates in the western area and has abundant charcoal and burnt bone. The maximum and minimum ages for the DB Sand 3 and 2 are 102 ka and 91 ka. Despite being sedimentologically similar the DB Sand horizons vary considerably in age (Herries and Fisher 2010; Jacobs 2010; Karkanas and Goldberg 2010; Marean *et al.* 2010).

Light Brown Gray Sand Facies The lighter brown to gray sediments of the LBG Sand Facies are broken into LBG Sand 2, 3, and 4. The horizons are separated by the series of horizons that make up the DB Sand 4. These decalcified sediments are made up of aeolian sand with significant apatite probably from guano. This is one of the thickest and most laterally extensive aggregates but it is disturbed in several places by subsidence and slumping. There are lenses of finds scattered throughout but the archaeology is not as dense as in the DB Sands. Where the contact between the LBG Sands and the DB Sand 3 is sharp there are two OSL ages of 127 ± 7 ka and 122 ± 5 ka. Where the contact is less distinct there are two ages of 98 ± 4 ka and 99 ± 4 ka suggesting some truncation may have taken place (Herries and Fisher 2010; Jacobs 2010; Karkanas and Goldberg 2010; Marean *et al.* 2010).

Light Brown Sand Facies The LB Sand Facies sits above the dark DB Sands 2 and 3 and is archaeologically rich. The sediments are coarse grained with substantial amounts of roofspall. MS values are low compared to the DB Sand 3 suggesting less burning took place. There are two OSL samples from this facies, one in the middle at 90 ± 4 ka and one just above the contact also at 90 ± 4 ka. A U-Th sample from the lower part of the facies is dated to 94.7 ± 1.1 ka which provides a maximum age (Herries and Fisher 2010; Jacobs 2010; Karkanas and Goldberg 2010; Marean *et al.* 2010).

South Pit Fill This aggregate is loose fill sediment in a pit. It appears to be MSA in age (Marean *et al.* 2010).

Northeast Fill This aggregate is made up of light brown loose sandy sediment that is filling in a pit or gulley. The deposit thickens to the north reaching up to 50cm deep (Marean *et al.* 2010).

Surface Sediments This aggregate is the yellowish to brown surface deposits that have been trampled. It is primarily a coarse matrix of roofspall material.

Eastern Area

The Eastern excavation area covers several squares towards the mouth of the cave. In general the Eastern area lacks the major disturbances found in the Western area. This made it possible to expose larger areas horizontally. Cemented patches were regularly encountered corresponding to drip locations from the roof (Marean *et al.* 2010).

Bedrock The Bedrock sits at the base of the deposits. It consists of rounded and polished Table Mountain Sandstone that is fractured and fresh in some places. There are also smaller cobbles found that are likely the result of rounding during higher sea levels (Marean *et al.* 2010).

Lower Roofspall Facies The Lower Roofspall Facies sits above the bedrock. The deposit lies between the bedrock and as a thin layer over the top of the bedrock. The matrix consists mainly of small roofspall pieces with fresh edges in the south but it becomes more sandy towards the north.

Cemented patches are common although more so towards the south. Archaeological material is rare and finds are mainly found near the top of the aggregate. MS values are high and the weighted mean OSL age for two samples is 110 ± 4 ka (Herries and Fisher 2010; Jacobs 2010; Karkanas and Goldberg 2010; Marean *et al.* 2010).

Upper Roofspall and Shelly Brown Sand Facies The Upper Roofspall and Shelly Brown Sand Facies are two distinct aggregates in some areas but in others areas the two cannot be distinguished. The deposits thicken from the south to the north. Multiple small, thin, well preserved hearths were identified. These are very distinct in the south as discreet bands of ash, charcoal, and reddish brown baked sediment. In the north they merge together forming horizons of dark burnt material. Lithics, shellfish and fauna are dense, with finds found both in and around hearths. MS values are high as would be expected. The adjusted maximum and minimum ages based on six OSL samples are 98 ka and 91 ka respectively (Herries and Fisher 2010; Jacobs 2010; Karkanas and Goldberg 2010; Marean *et al.* 2010).

Truncation Fill This dark, rocky, and organic rich horizon sits above a truncation at the top of the Upper Roofspall Facies. The truncation is thought to have been caused by gravity and water, perhaps from sea spray induced slumping during higher sea levels. The fill is thought to be a mobilized MSA deposit but is far more recent than the MSA directly beneath it. Lithic and faunal material is fairly dense. The fill has an AMS age of 35 ka. This corresponds with the final U-Th age on the LC-MSA flowstone marking the reopening of the cave (Karkanas and Goldberg 2010; Marean *et al.* 2010).

Redeposited Disturbance This disturbed layer sits just below the surface. It included modern bird feathers and modern artifacts. It is believed the material has been redeposited from a modern disturbance in the Western excavation area. There is a traceable spill of material coming down the cave slope from the back to the front (Marean *et al.* 2010).

Surface Sediments These surface deposits are the same as those described in the Western excavation area. This material is more fine grained and ashy because of fishermen making fires in the mouth of the cave (Marean *et al.* 2010).

PP5-6

PP5-6 is a rockshelter in the quartzitic cliffs at PP. Eight excavation seasons have been conducted since 2006 as part of the SACP4 Project. Three areas of excavation have been opened at PP5-6 (Fig. 3.2). The Erosion Gully and the Northwest Remnant were both excavated briefly during a single season. The Erosion Gully failed to turn up intact archaeological deposits despite promising surface scatter. The Northwest Remnant is further described below. The main deposit at PP5-6 is referred to as the Long Section. This is a 30 m high cone of MSA deposit built up against a cliff face and partially under a rock shelter. There is an active erosion gully between the upper half of the cone and the cliff face that reveals 19.5 m of stratified MSA deposit rich with fauna, lithics, ochre, ostrich eggshell, and hearths. The majority of work at PP 5-6 has focused on these deposits. Deposits continue deeper and it is unclear how far back in time the section might continue. Like at PP13B, excavated stratigraphic units are grouped into larger stratigraphic aggregates (similar to layers) based on similarities in geogenic and anthropogenic characteristics of the deposits. Preliminary descriptions of these aggregates have been presented (Bernatchez *et al.* 2008) and published (Brown *et al.* 2009). They are summarized below.

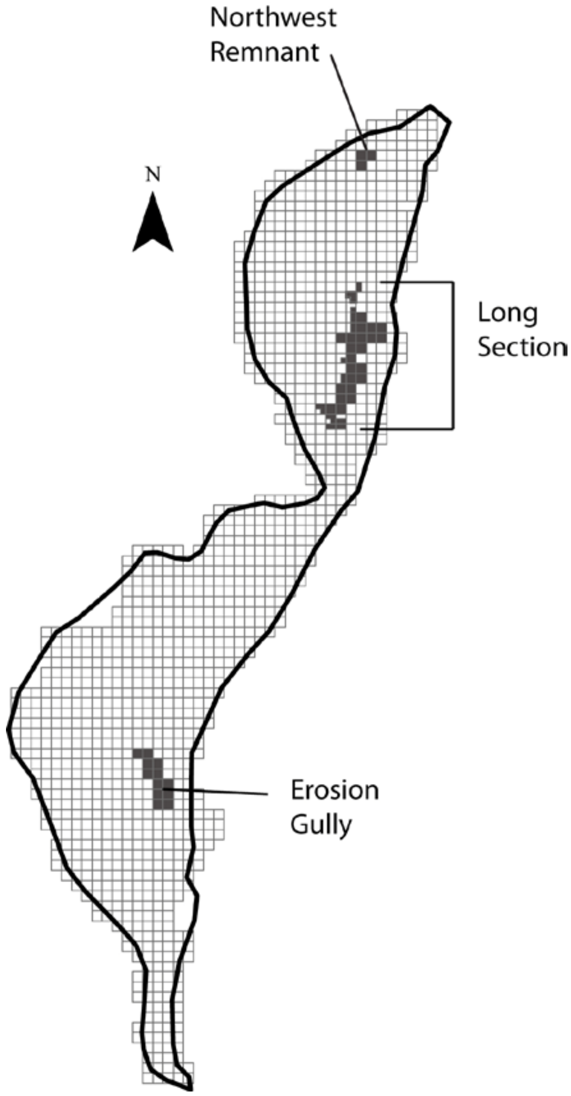

Fig. 3.2. Layout of PP5-6 with excavated squares

The cataloged ochre assemblage currently has 511 pieces including plotted finds and material from the 10mm sieves. Material from the 3mm sieves and the most recent excavations is not included in this total.

The Long Section

Excavation at the Long Section of PP 5-6 was initially carried out in three excavation areas, the Upper Long Section, Middle Long Section, and the Lower Long Section. A nearly continuous 11 meter excavated profile now exists at the Long Section (Fig. 3.3). StratAggs are described from the base of the excavated sequence to the top.

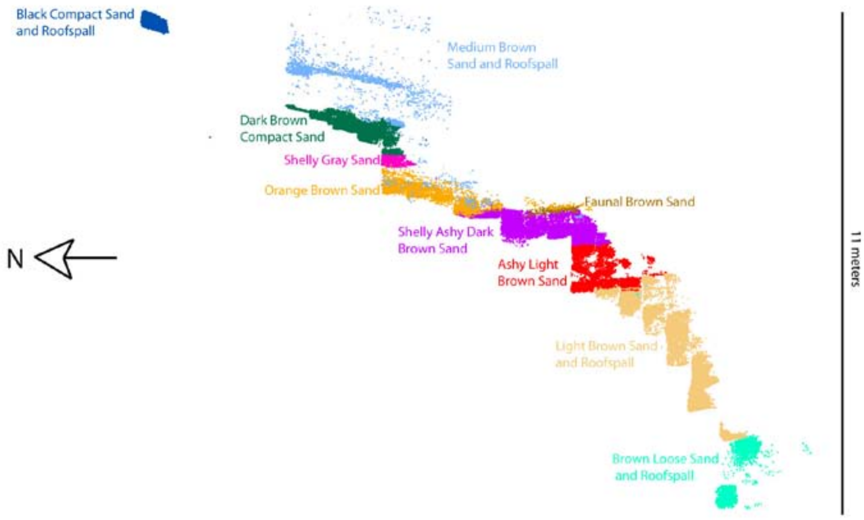

Fig. 3.3. Schematic of the Long Section eastern profile

Yellow Brown Sand and Roofspall (YBSR) This aggregate consists of coarse grained sediment with rocks and roofspall. The matrix is mostly loose but some areas with large concretions were excavated. Burnt features are scattered throughout and the material is thought to be *in situ* archaeology. OSL samples have been taken but ages are not yet available. Finds from this aggregate have not yet been cataloged as it was only excavated in the most recent field season.

Brown Loose Sand and Roofspall (BLSR) This aggregate consists of yellow brown fine grained sand. The sediment is very loose and abuts the eroded profile of the Light Brown Sand and Roofspall (see below). The matrix contains abundant MSA material but appears to be intrusive mixed fill. Layering was rarely discernable and artifacts encountered were jumbled rather than consistently bedded. OSL dating for this aggregate is currently in progress and should confirm the nature of these deposits. However, based on observations during excavations it appears that this material post dates the primary erosion of the LBSR and has most likely been relocated from higher up in the deposit.

Artifacts were plotted in the early stages of excavation in this aggregate. We stopped plotting (n = 4018) when it became clear that the material was disturbed. All material was still sieved, however. Cataloged artifacts from this aggregate include lithics, fauna, shell, and ostrich eggshell. Although no plotted ochre has yet been cataloged, 57 pieces have been described from the 10mm sieved material.

Light Brown Sand and Roofspall (LBSR) The LBSR occurs at the base of the excavated and eroded profile of the Long Section. The deposits overlying this aggregate have been eroded away leaving the LBSR exposed. The BLSR abuts the eroded profile of the LBSR in the lower half of this aggregate. The LBSR consists of fine grained yellow sand with a significant decomposing roofspall component. Patches of this aggregate are heavily cemented particularly close to the eroded edge of the Long Section. Further into the deposit the sediments tend to be looser and easier to excavate. These deposits consist of well defined layers that are nearly sterile alternating with layers containing primarily shell with some bone fragments, lithics, pigments and other material culture. Within the non-sterile layers there are numerous well defined burning features with characteristic charcoal, ash, and red burnt sediment lenses typically with significant shellfish remains including mussels and limpets. These features appear to be *in situ* hearths and this should be confirmed by micromorphology.

Cataloged finds include lithics, fauna, shell, ochre, ostrich eggshell, and FMR. The lithic assemblage is mainly produced on quartzite and appears aimed at the production of large flakes and flake blades.

A total of 25 OSL samples have been collected from the LBSR. Ages are available for 11 of these samples (Brown *et al.* 2009; Jacobs personal communication). The stratigraphically highest sample in the LBSR profile is dated to 79 ± 3 ka (46801) and the lowest dated sample in the profile is 86 ± 3 ka (46793). The additional samples were taken from the exposed profile going down another 2.5 meters and so the time span of the LBSR will be expanded.

Ashy Light Brown Sand (ALBS) The ALBS is directly above the LBSR stratigraphically. The matrix of this aggregate is made up of yellow sand that is lighter than the LBSR and includes a fine gray ash component.

The plotted finds recovered from the ALBS include shell, bone, lithics, ostrich egg shell fragments, ochre and potentially fire modified rock. The lithics from the upper portion of the aggregate are similar to the SADBS while the lower is more similar to the underlying aggregate, the Light Brown Sand and Roofspall.

Four OSL samples have been dated from the ALBS but are preliminary (Jacobs personal communication). A sample from the top of the ALBS has been dated to 76 ± 3 ka (46784) and a sample from the bottom has been dated to 79 ± 3 ka (46802). The two other unfinalized samples are stratified between these samples with ages of 79 ± 4 ka (162508) and 75 ± 4 ka (162661).

Shelly Ashy Dark Brown Sand (SADBS) The SADBS sits stratigraphically above the ALBS near the middle of the Long Section. The matrix of this aggregate is far darker in color than the material below, but the top of the ALBS grades into the SADBS by becoming more ashy. The SADBS has a significant ash and charcoal component. The sediments of this aggregate are compact and particularly dense with artifacts and ecofacts. Numerous lenses of darker more charcoal rich layers and lighter colored more ash rich layers were identified within the aggregate.

Cataloged finds include shell, bone, lithics, ostrich eggshell, ochre, and fire modified rock. The majority of the plotted finds appear to be burned. Common shell in this aggregate includes various limpet species, mussels, *Turbo* and chiton. The lithic assemblage is dominated by bladelet products. Most of the blades are small, very thin, and are triangular or trapezoidal in cross-section. The majority of the lithics are made from silcrete, opaline, and quartz and very little quartzite.

Six ages are available for the SADBS. These ages have a weighted mean of 70.6 ± 2.3 ka (Jacobs personal communication).

<u>Orange Brown Sand 1 (OBS1)</u> The OBS 1 is an orange colored aeolian sand that occurs above the SADBS and below the Dark Brown Compact Sands (DBCS - see below). Evidence for occupation in this aggregate is intermittent and sparse and the sand appears to have accumulated quickly.

Catalogued finds include fauna, lithics, shell, ochre, and fire modified rock. Most plotted finds are relatively well preserved faunal remains. The small lithic sample shows sporadic flake and blade production on silcrete, quartzite, and quartz. There is one unmodified silcrete cobble indicating that at least some silcrete is being collected from a secondary context.

Three OSL samples from the OBS1 have a weighted mean age of 66.0 ± 2.8 ka (Jacobs personal communication). This aeolian sand may represent a dune incursion, dating to MIS 4, and may be related to other dunes along the coast that are dated to ~70 ka, such as that at Blombos Cave. Cemented dune adheres to the rock wall face opposite the base of the long section. Two OSL samples have been taken from here. One (142626) has an age of 69 ± 4 ka (the other is undated) and it appears that this material is a remnant of the OBS dune (Jacobs personal communication).

Shelly Gray Sand (SGS) The SGS consists of dark and light gray sands with a fine grained ash component with clear evidence of *in situ* burning. The aggregate's matrix differs considerably from the OBS below and has evidence of far more intense occupation. The SGS is set apart from the DBCS (see below) above it by the frequent occurrence of shell. No OSL ages are yet available for this aggregate but it is constrained by the OBS below and the DBCS above.

Dark Brown Compact Sand (DBCS) The DBCS occurs above the SGS in the upper Long Section. The matrix consists of a dark brown compact sand that slopes to the south. Within this aggregate there are artifact/ecofact rich lenses separated by nearly sterile lenses of aeolian sand. Overall the DBCS is regarded as a debris flow of sediment.

Catalogued finds include lithics, fauna, ochre and FMR. Shell and ostrich eggshell fragments are present but rare. There is only one fragment of ostrich eggshell cataloged. The lithic assemblage shows a strong preference for silcrete over quartzite. Core reduction is focused on the production of small blades several of which are retouched into backed blade segments characteristic of the Howiesons Poort (HP). Cores are small and intensively worked, and there are some larger quartzite flakes and blades that occur alongside the smaller fine-grained blades. The largest sample of ochre comes from this aggregate with 110 catalogued pieces, many of which show clear grinding facets. Fauna is highly fragmented. Some artifacts show evidence of burning, and some layers also contain charcoal and possible fire modified rock.

Three OSL samples were taken from within these deposits. The ages range from 58 ± 4 to 65 ± 4 ka (Jacobs personal communication). These ages are in accordance with others published by Jacobs for the HP (Jacobs *et al.* 2008).

<u>Red Brown Sand and Roofspall (RBSR)</u> The RBSR occurs above the archaeological deposits in the middle and upper portions of the Long Section. The upper portion of this material is considered to be a second layer of disturbed overburden that in some places is over a meter thick. The matrix is a nearly sterile brown dune sand with a significant roofspall component ranging in size from less than 5mm to large boulders up to a meter in length. Patches of the dune sand are slightly cemented and are stained a more orange brown color. Numerous roots penetrate this aggregate and some are up to 10cm in diameter. The few artifacts found in these deposits were clearly disturbed and rarely conformed to a surface. Often they were also in association with larger roots which may have moved up from the underlying archaeological deposits.

Some undisturbed sediments do occur in this aggregate near the middle and bottom, and there appears to be a single short MSA occupation horizon within the rapid buildup of sediment in the RBSR. The artifact sample consists of silcrete and quartzite blades, and faunal remains are preserved. Lithics of interest are a well-shaped silcrete burin and a thick silcrete biface.

Seven OSL samples have been dated from the RBSR. The ages are statistically consistent and have a weighted mean of 53.9 ± 1.7 ka (Jacobs personal communication). These dates cover approximately a meter of deposit and indicate a rapid sedimentation rate for this aggregate.

Loamy Sand Overburden (LSO) The LSO is found on the surface capping the entire Long Section. This aggregate is consists of a root mat and decaying organic material mixed with dune sand. A few artifacts including lithics, fauna, and shell were recovered along with modern trash.

Black Compact Sand and Roofspall (BCSR) The BCSR is a small excavated area (1 quadrant) located further upslope from the rest of the Long Section. An eroded profile existed here prior to excavation. This quadrant was opened during the May-June 2009 field season to try to better understand the relationship between the Long Section and the Northwest Remnant (see below). The compact sandy sediments are rich in organic material and have a high artifact density. However, excavators noted a predominance of silcrete, and the general impression is that this material is similar to the Dark Brown Compact Sand of the Long Section (described above). Three OSL samples (162517-162519) have been taken from dune sands below this aggregate. OSL ages are pending but should help resolve the connection of this section to the Long Section and to the NWR.

The Northwest Remnant

Excavations were conducted into the Northwest Remnant partially as a salvage excavation, but also as exploratory excavations taking advantage of naturally occurring erosion. Water had cut a 1m section exposing a rich MSA horizon sandwiched between sandy horizons which we excavated directly into. This deposit was initially believed to correlate with the top of the exposed, eroded section. Based on OSL dates from the Remnant and the Long Section, this no longer appears to be the case.

In 2003, prior to any excavation taking place at the site, we sampled exposed sandy horizons in the Northwest Remnant above and below the main archaeological horizon (20701 and 20739 respectively) and across the main erosion gulley (20700) in what appeared to be sediments above all other exposed sediments. 20700 (across the gulley) yielded an OSL age of 69 ± 3 ka. Sample 20701, above the MSA deposit, yielded an OSL age of 70 ± 5 ka while sample 20739, from below the main deposit, yielded an age of 86 ± 5 ka (Jacobs personal communication). Three more OSL samples have been taken from the NWR to attempt to better understand the chronology. Sample 142622 was taken from the upper MSA layers and has yielded an age of 59 ± 2 ka. Sample 142623 comes from the sands just below the archaeological layers and is aged at 68 ± 2 ka. The third sample has not yet been dated (Jacobs personal communication).

The stratigraphic relationship of the Northwest Remnant and the Long Section is currently unclear. A micromorphology sample (110602) was also taken from the remnant which could aid in stratigraphic interpretation, and analysis is ongoing. Four stratigraphic aggregates were identified during the Oct-Nov 2006 excavations of the Northwest Remnant, listed from bottom to top.

<u>Coarse Grained Dark Brown Sand (CGDBS)</u> This aggregate has a matrix of long course grained sand with small bits of roofspall (under 5cm). Bone, lithics, OES and ochre were all recovered from this aggregate along with a small sample of shell.

<u>Compact Brown and Red Sands</u> This aggregate consists of a compact brown and red mottled sand with small bits of fragmented roofspall. Artifacts are found in this aggregate only at a low density. These included primarily bone and lithics.

<u>Dark Brown Silty Sands</u> This aggregate is a compacted fine grained horizon. Most of the roofspall in this aggregate was under a few centimeters but some fragments up to 10cm in length were found. Artifacts are dense in this aggregate and include lithics, bone, ochre and only two pieces of fragmentary shell. Some of the artifacts also appeared to have been burnt and the presence of charcoal was also noted.

<u>Sandy Cobble Horizon</u> This thin aggregate occurs just below a disturbed sandy layer on the modern ground surface. The aggregate contains relatively few artifacts, the majority of which are fragmentary and burnt faunal remains.

Conclusion

Excavations at PP13B are completed for the time being and all plotted materials have been cataloged. All ochre identified from this site has been studied either by Ian Watts (2010) or me. Work at PP5-6 is ongoing. Each new season sample sizes for known StratAggs are enlarged and the base of the sequence has yet to be reached. Relationships between the NWR, the BCSR, and the Long Section continue to be debated. Despite the fact that work continues at the site there is more than enough ochre from the first six field seasons to investigate ochre use.

PP13B captures periodic intense occupation between approximately 162 ka and 90 ka years ago. At this time the cave is sealed by a dune until around 40 ka (Marean 2010). Periodic intense occupation begins at PP5-6 by at least 90 ka years ago when PP13B is no longer available. Together the two sites make up one of the longest MSA sequences available. The two are certainly the most meticulously excavated and dated sequences available in the region making them ideal for addressing any number of questions about MSA behavior.

CHAPTER 4: THE ARCHAEOLOGICAL OCHRE

Introduction

Before the research questions of interest can be addressed, two major assumptions must be met. The first assumption is that ochre occurring in these sites has been procured and transported by hominids. The ochre cannot be a geological feature of the caves themselves. Fortunately, this assumption is easily met. These sites occur in Table Mountain Sandstone and although some ochreous veins do occur in this context, the material is spare and very coarse grained and sandy. Low quality material of this type makes up a very small portion of the ochre assemblages at PP. The second assumption is that ochre has actually been utilized by the sites inhabitants. Meeting assumption two requires a careful description of the archaeological assemblage coupled with a comparative study of experimentally modified ochre to demonstrate that the ochre is in fact utilized.

Descriptive methods

All archaeological ochre from PP13B and PP5-6 was analyzed and described at the MAP/SACP4 lab facility located at the Dias Museum in Mossel Bay, South Africa. While I did review the material from PP13B, the majority of the coding was previously done by Ian Watts (2010). I coded the material from PP5-6 and a small sample (n=8) from PP13B that was cataloged after Watts completed his descriptions. The descriptive coding system used here is a modification of that used by Watts (2010). All the information recorded in this coding system was also recorded by Watts. Some attributes recorded by Watts, however, were not included in this coding system as they were deemed redundant or overly subjective. The system is summarized in Table 4.1 and is described in detail below.

Table 4.1
Coding system for archaeological ochre fragments

Attribute	Description
Shape	Chip, chunk, lump, tabular, flake, powder, pencil
Mass	in grams
Length	longest dimension of the fragment (mm)
Width	90 degrees from length in horizontal plane (mm)
Height	90 degrees from length in vertical plane (mm)
Weathering	Fresh, rounded, discolored (patina), burnt
Texture	Sand-silt-clay
Friability	Friable, moderately cemented, well cemented
Magnetism	Strongly magnetic, weakly magnetic, not magnetic
Hardness	Modified Moh's scale
Luster	Earthy (dull), lustrous, sub-metallic, metallic
Inclusions	Abundance and relative size of mica, quartz grains etc
Surface color	Lab color taken from surface
Streak color	Lab color taken from streak
Staining power	Good, mediocre, poor
Modification assessment	Definite, probable, possible, unutilized
Form of modification	Ground, scraped, polished, flaked, notched
Proportion modified	% of fragment with identified modification
Number of facets	Number of modified surfaces
Profile of facets	Flat, concave, convex
Pigment assessment	Definite, probable, possible, doubtful, not pigment

Before coding, each ochre sample was rinsed with water. Some were also lightly brushed to remove adhering sediment and concretions. Vigorous brushing was avoided so as not to disturb any preserved use wear on the fragments. After cleaning, samples were left to dry minimally overnight.

Coding the archaeological ochre from PP5-6 involved collecting data on the following attributes: shape, mass, length, width, height, weathering, texture, friability, magnetics, hardness, luster, inclusions, surface color, streak color, streak-ability and staining power, modification assessment, forms of modification, proportion of modification, number and profiles of facets, and pigment assessment.

A general descriptive shape term was first applied to each fragment. These terms included chip, chunk, lump, tabular, flake, powder, and pencil. A chip was a small, thin piece. A chunk was a larger angular fragment. A lump was an irregularly rounded fragment. A tabular piece was thin and had two relatively flat opposing surfaces. A flake was similar to a chip but larger in size. It does not necessarily imply that the piece had the attributes of a stone flake. Powder was material that was ground up, usually mixed with sediment. A pencil (or crayon) was a piece that was modified on at least three adjacent converging faces.

After assigning one of these descriptive shape terms, all fragments were weighted and measured. Mass was recorded in grams to three decimal places using a standard digital laboratory scale. Length, width, and height were all recorded in millimeters to two decimal places using digital calipers. Because fragments were irregularly shaped, a protocol was followed for determining where these measurements were collected. Length was taken at the longest point on the fragment. Width was the widest point in the same plane ninety degrees from the length. The height was taken at the highest point in the plane ninety degrees from the width and length.

Any evidence of weathering, or post-depositional alteration was next recorded. Some pieces were described as fresh. Others were described as having varying degrees (coded as minor, moderate or extreme) of rounding or wear and discoloration or patina. Any evidence suggestive of burning was also recorded under this category.

Texture was recorded as falling somewhere on a continuum from silt to coarse grained sand. These assessments were made after looking at the piece under 10-40X magnification. Watts (2010) did not record texture outright but rather recorded geological type which included categories such as sandstone, siltstone, and mudstone. A general comparison is possible between these categories.

Friability was used to describe the general cohesiveness of the ochreous material. Fragments described as friable were fragile and “crumbly”. Pieces described as moderately cemented held together but rubbed off on fingers. Other pieces were described as well cemented and left no residue on fingers.

Magnetism was tested for each fragment using handheld magnets. Pieces were described as not magnetic, weakly magnetic or strongly magnetic. Pieces that were strongly magnetic could be picked up by the magnet (or could pick the magnet up depending which was larger). Pieces that were described as weakly magnetic were attracted to the magnet but not strongly enough to be picked up. Pieces that were only attracted to the magnet on a particular location of the fragment were also described as weakly magnetic.

Hardness was recorded using a modified Mohs Scale. If the ochre fragment could mark paper it received a hardness value of approximately 1.

Pieces that marked cloth but not paper had a hardness of 2. Pieces of ochre that scratched a fingernail had a hardness of ~2.5. Pieces that scratched a copper penny had a hardness of ~3. Those that scratched a steel nail had hardness of at least 5.5, and those that scratched a ceramic plate had a hardness of 6.5 or greater.

Luster was recorded as earthy, earthy-shiny, earthy-waxy, and sub-metallic.

Any inclusions visible to the eye or under magnification were also recorded. Most frequently these were mica or quartz grains. Note was also taken of the relative size of the particles, small, medium, and large.

All ochre samples were streaked on white ceramic plates. Because this causes minor damage to the specimen, streaking was only conducted after assessments about modifications were completed. After streaking, comments were recorded about the ease of attaining a streak and also the staining power of the pigment. Samples either had good staining power, mediocre staining power, poor staining power, or left no streak at all.

Color was recorded for the surface of each fragment. These measurements were taken in the CIEL*a*b* color space using a Konica-Minolta CR-400 series colorimeter. Color was also taken for the streak of each sample as the internal and external colors are likely to vary due to post-depositional disturbance of the ochre surface. These measurements were taken from photographs of streak plates.

Each sample was examined under a 10-40X zoom binocular microscope and evidence of use wear was recorded and compared to an experimental use wear collection (described below). The likelihood of modification was recorded as Definite, Probable, Possible, or Unutilized. For each piece with definite to possible modification, the most likely type of modification (based on comparison with the experimental collection) was recorded. Types of modification encountered included flaked, ground, scraped, polished, and notched/grooved. The proportion of the piece that was covered by the modification was also estimated. Other attributes recorded included number and profile (flat, concave, convex) of facets and descriptive comments on the modification and its location on the ochre fragment.

After all these attributes had been considered and recorded, an assessment about the likelihood of each piece being useable as a pigment was made. Pigment status was definite, probable, possible, doubtful, or non-pigment. Pieces that were definite pigment were modified, streaked easily, and had good staining power. Pieces that were probable pigment were not modified but streaked easily and had good staining power. Pieces that were possible pigment were not modified and had mediocre staining power. Doubtful pieces had poor streaks, and pieces classified as non-pigment did not streak, were often coarse grained, and were frequently similar to material naturally found in the sites.

All fragments were extensively photographed for archiving purposes using both standard 35mm and microscope mounted 10-40X digital photography. Photographs of modified pieces are included below.

Experimental comparative collection

A modified ochre comparative collection was generated from numerous geological sources near PP. These were used to identify the type of modification present on archaeological samples. Equal numbers of samples (24) were scraped with the edge of stone tools, engraved with stone points, and ground on sandstone grindstones for a fixed amount of time. Each type of modification was studied and photographed under magnification, and this collection was instrumental in demonstrating that the ochre at the PP sites has been utilized. Several observations were noted for each type of modification. Examples can be seen in Fig. 4.1. Similar observations were recently published for ochre collected near Sibudu Cave (Hodgskiss 2010).

Samples that were ground produced unnaturally flat surfaces. Striations were usually visible with the naked eye. Material with larger grain sizes did not always produce visible striations. These striations were parallel to semi-parallel and always continued to the edges of the flattened plane. In fine-grained samples, micro-striations were also visible within striations under magnification. Striations under magnification tended to be shallower with gently sloping walls in comparison to marks made by scraping and deliberate engraving. Striations also tended to be all of similar depth.

Samples that were scraped with stone tools to produce powder led to irregular convex surfaces. Striations were usually not straight and tended to be of irregular depths and shapes. These striations also tapered off irregularly and rarely reached the edge of the piece.

Deliberate engraving with stone tools left deep grooves with patterned formations. Mini-striations were visible along the side walls of grooves. The ends of striations were frayed under magnification (and sometimes to the naked eye). This seemed to result from the need to use multiple stokes to produce a clearly visible marking. Microscopic stone flakes were also seen in many of the markings, perhaps due to pressure applied to the tip during engraving.

Although polishing was not included in the comparative collection it was considered. Pieces that are polished have unusually rounded and smoothed surfaces. It is difficult, however, to differentiate natural polish from water or exposure to elements from deliberate polishing.

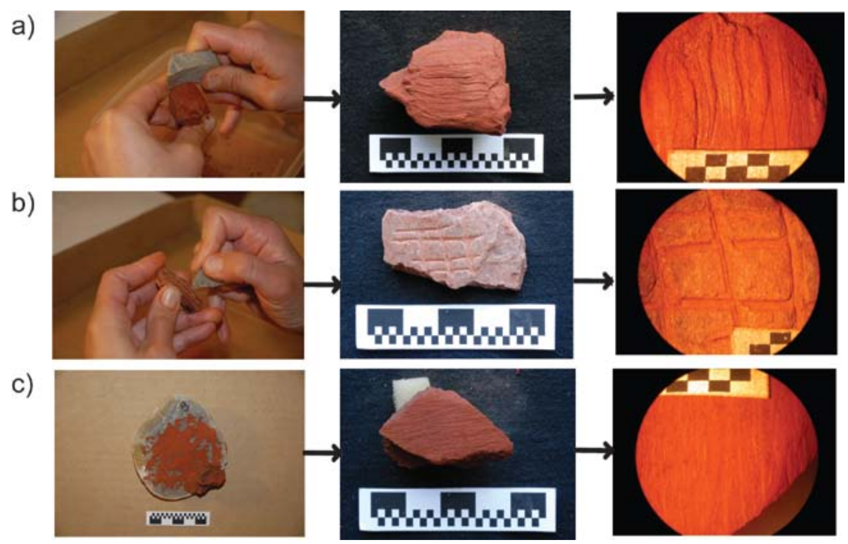

Fig. 4.1. Examples of a) scraping b) engraving c) grinding

PP13B description

Some of the PP13B ochre was previously described by Watts (2010). I reviewed the collection and his assessments in preparation for describing the PP5-6 ochre. Here I review his descriptions, to be able to compare them to PP5-6. While Watts (2010) only presented data on pieces he deemed "pigment" here I present the full ochre dataset that he originally described (Watts unpublished). 637 pieces were classified as ochre at PP13B (including 121 plotted finds, 164 pieces from the 10mm sieved fraction, and 352 pieces from the 3mm sieved fraction). Of these Watts classified 380 as pigment in publication, and he did not discuss the remainder of the collection. By only discussing "pigment" pieces, Watts presumes the ochre is being used only as a pigment for symbolic behaviors. As the purpose of this study is to test for different ochre related behaviors, all ochre (anything that leaves a colored streak) must be described. The descriptions that follow are summarized from Watt's original coded dataset. There are 8 samples from PP13B described here that were not analyzed by Watts as they were excavated and cataloged after he completed his analyses. Further, there are some discrepancies in Watt's published counts by aggregate and those counts in the original dataset. Stratigraphic aggregate assignments were continually refined at PP13B until excavations were completed. It seems that Watts may have used an older set of assignments (instead of the finalized one) when identifying which ochre samples belonged in which aggregate. Here I present aggregate counts based on the most recent and finalized Stratigraphic aggregate assignments.

Totals are presented for disturbed aggregates but this material is not further discussed.

Table 4.2
Frequency, mass distribution and density of ochre pieces by aggregate (sediment volumes from Marean *et al.* 2010 used to calculate density)

Excavation Area	Stratigraphic Aggregate	N	Total mass (g)	Density (g/m^3)
Western	Northeast Fill	2	1.4	20.8955
	South Pit Fill	1	1	30.303
	LB Sand 1	36	79.1	244.136
	DB Sand 2	33	328.7	2266.9
	LB Sand 2	15	1.7	33.3333
	DB Sand 3	72	443.2	938.983
	LBG Sand 1	23	89.6	120.107
	DB Sand 4b	2	0.7	15.2174
	DB Sand 4c	6	18.6	138.806
	LB Silt	3	3	14.7059
	LB Silt-G	1	0.1	0.53191
	Laminated Facies	4	1	0.84962
	Western totals	***198***	***968.1***	***269.891***
Eastern	Re-Deposited Disturbance	35	115.4	1625.35
	Truncation Fill	41	42.7	104.146
	Shelly Brown Sand	10	36.3	38.2105
	Roofspall-Upper	73	217.85	420.56
	Roofspall-Lower	46	43.9	80.1095
	Eastern totals	***205***	***456.15***	***182.679***
Northeastern	LC-MSA Upper	1	0.4	8.51064
	LC-MSA Middle	5	1.4	8.13953
	LC-MSA Lower	65	122.15	229.605
	Northeastern totals	***71***	***123.95***	***165.047***
Surface/Section Cleaning		163	162.58	84.68
Overall totals		***637***	1710.78	***195.41***

Northeast Area

LC-MSA Lower There are a total of 65 ochre pieces from the LC-MSA Lower. Watts described the LC-MSA Lower ochre assemblage as dominated by pinkish brown or reddish brown siltstone and coarse siltstone. He argues that the overall similarities of pieces from this aggregate may suggest collection from a single source on the landscape (Watts 2010; Marean *et al.* 2007). Most of the pieces are under 5g (Fig. 4.2). Only five pieces are larger and only two are above 20g. The majority of the pieces from this aggregate are described as fresh with a few pieces showing minor to moderate wear or patina. Watts recorded hardness values ranging from 2 to 6 with most pieces being a 3 or 4 (Table 4.3). There are seven cases of magnetism assigned to this StratAgg. Watts did not make consistent notes on the streak quality of each piece so it is difficult to assess the assemblage as a whole (this information was recorded for PP5-6 and is discussed below). Watts did, however, deem all but 9 of the pieces from this aggregate as definite to possible pigment, suggesting that the vast majority left at least a mediocre streak (Table 4.4).

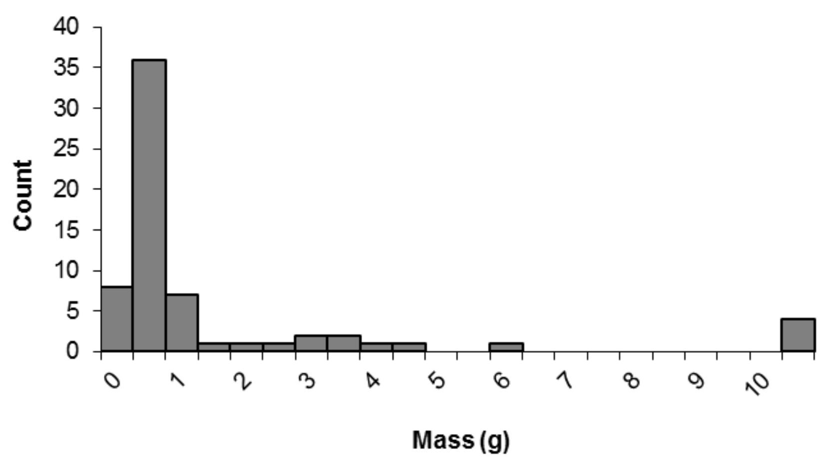

Fig. 4.2. LC-MSA Lower mass of fragments

Table 4.3
LC-MSA Lower hardness values

Hardness	Count	%
1	0	0.00
2	2	3.08
3	36	55.38
4	17	26.15
5	5	7.69
6	5	7.69
	65	100.00

Table 4.4
LC-MSA Lower pigment assessment

Pigment	Count	%
Definite	10	15.38
Highly Probable	2	3.08
Probable	42	64.62
Possible	2	3.08
Doubtful	4	6.15
Not Pigment	5	7.69
	65	100.00

Watts identified 11 pieces from the LC-MSA Lower as modified. 9 are classified as Definite and 2 as Probable. These are described below.

Specimen Number: 81.1 Modification Assessment: Definite

This chunk of ochre is described as possibly burnt or weathered, fine-grained sandstone that is moderately cemented. The piece has traces of fine grained mica. It has a hardness of about 4, is not magnetic, and leaves a good streak (described as “rich” by Watts). It is definitely ground over about 25% of a convex surface. Fine striations are visible on this surface. Watts has further classified the piece as definite pigment.

Specimen Number: 177.2 Modification Assessment: Definite

This chunk of ochre is described as shale with clay sized particles. It is either fresh or has minor weathering and is well cemented. The piece has moderate amounts of fine grained mica inclusions. It has a hardness of about 4 and is not magnetic. The piece has been ground on a flat surface (about 25% of the piece). There are striations visible. Watts also identified two short cut marks next to the grinding and two flake scars located on the opposite face.

Specimen Number: 79092 Modification Assessment: Definite

This chunk of ochre is fresh with silt sized particles and is moderately well cemented. There is a mica component or possible salt grains in the matrix. The piece is not magnetic and has a hardness of about 4. The piece has been ground and notched. There is one main flat ground surface with visible striations. A 2mm, u-shaped notch exists on one edge.

Specimen Number: 79414 Modification Assessment: Definite

This triangular tabular piece of ochre is relatively fresh but still has some ash adhering to its surfaces. It is described as shale with clay sized particles and is moderately cemented. The piece has abundant very fine mica inclusions, a hardness of 3 and is not magnetic. This specimen has one ground facet accounting for about 10% of the surface area of the whole piece. There are striations restricted to one end of the ground area. Watts classified the piece as definite pigment.

Specimen Number: 80337 Modification Assessment: Definite

This chunk of ochre has minor worn surfaces, silt sized particles, and is moderately cemented. There are abundant fine grained mica inclusions. It is not magnetic and has a hardness of 3-4. The piece is definitely ground on one flat edge. Coarse u-shaped striations were identified and the specimen is classified as definite pigment by Watts.

Specimen Number: 81614 Modification Assessment: Definite

Watts refers to this specimen as a slender tabular stick that tapers at both ends and has moderately worn surfaces. Particles are silt to clay sized and the piece is moderately cemented. Fine grained mica particles are also abundant. The hardness is about 3 and no magnetism was detected. The piece is ground on one main flat face and one flat edge making up about 50% of the total surface area. The piece is classified as definite pigment.

Specimen Number: 81681 Modification Assessment: Definite

This chip of ochre has minor worn surfaces, silt to clay sized particles, and is moderately cemented. There are abundant fine grained mica inclusions. The piece is not magnetic and has a hardness of about 3. The specimen has one flat definitely ground facet with clear striations accounting for about 50% of its surface area. Watts describes the piece as definite pigment.

Specimen Number: 81770 Modification Assessment: Definite

This tabular piece of ochre is relatively fresh, has silt to clay sized particles and is well cemented. There are moderate amount so fine grained mica inclusions. It has a hardness of about 4 and is not magnetic. The piece is definitely ground and probably scraped. There is one main surface which is mostly flat except for a concave spot in the center. There are some broad striations in this concave area that may be the result of scraping. The piece is classified as definite pigment.

Specimen Number: 111510 Modification Assessment: Definite

This piece was recovered from the 10mm sieved fraction. The chunk is relatively fresh, with silt to clay sized particles and is brittle. The piece is not magnetic and has a hardness of about 4. The piece has been scraped. There is one deep and wide u-shaped striation found on the main surface and over one edge. The piece was given a pigment classification of definite.

Specimen Number: 81439 Modification Assessment: Probable

This tabular piece of ochre is relatively fresh, has silt to clay sized particles, and is moderately cemented. The piece has abundant fine grained mica inclusions, is not magnetic and has a hardness of about 3. It is described as probably scraped on one flat surface. There were at least two striations identified. Watts gave the specimen a pigment status of highly probable.

Specimen Number: 3mm piece Modification Assessment: Probable

This chip of ochre from the 3mm fraction was not given a specimen number. The piece has moderately worn surfaces, silt sized particles, and is moderately cemented. There are only trace amounts of very fine mica inclusions. It is not magnetic and has a hardness of about 3. There are no obvious striations but on the smoothest main surface a little less than half the area is polished. Watts classifies this as probable grinding, although it could have also resulted from rubbing on an organic surface such as hide or skin. Watts classifies the specimen as highly probable pigment.

LC-MSA Middle There are only five pieces cataloged as ochre from the LC-MSA Middle. This is not surprising given the low artifact counts in general for this aggregate. Each piece weights less than 1 gram (Fig. 4.3). Of these five pieces, four are described as fresh and one has extensive discoloration. They have hardness ranging from three to six (Table 4.5), and three are magnetic. The pieces are dark brown to dark gray in color. None of the pieces had evidence of modification. Watts classified two as non-pigment, two as probable pigment and one as possible pigment (Table 4.6).

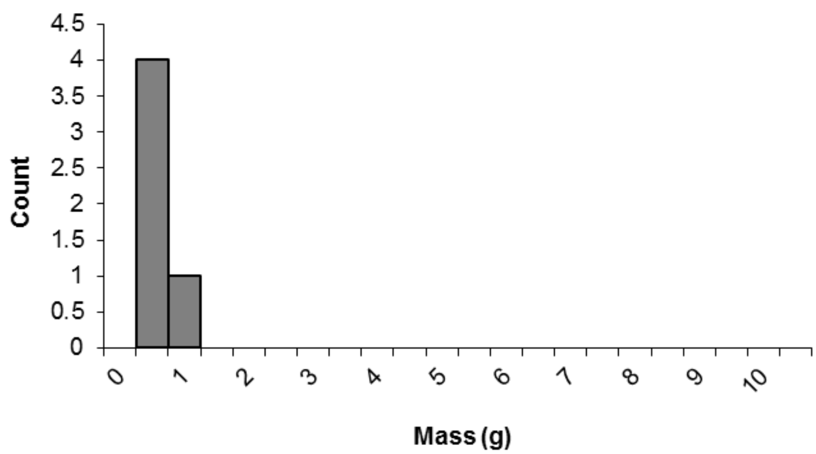

Fig. 4.3. LC-MSA Middle mass of fragments

Table 4.5
LC-MSA Middle hardness values

Hardness	Count	%
1	0	0
2	0	0
3	2	40
4	0	0
5	2	40
6	1	20
	5	100

Table 4.6
LC-MSA Middle pigment assessment

Pigment	Count	%
Definite	0	0
Highly Probable	0	0
Probable	2	40
Possible	1	20
Doubtful	0	0
Not Pigment	2	40
	5	100

<u>LC-MSA Upper</u> The LC-MSA Upper only yielded one piece of ochre (0.4g) that Watts (2010) describes as moderately hematized siltstone. He identified probable evidence for utilization on this fragment.

Specimen Number: 58610 Modification Assessment: Probable

This chunk of ochre has moderately worn surfaces and was coated in white ash on three surfaces. It has silt sized particles with trace amounts of very fine mica inclusions and is well cemented. The piece is strongly magnetic and has a hardness of about 4. The piece is probably ground on one flat facet where there are possible faint striations. The specimen is classified as highly probable pigment by Watts.

Eastern Area

Lower Roofspall Facies There are 46 ochre pieces cataloged from the Lower Roofspall Facies. All but one piece is smaller than 5 gram with the majority less than 1 gram (Fig. 4.4). Ten pieces have minor to extreme wear while the rest are described as fresh. Hardness values recorded by Watts ranged from three to six with three and four being most common (Table 4.7). Only two pieces were found to be magnetic. Color ranged from yellow to red with some darker grays and browns as well. Watts classified all but ten samples as definite to possible pigment (Table 4.8). Watts argues most of this material is likely pigment processing waste (2010).

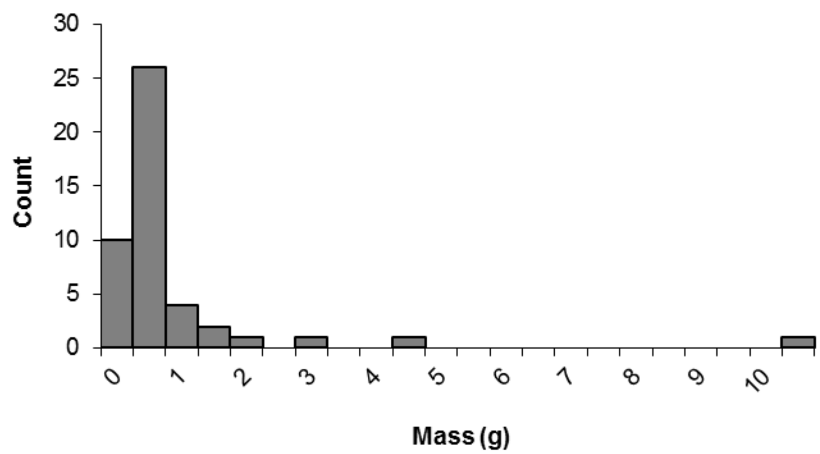

Fig. 4.4. Lower Roofspall Facies mass of fragments

Table 4.7
Lower Roofspall Facies hardness values

Hardness	Count	%
1	0	0.00
2	0	0.00
3	20	44.44
4	15	33.33
5	5	11.11
6	5	11.11
	45*	100.00

*one sample is powder and does not have a hardness value

Table 4.8
Lower Roofspall Facies pigment assessment

Pigment	Count	%
Definite	1	2.17
Highly Probable	0	0.00
Probable	35	76.09
Possible	0	0.00
Doubtful	2	4.35
Not Pigment	8	17.39
	46	100.00

There are only two pieces from this aggregate that may be modified. One, a piece from the 10mm fraction, is classified as definitely modified. The other is a 3mm fragment classified as possibly modified.

Specimen Number: 59518 Modification Assessment: Definite

This tabular piece of ochre is relatively fresh. The piece has clay sized particles with abundant very fine mica inclusions, and it is moderately cemented. It is not magnetic and has a hardness of about 3. The specimen is definitely ground on one flat edge. It is classified as definite pigment.

Specimen Number: 3mm fragment   Modification Assessment: Possible

This chip of ochre is relatively fresh, has silt sized particles, and is moderately cemented. Abundant fine mica inclusions were identified. It is not magnetic and has a hardness value of about 3. There is one flat main surface that is possibly ground. Watts classified the fragment as probable pigment.

Upper Roofspall Facies Seventy-three pieces of ochre have been cataloged from this aggregate. The majority of pieces are less than 5g although there are a few larger fragments including one 104.8g tabular specimen (Fig. 4.5). Most of the material from this aggregate is described as fresh with a few pieces showing minor to moderate wear. Recorded hardness values ranged from two to five, with most having a hardness of three or four (Table 4.9). Only four pieces of ochre were found to be magnetic. Most of the pieces are various shades of brownish red but white, yellow, gray, and pink are also represented. Watts classified all but three pieces as definite to possible pigment (Table 4.10). Watts (2010) argues that this is the first aggregate with some very dark streaks represented.

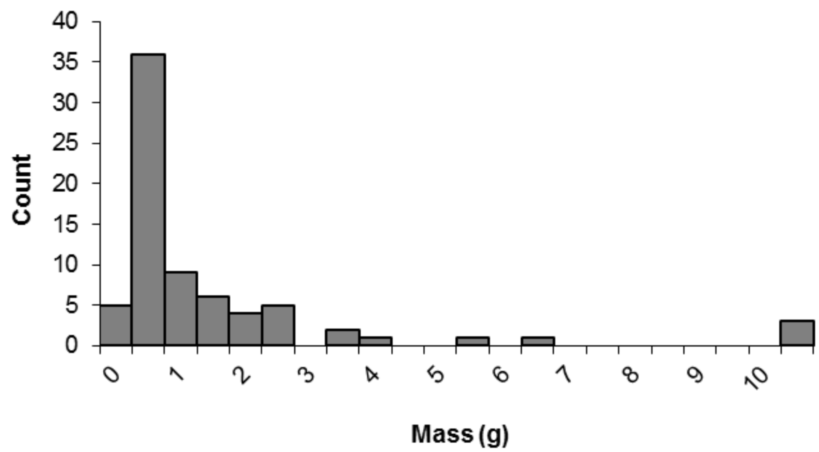

Fig. 4.5. Upper Roofspall Facies mass of fragments

Table 4.9
Upper Roofspall Facies hardness values

Hardness	Count	%
1	0	0.00
2	6	8.22
3	31	42.47
4	33	45.21
5	3	4.11
6	0	0.00
	73	100.00

Table 4.10
Upper Roofspall Facies pigment assessment

Pigment	Count	%
Definite	4	5.48
Highly Probable	1	1.37
Probable	56	76.71
Possible	9	12.33
Doubtful	2	2.74
Not Pigment	1	1.37
	73	100.00

Watts identified 6 pieces of potentially modified ochre from this aggregate. Five of the pieces were classified as definite and one as possible. These are described below.

Specimen Number: 27067 Modification Assessment: Definite

This plotted find is a chunk of worn ochre with sand and silt sized particles. The piece has large quartz clasts, trace amounts of fine mica inclusions, and is moderately cemented. It is not magnetic and has a hardness of about 4. The piece has been ground over about 25% of its surface area on one main convex facet and one flat edge. The piece is classed as definite pigment.

Specimen Number: 29689 Modification Assessment: Definite

This very large (104.8g) tabular fragment was discovered in the 10mm sorting fraction. The material is relatively fine grained with silt and sand sized particles. There are some large quartz clasts and moderate amounts of fine grained mica inclusions. The piece is not magnetic and has a hardness of about 4. Watts states that the piece does not streak normally but must be crushed and then spread around. The piece is definitely ground intensively over about 50% of its surface area. There are five flat facets. Two opposed surfaces and three of the edges. The piece is classed as definite pigment.

Specimen Number: 111487 Modification Assessment: Definite

This chunk of ochre is relatively fresh. It has silt to clay size particles and is moderately cemented. The piece is impregnated with salt. It is not magnetic and has a hardness of about 3. The specimen is definitely ground on one main flat surface accounting for about 15% of its surface area. There are fairly clear striations on this surface. The piece is classified by Watts as probable pigment.

Specimen Number: 111506 Modification Assessment: Definite

This small chunk of ochre was recovered from the 3mm sieved fraction. The piece is relatively fresh, has silt to clay sized particles and is moderately cemented. It is not magnetic and has a hardness of about 4. The specimen is definitely ground on one flat minor surface (about 5% of the surface area). Watts argues this may be just a remnant of the original surface. He suggests the rest may have spalled off perhaps due to heating. The piece is classified as definite pigment.

Specimen Number: 111513 Modification Assessment: Definite

This relatively fresh chunk of ochre was recovered from the 10mm fraction. Particles range in size from clay to fine grained sand and the piece is well cemented. It is not magnetic and has a hardness of about 4. The piece has been ground on one convex facet at the “distal” end. The modification covers about 10% of the fragment and fine striations are visible. The piece is classified as definite pigment.

Specimen Number: 59545 Modification Assessment: Possible

This chunk of ochre was recovered from the 10mm fraction and is heavily corroded with salt. Particle sizes range from clay to fine grained sand, quartz grains are rare and the piece is moderately cemented. It is not magnetic and has a hardness value of about 3. The piece is possibly ground on 2 flat adjacent surfaces. There are not clear striations but this could be due to the salt corrosion on the piece. The piece is classified as highly probable pigment.

Shelly Brown Sand There are only ten pieces of ochre attributed to the Shelly Brown Sand. The material from this aggregate is all fairly fresh with two cases of moderate wear and patina. Most of the pieces are small (less than 3 grams) but there is one larger fragment (27.6g) (Fig. 4.6). Watts recorded hardness values ranging from three to five (Table 4.11). There is only one magnetic fragment. Seven of the pieces are various shades of red brown while three are yellow brown. Watts classified eight of the cases as definite to possible pigment (Table 4.12).

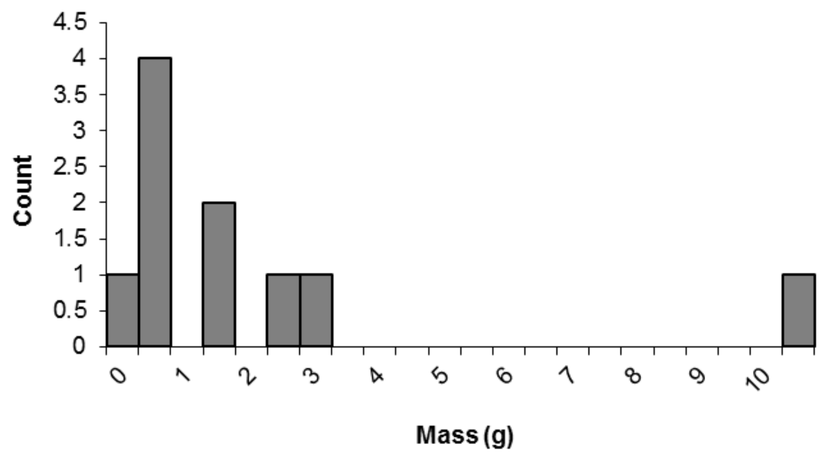

Fig. 4.6. Shelly Brown Sand mass of fragments

Table 4.11
Shelly Brown Sand hardness values

Hardness	Count	%
1	0	0.00
2	0	0.00
3	6	60.00
4	2	20.00
5	2	20.00
6	0	0.00
	10	100.00

Table 4.12
Shelly Brown Sand pigment assessment

Pigment	Count	%
Definite	1	10.00
Highly Probable	0	0.00
Probable	6	60.00
Possible	1	10.00
Doubtful	1	10.00
Not Pigment	1	10.00
	10	100.00

There is one definitely modified ochre fragment that comes from the SBS 3mm sorted fraction. There is also one grindstone fragment found in this aggregate.

Specimen Number: 3mm fragment Modification Assessment: Definite

This chip of ochre is relatively fresh with silt and clay sized particles and moderate amounts of fine grained mica inclusions. It is moderately cemented, not magnetic and has a hardness of about 3. The piece has definite evidence of grinding on about 50% of its surface area. There are two adjacent flat surfaces with just visible striations. These striations converge at 45 degrees to each other. The piece is classified as definite pigment.

Specimen Number: 52966 Modification Assessment: Definite

This large pebble fragment is fine grained and well cemented. It is not magnetic and has a hardness value of about 5. Watts describes the piece as a grindstone fragment. It did not leave a good streak but is ground flat on one main surface and one edge surface.

Truncation Fill There are 41 pieces of ochre cataloged from the Truncation Fill. Only two fragments weigh more than five grams (Fig. 4.7). All the material from this aggregate is described as relatively fresh except one piece with minor wear. All but four fragments are not magnetic and hardness values range from 3 to 6 (Table 4.13). Much of the assemblage is various shades of red brown. However, there is also a good amount of yellow to orange and brown pieces. Only eight cases are not classified by Watts as definite to possible pigment (Table 4.14).

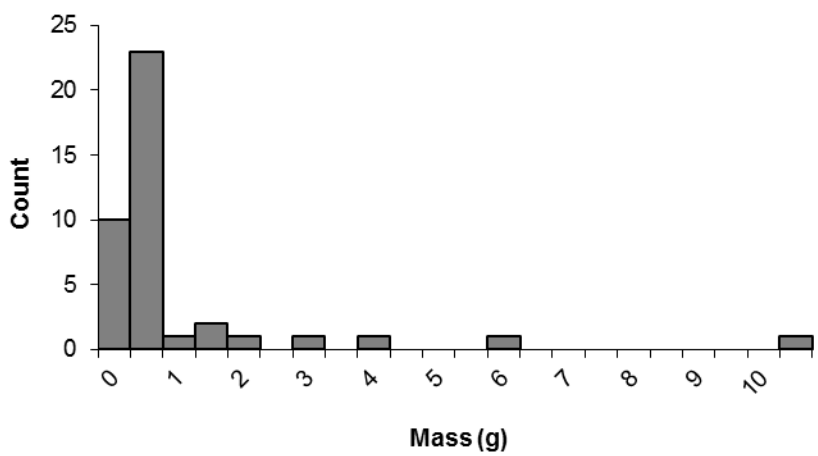

Fig. 4.7. Truncation Fill mass of fragments

Table 4.13
Truncation Fill hardness values

Hardness	Count	%
1	0	0.00
2	0	0.00
3	18	43.90
4	6	14.63
5	8	19.51
6	9	21.95
	41	100.00

Table 4.14
Truncation Fill pigment assessment

Pigment	Count	%
Definite	1	2.44
Highly Probable	1	2.44
Probable	28	68.29
Possible	3	7.32
Doubtful	3	7.32
Not Pigment	5	12.20
	41	100.00

Three pieces were found with possible modification, one definite, one probable, and one possible.

Specimen Number: 59506 Modification Assessment: Definite

This chunk of ochre has very corroded surfaces with a lot of salt crystals. It has silt to sand sized particles with trace amounts of fine mica inclusions and is moderately cemented. It is not magnetic and has a hardness value of about 3. The piece is definitely ground on over 60% of its surface area. There are three possible four convergent flat surfaces. Watts labeled this piece as a potential crayon and definite pigment.

Specimen Number: 1203.01 Modification Assessment: Probable

This chunk of ochre has minor worn surfaces. It has silt sized particles with moderate fine mica inclusions. It is well cemented, not magnetic and has a hardness value of about 4. It is probably ground on one main flat facet. The area is smooth but no striations are preserved. Watts classified the piece as highly probable pigment.

Specimen Number: 3mm fragment Modification Assessment: Possible

This chunk of ochre was recovered from the 3mm sorted fraction and is well cemented. It is relatively fresh with medium sand sized particles and medium to coarse grained quartz inclusions. It is not magnetic and has a hardness value of about 4. The piece is possible ground on one main flat surface but there are no signs of striations. Watts classified the piece as probable pigment.

Redeposited Disturbance There are 35 ochre fragments from this aggregate. Most of this material has likely been redeposited from the Western excavation area towards the back of the cave. Again, most of the pieces are smaller than 5 grams although there are a few larger specimens (Fig. 4.8). Most of the material from this aggregate was fresh with some pieces showing minor to moderate wear. Most had hardness values of 3-4 (Table 4.15), and only two were found to be magnetic. Watts reports that the streaks from this aggregate were exceptionally variable (Watts 2010). The color range includes black, gray, brown, and red in various shades. All the ochre from this aggregate was classified as definite to probable pigment (Table 4.16).

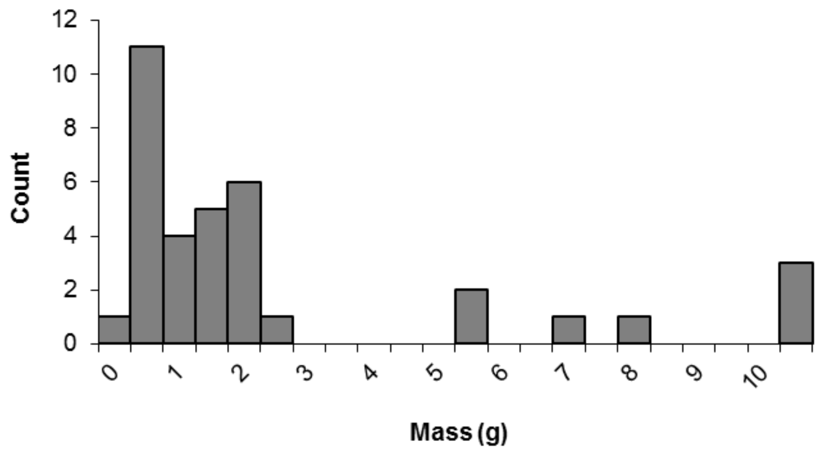

Fig. 4.8. Redeposited Disturbance mass of fragments

Table 4.15
Redeposited Disturbance hardness values

Hardness	Count	%
1	0	0.00
2	0	0.00
3	20	57.14
4	14	40.00
5	1	2.86
6	0	0.00
	35	100.00

Table 4.16
Redeposited Disturbance pigment assessment

Pigment	Count	%
Definite	4	11.43
Highly Probable	2	5.71
Probable	28	80.00
Possible	1	2.86
Doubtful	0	0.00
Not Pigment	0	0.00
	35	100.00

Seven pieces from the Redeposited Disturbance show potential evidence of use. There are four pieces with modification classifications of definite, two of probable, and one of possible. Although these are out of original context, they are likely to be MSA in age and are described below.

Specimen Number: 61610 Modification Assessment: Definite

This wedge shaped chunk of ochre was recovered from the 10mm sorted fraction. It is relatively fresh with clay to silt sized particles and is moderately cemented. It is not magnetic and has a hardness value of about 4. The material has unusually abundant coarse grained mica inclusions. The specimen has been definitely ground over about 75% of its surface area. There are two main faces which are ground flat and have fine striations. Where the two faces meet there is beveled surface that is slightly concave. The piece is classified by Watts as definite pigment.

Specimen Number: 111488 Modification Assessment: Definite

This tabular fragment was recovered from the 10mm fraction and has minor worn surfaces. The piece has clay to silt sized particles with moderate amounts of fine mica inclusions, and it is moderately cemented. The specimen is not magnetic and has a hardness value of around 4. This piece of ochre has been ground on two flat edge surfaces. Striations were identified on both surfaces although they are clearer on one. Watts classified the piece as definite pigment.

Specimen Number: 111490 Modification Assessment: Definite

This chunk of ochre was recovered from the 10mm sieved material. It has moderately worn surfaces and is moderately cemented. The particles are clay sized and mica inclusions are not present. The piece is not magnetic and has a hardness value of about 3. The piece is definitely ground on more than 30% of its surface area. There is one main flat surface and one flat edge surface with characteristic grinding striations. Watts classified the specimen as definite pigment.

Specimen Number: 10mm fragment Modification Assessment: Definite

This chunk of ochre was recovered from the 10mm fraction but was not given a specimen number. The piece is relatively fresh fine-grained sandstone that is somewhat friable. Trace amounts of fine grained mica inclusions were identified. The piece is not magnetic and has a hardness value of about 3. The piece has been definitely ground and possibly engraved. There is one main flat surface. On this surface there are faint striations from grinding as well as one clear straight deep striation. Watts identified one possible two fainter striations parallel to this main one. The piece was classified as definite pigment.

Specimen Number: 59544 Modification Assessment: Probable

This chunk of ochre was found in the 10mm fraction. It has clay to silt sized particles and is moderately cemented. The piece is not magnetic and has a hardness value of about 3. The piece is probably ground on one flat surface where there are traces of possible striations. Watts classified the piece as highly probable pigment.

Specimen Number: 10mm fragment Modification Assessment: Probable

This tabular piece of ochre was recovered from the 10mm but was not given a specimen number. It is relatively fresh with clay to silt sized particles, abundant fine grained mica inclusions, and is moderately cemented. The piece is not magnetic and has a hardness value of about 3. The piece is probably ground on one flat edge. There are no clear striations but Watts makes the point that they would be difficult to see as they would have been aligned with the natural platelets. He classified the piece as highly probable pigment.

Specimen Number: 10mm fragment Modification Assessment: Possible

This tabular piece of ochre was recovered from the 10mm fraction but was not given a specimen number. The piece is relatively fresh and moderately cemented with clay to silt sized particles. There are abundant moderate sized mica inclusions. It is not magnetic and has a hardness value of about 3. The piece has been possibly scraped. One flat surface has faint traces of isolated scraping striations. Watts classified the piece as probable pigment.

Western Area

<u>Boulder Facies</u> No ochre was recovered from the Boulder Facies

<u>Laminated Facies</u> Only four pieces of ochre were recovered from this aggregate, all weighing less than a gram. Three were described as fresh and one as ambiguously worn. They are not magnetic and had hardness values ranging from

4 to 6. Three of the pieces are brown while one is more yellow. Watts described one piece as probable pigment, two as possible and one as doubtful. None of the pieces had evidence of modification.

Light Brown Silt Facies Only four pieces of ochre were found in this aggregate, three from the LB Silt and one from the LB Silt-G. These pieces are all fairly small (Fig. 4.9). The largest is only 1.8g. Three pieces are fresh while the fourth had moderate patina. None of the pieces were magnetic and two had hardness values of 2 and two had hardness values of 4 (Table 4.17). These ochre fragments were white, yellow, and brown. No red pieces were recorded. Two pieces were classified as probable pigment, one as possible, and one as doubtful (Table 4.18). No traces of use wear were identified.

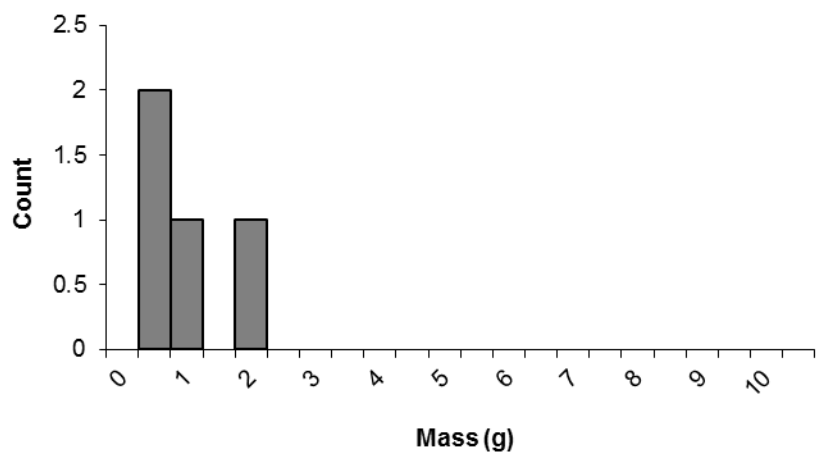

Fig. 4.9. Light Brown Silt Facies mass of fragments

Table 4.17
Light Brown Silt Facies hardness values

Hardness	Count	%
1	0	0
2	2	50
3	0	0
4	2	50
5	0	0
6	0	0
	4	100

Table 4.18
Light Brown Silt Facies pigment assessment

Pigment	Count	%
Definite	0	0.00
Highly Probable	0	0.00
Probable	2	50.00
Possible	1	25.00
Doubtful	1	25.00
Not Pigment	0	0.00
	4	100.00

<u>Dark Brown Sand Facies</u> Thirty-three fragments of ochre were cataloged and coded from DB Sand 2. Most pieces are less than five grams but there are a few that are larger (Fig. 4.10). There is one exceptionally large flake of 228 grams (21199). Most of the material is relatively fresh. Only four fragments were described as having moderate wear. Magnetism is rare and was only identified in two samples. Hardness values range from 3 to 5 (Table 4.19). Color ranges from dark red brown to light red brown and there are eight cases of yellow brown to orange fragments. Watts classified all but four ochre pieces as definite to probable pigment (Table 4.20).

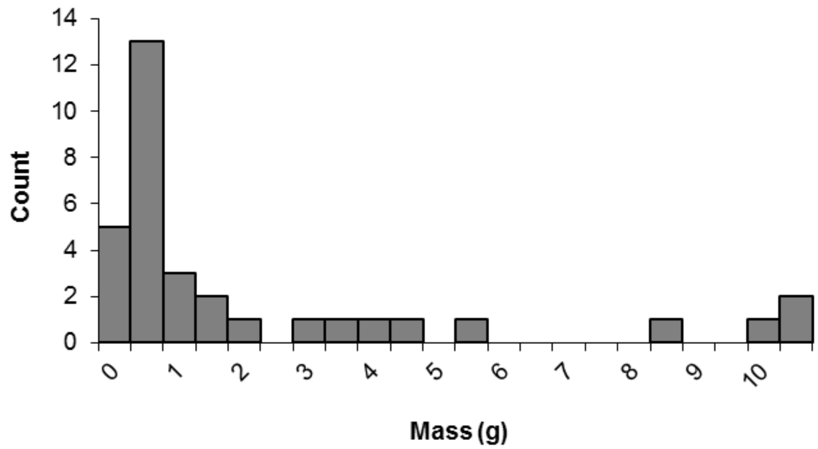

Fig. 4.10. DB Sand 2 mass of fragments

Table 4.19
DB Sand 2 hardness values

Hardness	Count	%
1	0	0.00
2	1	3.03
3	13	39.39
4	13	39.39
5	6	18.18
6	0	0.00
	33	100.00

Table 4.20
DB Sand 2 pigment assessment

Pigment	Count	%
Definite	0	0.00
Highly Probable	3	9.09
Probable	3	9.09
Possible	23	69.70
Doubtful	4	12.12
Not Pigment	0	0.00
	33	100.00

Three pieces with modification were identified, one definite and two probable.

Specimen Number: 21199 Modification Assessment: Definite

This large flake of ochre is yellow-brown in color. It is relatively fresh with medium sand sized particles and it is well cemented. It is not magnetic and has a hardness value of about 4. The piece itself is a large flake with at least three flake scars from previous removals.

Specimen Number: 29916 Modification Assessment: Probable

This relatively fresh chunk of ochre was recovered from the 10mm sieved fraction. The material has a sandy appearance with some quartz clasts. It is moderately cemented. It is not magnetic and has a hardness value of about 4. The piece is probably ground over about 25% of its surface area. There is one main flat surface. There are no obvious striations but they may not be expected given the grain size. Watts did suggest there may be some faint striations on the hematite vein that runs across the flat surface. He classified the piece as highly probable pigment.

Specimen Number: 45882 Modification Assessment: Probable

This chunk of ochre is moderately worn. It has silt sized particles with trace amounts of fine grained mica inclusions and is well cemented. It is not magnetic and has a hardness value of about 4. The piece is probably ground over more than 30% of its surface area. There is one main flat surface. Most of the surface is rough but Watts identified sufficient evidence to infer grinding along one edge. He classified the piece as highly probable pigment.

Seventy-two fragments were coded from the DB Sand 3. The majority of the finds are under 5g although there are a few larger pieces (Fig. 4.11). The biggest fragment is 189.9g, making up more than half of the total mass for the aggregate. The majority of pieces were described as fresh, but fourteen fragments had various degrees of wear and two fragments had possible patina. Only five samples were magnetic and hardness values ranged between 3 and 6 (Table 4.21). Hardness of three was the most common. Colors include varying shades of brown, red brown, and yellow brown. All but four pieces from this aggregate were classified by Watts as possible, probable, or definite pigments (Table 4.22).

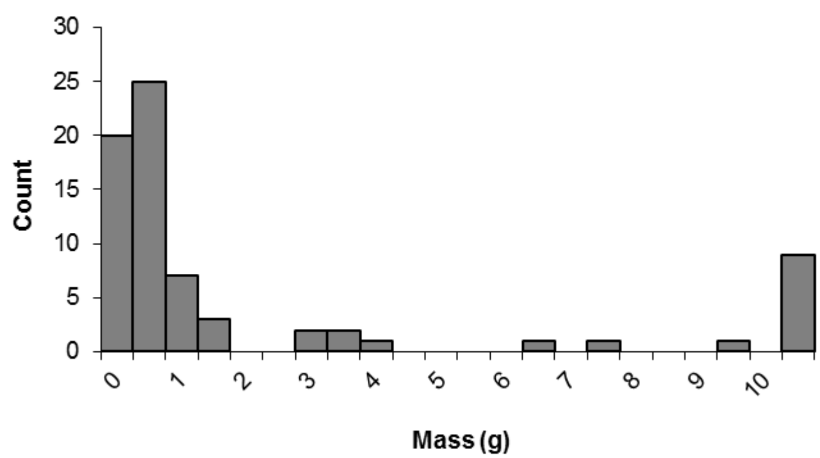

Fig. 4.11. DB Sand 3 mass of fragments

Table 4.21
DB Sand 3 hardness values

Hardness	Count	%
1	0	0.00
2	1	1.39
3	35	48.61
4	31	43.06
5	4	5.56
6	1	1.39
	72	100.00

Table 4.22
DB Sand 3 pigment assessment

Pigment	Count	%
Definite	11	15.28
Highly Probable	2	2.78
Probable	53	73.61
Possible	2	2.78
Doubtful	2	2.78
Not Pigment	2	2.78
	72	100.00

There are fifteen cases of identified modifications for this aggregate. Thirteen were classified as definite, one probable, and one possible. These are described below.

Specimen Number: 21419 Modification Assessment: Definite

This relatively fresh chunk of ochre was heavily impregnated with salt crystals. It has silt to fine grained sand particles and is moderately cemented. The piece is not magnetic and has a hardness value of four. The piece is definitely ground over at least 30% of its surface area. There are two main adjacent flattened facets with moderate to coarse striations. There are also two large chips removed from these surfaces. The piece is classified by Watts as definite pigment.

Specimen Number: 21536 Modification Assessment: Definite

This relatively fresh chunk of ochre is composed of medium sized sand particles with quartz inclusions. It is moderately cemented, not magnetic, and has a hardness value of about four. The piece has been definitely ground over about 25% of its surface area. There are two adjacent main surfaces, one flat and one convex. There are striations on about half of one surface near the darker end and on a smaller area on the other surface. The piece is classified as definite pigment. Watts also notes that it leaves a surprisingly poor streak.

Specimen Number: 22075 Modification Assessment: Definite

This chunk of ochre has moderately worn surfaces. The piece has medium sized sand particles with medium sized quartz inclusions and is well cemented. It is not magnetic and has a hardness value of about four. The whole piece has been definitely flaked. There are about five flake scars from previous removals. Watts classified the piece as highly probable pigment.

Specimen Number: 22289 Modification Assessment: Definite

This fairly large (45.4g) piece of ochre is vaguely pyramidal in shape. It has medium sized sand to silt particles with few quartz clasts and trace amounts of very fine mica inclusions. The piece is not magnetic and has a hardness value of about three. The piece has been ground and scraped over more than 90% of its surface area. Watts counted 14 modified convex and flat facets. Striations are visible on most surfaces and there are deep scraping/engraving marks creating a chevron shape on one surface. The piece is classified as definite pigment.

Specimen Number: 34783 Modification Assessment: Definite

This relatively fresh chunk of ochre has silt to fine grained sand particles with fine to medium sized quartz inclusions and is moderately cemented. It is not magnetic and has a hardness value of about four. The piece has been ground and scraped on over 60% of its surface area. There are four concave and flat surfaces. The largest surface was first ground flat and then was scraped over about two thirds of the surface making the face slightly concave. An adjacent face has a wide deep furrow with striations. The third surface is ground flat and has two possible notches. The last face is also ground flat. Watts classified the piece as definite pigment.

Specimen Number: 59513 Modification Assessment: Definite

This relatively fresh tabular piece of ochre was recovered from the 10mm sieved fraction. The piece has clay sized particles, abundant very fine mica inclusions and is moderately cemented. It is not magnetic and has a hardness value of about three. The piece has been ground on about 10% of its surface area. There are two flat ground edges. Striations may be present but they are difficult to distinguish because the surface has the natural corrugated texture of shale. The piece is classified as definite pigment.

Specimen Number: 82470 Modification Assessment: Definite

This chunk of ochre has minor worn surfaces. It has sand to silt sized particles with abundant fine grained quartz inclusions, and moderate medium sized mica inclusions. The ochre is well cemented, is not magnetic, and has a hardness value of five. The piece is definitely ground on more than 30% of its surface area. There is one main surface that is partially convex and partially flat. Half the surface is corroded but striations are preserved on the remainder. The piece is classified as probable pigment.

Specimen Number: 82471 Modification Assessment: Definite

This specimen consists of three conjoining fragments that make up a "crayon". Surfaces are corroded and the piece is heavily impregnated with salt crystals and possible calcium carbonate. It has silt to clay sized particles with moderate amounts of very fine mica inclusions and is friable. It is not magnetic and has a hardness value of about three. The piece has been ground on about 50% of its surface area. There is one main flat surface and one flat edge with coarse striations. The proximal end is also very smooth. Watts describes the piece as definite pigment.

Specimen Number: 82565 Modification Assessment: Definite

This chunk of ochre has extensively worn surfaces. It has clay to sand sized particles with moderate amounts of fine grained mica. The piece is friable and was broken into two pieces during excavation. It is not magnetic and has a hardness value of about three. The piece has been ground on about 50% of its surface area. There are two adjacent main flat surfaces with striations only just visible. The piece was classified as definite pigment.

Specimen Number: 3mm Modification Assessment: Definite

This relatively fresh piece of tabular ochre was recovered from the 3mm sieved fraction but not assigned a specimen number. The piece is shale with clay sized particles and abundant very fine mica inclusions. It is moderately cemented, not magnetic and has a hardness value of about three. The piece has definite evidence of grinding on about 5% of its surface area. There is one flat edge with clear striations parallel to the bedding along the long axis. The piece is classified as definite pigment.

Specimen Number: 3mm Modification Assessment: Definite

This relatively fresh chunk of ochre was recovered from the 3mm sieved fractions but not assigned a specimen number. The piece has silt to clay sized particles with a few coarse quartz clasts and moderate amounts of very fine mica inclusions. The piece is moderately cemented, not magnetic, and has a hardness value of about three. The piece is ground on about 5% of its surface area. There is one main flat surface that is polished. There are not clear striations but some probable ones are visible at 30X magnification at one end of the surface. The piece is classified as definite pigment.

Specimen Number: 3mm Modification Assessment: Definite

This tabular piece of ochre was recovered from the 3mm sieved fraction but was not given a specimen number. The piece has moderately worn surfaces. It has clay to silt sized particles with abundant very fine mica inclusions and is moderately cemented. The ochre is not magnetic and has a hardness value of about three. The piece has evidence of grinding on about 5% of its surface area. There is one flat edge, perhaps a remnant of a larger ground facet. The piece is classified as definite pigment.

Specimen Number: 111495 Modification Assessment: Probable

This small relatively fresh chip of ochre was recovered from the 10mm sieved fraction. It has clay to silt sized particles with moderate amounts of fine grained mica inclusions and is moderately cemented. It is magnetic and has a hardness value of about four. The piece is probably ground over about 50% of its surface area. There is one main flat surface but no clear striations were identified. The piece was classified as highly probable pigment.

Specimen Number: 3mm Modification Assessment: Possible

This relatively fresh chunk of ochre was recovered from the 3mm sieved fraction but was not assigned a specimen number. The piece has silt to clay sized particles with moderate amounts of very fine mica inclusions. It is well cemented, not magnetic and has a hardness value of about three. The piece is possible ground over about 25% of its surface area. There is one main flat surface with two deep depressions. It is very smooth but has no clear striations. The piece is classified as probable pigment.

DB Sand 4b has only two ochre pieces associated with it. Both come from the 3mm sieved fraction and weigh less than one gram. Both have some degree of wear on their surfaces. Both are well cemented with fine grained particles. Watts classified one piece as definite pigment and one as probable. One of these pieces is definitely modified.

Specimen Number: 3mm   Modification Assessment: Definite

This small chunk of ochre has moderately worn surfaces. It is well cemented with silt sized particles and moderate amounts of very fine mica inclusions. It is not magnetic and has a hardness value of about five. The fragment is ground over about 15% of its surface area. There is one main flat surface with clear striations which extend slightly over the edge. The piece is classified as definite pigment.

DB Sand 4c has 6 ochre pieces associated with it. All but one of the pieces are very small (three were too small for measurement) (Fig. 4.12). All the pieces are described as fresh. None of the pieces are magnetic and hardness values ranged from two to six (Table 4.23). There is one piece of yellow ochre, one gray and one brown. The other three are light red to red brown. Watts classified three of these pieces as probable pigment (Table 4.24). None of these finds had evidence of use.

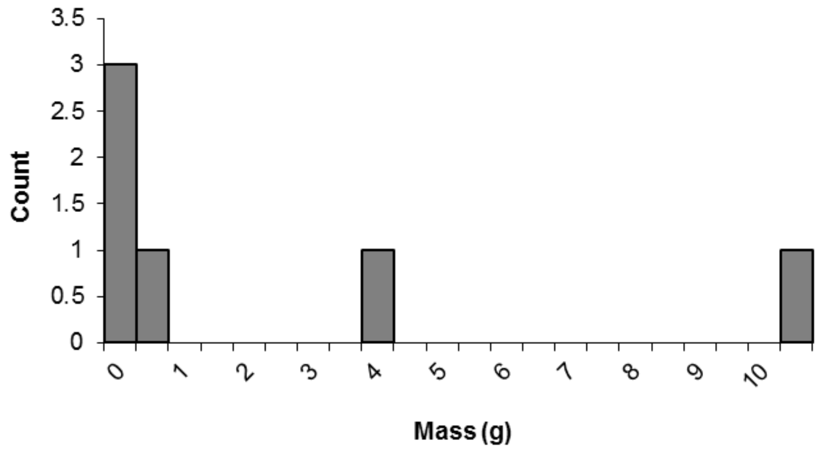

Fig. 4.12. DB Sand 4c mass of fragments

Table 4.23
DB Sand 4c hardness values

Hardness	Count	%
1	0	0.00
2	1	16.67
3	3	50.00
4	1	16.67
5	0	0.00
6	1	16.67
	6	100.00

Table 4.24
DB Sand 4c pigment assessment

Pigment	Count	%
Definite	0	0.00
Highly Probable	0	0.00
Probable	3	50.00
Possible	0	0.00
Doubtful	2	33.33
Not Pigment	1	16.67
	6	100.00

<ins>Light Brown Gray Sand Facies</ins> A total of 23 pieces were cataloged and coded from the LBG Sand 1. No ochre was recovered from the rest of the LBG Sand

series. There are only two larger fragments from this aggregate (Fig. 4.13). Most of the material from this aggregate is described as fresh but there are two cases of minor to moderate wear. Only one sample was found to be magnetic and hardness values were either three or four (Table 4.25). Color choices varied from dark red brown to lighter red brown with two yellowish pieces and two more orange pieces. All the pieces were classified as definite or probable pigment (Table 4.26).

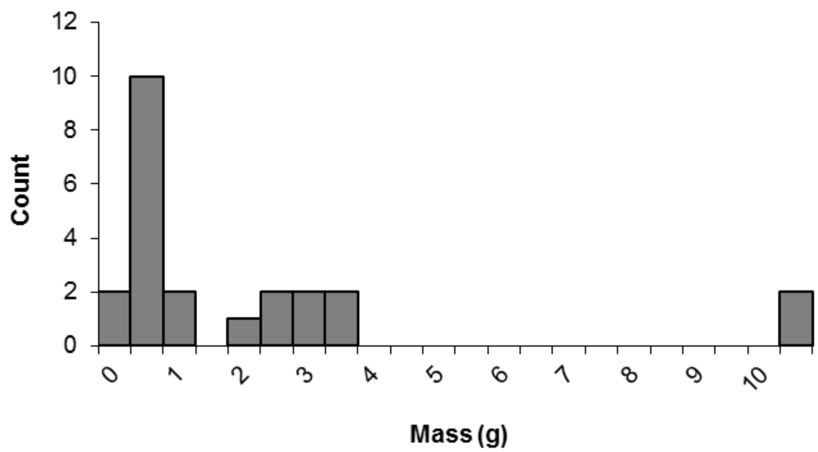

Fig. 4.13. LBG Sand 1 mass of fragments

Table 4.25
LBG Sand 1 hardness values

Hardness	Count	%
1	0	0.00
2	0	0.00
3	14	60.87
4	9	39.13
5	0	0.00
6	0	0.00
	23	100.00

Table 4.26
LBG Sand 1 pigment assessment

Pigment	Count	%
Definite	1	4.35
Highly Probable	0	0.00
Probable	22	95.65
Possible	0	0.00
Doubtful	0	0.00
Not Pigment	0	0.00
	23	100.00

Only one fragment had evidence of modification.

Specimen Number: 53695 Modification Assessment: Definite

Watts describes this chunk of ochre as pseudo-tabular shaped. It is relatively fresh with silt sized particles and moderate amounts of very fine grained mica inclusions and is well cemented. It is not magnetic and has a hardness value of about 4. The piece is definitely ground on about 50% of its surface area. The specimen has on main ground surface and four beveled edge facets. Another possible ground surface was identified at the tip. Watts classified the piece as definite pigment.

<u>Light Brown Sand Facies</u> Thirty-six ochre pieces were recovered from the LB Sand 1. Most pieces are less than five grams (Fig. 4.14). There is one larger fragment of 34.3g. About a third of the pieces from this aggregate have minor to moderate wear. The remainder are described as fresh. Only one fragment is magnetic and hardness values ranged from three to six but three and four are most common (Table 4.27). Dark to light reddish browns are most common but there are some brown, gray and black pieces as well as one yellow brown fragment. Watts described all but one fragment as definite to possible pigment (Table 4.28).

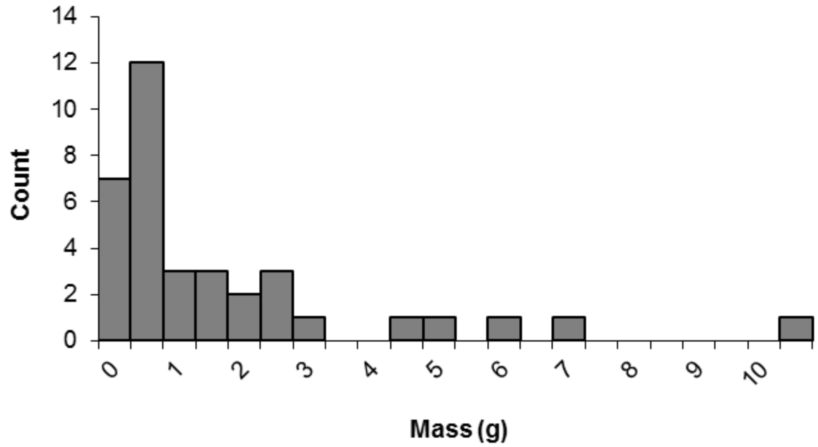

Fig. 4.14. LB Sand 1 Facies mass of fragments

Table 4.27
LB Sand 1 hardness values

Hardness	Count	%
1	0	0.00
2	0	0.00
3	18	50.00
4	16	44.44
5	0	0.00
6	2	5.56
	36	100.00

Table 4.28
LB Sand 1 pigment assessment

Pigment	Count	%
Definite	4	11.11
Highly Probable	1	2.78
Probable	29	80.56
Possible	1	2.78
Doubtful	1	2.78
Not Pigment	0	0.00
	36	100.00

Five pieces had evidence of use. Four of these were considered definite and one probable.

Specimen Number: 22670 Modification Assessment: Definite

This chunk of ochre has minor worn surfaces and is moderately cemented. It grades from a silt-clay texture to coarser grained and has moderate amounts of fine grained mica inclusions. It is not magnetic and has a hardness value of about four. It is definitely ground on about 10% of its surface area. There is one main flat surface that Watt's is confident was ground. There is an adjacent smaller face that also appears ground. The piece is classified as definite pigment.

Specimen Number: 45739 Modification Assessment: Definite

This large chunk of ochre (34.3g) is heavily impregnated with salt and is very friable. It has fragmented into four pieces and the surfaces show some evidence of wear. It has clay, silt, and sand sized particles with abundant fine grained mica inclusions. It is not magnetic and has a hardness value of about three. The piece is definitely ground on about 50% of its surface area. There is one main flat surface parallel to the pieces bedding. There is a beveled surface on one edge and another beveled facet on the opposite surface. Watts classified the piece as definite pigment.

Specimen Number: 59537 Modification Assessment: Definite

This relatively fresh chunk of ochre was recovered from the 10mm sieved fraction. It is moderately cemented with sand and silt sized particles and moderate amounts of fine grained mica inclusions. It is not magnetic and has a hardness value of three. It is definitely ground on about 25% of its surface area. There is one smooth flat face with visible striations. The piece was classified as definite pigment.

Specimen Number: 111496 Modification Assessment: Definite

This relatively fresh chunk of ochre is moderately cemented. It has clay and silt sized particles with moderate amounts of very fine grained mica inclusions. The piece is not magnetic and has a hardness value of about four. The piece is definitely ground over about 25% of its surface area. There is one main flat surface but no visible striations. Watts describes one tip as “nibbled” through utilization. The piece is classified as definite pigment.

Specimen Number: 111505 Modification Assessment: Probable

This chunk of ochre was recovered from the 3mm sieved fraction. Watts describes it as possible manganese as it is black. It has moderately worn surfaces and is moderately cemented. The piece has clay sized particles with trace amounts of very fine grained mica inclusions. The piece is not magnetic and has a hardness value of about three. The piece is probable ground over about 5% of its surface area. There is a remnant of a flat face on the distal end and possible grinding along a ridge above a natural groove along the long axis. Watts classified the piece as highly probable pigment.

There were 15 pieces of ochre from the LB Sand 2. All the pieces are very small, less than 0.5g (Fig. 4.15) and all but one were recovered from the 3mm sieved fraction. All were described as fresh. None of the pieces are magnetic and hardness values ranged from three to five (Table 4.29). Colors included various shades of brown, red brown, yellow brown, gray and white. All the pieces were classified as probable or possible pigments (Table 4.30). None of these pieces had evidence of modification

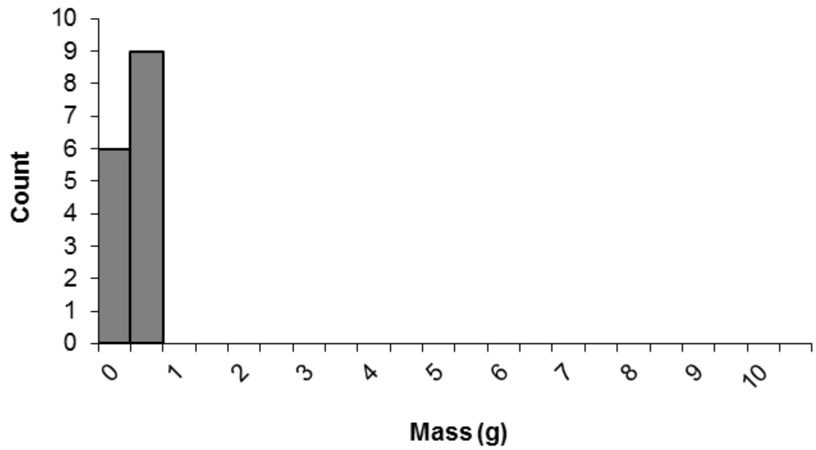

Fig. 4.15. LB Sand 2 mass of fragments

Table 4.29
LB Sand 2 hardness values

Hardness	Count	%
1	0	0.00
2	0	0.00
3	10	66.67
4	4	26.67
5	1	6.67
6	0	0.00
	15	100.00

Table 4.30
LB Sand 2 pigment assessment

Pigment	Count	%
Definite	0	0.00
Highly Probable	0	0.00
Probable	12	80.00
Possible	3	20.00
Doubtful	0	0.00
Not Pigment	0	0.00
	15	100.00

PP5-6 description

To date, 507 pieces of ochre have been cataloged from PP5-6. Of these, 306 are plotted finds and 201 are fragments recovered from the 10mm sieve. These fragments total to approximately 1784g of ochreous material (Table 4.31). Material from the 3mm and 1.5mm sieves was not included in this project as sorting of the material is still in progress. Material from excavations in Oct/Nov 2010 and later are also not included here as they had not been cataloged at the time of this project. The exception is a handful of plotted ochre pieces that were identified in the field in 2010 and were set aside. These are included here. The full suite of data attributes were recorded for all fragments that were larger than 3mm. For smaller pieces, attributes were collected when possible. Material from the intact stratigraphic aggregates is described below (BLSR, LSO, Overburden, Slopewash and Disturbance are not discussed as these are known to be out of context).

Table 4.31
Mass and density of ochre finds at PP5-6 from major stratigraphic aggregates

Excavation Area	*Aggregate*	*N*	*Total mass (g)*	*Density (g/m^3)*
Long Section	RBSR	68	270.8	72.5
	OBS	20	146.0	125.0
	DBCS	131	293.1	1755.4
	BCSR	17	61.5	586.0
	SGS	12	24.6	724.2
	SADBS	38	112.1	225.5
	ALBS	20	36.2	95.2
	LBSR	34	58.5	61.5
	BLSR	65	251.2	165.6
	LSO	5	73.9	6.8
	Overburden	13	18.5	0.7
	Slopewash	19	169.2	189.5
	Disturbance	25	73.3	0.3
Northwest Remnant	All	40	194.7	631.2
Total		***507***	*1783.6*	*58.7*

The Long Section

Light Brown Sand and Roofspall Thirty-four pieces of ochre have been cataloged from the LBSR, 17 plotted finds and 17 pieces from the 10mm sieves. Of these finds, 29 were large enough for complete coding. The remaining 5 samples were coded on any attributes that were possible to discern. All but one fragment from this aggregate had a mass less than 5g (Fig. 4.16). Overall the assemblage from this aggregate was classified as fresh or with minor to moderate amounts of rounding and discoloration. Despite the existence of well-preserved hearths in this aggregate very few of the samples appeared obviously burnt. However, many of the pieces did have concreted ashy sediment adhering to their surfaces. Over 70% of the pieces recovered from this unit had hardness values less than 3 on the modified Moh's scale (Table 4.32). Therefore, the majority of material would have been relatively easy to reduce to powder for use. In conjunction, 80% of the pieces had good to mediocre staining power when streaking ceramic plates. All but seven pieces are categorized as definite to possible pigment (Table 4.33)

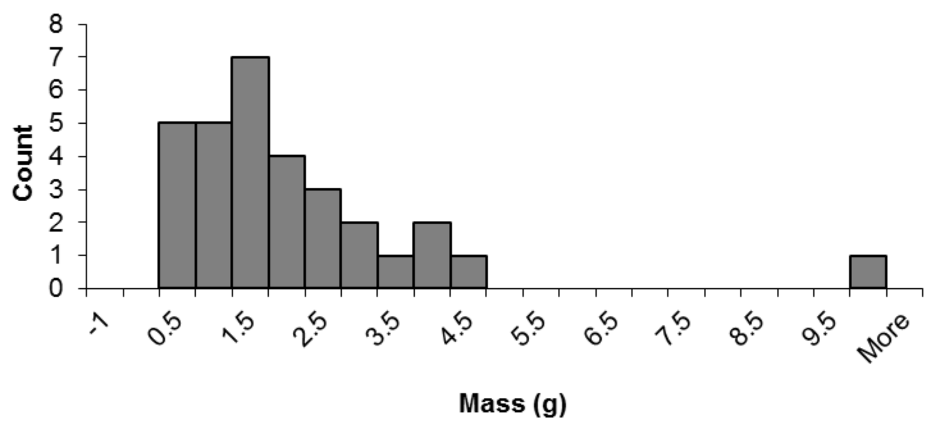

Fig. 4.16. LBSR mass of fragments

Table 4.32
LBSR hardness values

Hardness	count	%
1-3	22	70.97
3-5.5	6	19.35
5.5-6.5	3	9.68
>6.5	0	0
	31	100

Table 4.33
LBSR pigment assessment

Pigment	Count	%
Definite	3	8.82
Probable	13	38.24
Possible	11	32.35
Doubtful	5	14.71
Not Pigment	2	5.88
	34	100.00

Twenty-seven of the 34 fragments from this aggregate showed no evidence of utilization. Of the seven that suggested utilization, four were definite and three were possible. These are described individually below.

Specimen Number: 257288 Modification Assessment: Definite

This specimen is a chunk of sandy-silty material with small mica inclusions. It is described as moderately cemented with moderate discoloration on the surface. The piece has a hardness of 1-2 with an earthy luster, is not magnetic, and has good staining power. The specimen has 4-5 concave flaked facets and one possible notch.

Specimen Number: 257400 Modification Assessment: Definite

This specimen is a chunk of moderately cemented ochre with some ashy sediment still adhering. It is not magnetic, has an earthy luster, and a hardness of about 2 on the modified Mohs scale. The piece has been ground and scraped over about 20% of its surface area. The modification are visible on the exposed (clear of adhering sediment) edge. The main portion is ground and flat and scrape marks are visible just on the edge which is concave. More modification might exist under the adhering matrix. There is an exposed flaked portion on the bottom of the piece that has possible scrape marks as well. This piece could definitely have served as pigment.

Specimen Number: 257443 Modification Assessment: Definite

This specimen is a chunk of moderately cemented fresh fine grained siltstone. The piece is not magnetic, has an earthy luster with mica inclusions (visible only at 40X magnification), and a hardness value of about 1. The ochre was described as having good staining power when streaking. The piece has been flaked and possibly scraped or ground. 100% of the piece is modified as it appears to be a piece of angular debris resulting from flaking action. There are a few possible striation but these are not definite. 3 “modified” faces exist forming a triangular fragment. One face is flat, one convex, and one concave. This piece was classed as probable pigment.

Specimen Number: 257444 Modification Assessment: Definite

This ochre fragment is a tabular piece of fresh fine grained moderately cemented siltstone. It is not magnetic, has an earthy luster with small mica and quartz inclusions, and has a hardness of about 1. The piece has good staining power when streaking. The piece appears to be a broken flake blade with at least 2 flake scars. There are no other obvious modifications but it looks like the whole piece was not very large. This specimen has been classed as probable pigment.

Specimen Number: 131512.1 Modification Assessment: Possible

This chunk of moderately cemented siltstone has minor rounding and evidence of exposure to heat. The piece is not magnetic, has an earthy luster with small mica inclusions and a hardness value of about 1. The piece has good staining power when streaking. It has been possibly scraped or ground over about 40% of the piece. The modification is not certain as there are no clear striations but the one surface is unnaturally flattened. The striations may have faded due to weathering or the piece may have been rubbed after grinding. The piece was classed as definite pigment.

Specimen Number: 133281 Modification Assessment: Possible

This chunk of well cemented siltstone has an ashy sediment adhering to it. The piece is not magnetic, has a hardness value of about 3, and an earthy luster with small mica inclusions. This ochre fragment has good staining power. It is possibly a flake of ochre struck off a larger piece. It could probably have been used for pigment.

Specimen Number: 257449 Modification Assessment: Possible

This fragment is a chunk of well cemented silty-sandy material with moderate discoloration or patina. It is not magnetic and has a hardness of 5.5 to 6.5. The luster can be described as earthy in some areas but almost submetallic in others. The piece stains well and is possibly ground on about 20% of its surface. One surface is flat but has no obvious striations to make the grinding definite. This piece was probably used as pigment.

Ashy Light Brown Sand Twenty pieces of ochre come from the ALBS including 19 plotted finds and 1 piece from the 10mm sieve. Of these, 17 were fully coded. The remaining three were coded on any attributes possible. The majority of fragments weighted less than 5g (Fig. 4.17). Overall, the assemblage was described as fresh but with ashy concreted sediment adhering. Some sediment was removed but it was difficult to completely clean the pieces without damaging the surfaces erasing any potential evidence of use. The pieces were all described as moderately to well-cemented. Only 42% of this collection had hardness values less than 3 (Table 4.34). The remaining fragments had hardness values between 5.5 and 3. It would have required more effort to reduce these pieces to powder. Staining power was quite different from the LBSR. Only about 61% of the material from this aggregate had a good or mediocre streak. The remaining material had a streak that was described as poor to nonexistent. All but seven pieces were described as possible to definite pigment (Table 4.35).

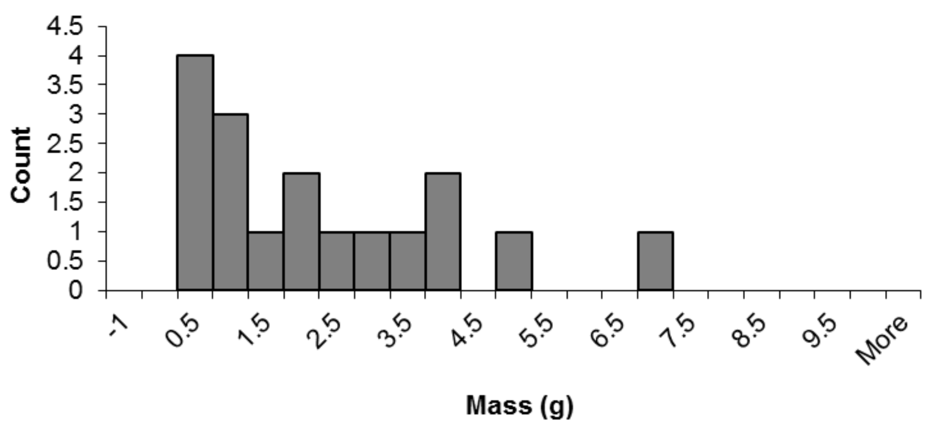

Fig. 4.17. ALBS mass of fragments

Table 4.34
ALBS hardness values

Hardness	Count	%
1-3	8	42.11
3-5.5	11	57.89
5.5-6.5	0	0
>6.5	0	0
	19	100

Table 4.35
ALBS pigment assessment

Pigment	Count	%
Definite	2	10.00
Probable	6	30.00
Possible	5	25.00
Doubtful	2	10.00
Not Pigment	5	25.00
	20	100.00

Of the twenty pieces of ochre from the ALBS, 11 were classified as unutilized. Four fragments were classified as definitely modified, 2 as probable, and 3 more as possibly modified. These are described below.

Specimen Number: 139333 Modification Assessment: Definite

This well cemented flake of ochre has a silt-sand texture. There is some ashy sediment adhering which is common for this aggregate. The piece is magnetic and has a hardness of 1-2. The luster is earthy with some small mica inclusions. The piece gives only a moderate streak but is definitely ground on 1 facet taking up approximately 50% of its surface area. The grinding occurs on a flat to convex surface on the cleaner side of the fragment. It was not possible to remove all the ashy sediment without compromising evidence for utilization. It is entirely possibly the piece is ground on the opposite surface as well.

Specimen Number: 172814 Modification Assessment: Definite

This flake like piece of ochre has a silt-sand texture and is well cemented. The piece is mostly fresh with some ashy sediment adhering that could not be removed. The piece is not magnetic and has a hardness value of 1 with an earthy luster and frequent small mica inclusions. The piece has good staining power and is definitely flaked. The whole piece is a flake and two previous flake scars are visible. This piece is similar to several other pieces found in this lot. The material could probably have been used as pigment.

Specimen Number: 172814.1 Modification Assessment: Definite

This flake of material is similar to 172814. It is well cemented with sand-silt sized particles. Some ashy matrix adheres to the specimen. It is not magnetic and has a hardness of 3.5 to 5.5. The luster is earthy with frequent small mica inclusions. The piece leaves a good stain. The piece has been flaked off a larger fragment and there are two possible flake scars. This material could probably have been used as pigment.

Specimen Number: 172854 Modification Assessment: Definite

This specimen is also a flake with some ashy matrix that could not be removed. Again the texture is sand-silt and the piece is well cemented and not magnetic. The hardness value falls between 2.5 and 3.5. The texture is earthy with small mica inclusions and the fragment leaves a good streak. The piece has several flake scars from previous removals as well as two possible notches. This material appears to be very similar to 172814 and 172814.1.

Specimen Number: 156972 Modification Assessment: Probable

This specimen is a chunk of well cemented sandy-silty material. The piece appears fresh but as some ashy sediment adhering to it. The ochre is not magnetic and has a hardness value between 3.5 and 5.5. IT has an earthy luster with small mica inclusions and leaves a good streak. The piece is flaked over about 70% of its surface area. Five to six flake scars were identified leaving concave surfaces. The material is hard but relatively fine grained and probably could have been used as pigment.

Specimen Number: 172814.2 Modification Assessment: Probable

This flaked piece is moderately cemented sandy-silty material with some ashy matrix adhering. The piece is not magnetic and has a hardness of about 1. It has an earthy luster, small mica inclusions and leaves a good streak. The potential flaking of this piece is not as clear as the other two pieces plotted with it (172814 and 172814.1) but the material is clearly the same and the material could probably have been used as pigment.

Specimen Number: 169724 Modification Assessment: Possible

This tabular piece of coarse grained sandstone is fresh and moderately cemented. It is not magnetic and has a hardness of 3.5 to 5.5. The piece has an earthy luster with small mica and medium sized quartz inclusions. It leaves only a mediocre streak. The piece has been possibly scraped over about 40% of its surface area but due to the coarseness of the material it is not certain. There is one flat redder fresher face where the modification is thought to exist. The piece could possibly have been collected as pigment but it is of lower quality.

Specimen Number: 178324 Modification Assessment: Possible

This chunk of shale is moderately cemented with minor rounding. It is not magnetic and has a hardness of 1. The piece has an earthy luster with small mica inclusions. It leaves a streak but the color is very light. It is possibly ground on about 40% of its surface area. There are some possible striations on the largest flat surface but they are not clear enough to be certain. Although the streak color is quite light it also has a sparkly quality and should not be ruled out at possible pigment.

Specimen Number: 215481 Modification Assessment: Possible

This chunk of well cemented sandy-silty material shows minor rounding and possible burning. The piece is not magnetic and has a hardness of about 2. There is an earthy luster with small mica inclusions and a good quality streak. The piece is possibly ground on 1 flat surface over about 10% of its surface area. Striations are not clear but the piece is probably useable as pigment.

<u>Shelly Ashy Dark Brown Sand</u> Thirty-eight pieces come from the SADBS including 31 plotted finds and 7 pieces from the 10mm sieve. It was possible to fully code only 28 of the pieces from the SADBS. Any details possible were recorded for the remaining pieces. The material from the SADBS is quite fragmented compared to other aggregates (Fig. 4.18). Only a handful of samples

were more than 3 grams. The largest of which (42g) barely left a streak and was not classified as pigment. Six of the plotted finds cataloged as ochre were only collections of ochre powder mixed with sediment. These were not weighed since it was impossible to separate the powder from the sediment. Most of the ochre fragments from this aggregate had dark ashy material adhering. It was not possible to remove all this sediment. Many of the pieces from this aggregate were also described as possibly burnt. Most of the ochre was described as moderately to well-cemented. Only 5 pieces were classed as friable. Most of the ochre from this aggregate had a hardness of less than 3, about 62% (Table 4.36). Another 21% had hardness between 3 and 5.5. The remaining 17% were harder than 5.5. About 55% of the collection had good to mediocre staining power with the remainder leaving no streak or a poor streak. Twenty-seven of the pieces could be classified as possibly to definitely useable as pigment (Table 4.37).

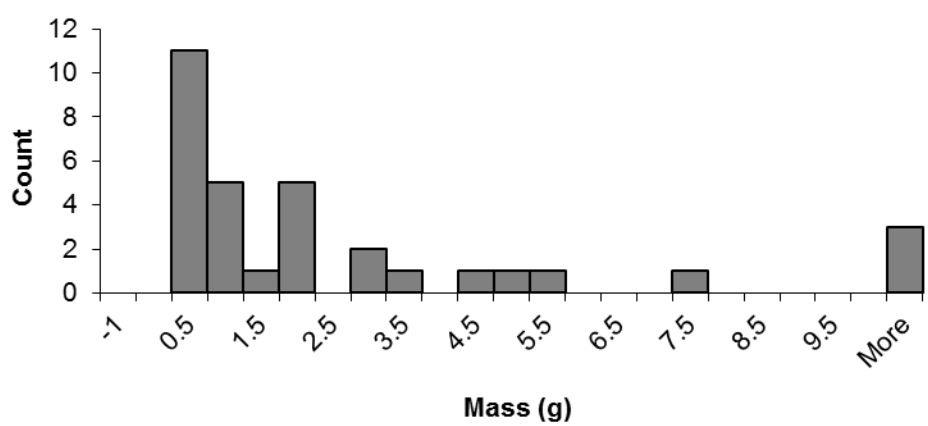

Fig. 4.18. SADBS mass of fragments

Table 4.36
SADBS hardness values

Hardness	count	%
1-3	18	62.07
3-5.5	6	20.69
5.5-6.5	4	13.79
>6.5	1	3.45
	29	100

Table 4.37
SADBS pigment assessment

Pigment	Count	%
Definite	1	2.63
Probable	8	21.05
Possible	18	47.37
Doubtful	7	18.42
Not Pigment	4	10.53
	38	100.00

Of the thirty-eight pieces of ochre from the SADBS, 34 were classified as unutilized. Some of these pieces were simply too small to be expected to preserve identifiable evidence of use. Some of these finds were also powder which may in fact be evidence of use. However, in the absence of stained grinding stones, it is difficult to determine if the power was intentionally created or resulted from post depositional processes. Two fragments were classified as definitely modified and another two were possibly modified. These are described below.

Specimen Number: 120218 Modification Assessment: Definite

This chunk of well cemented sandstone is fresh. It is not magnetic and has a hardness of 5.5 to 6.5. The luster is earthy with small mica inclusions and the piece has poor staining power leaving almost no steak. The piece has been definitely flaked on one side, about 40% of its surface area. This side is borderline silcrete while the other side of the piece is better described as ochre. There are three clear flake scars on the "silcrete" side leaving concave surfaces. The ochreous side of the piece is sandy and would not be very useful as pigment. It is possible the piece was being tested as either lithic raw material or ochre raw material.

Specimen Number: 136896 Modification Assessment: Definite

This chunk of well cemented sandy-silty material still has some ashy sediment adhering. The piece is not magnetic and has a hardness value between 1 and 2.5. The luster is earthy with small mica inclusions. The piece has good staining power. It is definitely ground over about 40% of the piece with clearly visible striations. An adjacent flat face to the ground face may also be modified but it is not possible to tell due to adhering ash.

Specimen Number: 140806 Modification Assessment: Possible

This chunk of rounded sandy-silty material is well cemented and not magnetic. It has a hardness value between 3.5 and 5.5. The luster is earthy with small mica inclusions and the piece has a poor streak lacking staining power. This piece of ochre is possibly polished over about 25% of its surface. There is one convex polished surface which is also the reddest portion of the piece. It is also possible that this rounding polish is due to post depositional effects. The piece is only classified as possible pigment due to the weak streak.

Specimen Number: 148626 Modification Assessment: Possible

This chip of moderately cemented sandy ochre shows evidence of rounding and still has some ashy sediment adhering. The piece is not magnetic, has a hardness value between 1 and 2, and has an earthy luster with small mica inclusions. This specimen leaves a mediocre streak. The piece has a possible groove visible on a patch of ochre free of sediment. Because the piece is very small the grooves assessment is not certain. The piece was inferred to be possible pigment waste.

<u>Orange Brown Sand 1</u> Twenty ochre pieces were found in the OBS1. Eight of these are plotted finds and 12 are from the 10mm sieve. It was possible to code 19 of the pieces from the OBS1. Most pieces are less than 5 grams with a few larger than 10 grams (Fig. 4.19). The pieces are mostly fresh with some evidence of moderate discoloration and rounding. Five pieces were identified as possibly burnt. All but five pieces were described as moderately to well-cemented. The remaining five were classified as crumbly or friable. Most pieces have hardness between 1 and 3 (Table 4.38) and all but one have hardness less than 5.5 and are therefore capable of producing at least a poor streak. All but three pieces could be described as possible to definite pigment (Table 4.39).

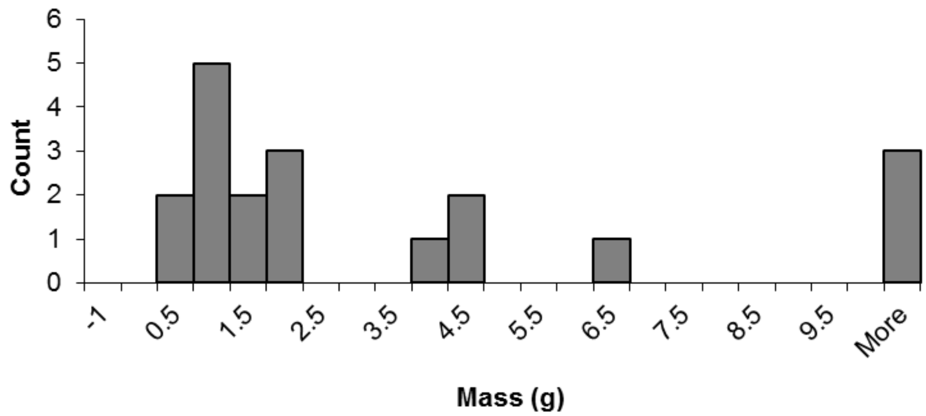

Fig. 4.19. OBS1 mass of fragments

Table 4.38
OBS1 hardness values

Hardness	Count	%
1-3	13	68.42
3-5.5	5	26.32
5.5-6.5	1	5.26
>6.5	0	0
	19	100

Table 4.39
OBS1 pigment assessment

Pigment	Count	%
Definite	3	15.00
Probable	8	40.00
Possible	6	30.00
Doubtful	3	15.00
Not Pigment	0	0.00
	20	100.00

Of the twenty pieces from the OBS, 17 were classified as unutilized and 3 were classified as definitely utilized. These are described below.

Specimen Number: 257320 Modification Assessment: Definite

This chunk of ochre has sand-silt sized particles and is moderately cemented. There is some moderate rounding and the piece is possibly burnt. The ochre is not magnetic, has a hardness of 1 and has an earthy luster with small mica inclusions. The piece leaves a good streak. This piece has definite evidence of scraping over about 10% of its surface area. There is one concave surface on the edge of the piece on the wider side with scrape marks preserved. It is possible more modifications existed but the piece looks worn and marks may have been lost. The piece is described as definite pigment.

Specimen Number: 257321 Modification Assessment: Definite

This chunk of ochre has sand-silt sized particles, is moderately cemented, and appears to have been exposed to fire. It is not magnetic, has a hardness value between 1 and 2, and has an earthy luster with small mica inclusions. The piece leaves a good streak and is definitely ground on about 10% of its surface area. There is a flat surface with obvious striations at the base of the piece opposite the tip. The piece is described as definite pigment.

Specimen Number: 257355 Modification Assessment: Definite

This sandy-silty well cemented flake of ochre appears relatively fresh. It is not magnetic and has a hardness of about 2. The luster is earthy with frequent mica inclusions. The piece leaves a mediocre streak but is definitely ground over about 20% of its surface area. There are clear striations running along the rounded smoothed edge of the piece. The striations run over both red and yellow coloring.

It appears the piece has broken off a larger ochre fragment perhaps during processing. It has been classified as definitely useable for pigment.

Shelly Gray Sand There are twelve cataloged ochre pieces from the SGS including 8 plotted finds and 4 10mm fragments. 9 of these fragments were fully coded. Some attributes were recorded for the remaining fragments when possible. 7 of these pieces were less than 5g (Fig. 4.20). The pieces were mostly described as fresh but two had minor rounding. Two others are possibly burnt. Of the nine pieces described, five were moderately to well cemented and the remaining four were quite friable or crumbly. Hardness was recorded for all 12 ochre pieces from the SGS. 8 pieces had a hardness below 3 and another three had a hardness between 3 and 5.5 (Table 4.40). All these pieces could conceivably be reduced to powder. Only one piece had a hardness greater than 6.5. Only two fragments were not likely usable as pigment (Table 4.41)

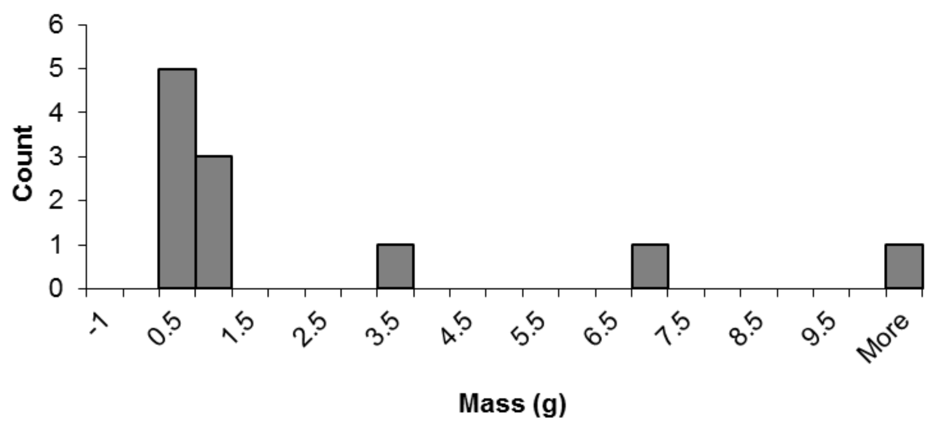

Fig. 4.20. SGS mass of fragments

Table 4.40
SGS hardness values

Hardness	Count	%
1-3	8	66.67
3-5.5	3	25
5.5-6.5	0	0
>6.5	1	8.33
	12	100

Table 4.41
SGS pigment assessment

Pigment	Count	%
Definite	2	16.67
Probable	5	41.67
Possible	3	25.00
Doubtful	1	8.33
Not Pigment	1	8.33
	12	100.00

Of the 12 pieces of ochre identified in the SGS, 3 pieces were too small to determine use wear reliably and another 6 pieces were classified as unutilized. Two pieces were classed as definite and one as probable. These are described individually below.

Specimen Number: 138303 Modification Assessment: Definite

This chunk of sandy-silty moderately cemented ochre has minor rounding. It is not magnetic, has a hardness of about 1, and an earthy luster with small mica inclusions. The piece leaves a mediocre sandy streak but it is definitely ground over about 50% of its surface area. The piece is heavily worked with most striations on the flat surfaces running parallel to the length of the piece. There are also some striations running perpendicular towards the wider end. This piece is described as definitely useable for pigment.

Specimen Number: 163079 Modification Assessment: Definite

This chunk of coarse sandstone is rounded and rather crumbly. It is not magnetic and has a hardness value around 1. The piece has an overall earthy luster with small mica inclusions and visible quartz grains. Streak could not be recorded as the piece just crumbed. Despite its apparent poor quality the piece has been modified. It appears to be ground over about 40% of its surface. The area is very flat but no striations are preserved. Striations were rarely visible on material of this quality in the experimental collection so this is not surprising. The surface identified as ground is opposite the surface with sediment still adhering.

Specimen Number: 164220 Modification Assessment: Probable

This chunk of silty well cemented ochre appears relatively fresh. The piece is magnetic and has a hardness value between 3.5 and 5.5. The piece has an earthy-shiny luster and leaves a mediocre streak. The piece is probably flaked over about 50% of its surface area. There are at least three noticeable flake scars. These surfaces are concave and are opposite the "cortex". The piece almost looks like silcrete it is so fine grained but the material leaves a better streak. It is classified as possible pigment.

Dark Brown Compact Sand The DBCS has 131 ochre fragments. This is the highest concentration both in numbers, mass, and density of finds for any aggregate at PP5-6. The aggregate includes 114 plotted finds and 17 pieces from the 10mm sieve. 84 fragments from the DBCS were large enough to be fully described. Many of the remaining pieces were tiny flecks of ochre or patches of powder. While most of the fragments are smaller than 5 grams, there are a handful (n=13) that are larger (Fig. 4.21). The largest fragment in the collection weights 49.69g. Many of these larger pieces had poor streaks which may explain why they were not further reduced to smaller pieces like the remainder of the collection. 40 of the pieces were described as fresh, 28 pieces had evidence of minor to moderate rounding, and 17 pieces had discoloration suggestive of exposure to fire. Only 7 fragments were described as friable or crumbly. The remaining pieces were all moderately to well-cemented. 69.89% of the assemblage had hardness values less than 3 making these pieces ideal for grinding into powder (Table 4.42). Another 21.51% had hardness values less than 5.5. 80.5% of the collection was deemed possibly to definitely useable as pigment (Table 4.43)

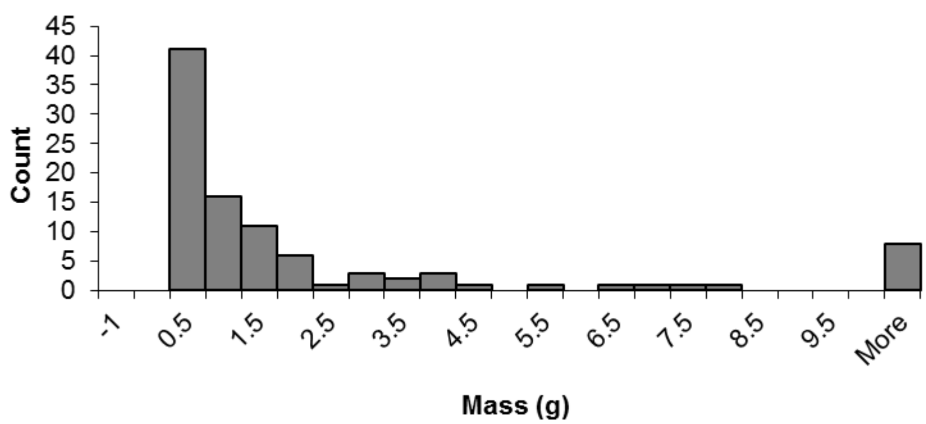

Fig. 4.21. DBCS mass of fragments

Table 4.42
DBCS hardness values

Hardness	Count	%
1-3	65	69.89
3-5.5	20	21.51
5.5-6.5	7	7.53
>6.5	1	1.07
	93	100

Table 4.43
DBCS pigment assessment

Pigment	Count	%
Definite	8	6.11
Probable	57	43.51
Possible	51	38.93
Doubtful	11	8.40
Not Pigment	4	3.05
	131	100.00

Of the 131 fragments in the DCBS, 47 pieces were too small to identify use wear. However, the presence of so many tiny fragments and of powder, would suggest that grinding or pounding was taking place in this period. Of the pieces which could be examined, 70 did not have identifiable use wear. 6 pieces were classed as possibly modified, five as probably modified, and 3 as definitely modified. These are described below.

Specimen Number: 121931 Modification Assessment: Definite

This chunk of ochre is silty, moderately cemented, and shows minor rounding. The piece is not magnetic and has a hardness value of about 1. It has an earthy luster with small mica inclusions. The piece has good staining power when streaking. It has been definitely scraped over about 40% of its surface area. The scraping can be found on the longest concave facet. The piece is classified as definite pigment.

Specimen Number: 171521 Modification Assessment: Definite

This chunk of medium grained red sandstone is moderately cemented and relatively fresh. It is not magnetic and has a hardness value of about 1. The piece has an overall earthy luster with frequent small mica inclusions and quartz grains visible. The piece has mediocre staining power but it definitely ground over about 40% of its surface area. The piece has three very flat surfaces with faint striations. The faint striations would be expected on this type of material. There is one large flat face with two smaller flat adjacent faces. The piece is described as definitely useable for pigment.

Specimen Number: 183316 Modification Assessment: Definite

This chunk of silty, well cemented ochre is possible burnt. It is not magnetic and has a hardness value of about 2 with an earthy luster and small mica inclusion. The piece has good staining power and has been definitely scraped and possibly flaked. About 40% of the surface area appears modified. There are scrapes on the convex surface as well as the smoothed edge (possibly polished). Potential flake scars exist on the opposite surface of the flat surface. The piece is described as definitely useable for pigment.

Specimen Number: 150774 Modification Assessment: Probable

This chunk of sandy-silty moderately cemented ochre is not magnetic. It has a hardness value of about 1 with an earthy luster and small mica inclusions.

The piece has good staining power and is probably ground over about 40% of its surface area. Although the piece is small there are two clearly flat adjacent faces. There are no obvious striations suggesting the piece may have also been polished. The piece is described as definitely useable for pigment.

Specimen Number: 151017 Modification Assessment: Probable

This flake of fresh sandy silty well cemented material is not magnetic and has an earthy luster with small mica inclusions. The piece leaves a very poor streak and lacks staining power. The piece appears to be a flake of ochre complete with a bulb of percussion. However, the pigment is very poor quality. It is possible the material was being tested out either as lithic raw material or as possible pigment.

Specimen Number: 166212 Modification Assessment: Probable

This chunk of sandy-silty well cemented ochre is relatively fresh. It is not magnetic and has a hardness of between 1 and 2. The piece has an earthy luster with small mica inclusions and good staining power. The piece is probably flaked over about 40% of its surface area. There are at least two concave flake scars around the edge of the piece. The piece is described as probable ochre processing debris.

Specimen Number: 257351 Modification Assessment: Probable

This yellow chunk of sandy-silty material is very friable. It has a hardness of about 1 with an earthy luster and small quartz and mica inclusions. The piece has good staining power and is probably ground and possibly polished over about

40% of its surface area. There is a very flat surface but striations are not clear despite the fairly fine grain size. There is also a groove through the middle of the ground surface. The piece is described as definitely useable for pigment.

Specimen Number: 257441 Modification Assessment: Probable

This chunk of shale like material is moderately cemented and shows minor discoloration. The piece is not magnetic, has a hardness value of 1 and has an earthy luster with small mica and quartz inclusions visible. The piece has good staining power and is probably ground and possibly polished over about 50% of its surface area. There are two smooth rounded surfaces but no clear striations. The other two surfaces of the piece appear to be broken and unmodified. The piece is described as probable pigment.

Specimen Number: 119213 Modification Assessment: Possible

This chunk of sandy well cemented material is relatively fresh. It is not magnetic and has a hardness of 5.5 to 6.5. The luster is earthy with small mica. The piece gives a mediocre streak which is difficult to get. The piece is possibly ground over about 10% of its surface area. There is a small flattened point opposite the largest triangular face. The piece is classed only as possible pigment due to its hardness and difficulty in streak. It would be difficult to reduce this material to useable powder.

Specimen Number: 122117 Modification Assessment: Possible

This chunk of moderately cemented silty ochre shows minor rounding and is not magnetic. It has a hardness value between 1 and 2 with an earthy luster and small mica inclusions. The piece has good staining power and is possibly ground or scraped over about 40% of its surface area. There is one flat facet, the second largest face on the piece. The ochre specimen is likely shale and is of good quality. It is definitely useable as pigment.

Specimen Number: 132372 Modification Assessment: Possible

This tabular fragment of sandy well cemented material has minor rounding. The piece is not magnetic and has a hardness value of about 1. The piece has an earthy luster with small mica inclusions. It has good staining power and is possibly ground over about 50% of its surface area. There is one flat smoothed face but it is not convincing due to its small size. However, the piece is definitely useable as pigment.

Specimen Number: 149739 Modification Assessment: Possible

This chunk of sandy-silty moderately cemented material shows minor rounding. It is not magnetic and has an earthy luster with small mica inclusions. The piece has good staining power and is possibly ground over about 40% of its surface area. The piece is small but the largest face is very flat. It is possible that this piece broke off a larger fragment during processing. The piece is described as probable pigment.

Specimen Number: 168843 Modification Assessment: Possible

This lump of medium grained reddish sandstone is moderately cemented and rounded. It is not magnetic and has a hardness value of about 1. The overall luster is earthy with small mica and quartz inclusions. The piece has good staining power and has a possible notch or groove. The piece is described as probable pigment. It has good color although it is a bit sandy.

Specimen Number: 257278 Modification Assessment: Possible

This tabular piece of well cemented shale is relatively fresh. It is not magnetic and has a hardness value of about 1. The luster is earthy with small mica inclusions. The piece has good staining power and is possibly ground over about 50% of its surface area. However, natural wear could not be ruled out and no obvious striations were detected. The piece is definitely of sufficient quality for pigment use.

Black Compact Sand and Roofspall There are 17 ochre pieces from the BCSR with 8 plotted finds and 9 pieces from the 10mm sieve. 15 of these fragments were fully described. 12 pieces were smaller than 5.5g while four were larger (Fig. 4.22). One exceptionally large piece was nearly 30g. Weathering ranged from fresh pieces to some with minor discoloration and rounding. Three pieces appeared burnt but this could also be related to the darkness of the sediment. All pieces were moderately to well cemented. All but one sample had a hardness of less than 5.5 (Table 4.44). The largest piece (nearly 30g) had a hardness value between 5.5 and 6.5. This may explain why this larger piece of ochre was not further reduced although the piece was tested (see modification below). All pieces were classified as probable or possible pigment (Table 4.45)

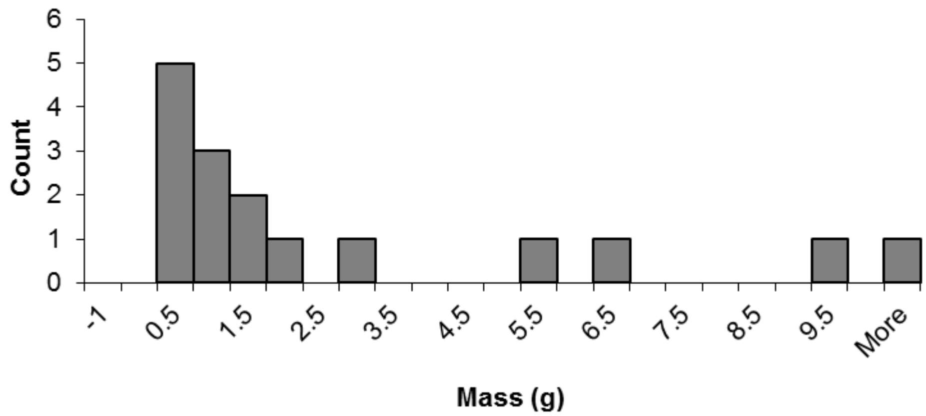

Fig. 4.22. BCSR mass of fragments

Table 4.44
BCSR hardness values

Hardness	Count	%
1-3	9	60
3-5.5	5	33.33
5.5-6.5	1	6.67
>6.5	0	0
	15	100

Table 4.45
BCSR pigment assessment

Pigment	Count	%
Definite	0	0.00
Probable	12	70.59
Possible	5	29.41
Doubtful	0	0.00
Not Pigment	0	0.00
	17	100.00

Of the 17 fragments from the BCSR, 15 were large enough to investigate use-wear. Two of these pieces were classed as definitely modified and two were classes as possibly modified. The remaining 11 fragments were unutilized. The definite and possible pieces are described below.

Specimen Number: 257434 Modification Assessment: Definite

This chunk of course sandy ochre is moderately cemented and shows minor discoloration and rounded edges. The piece is not magnetic and has a hardness value between 3.5 and 5.5. It has an earthy luster with small mica inclusions and larger quartz inclusions. It has good staining power and is definitely ground and polished and possibly notched. The modifications cover about 40% of the surface area of the fragment. There are two adjacent rounded polished sides with a wide (~3.3mm) and deep groove cutting through one face. These faces are flat to slightly convex. This piece is classified as definite pigment.

Specimen Number: 257439 Modification Assessment: Definite

This chunk of moderately cemented coarse sandy ochre shows moderate discoloration. The piece is not magnetic and has a hardness between 5.5 and 6.5. The piece has an earthy luster with a lot of quartz grains visible at 10x magnification. The pieces leaves a mediocre streak but is definitely ground over about 30% of its surface area. The piece is ground on one side, the upper portion near the tip. The piece was given a pigment classification of possible.

Specimen Number: 257438 Modification Assessment: Possible

This tabular piece of moderately cemented ochre is fine grained and shows minor discoloration and rounded worn edges. The piece is not magnetic, has a hardness of about 1, and an earthy luster with small mica inclusions and slightly larger quartz inclusions. It has good staining power and is possibly ground over about 40% of its surface area. One surface is flat with possible striations. The piece was inferred to be probable pigment due mainly to color and grain size.

Specimen Number: 257448 Modification Assessment: Possible

This flake of moderately cemented shale like material is fairly fresh. The piece is not magnetic and has an earthy to waxy luster with small mica particles. The piece has good staining power and is possibly scraped. There are 4-5 possible scrapes identified on the duller surface. Two are near the rounded edge of the left side and the others are lower and further to the right. Because there are so few scrapes it is possible this piece was broken off a larger piece during scraping or that the marks are post depositional in nature. The piece was inferred to be probable pigment.

Red Brown Sand and Roofspall There are 68 cataloged ochre pieces from the RBSR with 11 plotted finds and 57 pieces from the 10mm. 66 of the fragments were fully coded. The RBSR is considered mostly disturbed with the exception of a few intact horizons where most of the archaeological material was recovered. Much of the material was removed without plotted artifacts. Most of the fragments are smaller than 5.5g but there is a fair amount of pieces larger than 10g (Fig. 4.23). About half the pieces were described as having minor to moderate rounding perhaps indicative of the disturbance of the sediments. Another 6 pieces were described as possibly burnt. The remaining pieces were described as fresh. The majority of fragments had a sandy to silty texture while 6 were described as coarse sand. Only one piece was described as friable. All others were either moderately or well cemented. 49 samples had a hardness value less than 5.5, and 15 had a hardness value between 5.5 and 6.5 (Table 4.46). These harder pieces would have been difficult to reduce to powder. 82.4% of the pieces described were deemed possibly to definitely useable as pigment (Table 4.47).

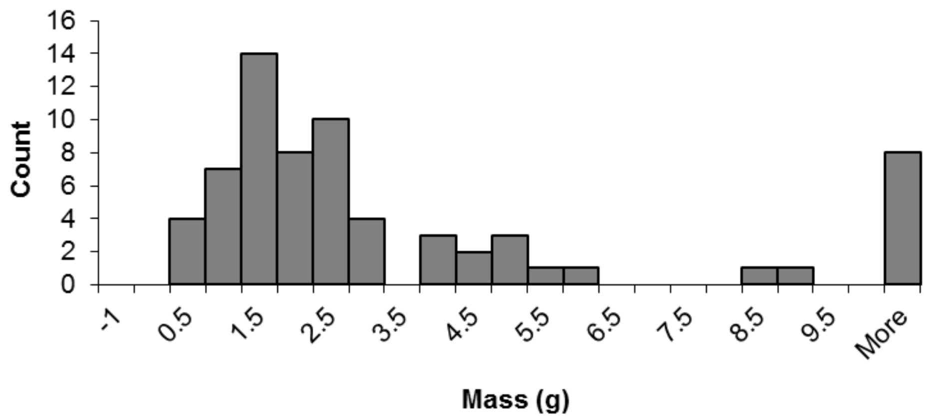

Fig. 4.23. RBSR mass of fragments

Table 4.46
RBSR hardness values

Hardness	Count	%
1-3	41	64.06
3-5.5	8	12.5
5.5-6.5	15	23.44
>6.5	0	0
	64	100

Table 4.47
RBSR pigment assessment

Pigment	Count	%
Definite	9	13.24
Probable	29	42.65
Possible	18	26.47
Doubtful	10	14.71
Not Pigment	2	2.94
	68	100.00

Of the 68 RBSR fragments, 66 were large enough to investigate for use wear. 52 of these were deemed unutilized. 6 were classified as definite, 2 as probable, and 6 as possible. These are described in detail below.

Specimen Number: 149632 Modification Assessment: Definite

This flake of fresh sandy moderately cemented ochre is not magnetic and has a hardness value between 5.5 and 6.5. The piece has an earthy to shiny luster with small mica inclusions. It has good staining power and is definitely ground and polished over about 50% of its surface area. There are three ground faces with the most obvious striations near the tip of the largest face. The piece is heavily modified possible shale and is classified as definite pigment.

Specimen Number: 257252 Modification Assessment: Definite

This piece of moderately cemented sandy ochre shows some minor rounding. It is not magnetic and has a hardness of about 1. The piece has an earthy luster with small mica inclusions and good staining power. It is definitely ground over about 10% of its surface area. The grinding occurs on one edge. The piece is definitely useable as pigment.

Specimen Number: 257254 Modification Assessment: Definite

This chunk of silty sandstone is well cemented and possibly burnt. It is not magnetic and has a hardness between 1 and 2 on its modified face. The other side of the piece is slightly harder. It has an earthy luster with small mica inclusions and good staining power. The piece has been scraped on a smoothed (possibly ground and polished) surface which takes up about 25% of its surface area. The smooth scraped face has both yellow and red coloring. The piece is definitely useable as pigment.

Specimen Number: 257256 Modification Assessment: Definite

This chunk of silty sandstone is well cemented with some discoloration. It is magnetic and has a hardness value between 1 and 2. The piece has an earthy luster with small mica inclusions and has good staining power. The piece is definitely ground on four flat adjoining faces. The piece is heavily worked and is classed as definite pigment

Specimen Number: 257296 Modification Assessment: Definite

This tabular piece of sandy silty ochre is moderately cemented and relatively fresh. It is weakly magnetic with a hardness between 1 and 2. The piece has an earthy luster with small mica inclusions and it has good staining power. The piece has been heavily ground over about 80% of its surface area. There are 5-6 flat facets that have at least some evidence of grinding. The piece is classified as definite pigment.

Specimen Number: 257300 Modification Assessment: Definite

This tabular piece of white silty moderately cemented ochre is relatively fresh. It is not magnetic and has a hardness value between 1 and 2. The luster is earthy with rare small mica inclusions and good staining power. The piece has been flaked and ground over about 50% of its surface area. The whole piece is a flake with ripple marks visible opposite the largest face. There are two flat grinding faces on the thicker edge of the piece. This fragment is definitely useable as ochre.

Specimen Number: 257314 Modification Assessment: Probable

This flake of fresh sandy-silty well cemented material is not magnetic and has a hardness of between 3.5 and 5.5. The luster is earthy with frequent small mica inclusions. The piece has good staining power and is probably flaked over about 20% of its surface area. There are 4 possible flake scars on one edge and a few more are possible on the ventral surface. The piece has been identified as probable pigment based on streak and modification.

Specimen Number: 257359 Modification Assessment: Probable

This chunk of material is well cemented and has a silt-sand texture. The piece is mostly fresh with some possible minor rounding. It is not magnetic and has a hardness between 1 and 2. The luster is earthy and there are medium to small quartz and mica inclusions. The piece has good staining power and is probably ground over about 10% of its surface area. There is one small flat facet with crude striations just visible. The face can be found on the thinner side of the fragment. The piece is definitely useable as pigment and veins of much redder material are visible.

Specimen Number: 105404 Modification Assessment: Possible

This tabular fragment has a sandy texture, is moderately cemented and is relatively fresh. It is not magnetic and has a hardness of about 1. The luster is earthy with small mica and quartz inclusions and good staining power. The piece is possibly ground over about 50% of its surface area. There is one yellow face that is very smooth but it is too small to be certain of the modification. It is classed as probably useable as pigment.

Specimen Number: 149634 Modification Assessment: Possible

This chunk of material has a sandy texture, is well cemented, and is relatively fresh. It is not magnetic and has a hardness between 5.5 and 6.5. The piece has an earthy luster with small mica inclusions and leaves a good streak despite its hardness. The piece has been possibly ground and/or polished over about 30% of its surface area. The largest face on this piece has a clearly flattened and smoothed surface but no visible striations. This is not surprising given the sandy texture of the material. The piece has been classed as probably useable as pigment.

Specimen Number: 257270 Modification Assessment: Possible

This tabular fragment has a silty texture and is moderately cemented and relatively fresh. The piece is magnetic and has a hardness value between 1 and 2. The luster is earthy with small mica inclusions and the piece has good staining power. It has been possibly ground over about 10% of its surface area. This possible grinding occurs on the longest edge of the piece. The fragment is described as definitely useable as pigment and is visually similar to material collected from the Bokkeveld Shales.

Specimen Number: 257305 Modification Assessment: Possible

This flake of material has a silty texture and is moderately cemented with minor rounding. It is not magnetic and has a hardness value of about 1. The luster is earthy with small mica inclusions and the piece has good staining power. The piece is possible ground over about 40% of its surface area. There is one clearly flat surface with possible faint striations just visible around the edge of the surface. The piece is definitely useable as pigment.

Specimen Number: 257319 Modification Assessment: Possible

This chunk of material has a sand-silt texture and is well cemented and relatively fresh. It is not magnetic and has a hardness between 5.5 and 6.5. The luster is earthy with small mica inclusions. The piece only leaves a mediocre streak. It is possibly ground and/or polished over about 25% of its surface area. There is one convex smoothed rounded face but no clear striations were identified. It remains possible that this modification is simply rounded cobble cortex. It is classed as possible pigment only.

Specimen Number: 257338 Modification Assessment: Possible

This chunk of material has a sandy texture and is moderately cemented and possibly burnt. It is not magnetic and has a hardness value between 3.5 and

5.5. The luster is sub-metallic and the piece leaves a poor streak lacking staining power. The fragment is black all the way through. There is one possible polished surface covering about 40% of the surface area. There is one smoothed rounded surface. The piece is classified as possible pigment but because it is so burnt it is difficult to tell what the original quality of the material would have been.

The Northwest Remnant

There are forty pieces of ochre cataloged from the NWR. Because Stratigraphic Aggregates have not been determined for all units from this area all ochre is discussed together here. Most of the pieces are under five grams, although there is one large piece (144.40g) dominating the assemblage (Fig. 4.24). Most of the pieces are fresh or have minor rounding wear. There are two cases of possibly burnt specimens. Most of the pieces have a hardness value less than two (Table 4.48) and there are seven pieces that are magnetic. Most of the samples that were large enough to streak provided good staining. There were three pieces that barely streaked and another three with mediocre streaks. All but three cases were classified as definite to possible pigment (Table 4.49).

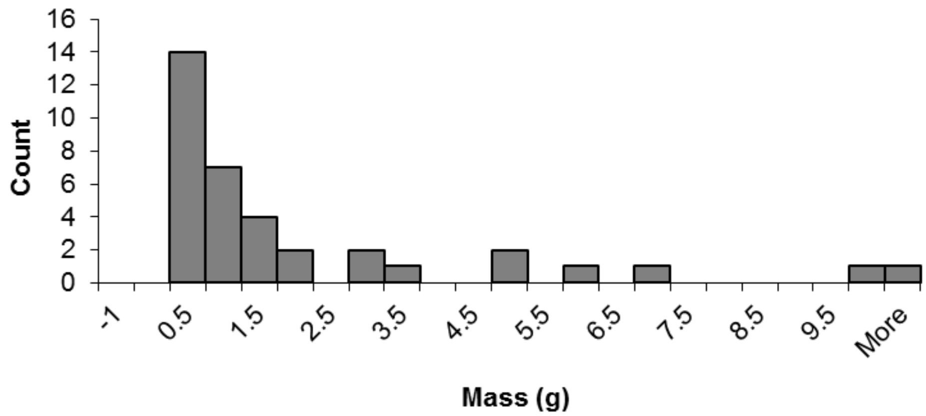

Fig. 4.24. NWR mass of fragments

Table 4.48
NWR hardness values

Hardness	Count	%
1-3	30	90.91
3-5.5	2	6.06
5.5-6.5	1	3.03
>6.5	0	0.00
	33	100.00

Table 4.49
NWR pigment assessment

Pigment	Count	%
Definite	7	17.50
Probable	22	55.00
Possible	8	20.00
Doubtful	0	0.00
Not Pigment	3	7.50
	40	100.00

There are nine cases of possible utilization from the NWR. Five of these cases are classified as definitely modified, one as probable and three as possible. These are described below.

Specimen Number: 102763 Modification Assessment: Definite

This chunk of ochre has a sandy-silty texture with small mica inclusions and is moderately cemented with minor rounding. It is not magnetic and has a hardness value of 1. The luster is earthy and the piece has good staining power. The piece is definitely ground on a very small surface (about 5% of the surface area) near the tip of the specimen. The piece is classified as definitely useable as pigment.

Specimen Number: 103028 Modification Assessment: Definite

This ochre specimen is a chunk of heavily worked sandy moderately cemented material. The piece is fresh with an earthy luster and small mica and medium quartz inclusions. The piece is not magnetic, has a hardness value of about 1, and leaves a good streak. This sample has been scraped on about 40% of its surface area. The visible striations are varied in size and depth on one flat surface. The piece is classified as definite for pigment.

Specimen Number: 103477 Modification Assessment: Definite

This chunk of ochre has a sandy-silty texture and is moderately cemented. The piece has some rounding. It is magnetic with a hardness value of 1. The luster is earthy and there are small mica inclusions. The piece has good staining power when tested on ceramic. The piece has been heavily scraped and notched on one concave to flat face. The modified surface accounts for about 30% of the total surface area. The piece could definitely have been used as pigment.

Specimen Number: 105486 Modification Assessment: Definite

This chunk of ochre has a sandy texture and is moderately cemented. The piece is magnetic and has a hardness value of 1. The luster is earthy with small mica inclusions. The piece has good staining power. It is ground on one flat surface and is definitely useable as pigment.

Specimen Number: 284006 Modification Assessment: Definite

This lump of ochre is relatively fresh with a sandy-silty texture. It is moderately cemented and has mica and quartz inclusions. The piece is not magnetic and has a hardness value of about 3.5. The piece only leaves a mediocre streak. The sample is ground on two flat surfaces. The piece is definitely useable as pigment although the unmodified surfaces seem to be poorer quality.

Specimen Number: 103190 Modification Assessment: Probable

This chip of ochre has minor rounding and a sandy-silty texture with small mica and quartz inclusions. It is moderately cemented and is not magnetic. It has a hardness value of one and leaves a good streak. The piece is probably scraped on one flat surface. The piece is small but two scrape marks were detected. The piece could definitely be used as pigment.

Specimen Number: 102438 Modification Assessment: Possible

This flake of ochre exhibits minor rounding, a sandy texture and is moderately cemented. The piece has an earthy luster with mica inclusions. The piece is not magnetic but was too small for determining hardness or for streaking.

The sample is possibly ground on two surfaces but is difficult to assess due to its small size. There is a small polished area near the tip of the specimen and on the opposite side near the base. The material could definitely be used as pigment.

Specimen Number: 102494 Modification Assessment: Possible

This chunk of ochre is slightly rounded and possible burnt. The piece has a sandy texture and is moderately cemented. It is not magnetic and has a hardness value of one. The luster is earthy and there are small mica inclusions. The piece has good staining power. There is one possible groove in a rounded surface. The material was classified as probably useable as pigment.

Specimen Number: 103699 Modification Assessment: Possible

This chunk of ochre is rounded and has a coarse sandy texture with small mica and medium to large quartz inclusions. The material is moderately cemented, is not magnetic and is fairly hard between 5.5 and 6.5 on the modified scale. The luster is earthy and the piece leaves almost no streak. The piece has been possibly polished over about 50% of its surface. This area is concave and very smooth. It is not possible to determine if this polish is natural or not. The piece is classified as not pigment based on its coarse grains, hardness, and difficulty in streaking.

Conclusion

In order for a study of ochre use to have merit, it must be demonstrated that the ochre in these sites has been utilized by MSA inhabitants. The data presented in this chapter clearly demonstrate that the assumption of ochre use in these sites is met.

At PP13B at total of 637 fragments have been identified totaling 1710.78g. 471 fragments come from the major aggregates (not including cleaning and surface deposits). By fragment count, 8.7% of this collection is definitely modified and another 3.4% is probably or possibly modified (Table 4.50). However, by mass, 48% of the collection is definitely modified and another 1.3% is probably or possibly modified (Table 4.51). The majority of this material, 89.8%, is of sufficient quality to have been used for pigment (definite to possible classifications) (Table 4.52).

Table 4.50
PP13B Frequency of utilization by number of fragments

Aggregate	Definite	Probable	Possible	Unutilized	Total
LC-MSA Lower	9	2	0	54	65
LC-MSA Middle	0	0	0	5	5
LC-MSA Upper	0	1	0	0	1
Lower Roofspall	1	0	1	44	46
Upper Roofspall	5	0	1	67	73
Shelly Brown Sand	1	0	0	9	10
Truncation Fill	1	1	1	38	41
Redeposited Dist.	4	2	1	28	35
Laminated Facies	0	0	0	4	4
LB Silt	0	0	0	4	4
DB Sand 2	1	2	0	30	33
DB Sand 3	13	1	1	57	72
DB Sand 4b	1	1	0	0	2
DB Sand 4c	0	0	0	6	6
LBG Sand 1	1	0	0	22	23
LB Sand 1	4	1	0	31	36
LB Sand 2	0	0	0	15	15
Totals	*41*	*11*	*5*	*414*	*471*

Table 4.51
PP13B frequency of modification by mass (g) and density (g/m^3)

	Aggregate	Definite		Probable		Possible		Unmodified		Totals	
		g	g/m^3	g	g/m^3	g	g/m^3	g	g/m^3	g	g/m^3
	LC-MSA Lower	44.8	84.2	0.5	0.9	---	---	76.9	144.5	122.2	229.6
North-east	LC-MSA Middle	---	---	---	---	---	---	1.4	8.1	1.4	8.1
	LC-MSA Upper	---	---	0.4	8.5	---	---	---	---	0.4	8.5
	Lower Roofspall	0.4	0.7	---	---	0.3	0.5	43.2	78.8	43.9	80.1
	Upper Roofspall	123.7	238.8	---	---	6.1	11.8	88.1	170	217.9	420.6
Eastern	Shelly Brown Sand	27.7	29.2	---	---	---	---	8.6	9	36.3	38.2
	Truncation Fill	5.6	13.7	1.2	2.9	0.2	0.5	35.7	87.1	42.7	104.1
	Redeposited Dist.	32.1	452.1	3.7	52.1	0.2	2.8	79.4	1118.3	115.4	1625.4
	Laminated Facies	---	---	---	---	---	---	1	0.8	1	0.8
	LB Silt	---	---	---	---	---	---	3.1	7.9	3.1	7.9
	DB Sand 2	228.0	1572.4	7.0	48.3	---	---	93.7	646.2	328.7	2266.9
]Western	DB Sand 3	184.5	390.9	0.5	1.1	0.1	0.2	258.5	547.7	443.6	939.8
	DB Sand 4b	0.5	10.9	---	---	---	---	0.2	4.3	0.7	15.2
	DB Sand 4c	---	---	---	---	---	---	18.6	138.8	18.6	138.8
	LBG Sand 1	51.7	69.3	---	---	---	---	37.9	50.8	89.6	120.1
	LB Sand 1	43.7	134.9	0.4	1.2	---	---	35	108	79.1	244.1
	LB Sand 2	---	---	---	---	---	---	1.7	33.3	1.7	33.3

Table 4.52
PP13 pigment assessment for all major aggregates (not including cleaning and surface collections)

Aggregate	Definite	Highly Probable/ Probable	Possible	Doubtful	Not Pigment	Total
LC-MSA Lower	10	44	2	4	5	65
LC-MSA Middle	0	2	1	0	2	5
LC-MSA Upper	0	1	0	0	0	1
Lower Roofspall	1	35	0	2	8	46
Upper Roofspall	4	57	9	2	1	73
Shelly Brown Sand	1	6	1	1	1	10
Truncation Fill	1	29	3	3	5	41
Redeposited Dist.	4	30	1	0	0	35
Laminated Facies	0	1	2	1	0	4
LB Silt	0	2	1	1	0	4
DB Sand 2	0	6	23	4	0	33
DB Sand 3	11	55	2	2	2	72
DB Sand 4b	1	1	0	0	0	2
DB Sand 4c	0	3	0	2	1	6
LBG Sand 1	1	22	0	0	0	23
LB Sand 1	4	30	1	1	0	36
LB Sand 2	0	12	3	0	0	15
Totals	*38*	*336*	*49*	*23*	*25*	*471*

There are changes in the density of ochre occurrences throughout the PP13B deposit (Fig. 4.25). Total grams of ochre per m^3 of sediment is highest for DB Sand 2, DB Sand 3 and the Redeposited Disturbance. These aggregates also have the highest density of utilized ochre (including definite, probable and possible classifications). The high density of ochre in the Redeposited Disturbance supports the conclusion that this material has been relocated from the back of the cave (Marean *et al.* 2010). In general, the degree of modification increases consistently with the total density of ochre for the aggregates. Those aggregates with higher overall ochre density also have the higher density of modified pieces.

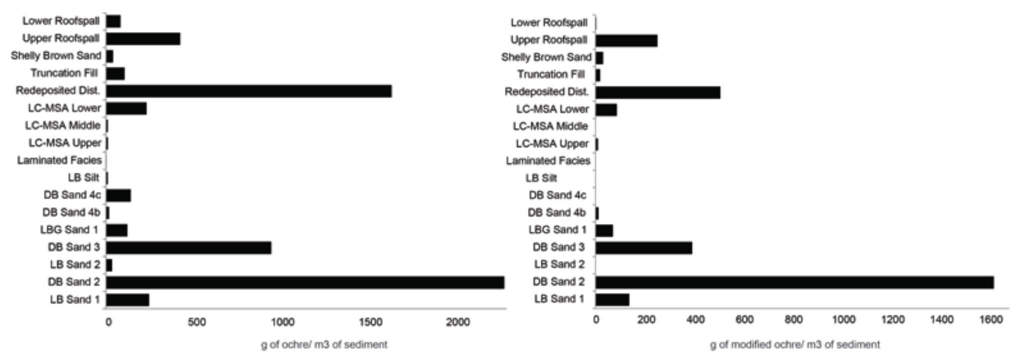

Fig. 4.25. Density of ochre at PP13B

At PP5-6 a total of 507 fragments have been identified to date for a total of 1754.83g. There are 1197.5g of ochre that come from the undisturbed aggregates presented above. By fragment count, 8.2 % of this collection is definitely modified and another 9.5% is probably or possibly modified (Table 4.53). By mass, 24% of the collection is definitely modified and another 14% is probably or possibly modified (Table 4.54). The majority of this material, 84.2%

by count, is of sufficient quality to have been used for pigment (definite to possible classifications) (Table 4.55).

Table 4.53

PP5-6 Frequency of utilization by count

Aggregate	Definite	Probable	Possible	Unutilized	Total
LBSR	4	0	3	27	34
ALBS	4	2	3	11	20
SADBS	2	0	2	34	38
OBS	3	0	0	17	20
SGS	2	1	0	9	12
DBCS	3	5	6	117	131
BCSR	2	0	2	13	17
RBSR	6	2	6	54	68
NWR All	5	1	3	31	40
Totals	*31*	*11*	*25*	*313*	*380*

Table 4.54

PP5-6 frequency of modification by mass (g) and density (g/m^3)

Aggregate	Definite		Probable		Possible		Unutilized		Total	
	g	g/m^3	g	g/m^3	g	g/m^3	g	g/m^3	g	g/m^3
LBSR	7.4	7.7	---		14.9	15.6	36.3	38.2	58.5	61.5
ALBS	15.7	41.4	0.9	2.3	9.7	25.6	9.8	25.9	36.2	95.2
SADBS	11.8	23.8	---		4.8	9.8	95.4	191.9	112.1	225.5
OBS	3.3	2.9	---		---		142.7	122.2	146.0	125.0
SGS	14.3	421.7	---		0.9	25.7	9.4	276.8	24.6	724.2
DBCS	14.6	87.6	5.4	32.3	23.2	138.8	250.0	1496.7	293.1	1755.4
BCSR	39.2	373.3	---		4.3	40.5	18.1	172.2	61.5	586.0
RBSR	26.5	7.1	36.2	9.7	53.4	14.3	154.7	41.4	270.8	72.5
NWR All	153.9	498.8	0.2	0.6	10.6	34.2	30.1	97.6	194.7	631.2

Table 4.55
PP5-6 pigment assessment for all major aggregates (not including cleaning, surface collections, and disturbed deposits)

Aggregate	Definite	Highly Probable/ Probable	Possible	Doubtful	Not Pigment	Total
LBSR	3	13	11	5	2	34
ALBS	2	6	5	2	5	20
SADBS	1	8	18	7	4	38
OBS	3	8	6	3	0	20
SGS	2	5	3	1	1	12
DBCS	8	57	51	11	4	131
BCSR	0	12	5	0	0	17
RBSR	9	29	18	10	2	68
NWR All	7	22	8	0	3	40
Totals	35	160	125	39	21	380

There are changes in the density of ochre occurrences throughout the PP5-6 deposit (Fig. 4.26). The DBCS has the highest density ochre, followed by the SGS, NWR and BCSR. Densities of modified pieces (definite, probable and possible classifications) area high in all these aggregates as well.

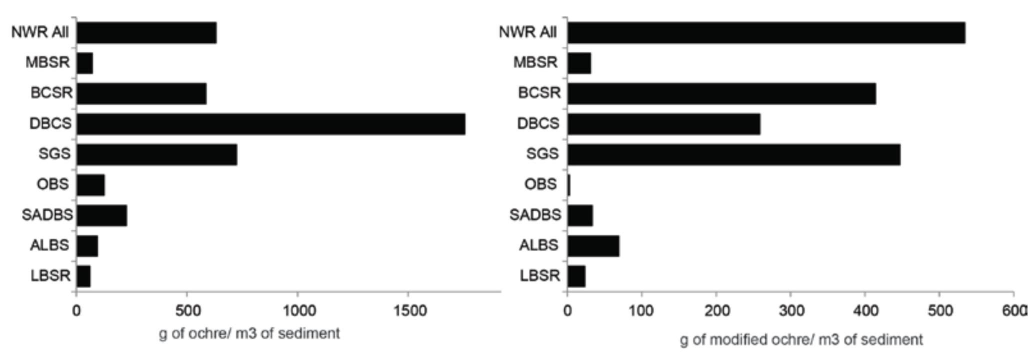

Fig. 4.26. Density of ochre at PP5-6

The total density of ochre at PP13B (not including cleaning and surface collections) is 229.5 g/m^3. The density of ochre at PP5-6 (not including disturbances and overburden material) is lower at only 163.0 g/m^3. There is more ochre recovered from PP13B. Also, more material at PP13B is modified. The total density of modified pieces is 113.3 g/m^3 while at PP5-6 it is only 61.4 g/m^3. This would suggest that ochre utilization was more intense at PP13B. The relationship of ochre density fluctuations to other changes in artifact types and environment context is further discussed in Chapter 10.

CHAPTER 5: TEST IMPLICATION 1A – GEOLOGICAL SURVEY AND CHARACTERIZATION OF POTENTIAL SOURCES

Introduction

Descriptions of each potential ochre source identified in the area will be presented below. These basic descriptions of the material are followed by results of XRD and PIXE for samples taken from these locations. These data sets are used in the next chapter to assess where on the landscape PP MSA hominids may have been collecting their ochre from.

Methods

Geological survey

Geological samples were collected from known ochre sources in the region surrounding PP. There are several small ochre occurrences within the cliff faces near the sites. Ochre also commonly occurs in Bokkeveld shale outcrops in the region as well as in association with silcrete formations. These occurrences have been mapped by the South African Geological Survey (Fig. 5.1). Following preliminary surveys in the region, these published observations proved quite reliable and they were used as the primary guide for further survey. The maps provide geological types for areas in the region. Each geological area was investigated at least in part to determine whether or not ochre was likely to be present. Areas where ochre was likely (Bokkeveld shale outcrops, silcrete formations, areas with high iron content exhibited by red soils) were then surveyed more extensively.

Fig. 5.1. South African Geological Survey maps

It is difficult if not impossible to determine the range size of MSA hunter-gatherer groups as this likely was dependent on numerous factors including population density, environmental conditions, and the abundance of resources. However, it was necessary to constrain the survey for ochre sources. A range of 30km inland from PP was established as a guideline although a large known ochre source slightly outside this region has been included here. This boundary is in accordance with range size reported for the Dobe !Kung (Lee 1965) and other African hunter-gatherer groups (Binford 2001). If preliminary sourcing results are inconclusive, the range may be expanded. Although, there is not yet convincing evidence for long distance trade in the MSA, it is theoretically possible that ochre was being traded over long distances as is common in the ethnographic literature.

The PP sites are located on the current coastline, and sea levels are known to have fluctuated during the long span of MSA occupation in the area. The possibility of ochre sources being submerged on the coastal platform must be considered. However, based on available sol ages from both sites and sea level models, it appears that the sea was relatively close (within several kilometers) to site during periods of major occupation (Fisher *et al.* 2010). Therefore, any potential sources on the coastal platform would not have been available during these times. Further, in his initial investigations of PP13B ochre, Watts identified no evidence of borings by marine organisms that would indicate coastal sources (2010). However, the potential for submerged sources has been considered throughout the project, and can be partially constrained by comparisons between archaeological levels when the coast was far verses close.

At small ochre sources, a minimum of two samples were taken. At sources that were larger than 1 meter, samples were taken at approximately 1 meter intervals throughout the exposure. This is necessary in order to fully describe the source as ochre deposits have been shown to be highly variable. At each site photographs were taken and GPS coordinates were recorded. Ochre samples were collected from 22 “source” localities (Fig. 5.2). Each identified source is briefly described below.

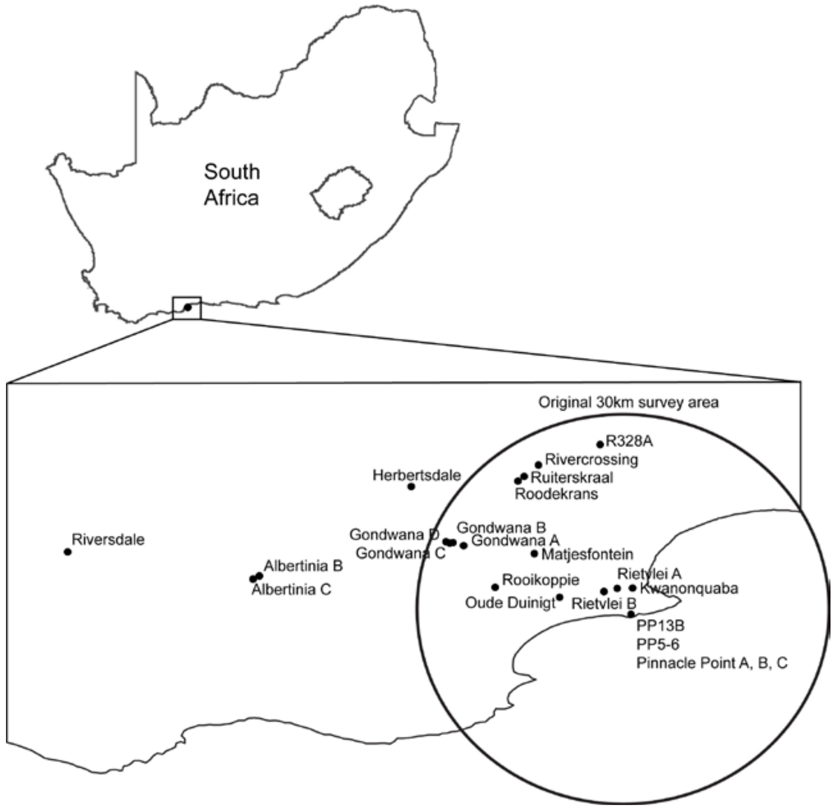

Fig. 5.2. Map of identified ochre localities within the vicinity of PP

XRD and PIXE methods

Archaeometric analyses were carried out for all geological ochre samples collected. Previous research has shown that characterization and grouping of similar ochre samples will be more successful if several types of data are assessed. It is beneficial to analyze the elemental and mineralogical composition of the material as well as deviations in its crystalline structure. These data are effectively attained through X-Ray Diffraction (XRD) (Cullity and Stock 2001) and Particle Induced X-Ray Emission (PIXE) (Dran *et al.* 2000). XRD was conducted in the Department of Chemistry and Biochemistry at Arizona State

University (http://www.public.asu.edu/~tlgroy/). These analyses yielded data on the mineralogical components and structure of each sample. PIXE analyses yielded elemental concentrations for each sample and were conducted in the IBeam facility (LeRoy Eyring Center for Solid State Science) at Arizona State University (http://le-csss.asu.edu/Groups/IBeam_Web/ibeam.html). Together these data are used to attempt to match archaeological ochre samples to geological sources from the survey collection in Chapter 6. The XRD data sets and the PIXE data sets will be presented for each geological source below.

XRD has been used widely in materials research. It has been used successfully on prehistoric archaeological and geological ochre samples in Europe, Australia, North America, and Africa (Clarke 1976; David *et al.* 1993; Weinstein-Evron and Ilani 1994; Tankersley 1996; Tankersley *et al.* 1995; Ellis *et al.* 1997; Jercher *et al.* 1998; Smith *et al.* 1998; Hughes and Solomon 2000; Marshall *et al.* 2005; Mortimore *et al.* 2004; Bernatchez 2008). All samples for XRD were ground using a ceramic mortar and pestle. Grinding tools were thoroughly cleaned with fresh sand and rinsed with distilled water to prevent contamination between samples. Notes were kept during grinding about the relative difficulty of reducing the sample to power (easy, moderate, hard) as well as about any unusual inclusions noticed. After samples had been allowed to completely dry, a small amount (several milligrams) of finely ground ochre powder was adhered to a glass (or quartz) slide using a sprayed solution of petroleum jelly and n-hexane in N_2 flow. The mounted powder was then analyzed using a Rigaku D/MAX-IIB X-ray diffractometer with Cu*K*∀ radiation. Scanning was done with 2θ equal to 5˚ to 65˚ at 2˚ per minute with a step size of .02˚. Every tenth sample was rerun on a different day to check for consistency of results. No discrepancies were detected. Diffraction patterns were analyzed using Jade© software.

Particle Induced X-Ray Emission (PIXE) is a well-developed method that has been used to identify the elemental composition of various artifacts. PIXE has several advantages: small samples can be used, there is minimal sample preparation, and there is a short analysis time (~15 minutes per sample). The technique has been used on Australian, North American, and African ochres and preliminary work suggests it can be used to identify the geological source of archaeological ochre fragments (David *et al.* 1993; 1995; Goodall *et al.* 1995; Erlandson *et al.* 1999; Bernatchez 2008). PIXE analysis was run on a 1.7MV tandem accelerator (General Ionex Tandertron) with a Si (Li) (lithium drifted silicon) detector. A 1.72 MeV proton (H+) beam was used to excite the low Z (atomic number) elements that comprise the bulk of the samples. These runs provided ppm concentration data on the following elements: Na, M, Al, Si, P, S, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu , and Zn. Results are most accurate for elements with atomic numbers lower than Fe. Na, M, Sc, Co, Ni, Cu, Zn were removed from the analyses as they were not detected in most samples. A second run for each sample was done with a 2.7MeV beam to study trace elements of higher atomic numbers (As, Rb, Sr, Y, Zr, and Pb). These data were not used for analyses as they were below the limit of detection in the majority of samples. Random samples were rerun on different days to check for consistency of results. GUPIX© software from the University of Guelph was used to convert the PIXE spectrum to elemental concentrations.

GUPIX reports elemental concentrations in ppm. A variety of data transformations were investigated for analyzing the data including standard normalization to percentages summing to 100, a log10 transform, and Fe based normalization, and a log10 transform of the Fe normalization. A regular Fe normalization, dividing all elemental concentrations by the Fe concentration proved most useful. Popelka-Filcoff (2006) first discussed this application for ochre elemental data and it has been used for subsequent research (Popelka-Filcoff *et al.* 2007a; Popelka-Filcoff *et al.* 2007b; Popelka-Filcoff 2008; MacDonald *et al.* 2010). Fe content in ochre is highly variable and can dilute the presence of other elements which may be diagnostic. Dividing all concentrations by the Fe concentration helps to standardize the data set.

Heat treatment methods

It has been suggested that some archaeological ochre may have been heat treated in the past. This changes the mineralogical makeup of ochre by transforming yellow goethite to red hematite. Therefore, it was necessary to heat treat some ochre from each source in order to have heat treated comparison samples to match to potential heat treated (intentionally or unintentionally) archaeological samples. Heat treatment is discussed in depth in Chapter 8.

Ochre samples were heated three ways, beneath a campfire and in two different furnaces. The campfire samples most closely resemble how heat treatment may have taken place in the past. Samples were buried in sand beneath active campfires. The temperature profiles of the fires were recorded using an electronic thermocouple with two probes. One probe was placed directly in the fire while the other was buried around the samples. In a few cases, samples were not buried but were placed on rocks around the fire and within the fire. Some samples were heated in a furnace in South Africa. These furnace experiments were designed to mimic the heating profile of an actual campfire. The furnace was allowed to heat slowly and the peak temperature was then maintained for several hours. Then the samples cooled over a long period as if they were being allowed to cool under an actual fire. A sub-sample of all samples taken was then heated in a furnace at ASU in the Goldwater Labs. In these experiments the primary objective was to obtain color and mineralogical transition. These furnace samples received the most controlled and standardized atmosphere and temperature possible. The samples were heated to 400ºC and held at that temperature for five hours. The samples were then cooled slowly in air.

Source descriptions and characterization results

Twenty-two potential ochre sources were identified within the search area. In most cases the sources were named after the farm they are currently located on. Sources not on farmland were named after the nearest town or associated landmark. From these sources a total of 260 samples were collected for archaeometric analyses.

Albertinia B (S34.14813 E21.53799)

Albertinia B is an historic ochre mine near the town of Albertinia. The site approximately 51 km (straight line distance) from PP. High quality fine grained red and yellow ochre sits below a silcrete crust at the site (Fig. 5.3). The material from this location grinds easily (15 samples described as easy to grind, 7 as moderate) and leaves a good streak. All samples except one had a hardness of less than 2. The remaining sample had a hardness of about 3. No cases of magnetism were detected.

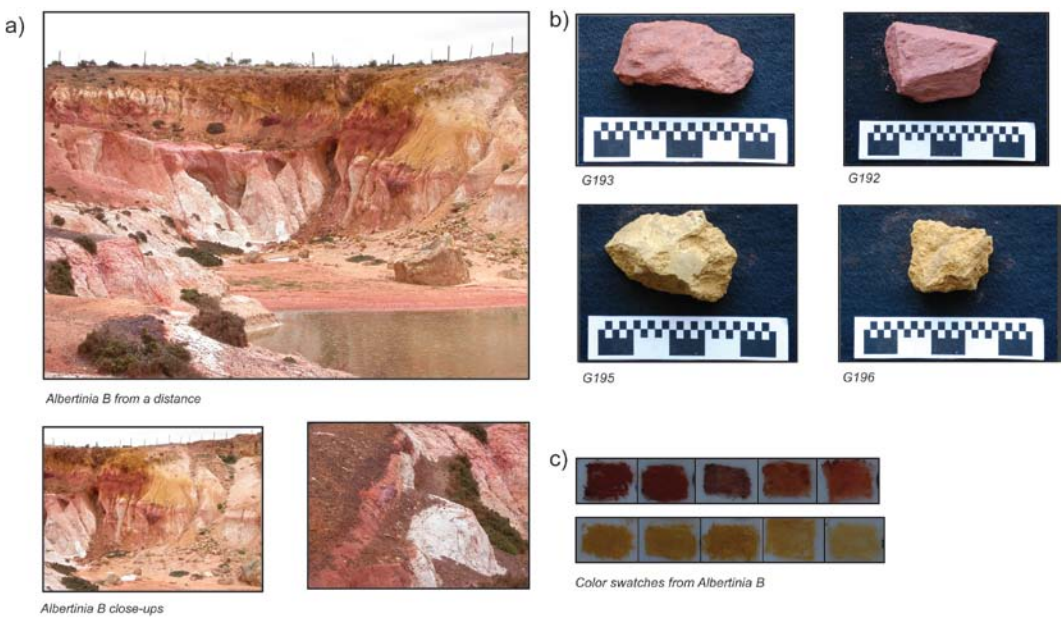

Fig. 5.3. a) Albertinia B locality, b) examples of ochre samples, c) examples of color swatches

Seven initial large samples were taken from the site. These were further subdivided for various treatments before XRD and PIXE analyses were conducted. Some samples were untreated, others were heat treated with fire, and others were heated in a furnace for a controlled burn. This resulted in a total of 22 samples from Albertinia B for characterization (Table 5.1). All heated yellow samples became redder in color. Samples that were red to begin with darkened in hue or stayed the same. The effects of heating on XRD results are further discussed in Chapter 8. Color is further discussed in Chapter 7.

Table 5.1
Albertinia B samples

Sample Number	Original Color	Treatment
G1	Yellow	Fire heated
G2	Red	Fire heated
G3	Red	Fire heated
G4	Yellow	Fire heated
G5	Red	Fire heated
G6	Yellow	Fire heated
G46	Yellow	Untreated
G47	Red	Untreated
G48	Red	Untreated
G49	Red	Untreated
G50	Yellow	Untreated
G51	Yellow	Untreated
G52	Red	Untreated
G192	Red	Furnace heated (ASU)
G193	Red	Furnace heated (ASU)
G194	Red	Furnace heated (ASU)
G195	Yellow	Furnace heated (ASU)
G196	Yellow	Furnace heated (ASU)
G275	Yellow	Fire heated
G276	Yellow	Fire heated
G277	Yellow	Fire heated
G278	Yellow	Fire heated

The XRD results are presented for all geological samples in Appendix A (Fig. A.1 to Fig. A.22). Red samples from Albertinia B, heated or unheated, typically contained hematite, quartz, kaolinite, and illite. Some samples also contained halite. Yellow unheated samples contained goethite, quartz, kaolinite and in some cases calcite. The kaolinite peaks in the yellow samples are minimal compared to the red samples. The heated yellow fragments have hematite, quartz, and calcite as the major identified minerals. Kaolinite, if it is present, is barely detectable. The mineralogy at Albertinia B is fairly consistent across the locality.

The LoE PIXE results are presented for all sources in Appendix B (Table B.1). All elemental concentrations have been divided by the Fe concentration. At Albertinia B, Fe concentrations were high but variable ranging from approximately 350,000ppm to 13,000ppm. The remaining matrix of the samples is dominated by Si, Al and K as would be expected given the known mineralogy.

Albertinia C (S34.17107 E21.51932)

The Albertinia C ochre source is located not far from Albertinia B about 52 km from PP. The exposure is smaller but of similar quality (Fig. 5.4). Available colors range from reds to yellows and purples. It is fine grained and grinding requires minimal to moderate effort. All samples had a hardness of about 1 and had good staining power. Untreated samples from this location are not magnetic.

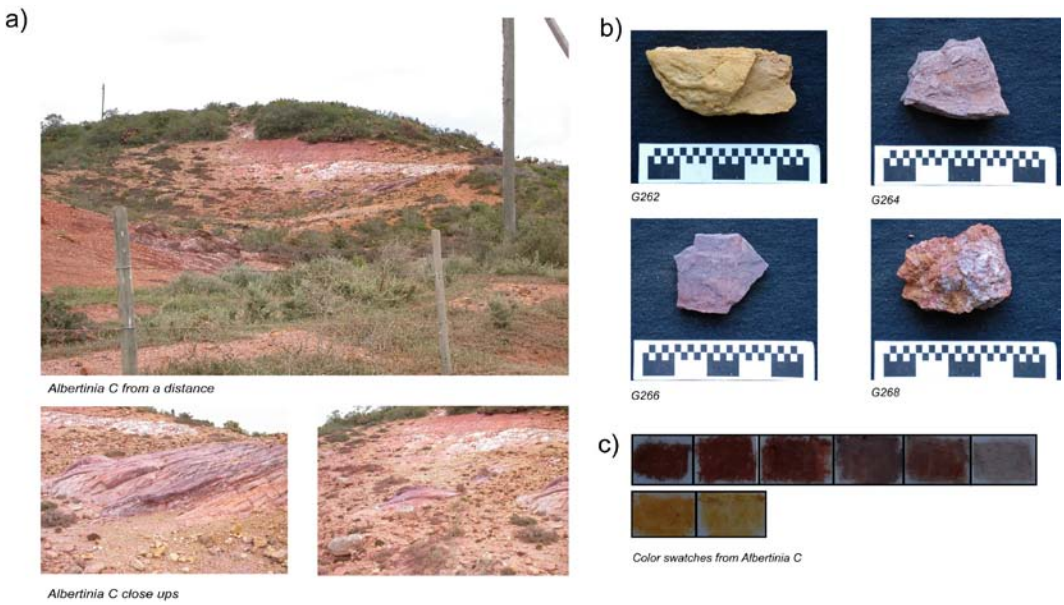

Fig. 5.4. a) Albertinia C locality, b) examples of ochre samples and c) examples of color swatches

A total of eight samples were taken from Albertinia C (Table 5.2). These were treated and subjected to XRD and PIXE analyses.

Table 5.2
Albertinia C samples

Sample Number	Original Color	Treatment
G261	Yellow	Untreated
G262	Yellow	Furnace heated
G263	Red	Untreated
G264	Red	Furnace heated
G265	Red	Furnace heated
G266	Red	Furnace heated
G267	Red	Untreated
G268	Red	Furnace heated

The XRD results are presented in Fig. A.23 to Fig. A.30. Red samples typically contained hematite, quartz, kaolinite, and illite regardless of heating. Halite was also sometimes present. The yellow unheated sample contained goethite, quartz, illite, and halite, and the yellow heated sample contained hematite, quartz, illite and halite. The LoE PIXE data are presented in Table B.2.

Fe concentrations were high but variable ranging from approximately 203,000 ppm to 67,000 ppm.

Glentana

Only one sample was collected from the Glentana site. It was collected by a SACP4 project member and contributed so photography and exact coordinates were not available for this location. However, since the material exists it has been included here. The large sample was divided into three smaller samples, one untreated, one fire treated, and one furnace treated (Table 5.3). The untreated material has a clayey texture and an orange brown color. The piece was moderately difficult to grind with a hardness of about 2-3. The material left only a mediocre streak.

Table 5.3
Glentana samples

Sample Number	Original Color	Treatment
G34	Orange	Fire heated
G65	Orange	Untreated
G257	Orange	Furnace heated

The XRD results are presented in Appendix A (Fig A.31 to Fig. A.33). Two of the Glentana samples contain hematite quartz, kaolinite, and illite. Hematite was not detected in the third sample, G34, but is likely present in trace amounts based on the color of the sample. The hematite at Glentana does not appear to be very well crystallized even in untreated samples making it difficult to differentiate between heated and unheated material from this source. The poor quality makes it an unlikely match for archaeological material recovered at the PP sites.

The LoE PIXE results are presented in Appendix B (Table B.3). All elemental concentrations have been divided by the Fe concentration. Fe concentrations were low compared to other sources and ranged from approximately 36,000 ppm to 26,000 ppm.

Gondwana A (S34.10326 E21.83918)

The Gondwana A locality is the first in a series of road cut outcrops along the fence border of Gondwana Game Reserve (Fig. 5.5). This collection point is approximately 26 km from PP. It was necessary in this area to collect ochre from these road cuts rather than look for naturally exposed ochre surfaces in the vicinity. The game park is home to large carnivores and we were not able to gain access to the grounds for survey. The geological make up (according to the South African Geological Service) is the same throughout the park so we hope any ochre contained within has a similar signature to that just outside the park’s boundaries. At Gondwana A, the material is fairly poor and occurs in lithified nodules in a soil horizon. The material is moderately difficult to difficult to grind due to hard inclusions, but it is useable. Hardness values varied but the average was about 3.5-5.5. The material leaves mediocre to good streaks on ceramic. Some material from this site became magnetic after heat treatment.

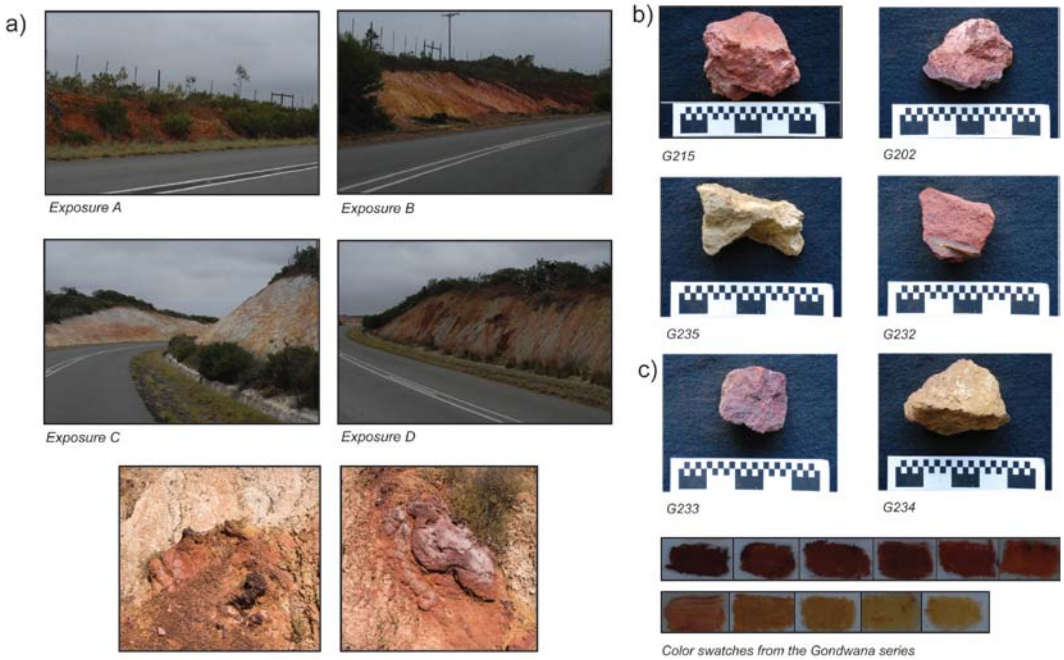

Fig. 5.5. a) Gondwana series locality, b) examples of ochre samples, c) examples of color swathes

There were 5 original samples taken from Gondwana A that were broken down into smaller samples for various treatments (Table 5.4). This resulted in a total of 11 samples, 4 untreated, 4 fire heated, and 3 furnace heated.

Table 5.4
Gondwana A samples

Sample Number	Original Color	Treatment
G26	Red	Fire heated
G27	Red	Fire heated
G28	Red	Fire heated
G29	Yellow	Fire heated
G66	Red	Untreated
G67	Yellow	Untreated
G68	Red	Untreated
G70	Red	Untreated
G201	Red	Furnace heated (ASU)
G202	Red	Furnace heated (ASU)
G203	Yellow	Furnace heated (ASU)

XRD results are presented in Appendix A (Fig. A.34 to Fig. A.44). The red unheated samples have hematite, quartz and kaolinite. One sample also has a feldspar signature. The yellow unheated sample contains goethite, quartz, and kaolinite. The heated yellow sample contains hematite, quartz, and kaolinite just like the original red samples. The red heated samples have hematite, and quartz. These samples also contain kaolinite and/or maghemite. The presence of maghemite accounts for the magnetism seen in some samples after heating and the increased intensity of the (110) peak.

The LoE PIXE results are presented in Appendix B (Table B.4). All elemental concentrations have been divided by the Fe concentration. Fe concentrations ranged from approximately 269,000 ppm to 36,000 ppm.

Gondwana B (S34.09916 E21.82386)

The Gondwana B locality is located about 27 km from PP. This higher exposure is much larger and consists of fine grained clay to shale material in reds and yellows (Fig. 5.5). Most samples were very easy to grind, two were more difficult due to harder inclusions. All samples had a hardness less than 2 and had very good staining power. None of the samples were magnetic before or after heating.

Seven original samples were collected and subdivided into 24 final samples (Table 5.5). This resulted in seven untreated samples, 10 fire heated samples, and 7 furnace heated samples.

Table 5.5
Gondwana B samples

Sample Number	Original Color	Treatment
G15	Red	Fire heated
G16	Yellow	Fire heated
G17	Red	Fire heated
G18	Yellow	Fire heated
G19	Red	Fire heated
G20	Red	Fire heated
G21	Red	Fire heated
G22	Yellow	Fire heated
G23	Yellow	Fire heated
G24	Red	Fire heated
G71	Red	Untreated
G72	Yellow	Untreated
G73	Red	Untreated
G74	Red	Untreated
G75	Red	Untreated
G76	Yellow	Untreated
G77	Red	Untreated
G210	Yellow	Furnace heated (ASU)
G211	Yellow	Furnace heated (ASU)
G212	Red	Furnace heated (ASU)
G213	Red	Furnace heated (ASU)
G214	Red	Furnace heated (ASU)
G215	Red	Furnace heated (ASU)
G216	Red	Furnace heated (ASU)

XRD results are presented in Appendix A (Fig. A.45 to Fig. A.68). The red unheated samples contain hematite, quartz, kaolinite, and/or illite. The hematite varies in intensity but has a normal crystal pattern. The yellow unheated samples also contain quartz, kaolinite, illite along with goethite as the color bearing mineral. Halite is also present in some samples. The heated red and heated yellow samples contain the same mineral identifications, quartz, kaolinite, illite, hematite, and sometimes halite.

The LoE PIXE results are presented in Appendix B (Table B.5). All elemental concentrations have been divided by the Fe concentration. Fe

concentrations were high but variable ranging from approximately 439,000 ppm to 35,000 ppm.

Gondwana C (S34.0996 E21.81881)

The Gondwana C locality is located about 28 km from PP. This material is similar in texture to Gondwana B but the material is white to light gray (Fig. 5.5). It is very soft and easy to grind with hardness values all less than 1. The samples left a good streak and are not magnetic. White ochre is rarely recovered in MSA sites but is used in later periods so one sample was collected and subdivided into three (Table 5.6).

Table 5.6
Gondwana C samples

Sample Number	Original Color	Treatment
G25	White	Fire heated
G78	White	Untreated
G256	White	Furnace heated (ASU)

XRD results for these three samples are presented in Appendix A (Fig. A.69 to Fig. A.71). The mineral composition of the samples did not change with heating. All samples contain quartz, illite, and kaolinite.

The LoE PIXE results are presented in Appendix B (Table B.6). All elemental concentrations have been divided by the Fe concentration. These samples consist mainly of Si, Al, and K owing to their largely clay composition. Fe content was low ranging from 6,000 ppm to 4,300 ppm.

Gondwana D (S34.09732 E21.81375)

The Gondwana D exposure is approximately 28 km from PP and is very similar to Gondwana B (Fig. 5.5). The ochre has a clay texture and ranges in color from red to yellow. The material is also easy to grind with all hardness values being less than 1. All pieces also left a good streak. None of the material was found to be magnetic before or after heating.

A total of four samples were originally collected. These were split into 12 final samples, 4 untreated and 8 furnace heated (Table 5.7). Four of these furnace heats were carried out in South Africa to replicate fire burning. The other four were carried out at ASU in a more controlled environment.

Table 5.7
Gondwana D samples

Sample Number	Original Color	Treatment
G122	Yellow	Untreated
G123	Yellow	Furnace heated (SA)
G124	Red	Untreated
G125	Red	Furnace heated (SA)
G126	Red	Untreated
G127	Red	Furnace heated (SA)
G128	Yellow	Untreated
G129	Yellow	Furnace heated (SA)
G232	Red	Furnace heated (ASU)
G233	Red	Furnace heated (ASU)
G234	Yellow	Furnace heated (ASU)
G235	Yellow	Furnace heated (ASU)

XRD results are presented in Appendix A (Fig. A.72 to Fig A.83). The red unheated samples contain poorly crystallized hematite, quartz, kaolinite, and/or illite. The heated red samples show more defined hematite peaks along with quartz, illite, and/or kaolinite. The yellow samples contain quartz, goethite, kaolinite, and illite. The heat treated yellow material contains quartz, kaolinite, illite and poorly crystallized hematite. Vermiculite, another clay mineral, was also identified in some samples.

The LoE PIXE results are presented in Appendix B (Table B.7). All elemental concentrations have been divided by the Fe concentration. Fe concentrations were fairly high and ranged from approximately 404,000 ppm to 122,000 ppm.

Herbertsdale (S34.0162 E21.7621)

This ochre locality is approximately 37 km from PP. This exposure is clay based and fairly soft. It is red-orange in color (Fig. 5.6). Most samples were described as easy to grind with hardness values less than 2. All samples left a good streak, and none of the material was found to be magnetic before or after heat treatment.

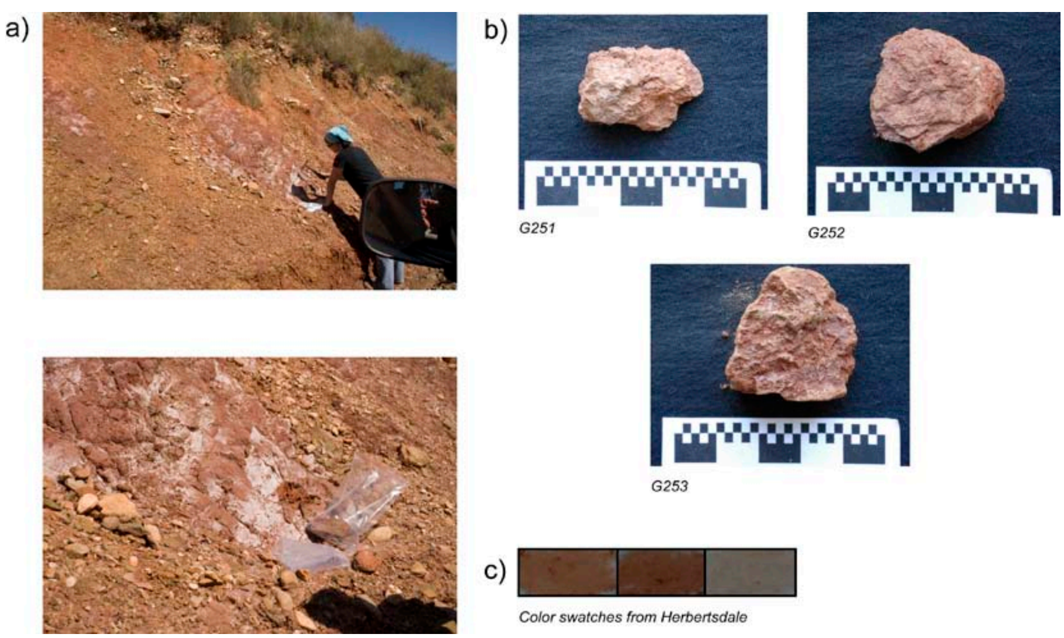

Fig. 5.6. a) Herbertsdale locality, b) examples of ochre samples and c) examples of color swatches

Three samples were taken initially and these were divided into 8 samples with various treatments (Table 5.8).

Table 5.8
Herbertsdale A samples

Sample Number	Original Color	Treatment
G163	Orange	Untreated
G164	Orange	Untreated
G165	Orange	Furnace heated (SA)
G166	Orange	Untreated
G167	Orange	Furnace heated (SA)
G251	Orange	Furnace heated (ASU)
G252	Orange	Furnace heated (ASU)
G253	Orange	Furnace heated (ASU)

XRD results are presented in Appendix A (Fig. A.84 to Fig. A.91). The unheated samples all contain quartz, illite, kaolinite, and feldspar. Calcite and halite were also identified in some samples. It is likely there are also trace amounts of goethite and/or hematite based on the orange color of the samples. The heated samples have a similar mineralogical makeup.

The LoE PIXE results are presented in Appendix B (Table B.8). All elemental concentrations have been divided by the Fe concentration. Fe concentrations for this source were fairly low and ranged from 47,000 ppm to 17,000 ppm.

Kwa-Nonqaba (S34.16625 E22.08863)

This exposure is found just outside the township of Kwa-Nonqaba. It is 5.5 km from PP. Material is exposed in the road cut but also along the surrounding hilltop (Fig. 5.7). This is the Bokkeveld exposure that Watts speaks off (2010). The material is fine grained shale and is mostly lighter in color but some pieces of more saturated hue can be found. The exposure contains yellows, reds, and purples. All samples were easy to grind with hardness values all about 1.

All the samples left good streaks and none of the material was found to be magnetic before or after heating.

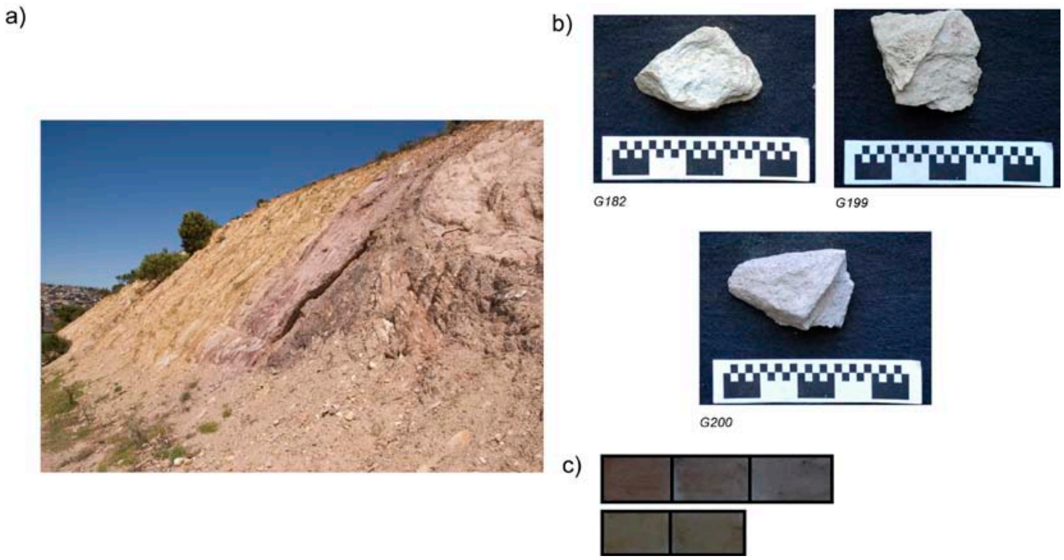

Fig. 5.7. Kwa-Nonqaba locality and examples of ochre samples

Five samples were collected from Kwa-Nonqaba in the early stages of this project (now called G281, G284-G286, G288). These samples were picked up at random and have not been treated. On a subsequent survey trip another 3 samples were taken which were subdivided into 9 samples for treatment and characterization (Table 5.9).

Table 5.9
Kwa-Nonqaba samples

Sample Number	Original Color	Treatment
G35	Yellow	Fire heated
G36	Purple	Fire heated
G37	Purple	Fire heated
G59	Purple	Untreated
G60	Purple	Untreated
G61	Yellow	Untreated
G182	Yellow	Furnace heated (ASU)
G199	Yellow	Furnace heated (ASU)
G200	Purple	Furnace heated (ASU)
G281	Yellow	Untreated
G284	Red	Untreated
G285	Red	Untreated
G286	Red	Untreated
G288	Red	Untreated

XRD results are presented in Appendix A (Fig A.92 to A.105). The untreated red samples contain hematite, quartz, kaolinite, illite, and sometimes halite. Goethite and vermiculite were identified in one sample each. The untreated purple samples contain quartz, kaolinite, and illite. Trace hematite is likely also present but was only detectable in one sample. The heated purple samples contain quartz, kaolinite, and illite with possible trace hematite. Vermiculite was identified in one sample. The two untreated yellow samples also contain quartz, kaolinite, and illite with possible trace goethite. Halite, montmorillonite, and vermiculite were also identified. The yellow heated samples have quartz, kaolinite, illite, and montmorillonite. Hematite was not detected but it may be present in small amounts.

The LoE PIXE results are presented in Appendix B (Table B.9). All elemental concentrations have been divided by the Fe concentration. Fe

concentrations were variable and ranged from approximately 292,000 ppm to 24,000 ppm.

Matjesfontein (S34.11510 E21.94404)

This exposure consists of silcrete and ochre nodules (Fig. 5.8). It is located about 17 km from PP. The ochre is rather sandy and coarse grained compared to other sources. Red and yellow are available at the site. However, the material is mixed, with most samples having swirls of red and yellow throughout. The material is easy to moderate to grind with hardness values ranging from 1 to 3.5 with most being about 1. None of the pieces were found to be magnetic before or after heating. The samples left good to mediocre streaks on ceramic.

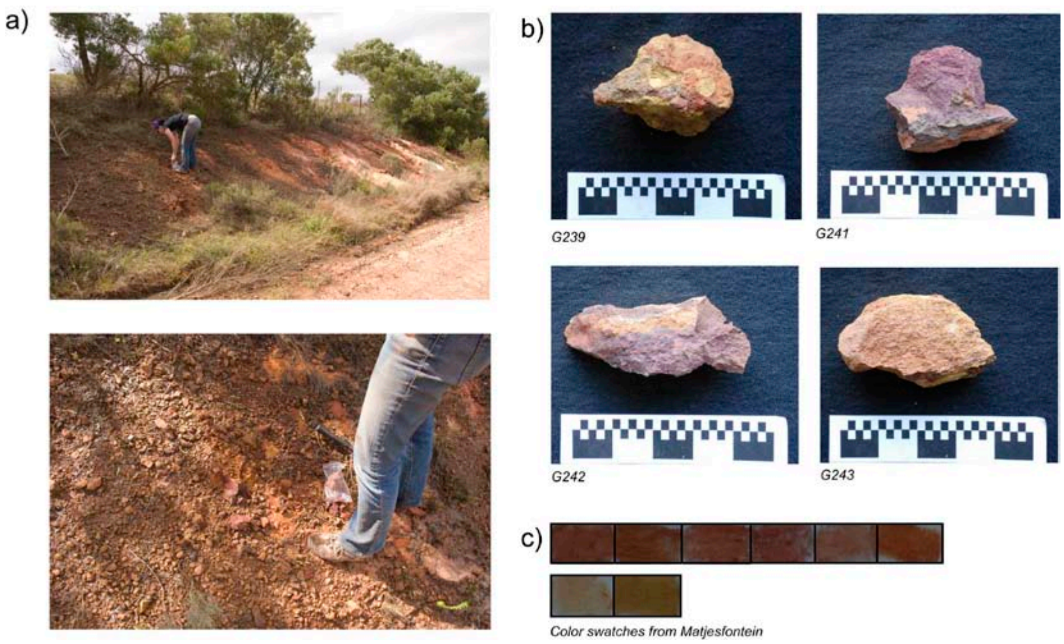

Fig. 5.8. a) Matjesfontein locality, b) examples of ochre samples and c) examples of color swatches

Six original samples were taken from the exposure (Table 5.10). These were further divided into 18 samples with different types of treatment prior to characterization. Original color is the color that makes up the majority of the sample, but as stated all samples contained red and yellow material. It was impossible to separate.

Table 5.10
Matjesfontein samples

Sample Number	Original Color	Treatment
G95	Orange	Untreated
G96	Orange	Furnace heated (SA)
G97	Orange	Untreated
G98	Orange	Furnace heated (SA)
G99	Orange	Untreated
G100	Orange	Furnace heated (SA)
G101	Yellow	Untreated
G102	Yellow	Furnace heated (SA)
G103	Yellow	Untreated
G104	Yellow	Furnace heated (SA)
G105	Orange	Untreated
G106	Orange	Furnace heated (SA)
G238	Orange	Furnace heated (ASU)
G239	Yellow	Furnace heated (ASU)
G240	Yellow	Furnace heated (ASU)
G241	Orange	Furnace heated (ASU)
G242	Orange	Furnace heated (ASU)
G243	Orange	Furnace heated (ASU)

XRD results are presented in Appendix A (Fig A.106 to Fig A.123). The unheated orange samples contain hematite, goethite, quartz, and kaolinite. The yellow unheated samples contain goethite, quartz, kaolinite, and illite. The orange and yellow heated samples typically contain hematite, quartz, kaolinite, and illite. Calcite was identified in one sample.

The LoE PIXE results are presented in Appendix B (Table B.10). All elemental concentrations have been divided by the Fe concentration. Fe

concentrations were variable and ranged from approximately 256,000 ppm to 23,000 ppm.

Oude Duinigt (S34.17983 E21.98147)

This location is 10 km from PP. The stream bed had several eroded samples that were collected. Material was also found along the banks of the stream embedded in the soil (Fig. 5.9). It is not clear if these are secondarily deposited from further upstream or part of the soil horizon. The material is of poor quality and was moderately difficult to grind but pulverizing first was helpful. The samples had hardness ranging from 1 up to approximately 5.5. Streaks were described as poor and no magnetism was detected before or after heating.

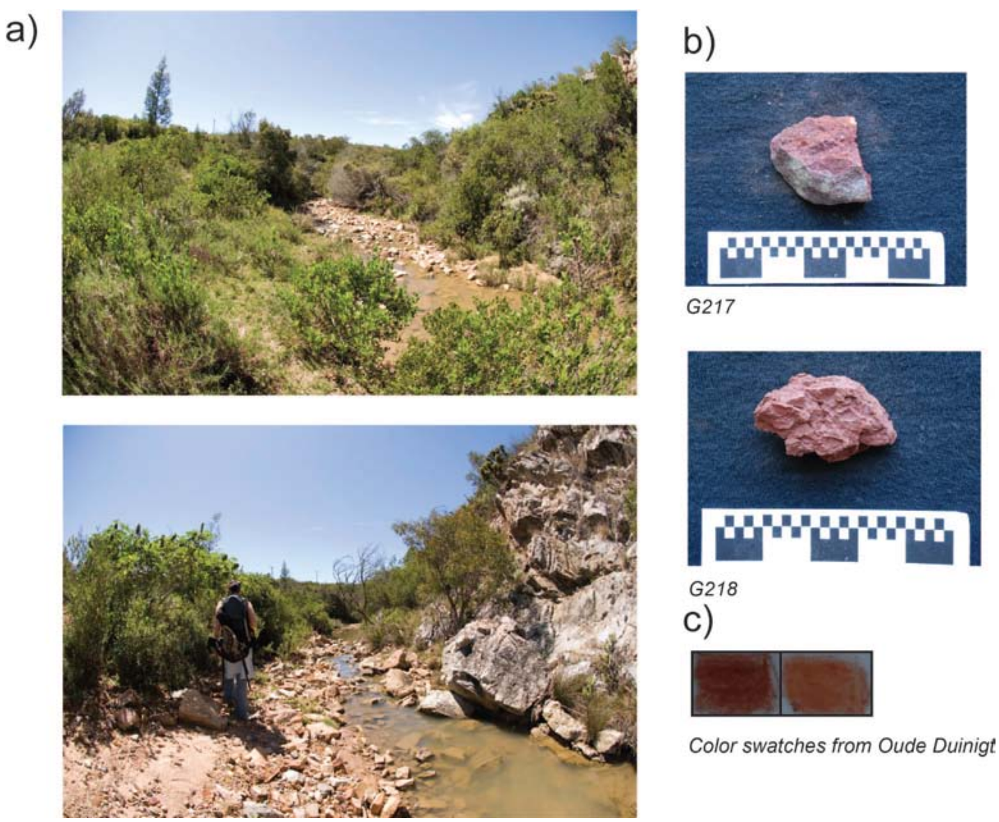

Fig. 5.9. Oude Duinigt locality and examples of ochre samples

Only two samples were kept for characterization analysis, later divided into five samples (Table 5.11).

Table 5.11
Oude Duinigt samples

Sample Number	Original Color	Treatment
G179	Red	Untreated
G180	Red	Furnace heated (SA)
G181	Red	Fire heated
G217	Red	Furnace heated
G218	Red	Furnace heated

XRD results are presented in Appendix A (Fig. A.124 to Fig A.127). The unheated and heated samples contain various combinations of hematite, quartz, kaolinite, and illite.

The LoE PIXE results are presented in Appendix B (Table B.11). All elemental concentrations have been divided by the Fe concentration. Fe concentrations ranged from approximately 98,000 ppm to 24,000 ppm.

PP A, B, and C

PP A is located directly above PP5-6. It is a vein of yellow ochreous material in the TMS. The sample was only available because it fell on excavators, the source could not be reached directly. The ochre is of very poor quality and is very limited in extent. It was moderately difficult to grind and required pulverizing first. The sample was divided into two and one half was heat treated in fire (Table 5.12). The unheated material had a hardness of about 3.5 and the heated sample about 2. The samples barely streaked ceramic and the heated sample was found to be magnetic.

Table 5.12
PP A samples

Sample Number	Original Color	Treatment
G30	Yellow	Fire heated
G62	Yellow	Untreated

PP B is a similar ochre vein located just around the corner from PP5-6 on a slope heading towards PP9. The material is visually identical to PP A and is basically roofspall with some ochre powder adhering. The material was moderately difficult to grind and also required pulverization. Hardness values were all about 3.5 and none of the samples were found to be magnetic before or after heating. The samples left very poor streaks at best. Three samples were taken and divided into seven samples for treatment and characterization (Table 5.13).

Table 5.13
PP B samples

Sample Number	Original Color	Treatment
G31	Yellow	Fire heated
G32	Yellow	Fire heated
G33	Yellow	Fire heated
G63	Yellow	Untreated
G64	Yellow	Untreated
G258	Yellow	Furnace heated
G260	Yellow	Furnace heated

The PP C location is actually two ochre veins located near PP13B. One vein is found in the rockshelter adjacent to the cave and the other is a small remnant of a vein in a piece of rock fall in the intertidal zone. The rockshelter vein is yellow while the intertidal remnant is red. These veins were very limited in extent and it was only possible to collect very small amounts of material. Because of this none of the samples were heat treated (Table 5.14).

Table 5.14
PP C samples

Sample Number	Original Color	Treatment
G279	Red	Untreated
G280	Yellow	Untreated
G282	Yellow	Untreated
G283	Yellow	Untreated

The XRD results for all PP ochre TMS veins are reported in Appendix A (Fig. A.128 to Fig. A.140). The red sample contains hematite, quartz and kaolinite. The yellow samples contain goethite, quartz, illite, kaolinite and salt. Gypsum was also identified in some samples. The heated yellow samples contain hematite, quartz, illite, kaolinite, and halite. The hematite signature in these samples is weak and difficult to detect.

The LoE PIXE results are presented in Appendix B (Table B.12). All elemental concentrations have been divided by the Fe concentration. Fe concentrations varied considerably from approximately 359,000 ppm to 11,000 ppm.

Rietvlei A (Jukani Game Reserve relocated material)

The Rietvlei A material came from a rock pile on the Jukani Game Reserve. The location is approximately 5 km from PP. This pile represents material relocated by farmers and game reserve staff from the surrounding fields. The original source of the material is not identified but must be in the immediate vicinity. The material is sandy but also sparkles which could have added value to the material. Red and yellow coloring are present but in the same samples. Red, yellow, and orange streaks of varying intensity are swirled through the samples (Fig. 5.10). The material was easy to grind but hard to reduce to finer particle size due to the sand grains. Hardness values were all about 1 expect for one piece with hardness 5.5-6.5. The samples left poor to no streak on ceramic but the material could have been used to make an attractive sparkly body paint so it has been included.

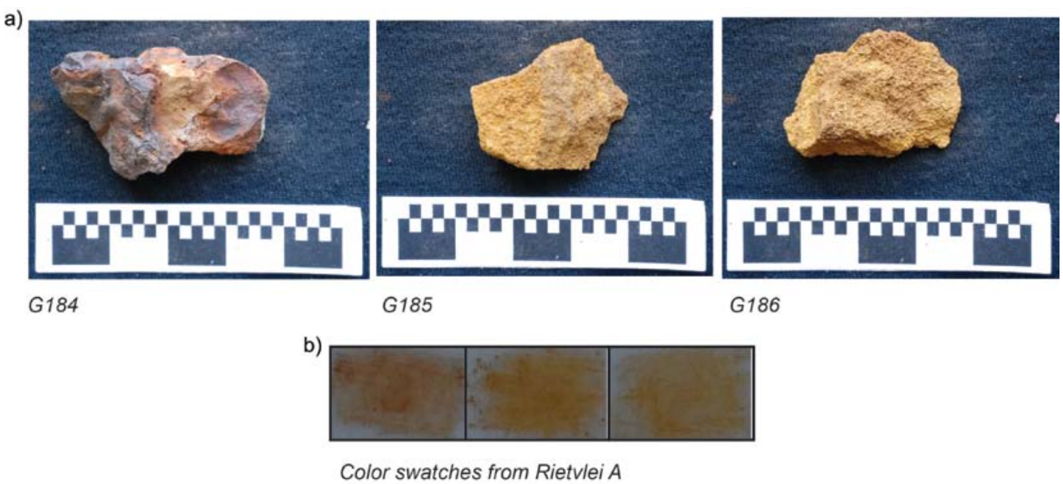

Fig. 5.10. a) Examples of Rietvlei A samples and b) examples of color swatches

Four original samples were collected and subdivided into 10 samples for various treatments (Table 5.15).

Table 5.15
Rietvlei A samples

Sample Number	Original Color	Treatment
G55	Red-orange-yellow	Untreated
G56	Red-orange-yellow	Untreated
G57	Red-orange-yellow	Untreated
G82	Red-orange-yellow	Furnace heated (SA)
G83	Red-orange-yellow	Furnace heated (SA)
G84	Red-orange-yellow	Furnace heated (SA)
G171	Red-orange-yellow	Fire heated
G184	Red-orange-yellow	Furnace heated (ASU)
G185	Red-orange-yellow	Furnace heated (ASU)
G186	Red-orange-yellow	Furnace heated (ASU)

The XRD results for Rietvlei A are presented in Appendix A (Fig. A.141 to Fig A.150). The unheated samples have a dominance of goethite and quartz, although some hematite is likely present. The heated samples contain hematite and quartz. One sample contains kaolinite. With the exception of G171, these samples show a classic pattern of disordered hematite. This is expected based on the presence of goethite in the unheated samples.

The LoE PIXE results are presented in Appendix B (Table B.13). All elemental concentrations have been divided by the Fe concentration. Fe concentrations were relatively high and ranged from approximately 399,000 ppm to 158,000 ppm.

Rietvlei B (S34.1707 E22.0466)

Rietvlei B is located on the Rietvlei farm behind the Jukani Game Reserve about 6 km from PP. The material is a fine grained shale with light coloration ranging from red to yellow brown (Fig. 5.11). This source is naturally exposed.

The material is very easy to grind. All samples had a hardness of about 1 and left a good streak on ceramic. Ochre from this source is not magnetic.

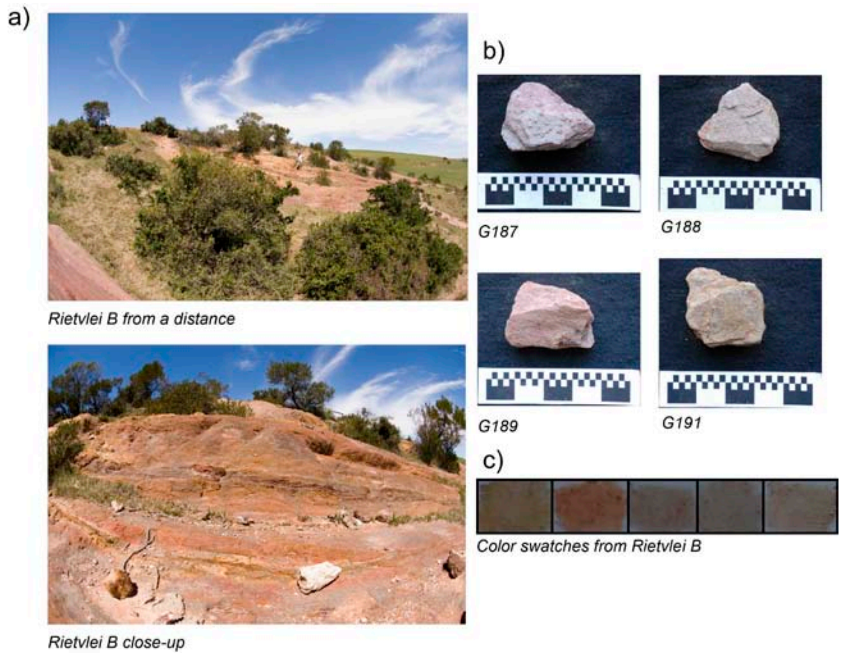

Fig. 5.11. a) Rietvlei B locality, b) examples of ochre samples and c) examples of color swatches

Five original samples were taken and subdivided into 20 smaller samples for treatment and characterization (Table 5.16).

Table 5.16
Rietvlei B samples

Sample Number	Original Color	Treatment
G107	Yellow	Untreated
G108	Yellow	Furnace heated
G109	Yellow	Fire heated
G110	Red Brown	Untreated
G111	Red Brown	Furnace heated
G112	Red Brown	Fire heated
G113	Red Brown	Untreated
G114	Red Brown	Furnace heated
G115	Red Brown	Fire heated
G116	Red	Untreated
G117	Red	Furnace heated
G118	Red	Fire heated
G119	Yellow	Untreated
G120	Yellow	Furnace heated
G121	Yellow	Fire heated
G187	Red Brown	Furnace heated
G188	Red Brown	Furnace heated
G189	Red	Furnace heated
G190	Yellow	Furnace heated
G191	Yellow	Furnace heated

The XRD results for Rietvlei B are presented in Appendix A (Fig. A.151 to Fig A.170). The unheated samples both red and yellow are dominated by quartz, illite, kaolinite, and montmorillonite. The heated samples have similar mineral compositions. Hematite and goethite are likely present in trace amounts based on the coloration of the samples but are barely detectable over the signature of the quartz and clays.

The LoE PIXE results are presented in Appendix B (Table B.14). All elemental concentrations have been divided by the Fe concentration. Fe concentrations for Rietvlei B were on the lower end of the spectrum compared to the larger geological data set. Measurements ranged from approximately 54,000 ppm to 11,000 ppm.

Rivercrossing (S33.99652 E21.93616) (S33.98457 E21.95031)

This location is about 28 km from PP. The material was found in a stream bed that only flows after heavy rains (Fig. 5.12). Samples were collected from two points and all material was a reddish orange color. The stream was traced but a primary source was not identified. The material was fairly hard, with hardness values ranging from 2 to 5.5. However, the material was only moderately difficult to grind if it was crushed first.

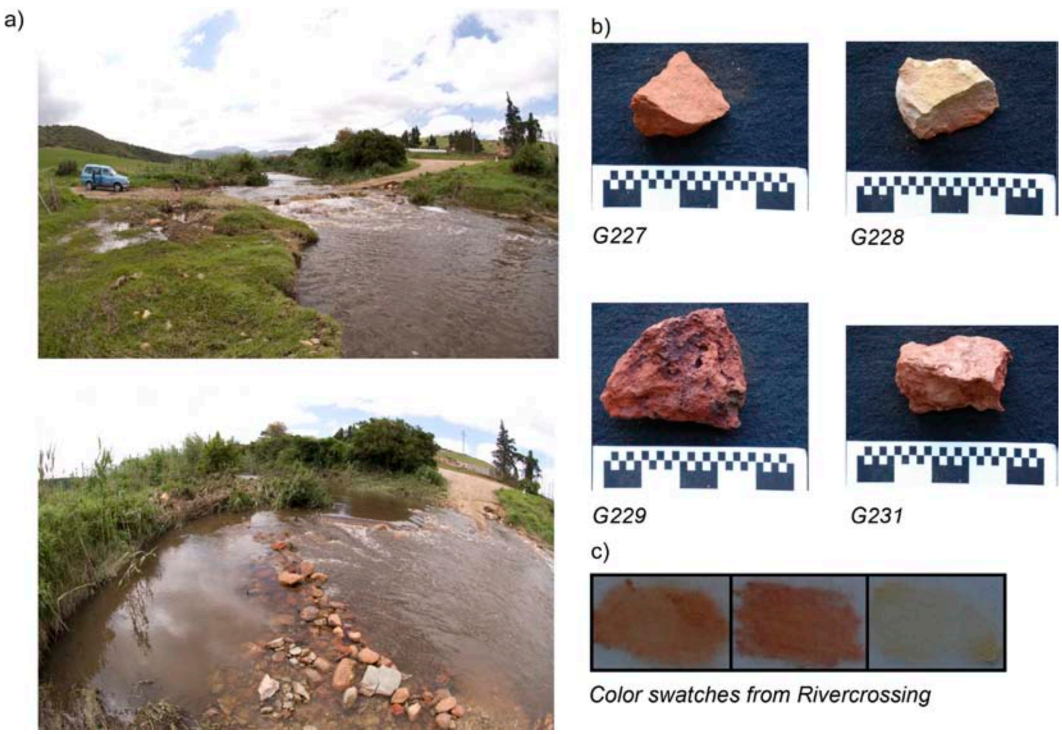

Fig. 5.12. a) Rivercrossing locality, b) examples of ochre samples and c) examples of color swatches

Five samples were originally collected and divided into 15 samples for treatment and characterization (Table 5.17).

Table 5.17
Rivercrossing samples

Sample Number	Original Color	Treatment
G140	Red-orange	Untreated
G141	Red-orange	Furnace heated (SA)
G142	Red-orange	Untreated
G143	Red-orange	Furnace heated (SA)
G144	Red-orange	Untreated
G145	Red-orange	Furnace heated (SA)
G146	Red-orange	Untreated
G147	Red-orange	Furnace heated (SA)
G148	Red-orange	Untreated
G149	Red-orange	Furnace heated (SA)
G227	Red-orange	Furnace heated (ASU)
G228	Red-orange	Furnace heated (ASU)
G229	Red-orange	Furnace heated (ASU)
G230	Red-orange	Furnace heated (ASU)
G231	Red-orange	Furnace heated (ASU)

XRD results for Rivercrossing are presented in Appendix A (Fig. A.171 to Fig. A.185). The unheated samples show hematite, quartz, and feldspar with barely detectable illite and possibly kaolinite and montmorillonite in some samples. The heated samples have the same mineral components.

The LoE PIXE results are presented in Appendix B (Table B.15). All elemental concentrations have been divided by the Fe concentration. Fe concentrations were low, in general, ranging from approximately 36,000 ppm to 10,000 ppm. One sample was an outlier with an Fe concentration of 82,000 ppm.

Riversdale (S34.11279 E21.25476)

This location is about 78 km from PP. The material occurs as a crust in an area with occasional water run off (Fig. 5.13). The material is reddish orange in color and is fairly fine grained but is of low quality. The ochre left poor to mediocre steaks. The material is mostly easy to grind and had hardness values less than 2. The material was not found to be magnetic.

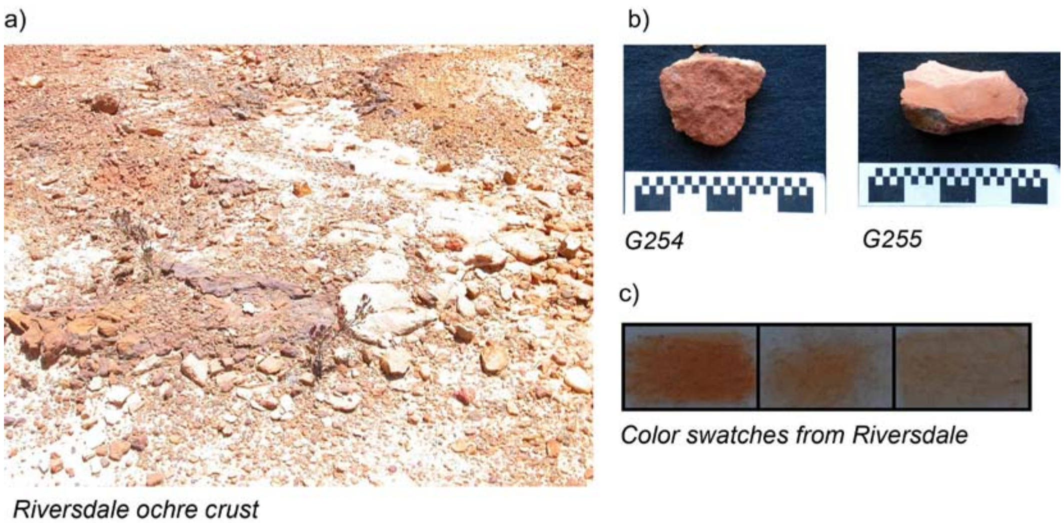

Fig. 5.13. a) Riversdale locality, b) examples of ochre samples and c) examples of color swatches

Two samples were originally collected and divided into six samples for treatment and characterization (Table 5.18)

Table 5.18
Riversdale samples

Sample Number	Original Color	Treatment
G53	Red-orange	Untreated
G54	Red-orange	Untreated
G79	Red-orange	Furnace heated (SA)
G81	Red-orange	Furnace heated (SA)
G254	Red-orange	Furnace heated (ASU)
G255	Red-orange	Furnace heated (ASU)

The XRD results for Riversdale are presented in Appendix A (Fig. A.186 to Fig. A.191). The heated and unheated samples are made up of hematite, quartz, and kaolinite.

The LoE PIXE results are presented in Appendix B (Table B.16). All elemental concentrations have been divided by the Fe concentration. Fe concentrations were relatively low and ranged from approximately 41,000 ppm to 15,000 ppm.

Roodekrans (S34.00581 E34.00581)

This source is naturally exposed and is located about 27 km from PP. The ochre occurs as large nodules with a hard cortex but the material inside the nodules is much softer and coarser grained (Fig. 5.14). The material is mostly red but there are some yellow streaks in some samples. Silcrete was also found at this location. The ease of grinding ranged from easy to hard depending on the cortex. The inner material had hardness values of 1-2 and was not magnetic. This ochre left poor to mediocre streaks on ceramic.

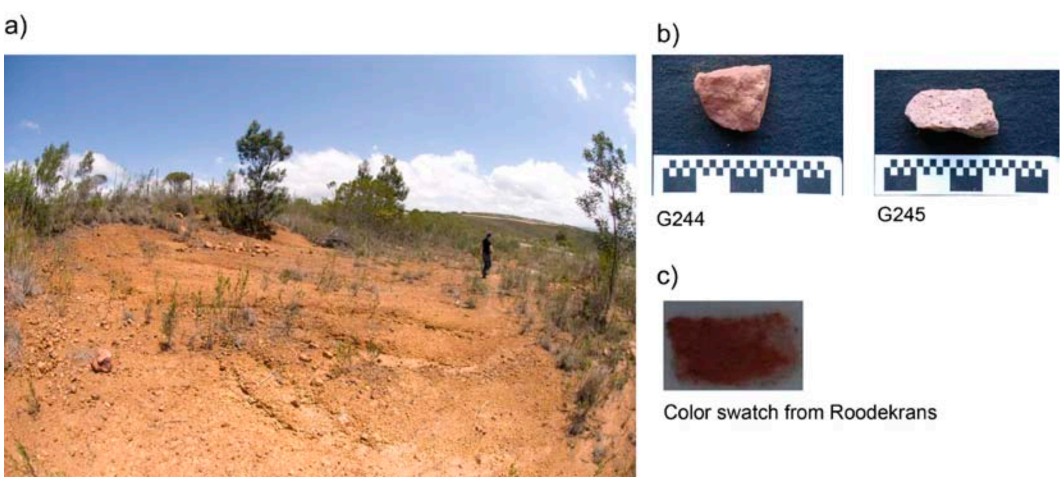

Fig. 5.14. a) Roodekrans locality, b) examples of ochre samples and c) examples of color swatches

Two samples were originally collected and divided into six samples for treatment and characterization (Table 5.19).

Table 5.19
Roodekrans samples

Sample Number	Original Color	Treatment
G175	Red	Untreated
G176	Red	Furnace heated (SA)
G177	Red	Untreated
G178	Red	Furnace heated (SA)
G244	Red	Furnace heated (ASU)
G245	Red	Furnace heated (ASU)

The XRD results are presented in Appendix A (Fig. A.192 to Fig. A.197). The unheated and heated samples consist of quartz, hematite, and feldspar. One sample may also contain kaolinite.

The LoE PIXE results are presented in Appendix B (Table B.17). All elemental concentrations have been divided by the Fe concentration. Fe concentrations ranged from approximately 71,000 ppm to 8,900 ppm.

Rooikoppie (S34.16473 E21.88590)

This source is located 19 km from PP. It occurs as the upper most crust on a hilltop. Both red and yellow ochre are present and the material seems to be of high quality (Fig. 5.15). The material is fairly fine grained with some harder inclusions sometimes making grinding moderately difficult. All samples have good staining power and are not magnetic.

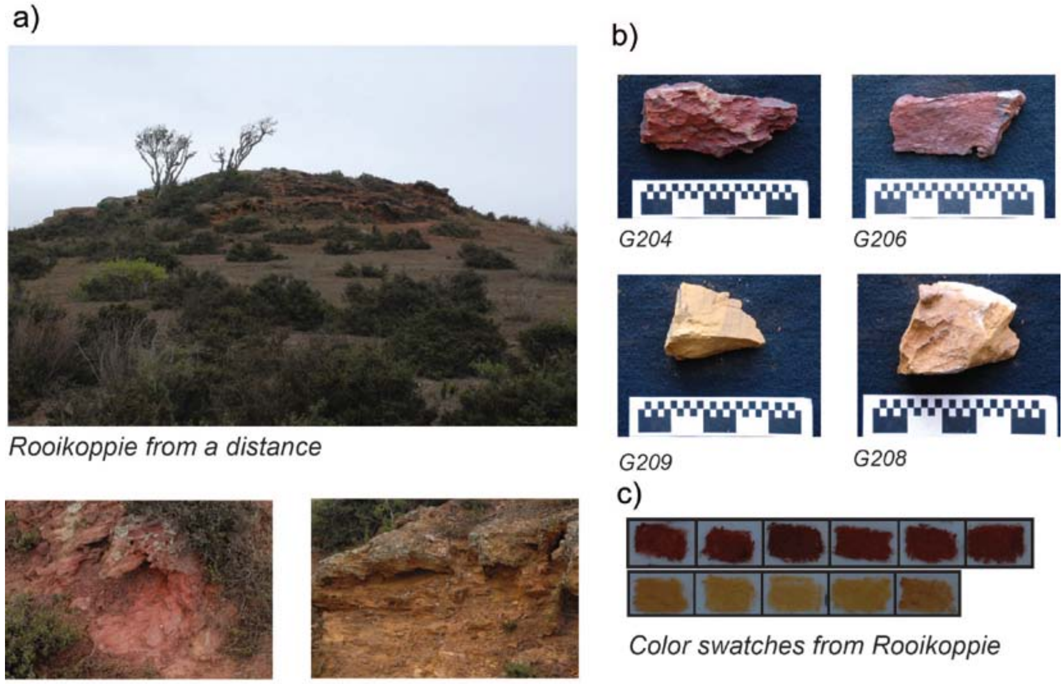

Fig. 5.15. a) Rooikoppie locality, b) examples of ochre samples and c) examples of color swatches

Eight samples were originally collected and later divided into 27 samples for treatment and characterization analysis (Table 5.20).

Table 5.20
Rooikoppie samples

Sample Number	Original Color	Treatment
G7	Red	Fire heated
G8	Red	Fire heated
G9	Yellow	Fire heated
G10	Yellow	Furnace heated (SA)
G11	Red	Fire heated
G12	Red	Furnace heated (SA)
G13	Yellow	Fire heated
G14	Yellow	Fire heated
G38	Yellow	Untreated
G39	Red	Untreated
G40	Yellow	Untreated
G41	Red	Untreated
G42	Red	Untreated
G43	Red	Untreated
G44	Yellow	Untreated
G45	Yellow	Untreated
G204	Red	Furnace heated (ASU)
G205	Red	Furnace heated (ASU)
G206	Red	Furnace heated (ASU)
G207	Yellow	Furnace heated (ASU)
G208	Yellow	Furnace heated (ASU)
G209	Yellow	Furnace heated (ASU)
G269	Yellow	Fire heated
G270	Yellow	Fire heated
G272	Yellow	Fire heated
G273	Yellow	Fire heated
G274	Yellow	Fire heated

XRD results for Rooikoppie are presented in Appendix A (Fig. A.198 to Fig. A.224). The red untreated samples are characterized by hematite and goethite with quartz, illite, and in some cases feldspar. The red heated samples show similar patterns but without the goethite and vermiculite was identified in some samples. The yellow unheated samples have goethite with quartz, illite, kaolinite, and pentlandite. The yellow heated samples show poorly crystallized disordered hematite, with quartz, illite, kaolinite and pendlandite.

The LoE PIXE results are presented in Appendix B (Table B.18). All elemental concentrations have been divided by the Fe concentration. Fe

concentrations were high in general but were variable. They ranged from approximately 555,000 ppm to 36,000 ppm.

Ruiterskraal (S34.00150 E21.92857)

This source is located 27 km from PP. It occurs on a slope just off the road. The material is exposed in the road cut but also at the surface (Fig. 5.16). It should have been accessible before the road was built. The material is very clay rich and soft with oranges, reds, and yellows represented. The ochre is mostly very easy to grind with the exception of a few pieces with some harder inclusions. All the samples collected had a hardness of about 1 and left good quality streaks on ceramic. This ochre was not found to be magnetic.

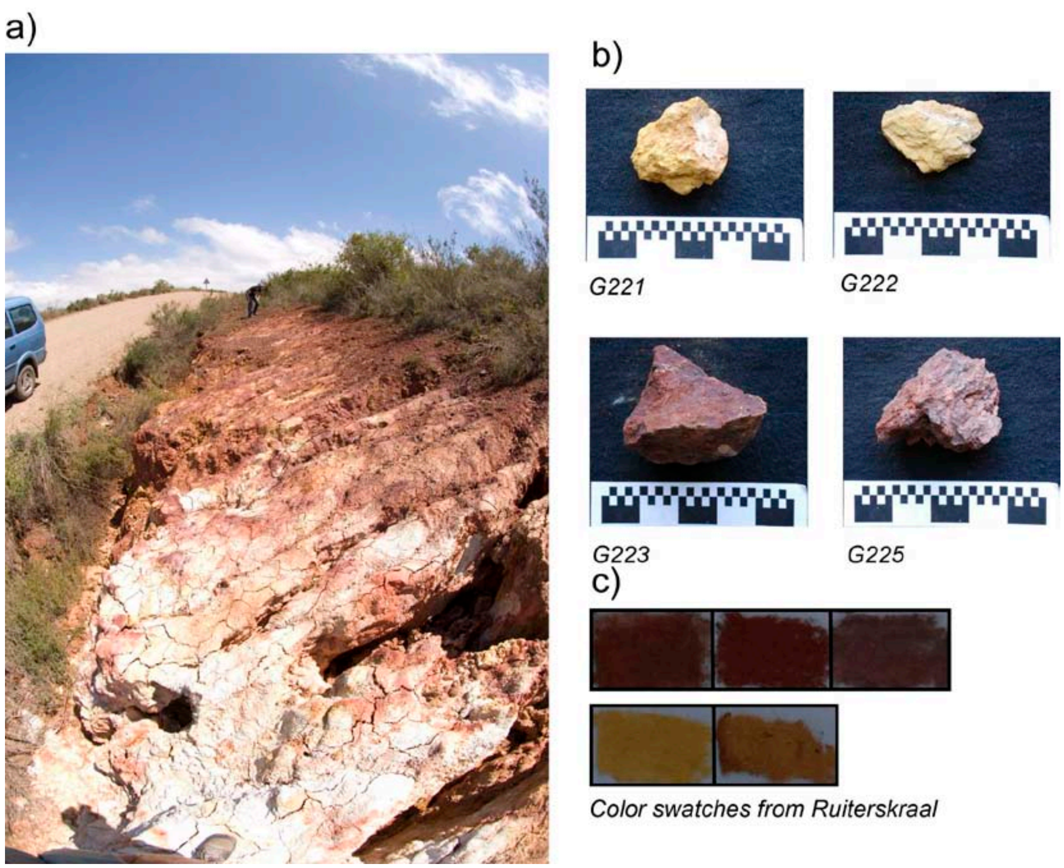

Fig. 5.16. a) Ruiterskraal locality, b) examples of ochre samples and c) examples of color swatches

Five samples were originally collected and divided into fifteen samples for treatment and characterization (Table 5.21).

Table 5.21
Ruiterskraal samples

Sample Number	Original Color	Treatment
G130	Yellow orange	Untreated
G131	Yellow orange	Furnace heated (SA)
G132	Yellow	Untreated
G133	Yellow	Furnace heated (SA)
G134	Red	Untreated
G135	Red	Furnace heated (SA)
G136	Red	Untreated
G137	Red	Furnace heated (SA)
G138	Red	Untreated
G139	Red	Furnace heated (SA)
G221	Yellow orange	Furnace heated (ASU)
G222	Yellow	Furnace heated (ASU)
G223	Red	Furnace heated (ASU)
G224	Red	Furnace heated (ASU)
G225	Red	Furnace heated (ASU)

The XRD results for Ruiterskraal are presented in Appendix A (Fig. A.225 to Fig. A.239). The red samples consist of hematite with quartz, kaolinite, and in one case illite. The red heated samples have the same mineral components but two samples may also contain montmorillonite. The yellow to orange samples consist of goethite with quartz, illite, and kaolinite. After heating these samples have hematite replacing the goethite.

The LoE PIXE results are presented in Appendix B (Table B.19). All elemental concentrations have been divided by the Fe concentration. Fe concentration values were high and ranged from approximately 437,000 ppm to 163,000 ppm.

R328 (S33.95448 E22.04092)

This source is located 29 km from PP. The material is exposed in a water cut profile in section below silcrete nodules surrounded by yellow and red sediment (Fig. 5.17). The quality of the material varies from fairly soft to harder nodules that have useable ochre inside when knocked open. The ease of grinding therefore varied from easy to very difficult. Hardness values ranged from 1 to 5. The softer pieces all had good staining power while the harder material was just mediocre. The samples were not found to be magnetic.

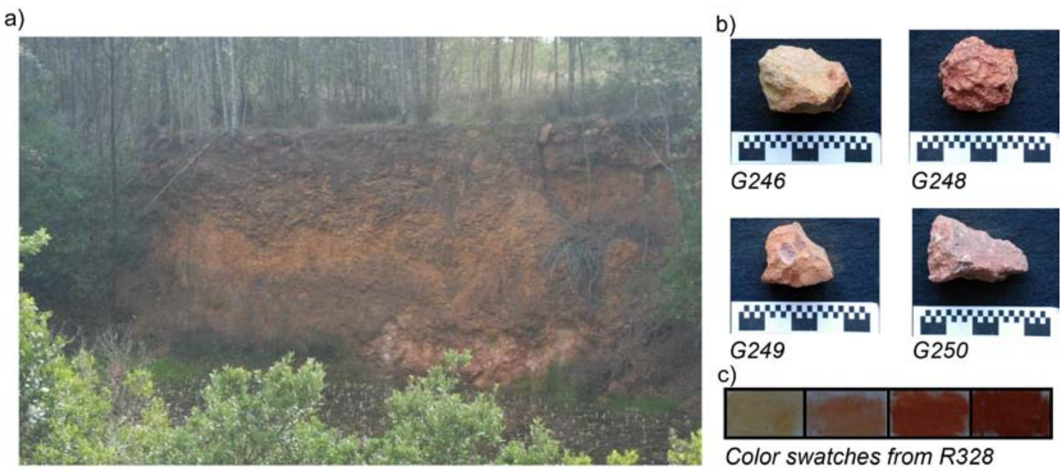

Fig. 5.17. a) R328 locality, b) examples of ochre samples and c) examples of color swatches

Five samples were collected in the field and later subdivided into 18 samples for treatment and characterization (Table 5.22).

Table 5.22
R328A samples

Sample Number	Original Color	Treatment
G150	Red	Untreated
G151	Red	Furnace heated (SA)
G152	Red	Fire heated
G153	Yellow	Untreated
G154	Yellow	Furnace heated (SA)
G155	Yellow	Fire heated
G156	Red	Untreated
G157	Red	Furnace heated (SA)
G158	Red	Fire heated
G159	Red	Furnace heated (SA)
G160	Red	Fire heated
G161	Red	Untreated
G162	Red	Furnace heated (SA)
G246	Yellow	Furnace heated (ASU)
G247	Red	Furnace heated (ASU)
G248	Red	Furnace heated (ASU)
G249	Red	Furnace heated (ASU)
G250	Red	Furnace heated (ASU)

The XRD results for R328A are reported in Appendix A (Fig. A.240 to Fig. A.257). The red samples all have hematite and quartz. Samples also have kaolinite, illite, or feldspar. After heating these samples contained the same minerals but with hematite often being more recognizable. The untreated yellow sample contains kaolinite, illite, and montmorillonite. Goethite was not detected but must be present in trace amounts because after heating there is evidence of disordered hematite in these samples.

The LoE PIXE results are presented in Appendix B (Table B.20). All elemental concentrations have been divided by the Fe concentration. Fe concentrations ranged from approximately 265,000 ppm to 49,000 ppm.

PIXE discussion

The PIXE data were thoroughly investigated to determine if sources were distinguishable based on their elemental contents. Graphical methods, Principal

Components Analysis (PCA) and Canonical Discriminant Analysis (CDA) were all used to help determine the best way to match archaeological samples to their sources on the landscape.

First, the range of concentrations for each element was examined for each of the sources. Box plots showing these ranges are presented in Figs. 5.18 to 5.29. It was hoped that some sources might have unusual elemental concentrations that set them apart from other sources. This is the most basic way to begin looking for differences between sources. For the LoE data some distinctions were noted. All samples contain at least some aluminum although Gondwana C and Riversdale contain samples with higher concentrations. All samples contain silicon but Gondwana C, PP B, Rivercrossing and Roodekrans have higher concentrations with a wider range of variability. P content is fairly variable with some sources having none detected while others show a range of variation. Sulfur concentrations are low in general, but Albertinia B, PP B and Rooikoppie samples showed a wider range of variation. Chlorine concentrations are similarly low except at Gondwana C, PP B, and Rietvlei B. Potassium concentrations are also similarly low with Gondwana C, PP B, and Rietvlei B more elevated. Calcium concentrations are consistently low across the dataset with the occasional outlying sample. Titanium concentrations are also low but Gondwana C, Rivercrossing, and Roodekrans have elevated levels compared to the other localities. Vanadium is detectable in most samples but only in small amounts. Chromium is also found in small amounts in all sources but is slightly more common at Gondwana C, PP B, and Roodekrans. Manganese is low in all sources but highest at PP A. Iron concentration is highly variable, as is common in ochres. However, Glentana, Gondwana C, Herbertsdale, PP B, Rietvlei B, Rivercrossing, Riversdale and Roodekrans have lower and less variable iron concentrations compared to the other localities.

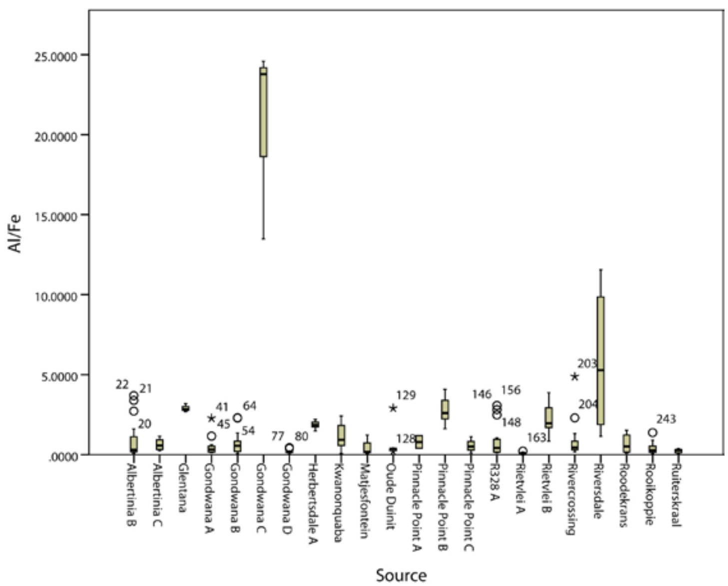

Fig 5.18. Aluminum concentrations from LoE PIXE

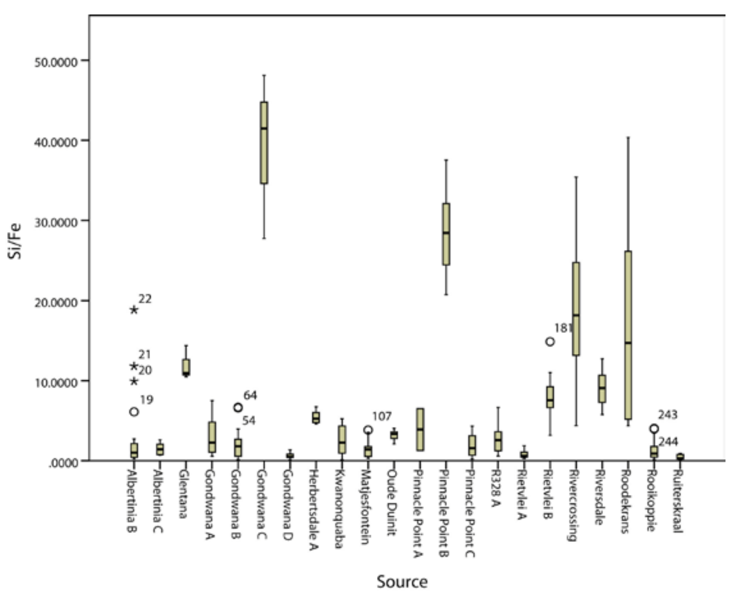

Fig. 5.19. Silicon concentrations from LoE PIXE

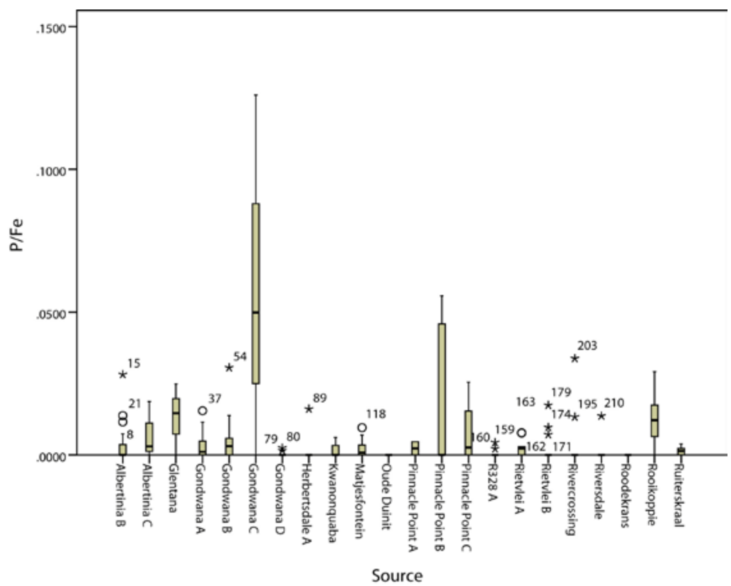

Fig. 5.20. Phosphorous concentrations from LoE PIXE

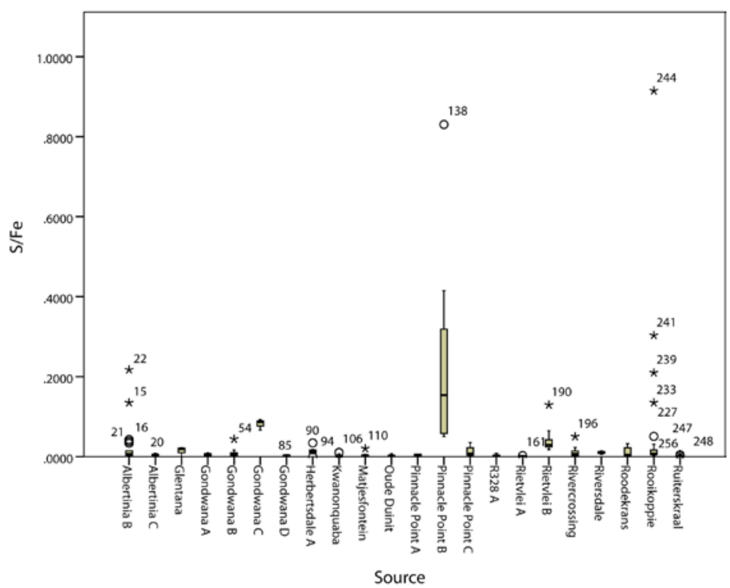

Fig. 5.21. Sulfur concentrations from LoE PIXE

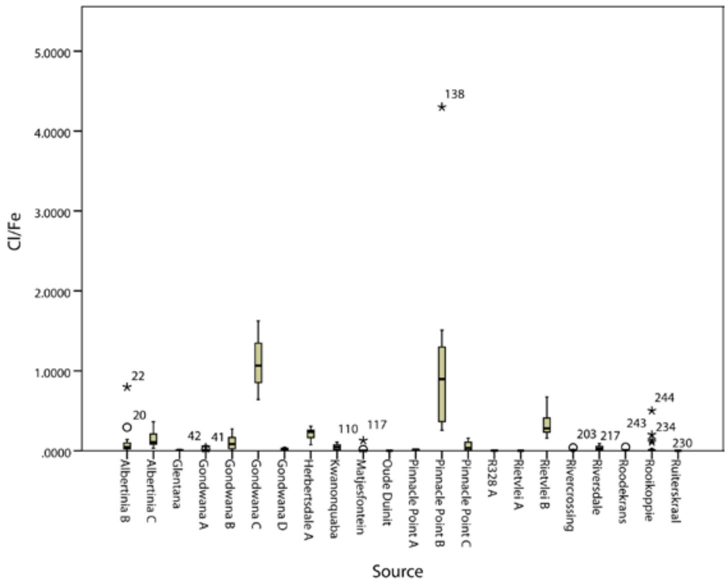

Fig. 5.22. Chlorine concentrations from LoE PIXE

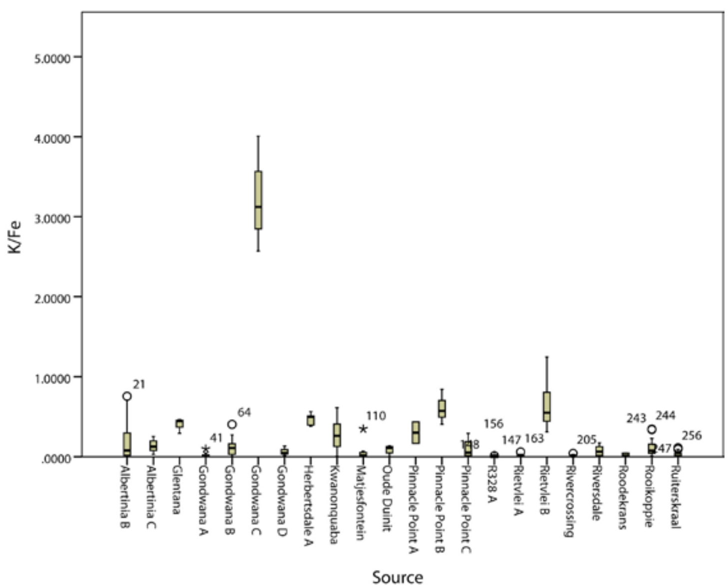

Fig. 5.23. Potassium concentrations from LoE PIXE

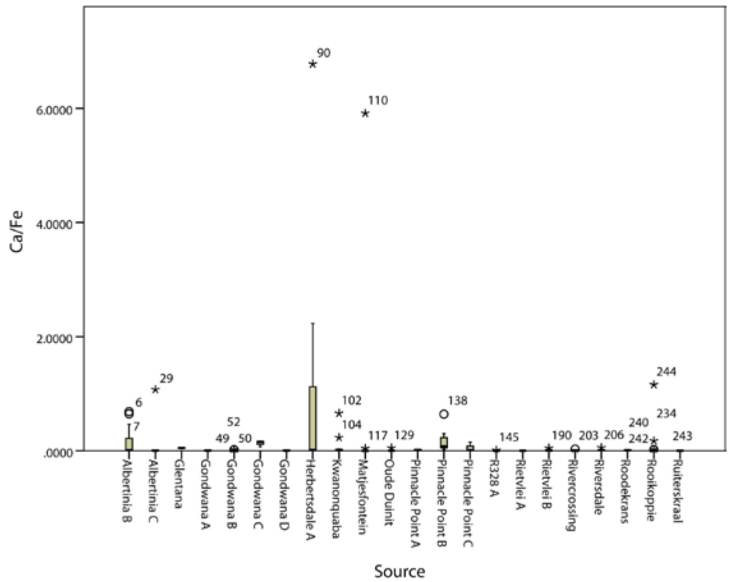

Fig. 5.24. Calcium concentrations from LoE PIXE

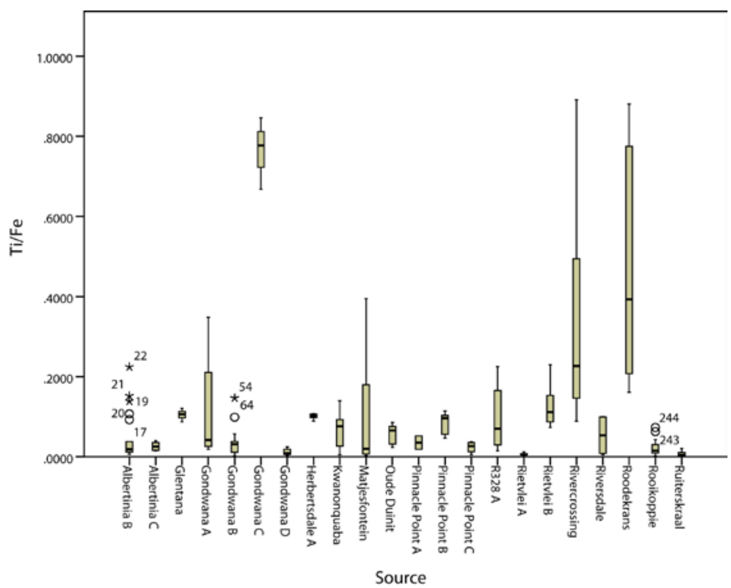

Fig. 5.25. Titanium concentrations from LoE PIXE

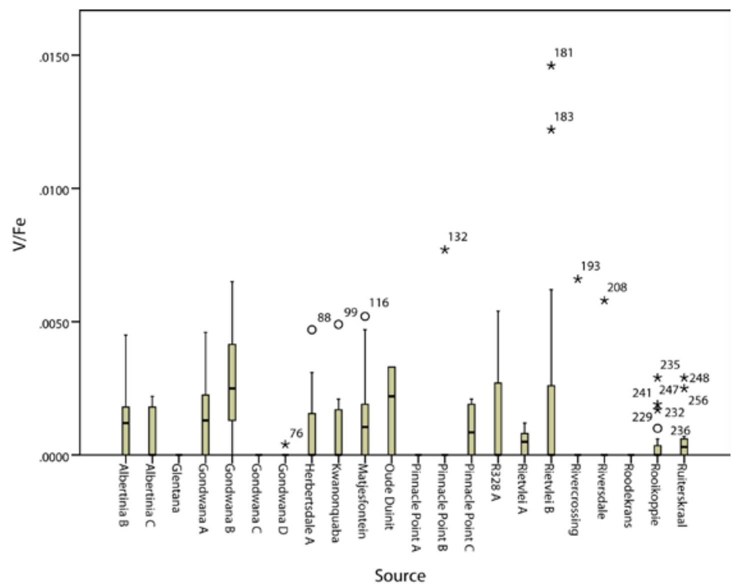

Fig.5.26. Vanadium concentrations from LoE PIXE

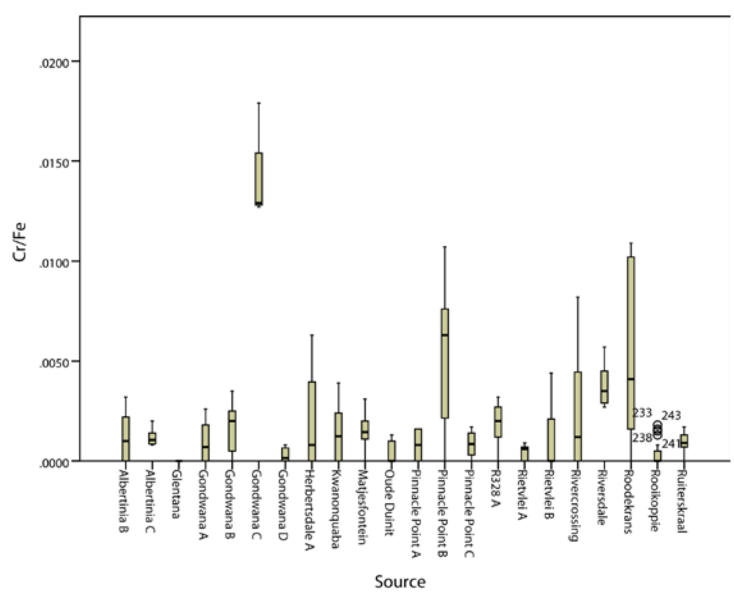

Fig.5.27. Chromium concentrations from LoE PIXE

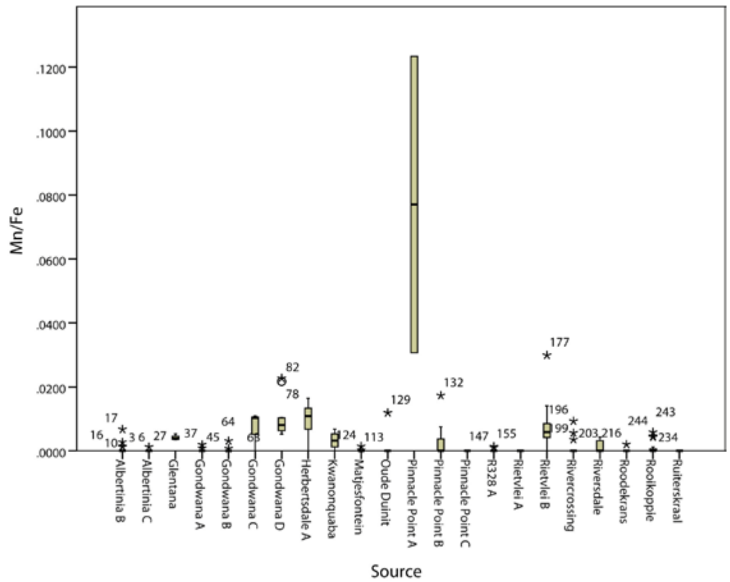

Fig. 5.28. Manganese concentrations from LoE PIXE

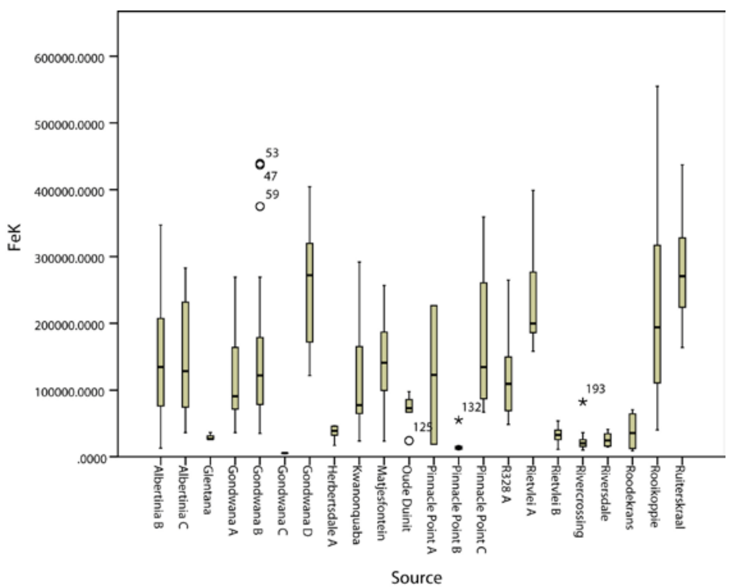

Fig. 5.29. Iron concentrations from LoE PIXE

PCA was used to determine if groups of sources or individual sources could be identified within the geological data. CDA was also explored to determine if samples could be correctly identified to their source in hopes that this would be a useful technique for assigning archaeological samples to potential sources.

PCA was run using a correlation matrix (Table 5.23) and no rotation. The first four components account for 68% of the variation in the data set (Table 5.24). All the elements except Ca, C, and Mn load on the first component with Al, Si, K and Ti loading the most (Table 5.25). The second component is driven primarily by S and Cl. The third component is driven by V, Mn, and P and the fourth by V and Mn and negatively by Ca. It is clear from the plots for these four components (Fig. 5.30) that differentiating sources based on LoE data alone is not possible. There is too much variation within sources and too much similarity between them.

Table 5.23

Correlation matrix for LoE Fe normalized PIXE data

		Al/Fe	Si/Fe	P/Fe	S/Fe	Cl/Fe	K/Fe	Ca/Fe	Ti/Fe	V/Fe	Cr/Fe	Mn/Fe
Correlation	Al/Fe	1.000	.587	.299	.167	.417	.848	.044	.459	-.028	.598	-.018
	Si/Fe	.587	1.000	.329	.271	.435	.538	.033	.784	-.060	.636	-.042
	P/Fe	.299	.329	1.000	.143	.150	.372	.030	.238	-.124	.157	.077
	S/Fe	.167	.271	.143	1.000	.682	.240	.132	.074	-.063	.208	-.014
	Cl/Fe	.417	.435	.150	.682	1.000	.508	.088	.176	.013	.418	-.009
	K/Fe	.848	.538	.372	.240	.508	1.000	.073	.416	.008	.501	.006
	Ca/Fe	.044	.033	.030	.132	.088	.073	1.000	.015	-.057	.003	-.013
	Ti/Fe	.459	.784	.238	.074	.176	.416	.015	1.000	-.100	.565	-.043
	V/Fe	-.028	-.060	-.124	-.063	.013	.008	-.057	-.100	1.000	-.041	-.043
	Cr/Fe	.598	.636	.157	.208	.418	.501	.003	.565	-.041	1.000	-.061
	Mn/Fe	-.018	-.042	.077	-.014	-.009	.006	-.013	-.043	-.043	-.061	1.000
Sig. (1-tailed)	Al/Fe		.000	.000	.001	.000	.000	.213	.000	.307	.000	.371
	Si/Fe	.000		.000	.000	.000	.000	.277	.000	.139	.000	.222
	P/Fe	.000	.000		.005	.003	.000	.292	.000	.013	.002	.081
	S/Fe	.001	.000	.005		.000	.000	.008	.091	.126	.000	.402
	Cl/Fe	.000	.000	.003	.000		.000	.057	.001	.407	.000	.438
	K/Fe	.000	.000	.000	.000	.000		.094	.000	.440	.000	.456
	Ca/Fe	.213	.277	.292	.008	.057	.094		.393	.153	.482	.407
	Ti/Fe	.000	.000	.000	.091	.001	.000	.393		.035	.000	.219
	V/Fe	.307	.139	.013	.126	.407	.440	.153	.035		.228	.218
	Cr/Fe	.000	.000	.002	.000	.000	.000	.482	.000	.228		.135
	Mn/Fe	.371	.222	.081	.402	.438	.456	.407	.219	.218	.135	

Table 5.24
Total variance explained by the principal components

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.971	36.104	36.104	3.971	36.104	36.104
2	1.394	12.670	48.774	1.394	12.670	48.774
3	1.136	10.328	59.102	1.136	10.328	59.102
4	1.027	9.337	68.439	1.027	9.337	68.439
5	.936	8.506	76.944			
6	.849	7.715	84.660			
7	.733	6.665	91.325			
8	.402	3.650	94.975			
9	.259	2.357	97.332			
10	.178	1.615	98.947			
11	.116	1.053	100.000			

Table 5.25
Component matrix

	1	2	3	4
Al/Fe	.826	-.139	-.047	.151
Si/Fe	.847	-.206	-.026	-.118
P/Fe	.434	-.085	.493	.174
S/Fe	.438	.773	.012	-.048
Cl/Fe	.654	.622	-.122	.093
K/Fe	.820	-.007	-.005	.219
Ca/Fe	.091	.332	.243	-.478
Ti/Fe	.700	-.447	.002	-.219
V/Fe	-.083	.044	-.677	.478
Cr/Fe	.766	-.165	-.176	-.081
Mn/Fe	-.033	.030	.572	.624

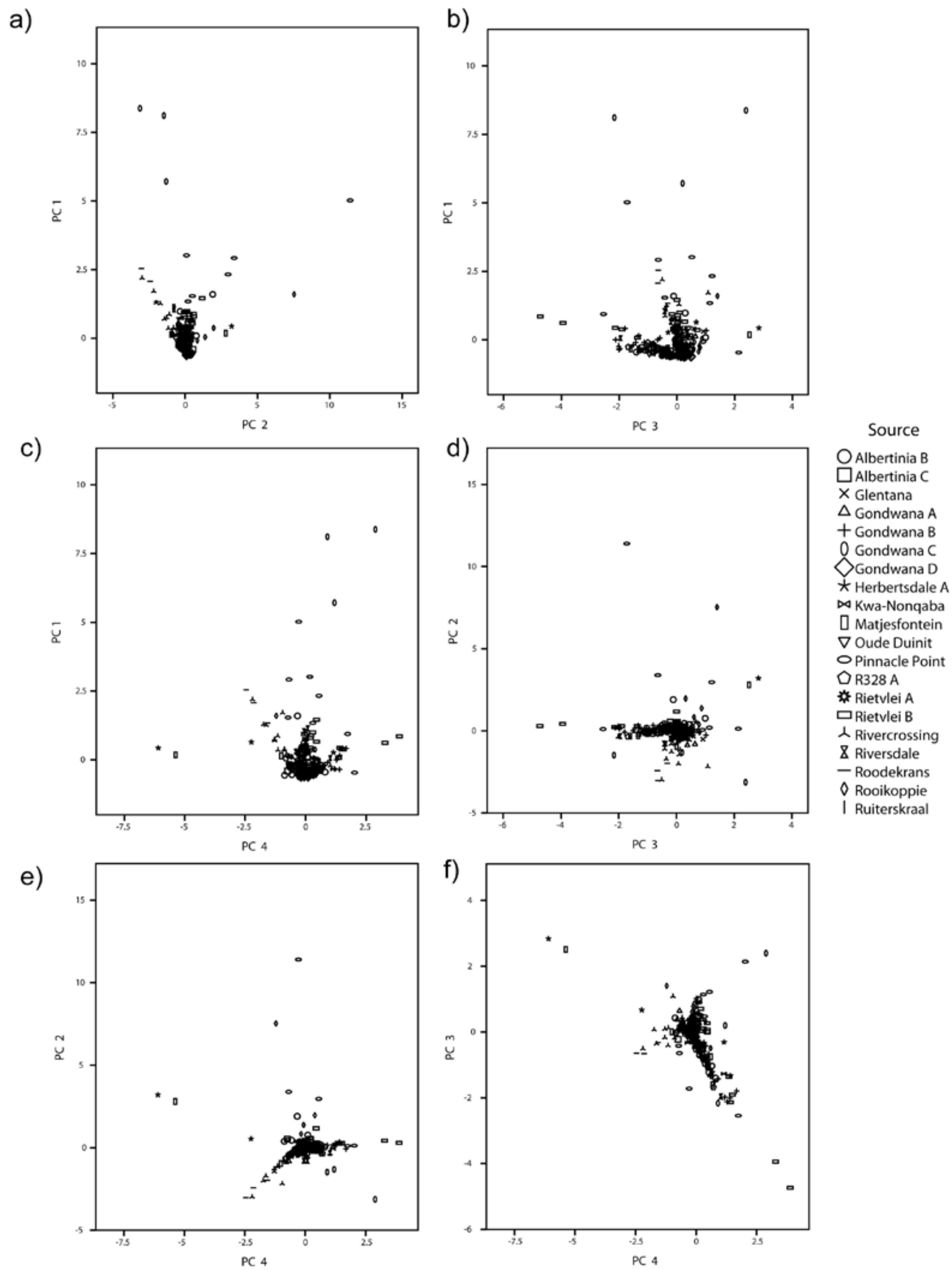

Fig. 5.30. Plots of first four PCA components from the LoE PIXE data for all geological sources. a) PC 1 vs. PC2, b) PC1 vs. PC3, c) PC1 vs. PC4, d) PC2 vs. PC3, e) PC2 vs. PC4, f) PC3 vs. PC4

A CDA was performed on all geological data after Fe normalizing. All the independent variables (LoE elements) were added into the analysis together. CDA was also unsuccessful at reliably differentiating known sources. Four discriminant functions have eigenvalues above one and describe a cumulative 93.6% of the assemblage (Table 5.26). Discriminant function coefficients are presented in Table 5.27. Unfortunately, these functions only correctly predict group membership 50.2% percent of the time. A stepwise CDA was also carried out but this resulted in correct predictions only 48.3% of the time. For this dataset, CDA of the LoE PIXE data would not be useful for helping to match archaeological samples to their sources on the landscape. This supports the conclusion from PCA that there is too much variability within sources and not enough variability between them.

Table 5.26
Percentage of variance explained for each discriminant function

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	9.825	63.5	63.5	.953
2	1.950	12.6	76.1	.813
3	1.673	10.8	86.9	.791
4	1.024	6.6	93.6	.711
5	.363	2.3	95.9	.516
6	.277	1.8	97.7	.466
7	.175	1.1	98.8	.386
8	.085	.5	99.4	.279
9	.047	.3	99.7	.213
10	.033	.2	99.9	.179
11	.015	.1	100.0	.120

Table 5.27
Standardized canonical discriminant function coefficients

	1	2	3	4	5	6	7	8	9	10	11
Al/Fe	.409	.069	-.764	.747	-.474	-.139	.011	.134	.260	.173	-.191
Si/Fe	-.846	1.046	.924	.310	-.307	-.222	-.092	.195	-.516	-.241	.231
P/Fe	-.010	.094	-.076	.464	.863	.022	-.064	.248	.005	.485	.192
S/Fe	-.312	-.066	-.120	.113	.192	-.523	-.030	.135	.751	-.997	-.028
Cl/Fe	.147	-.034	.351	.071	.035	.577	-.218	-.174	-.049	.945	-.844
K/Fe	.945	-.406	.576	-.637	.037	-.166	.011	-.079	-.203	-.298	.154
Ca/Fe	.033	-.003	.015	-.045	.032	.452	.614	.670	-.088	-.027	-.094
Ti/Fe	.334	.105	-.811	-.844	.167	-.001	-.014	.029	.526	.349	-.270
V/Fe	.071	-.063	-.049	-.035	-.100	.458	-.648	.473	.282	-.016	.283
Cr/Fe	.341	.068	-.303	.190	.521	.673	.119	-.386	-.144	-.412	.302
Mn/Fe	-.018	.302	.448	.212	-.145	.228	.337	-.181	.582	.260	.395

There are not many large scale characterization studies of ochre deposits available to compare to the range of variation seen in these geological sources. However, Popelka-Filcoff (2006) has reported on variation within several sources in Missouri. Two of these sources contained multiple samples taken from the same location within the larger source. A sample of these data are presented in Tables 5.28. These samples show a range of variation in the chemical data that is similar to or more extreme than that identified in the sources studied here. This suggests that the range of intrasource variation may not be particularly unusual.

Table 5.28
Examples of intrasource variation in ochre sources from Missouri (Popelka-Filcoff 2006)

Source	*Sample*	*Sub-sample*	*Fe(%)*
Meramac Park	A-I	JDR099	1.43
Meramac Park	A-I	JDR100	1.48
Meramac Park	A-I	JDR101	2.12
Meramac Park	A-I	JDR102	4.39
Meramac Park	A-II	JDR103	4.43
Meramac Park	A-II	JDR104	9.86
Meramac Park	A-II	JDR105	13.59
Meramac Park	A-II	JDR106	2.18
Meramac Park	A-II	JDR107	4.83
Meramac Park	A-III	JDR108	10.43
Meramac Park	A-III	JDR109	51.19
Meramac Park	A-III	JDR110	53.77
Meramac Park	A-IV	JDR112	60.03
Meramac Park	A-IV	JDR113	60.34
Meramac Park	A-IV	JDR114	63.18
Meramac Park	A-IV	JDR116	24.38
Meramac Park	A-V	JDR117	7.23
Meramac Park	A-V	JDR118	44.95
Meramac Park	A-V	JDR119	60.93
Meramac Park	A-V	JDR121	28.69
Doug Wood	B-I	JDR122	2.75
Doug Wood	B-I	JDR123	2.87
Doug Wood	B-I	JDR124	0.51
Doug Wood	B-I	JDR125	2.81
Doug Wood	B-I	JDR126	2.82
Doug Wood	B-II	JDR127	45.09
Doug Wood	B-II	JDR128	28.16
Doug Wood	B-II	JDR129	25.75
Doug Wood	B-II	JDR130	16.42
Doug Wood	B-II	JDR131	44.86
Doug Wood	B-III	JDR132	1.06
Doug Wood	B-III	JDR133	1.27
Doug Wood	B-III	JDR134	0.99
Doug Wood	B-III	JDR135	0.8
Doug Wood	B-III	JDR136	1.12

The intrasource variation also does not seem to be attributable to instrument error. A subset of samples was rerun on different days to check for consistency of results (Table 5.29). The RDS values for these samples are within the accepted range of error for PIXE of 5-10%.

Table 5.29
Samples rerun to check consistency of results

Sample	*Fe*	*RSD (%)*
G6 Run 1	205882.9	1.4
G6 Run 2	210038.4	
G7 Run 1	554930.8	4.2
G 7 Run 2	523177.1	
G10 Run 1	119902.8	2.8
G10 Run 2	124736.2	
G12 Run 1	463599	2
G12 Run 2	476921.7	
G4 Run 1	346973.4	5.4
G4 Run 2	374300.5	
G17 Run 1	150332.5	3.6
G17 Run 2	142838.1	
G21 Run 1	104690.7	2.1
G21 Run 2	107800.2	
G29 Run 1	52881.8	3.5
G29 Run 2	55583.6	
G37 Run 1	52833.6	5.93
G37 Run 2	57464.5	
G38 Run 1	275785.6	3.42
G38 Run 2	289482.4	

Conclusion

A considerable amount of ochre exists on the landscape within the 30km study region surrounding PP. Twenty-two sources were identified, described, and mineralogically and elementally characterized. The ochre is highly variable in composition within and between sources making clear statistical differentiation of sources difficult. However, using a combination of techniques it may still be possible to identify the most likely origin of some archaeological material. This is further discussed in Chapter Six.

CHAPTER 6: TEST IMPLICATION 1A- EXPLOITATION PATTERNS AND ARCHAEOLOGICAL SOURCING ANALYSES

Introduction

Archaeological ochre was excavated as part of the SACP4 project following excavation procedures previously published (Marean *et al.*2004). All excavated materials are currently housed in the SACP4 lab and storage facilities at the Dias Museum in Mossel Bay, South Africa. From the larger assemblage, ochre samples were chosen for sourcing analysis based on several criteria. Pieces were larger than 1 gram. If pieces had evidence of grinding or other use-wear, samples were taken from an unmodified surface after the piece has been extensively photographed. A range of colors were included in the sample in an attempt to capture the diversity of the assemblage.

A total of 22 samples were taken from the PP13B ochre assemblage for characterization and sourcing analyses (Table 6.1). The samples were originally chosen by Watts for magnetic analyses and were passed on for this project rather than destroying a new set of samples. The sample coverage is not distributed as evenly as for PP5-6.

Table 6.1
Samples taken from PP13B

Specimen	Excavation Area	StratAgg	Color
59504	Northeastern	LC-MSA Lower	Red
80427	Northeastern	LC-MSA Lower	Red
81745	Northeastern	LC-MSA Lower	Red
59549	Eastern	Upper Roofspall	Red
111483	Eastern	Upper Roofspall	Red
52493	Eastern	Shelly Brown Sand	Red
56924	Eastern	Shelly Brown Sand	Red
57070	Eastern	Shelly Brown Sand	Red
31404	Eastern	Truncation Fill	Red
59548	Eastern	Truncation Fill	Red
25992	Eastern	Redeposited Disturbance	Red
30255	Eastern	Redeposited Disturbance	Red
26091	Eastern	Surface	Red
59519	Eastern	Surface	Red
22873	Western	DB Sand 2	Red
22109	Western	DB Sand 3	Red
22151	Western	DB Sand 3	Red
34674	Western	DB Sand 3	Red
82307	Western	DB Sand 3	Red
53348	Western	LBG Sand 1	Red
53738	Western	LBG Sand 1	Red
45739	Western	LB Sand 1	Red

A total of 40 samples were selected from the PP5-6 ochre assemblage for characterization and sourcing analyses (Table 6.2). Thirty-six samples come from the Long Section and four were taken from the Northwest Remnant. There are two samples from the BCSR, seven from the RBSR, eleven from the DBCS, one from the SGS, three from the OBS, five from the SADBS, two from the ALBS and five from the LBSR. No samples were taken from the disturbed aggregates including the BLSR.

Table 6.2
Samples taken from PP5-6

Specimen	Excavation Area	StratAgg	Color
103053	NWR	DBSS	Red
103234	NWR	DBSS	Orange
103512	NWR	DBSS	Red
103759	NWR	DBSS	Red
257436	Long Section	BCSR	Red-black
257438	Long Section	BCSR	Red
153642	Long Section	RBSR	Red
257250	Long Section	RBSR	Red
257271	Long Section	RBSR	Red
257297	Long Section	RBSR	Red
257318	Long Section	RBSR	Orange
257324	Long Section	RBSR	Red
257326	Long Section	RBSR	Yellow
119208	Long Section	DBCS	Orange
120449	Long Section	DBCS	Red
120450	Long Section	DBCS	Red
121931	Long Section	DBCS	Red
122709	Long Section	DBCS	Red
133123	Long Section	DBCS	Red
138351	Long Section	DBCS	Red
168843	Long Section	DBCS	Red
170199	Long Section	DBCS	Red
181724	Long Section	DBCS	Red
257335	Long Section	DBCS	Red
257347	Long Section	SGS	Red
257329	Long Section	OBS	Red
257330	Long Section	OBS	Yellow
257357	Long Section	OBS	Red-black
131583	Long Section	SADBS	Orange
135335	Long Section	SADBS	Orange
135670	Long Section	SADBS	Red
151183	Long Section	SADBS	Yellow
257362	Long Section	SADBS	Yellow
172814.2	Long Section	ALBS	Red
181100.3	Long Section	ALBS	
257247	Long Section	LBSR	Yellow
257272	Long Section	LBSR	Red
257349	Long Section	LBSR	Red
257433	Long Section	LBSR	Red
257449	Long Section	LBSR	Red

XRD results

PP13B

LC-MSA Lower Three samples were taken from the LC-MSA Lower assemblage of sixty-five fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.1 to Fig. C.3). Sample 59504 contains hematite, quartz, and maghemite. Sample 80427 contains trace goethite with quartz, illite, kaolinite, and calcite. Sample 81745 contains hematite with quartz, illite, and kaolinite.

Upper Roofspall Facies There were two samples taken from the Upper Roofspall Facies assemblage of seventy-three fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.4 and Fig. C.5). Sample 59549 contains hematite, maghemite, quartz and kaolinite suggesting it has been exposed to heat. Sample 111483 contains hematite, quartz, and kaolinite.

Shelly Brown Sand Three samples were taken from the Shelly Brown Sand assemblage of ten fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.6 to Fig. C.8). Two samples are similar and contain hematite and quartz. The remaining sample, 52493, contains hematite, quartz, and maghemite.

Truncation Fill Two samples were taken from the Truncation Fill assemblage of forty-one fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.9 and Fig C.10). Sample 31404 was made up of hematite, and quartz, with some salt impregnation identified. Sample 59548 contains hematite, goethite, and quartz.

Redeposited Disturbance Two samples were taken from the Redeposited Disturbance assemblage of thirty-five fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.11 and Fig C.12). Both samples contain hematite and quartz while one also had illite and kaolinite identified.

Eastern Area Surface Two samples were taken from the Surface deposits in the Eastern excavation area. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.13 and Fig. C.14). Sample 26091 contains hematite, quartz, illite, kaolinite and gypsum. Maghemite may also be present. The second sample, 59519, contains hematite, illite and quartz.

DB Sand 2 One sample was taken from the DB Sand 2 assemblage of thirty-three fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.15). The sample contains hematite, goethite, quartz, and halite.

DB Sand 3 Four samples were taken from the DB Sand 3 assemblage of seventy-two fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.16 to Fig. C.19). Sample 22109 contains hematite and quartz. The remaining three samples all contain hematite, quartz, and kaolinite. Sample 22151 also contains halite and sample 34674 also contains illite.

LBG Sand 1 There were two samples taken from the LBG Sand 1 assemblage of twenty-three fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.20 and Fig. C.21). Both contain hematite and quartz but sample 53348 also has a clay component consisting of illite and kaolinite.

LB Sand 1 Only one sample was taken from the LB Sand 1 assemblage of thirty-six fragments. The XRD pattern and mineral identifications are presented in Appendix C (Fig. C.22). The sample contains hematite, quartz, and illite.

PP5-6

DBSS Four samples were taken from the DBSS assemblage of twenty-two fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.23 to Fig. C.26). Three of these samples have similar mineralogy containing hematite, quartz, illite, and kaolinite. The remaining sample, 103234, contains goethite, quartz, and feldspar.

BCSR Two samples were taken from the BCSR assemblage of seventeen fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.27 and Fig. C.28). Sample 257438 contains hematite, quartz, illite, and kaolinite. The other sample, 257436, seems to lack the clay components and only hematite and quartz were identified.

RBSR Seven samples were chosen for characterization and sourcing from the RBSR assemblage of sixty-eight fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.29 to Fig. C.35). Two samples

(153642 and 257271) contained hematite, quartz, illite, and kaolinite. One other sample (257297) was similar but kaolinite was not detected. For sample 257250, only hematite and quartz were detected. Sample 257318 contains hematite, quartz, and feldspar. The remaining two samples (257324 and 257326) contain goethite, illite, and quartz.

DBCS Eleven samples were chosen from the DBCS assemblage of one hundred and thirty-one fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.36 to Fig. C.46). Four samples (121931, 168843, 170199, and 181724) contain hematite and quartz with no clay component detected. Another four (120449, 120450, 122709, and 133123) contain hematite, quartz, and illite. Sample 120449 also contains feldspar. Sample 257335 contains hematite, quartz, illite, and kaolinite. Sample 119208 contains goethite and quartz, and sample 138351 contains hematite, quartz and maghemite.

SGS Only one sample was taken from the SGS assemblage of twelve fragments. The XRD pattern and mineral identifications are presented in Appendix C (Fig. C.47). Hematite and quartz were identified in the sample.

OBS1 There were three samples taken from the OBS1 assemblage of twenty fragments. The XRD pattern and mineral identifications are presented in Appendix C (Fig. C.48 to Fig. C.50). Sample 257329 contains hematite, quartz, and illite. Sample 257357 contains hematite and quartz, and sample 257330 contains goethite and quartz.

SADBS Five samples were selected from the SADBS assemblage of thirty-eight fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.51 to Fig. C.55). Sample 131583 contains hematite, quartz, and feldspar. Sample 135335 contains hematite, quartz, kaolinite, and illite. Sample 135670 contains hematite and quartz. For sample 151183 only quartz and feldspar were identified. However, the yellow color of the sample suggests that goethite may also be present in trace amounts. Sample 257362 contains goethite, quartz, kaolinite, illlite, and feldspar.

ALBS There were two samples selected from the ALBS assemblage of twenty fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.56 and Fig. C.57). One sample, 172814.2, contains hematite, quartz, illite and calcite. The other sample, 181100.3, contains goethite, quartz, kaolinite, and feldspar.

LBSR Five samples were taken from the LBSR assemblage of thirty-four fragments. The XRD patterns and mineral identifications are presented in Appendix C (Fig. C.58 to Fig. C.62). Sample 257247 contains goethite, quartz, and illite. Sample 257272 contains goethite, quartz, kaolinite, and illite. Sample 257349 contains hematite, quartz, and maghemite. Hematite, quartz, kaolinite, and illite were identified in sample 257433 and hematite goethite, and quartz were identified in sample 257449.

PIXE results

All archaeological samples were processed using the same methodology as the geological samples. A 1.72 MeV proton (H+) beam was used to excite the low Z (atomic number) elements that comprise the bulk of the samples (LoE PIXE). These runs provided ppm concentration data on the following elements: Na, M, Al, Si, P , S , Cl , K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu , and Zn. Results are most accurate for elements with atomic numbers lower than Fe. Na, M, and Sc were removed from the analyses as they were not detected in most samples. Random samples were rerun on different days to check for consistency of results. GUPIX© software from the University of Guelph was used to convert the PIXE spectrum to elemental concentrations. Fe normalized data are presented in Tables 6.3 and 6.4.

Table 6.3

LoE PIXE data for PP13B samples

Sample	Al/Fe	Si/Fe	P/Fe	S/Fe	Cl/Fe	K/Fe	Ca/Fe	Ti/Fe	V/Fe	Cr/Fe	Mn/Fe
22109	0.1044	0.3416	0.0032	0.0026	0.0136	0.0110	0.0271	0.0073	0.0006	0.0000	0.0000
22151	0.5471	1.1106	0.0211	0.0200	0.2036	0.0072	0.0388	0.0269	0.0000	0.0015	0.0012
22873	0.1701	1.2712	0.0169	0.0041	0.0511	0.0473	0.0183	0.0106	0.0008	0.0000	0.0021
25992	0.0964	0.2731	0.0074	0.0038	0.0162	0.0298	0.0091	0.0056	0.0005	0.0000	0.0000
26091	0.4213	1.4336	0.0049	0.0033	0.1492	0.1303	0.0442	0.0293	0.0039	0.0028	0.0012
30255	0.2832	0.6706	0.0033	0.0066	0.0811	0.0880	0.0118	0.0187	0.0000	0.0009	0.0000
31404	0.0805	1.4820	0.0057	0.0036	0.0309	0.0094	0.0120	0.0026	0.0000	0.0000	0.0014
34674	0.5488	1.2486	0.0074	0.0047	0.0951	0.1408	0.0155	0.0378	0.0000	0.0000	0.0024
45739	0.2077	0.9030	0.0117	0.0025	0.0706	0.0822	0.0105	0.0154	0.0016	0.0000	0.0009
52493	0.0739	0.2877	0.0167	0.0000	0.0237	0.0291	0.0278	0.0036	0.0000	0.0000	0.0458
53348	0.3175	1.3780	0.0047	0.0036	0.0447	0.0639	0.0065	0.0179	0.0000	0.0023	0.0008
53738	0.0438	0.1739	0.0035	0.0010	0.0157	0.0114	0.0055	0.0023	0.0003	0.0000	0.0038
56924	1.2180	16.2129	0.1443	0.0175	0.2918	0.4032	0.1460	0.1012	0.0000	0.0000	0.0062
57070	0.0367	0.1414	0.0000	0.0012	0.0045	0.0139	0.0018	0.0038	0.0000	0.0000	0.0000
59504	0.2857	2.1348	0.0059	0.0000	0.1357	0.0548	0.0521	0.0267	0.0018	0.0032	0.0000
59548	0.0204	0.0926	0.0018	0.0011	0.0205	0.0015	0.0037	0.0036	0.0003	0.0004	0.0000
80427	0.7115	2.2374	0.0842	0.0117	0.2537	0.2472	1.0829	0.0501	0.0000	0.0000	0.0113
81745	0.6392	1.5157	0.0000	0.0019	0.0806	0.1552	0.0094	0.0424	0.0000	0.0010	0.0031
82307	0.1333	0.5143	0.0000	0.0034	0.0156	0.0276	0.0025	0.0066	0.0016	0.0014	0.0000
111483	0.3211	1.3905	0.0061	0.0021	0.0307	0.0538	0.0154	0.0202	0.0012	0.0000	0.0010
59519	0.0808	0.0940	0.0011	0.0015	0.0219	0.0249	0.0019	0.0170	0.0010	0.0007	0.0000

Table 6.4
LoE PIXE data for PP5-6 samples

Sample	Al/Fe	Si/Fe	P/Fe	S/Fe	Cl/Fe	K/Fe	Ca/Fe	Ti/Fe	V/Fe	Cr/Fe	Mn/Fe
103053	0.3881	1.2592	0.0045	0.0017	0.0246	0.1207	0.0072	0.0195	0.0011	0.0000	0.0006
103234	0.1001	0.4525	0.0062	0.0020	0.0193	0.0377	0.0044	0.0028	0.0004	0.0000	0.0000
103512	0.2689	0.8278	0.0000	0.0085	0.0108	0.0744	0.0027	0.0219	0.0000	0.0005	0.0000
103759	0.3102	0.7562	0.0062	0.0008	0.0109	0.1165	0.0135	0.0228	0.0000	0.0011	0.0007
119208	0.0500	0.0673	0.0042	0.0012	0.0004	0.0021	0.0025	0.0015	0.0000	0.0000	0.0000
120449	0.1126	0.4766	0.0034	0.0023	0.0005	0.0457	0.0052	0.0090	0.0000	0.0004	0.0000
120450	0.2196	1.0308	0.0067	0.0015	0.0009	0.0881	0.0176	0.0185	0.0000	0.0010	0.0007
121931	0.0432	0.3222	0.0088	0.0008	0.0012	0.0118	0.0140	0.0069	0.0009	0.0009	0.0009
122709	0.2492	1.1917	0.0285	0.0029	0.0023	0.1094	0.0567	0.0186	0.0009	0.0010	0.0000
131583	0.3634	13.3423	0.0191	0.0147	0.0116	0.0211	0.1781	0.2663	0.0000	0.0059	0.0051
133123	0.5313	0.6025	0.0000	0.0014	0.0019	0.0715	0.0093	0.0097	0.0000	0.0007	0.0000
135335	1.8731	21.4677	0.0359	0.0000	0.0078	0.3904	0.2126	0.1029	0.0000	0.0089	0.0000
135670	0.0572	0.1699	0.0016	0.0005	0.0022	0.0149	0.0126	0.0031	0.0000	0.0000	0.0135
138351	0.2081	0.6372	0.0089	0.0011	0.0019	0.0536	0.0140	0.0112	0.0000	0.0000	0.0034
151183	0.4030	24.5392	0.0715	0.0406	0.0208	0.0352	0.3169	0.4516	0.0000	0.0052	0.0000
153642	0.2774	0.8942	0.0039	0.0033	0.0010	0.0983	0.0052	0.0162	0.0000	0.0000	0.0009
157183	0.4030	24.5392	0.0715	0.0406	0.0208	0.0352	0.3169	0.4516	0.0000	0.0052	0.0000
168843	0.0280	0.1651	0.0132	0.0005	0.0011	0.0057	0.0214	0.0020	0.0023	0.0015	0.0026
170199	0.0841	0.2546	0.0072	0.0005	0.0009	0.0182	0.0076	0.0035	0.0012	0.0006	0.0000
172814	0.1240	0.5874	0.0032	0.0034	0.0038	0.0496	0.0671	0.0133	0.0000	0.0006	0.0000
181100	0.5553	8.2110	0.0383	0.0128	0.0142	0.0198	0.1708	0.5805	0.0000	0.0045	0.0000
181724	0.0988	0.3897	0.0040	0.0012	0.0050	0.0354	0.0136	0.0059	0.0012	0.0000	0.2625
257247	0.1458	0.4700	0.0041	0.0014	0.0008	0.0753	0.0213	0.0129	0.0000	0.0007	0.0142

Table 6.4 Con’t

LoE PIXE data for PP5-6 samples

Sample	Al/Fe	Si/Fe	P/Fe	S/Fe	Cl/Fe	K/Fe	Ca/Fe	Ti/Fe	V/Fe	Cr/Fe	Mn/Fe
257250	0.0932	0.4163	0.0011	0.0037	0.0000	0.0355	0.0021	0.0082	0.0000	0.0004	0.0000
257271	0.2381	1.2988	0.0190	0.0010	0.0018	0.0645	0.0323	0.0110	0.0008	0.0000	0.0009
257272	0.1835	0.6162	0.0064	0.0000	0.0020	0.0591	0.0101	0.0538	0.0000	0.0000	0.0034
257297	0.1246	0.6614	0.0061	0.0035	0.0023	0.0450	0.0048	0.0098	0.0010	0.0020	0.0009
257318	0.3419	1.7583	0.0113	0.0013	0.0018	0.0062	0.0099	0.1594	0.0031	0.0018	0.0028
257324	0.1124	0.2624	0.0057	0.0000	0.0007	0.0469	0.0032	0.0060	0.0000	0.0000	0.0109
257326	0.2116	0.5313	0.0140	0.0000	0.0007	0.0702	0.0079	0.0107	0.0000	0.0008	0.0842
257329	0.1553	0.8916	0.0190	0.0014	0.0028	0.0710	0.0273	0.0049	0.0006	0.0000	0.0059
257330	0.0565	0.2174	0.0034	0.0005	0.0013	0.0132	0.0028	0.0024	0.0006	0.0000	0.0105
257335	0.5121	2.0626	0.0091	0.0016	0.0030	0.1616	0.0090	0.0391	0.0000	0.0017	0.0032
257347	0.1181	0.9763	0.0035	0.0011	0.0007	0.0285	0.0069	0.0137	0.0000	0.0011	0.0031
257349	0.0745	0.3474	0.0024	0.0008	0.0048	0.0221	0.0064	0.0039	0.0000	0.0005	0.0181
257357	0.0367	0.1467	0.0060	0.0000	0.0009	0.0104	0.0094	0.0023	0.0018	0.0000	0.0294
257362	0.2168	0.6027	0.0171	0.0000	0.0035	0.0924	0.0097	0.1522	0.0000	0.0006	0.0294
257433	0.3854	1.9579	0.0078	0.0000	0.0040	0.1739	0.0158	0.0235	0.0015	0.0016	0.0019
257436	0.0810	0.3527	0.0272	0.0018	0.0030	0.0328	0.0403	0.0103	0.0000	0.0000	0.5316
257438	0.3381	1.5342	0.0033	0.0024	0.0021	0.0670	0.0054	0.0204	0.0000	0.0011	0.0016
257449	0.0087	0.0775	0.0020	0.0003	0.0008	0.0005	0.0030	0.0000	0.0012	0.0000	0.0026

Source identification

The statistical identification of sources within the geological dataset (Chapter 5) was largely unsuccessful due to the variation within many sources exceeding the variation between sources. However, using a combination of simple elemental plots and PCA it is possible to make likely source identifications for many (but not all) of the archaeological samples.

Based on the LoE elemental ranges alone several sources can be excluded as possible matches for the archaeological material recovered from PP. The majority of archaeological samples have Fe concentrations higher than 100,000 ppm. This eliminates Glentana, Gondwana C, Herbertsdale, Oude Duingt, PP B, Rietvlei B, Rivercrossing, Riversdale, and Roodekrans as possible sources for the archaeological material. These sources can also be eliminated on the basis of several other elements. Cl and K content can eliminate Albertinia C, and K content adds PP A to the unlikely list of sources.

Principal components 1 through 3 from the PCA analysis of all geological samples (Fe normalized LoE PIXE data) and archaeological samples make it possible to restrict the source possibilities even further for the majority of the samples. Figs. 6.1 to 6.3 display only the archaeological samples for the first three principal components for simplicity. There is a distinct grouping within the archaeological dataset suggesting these samples are from the same source or very similar sources.

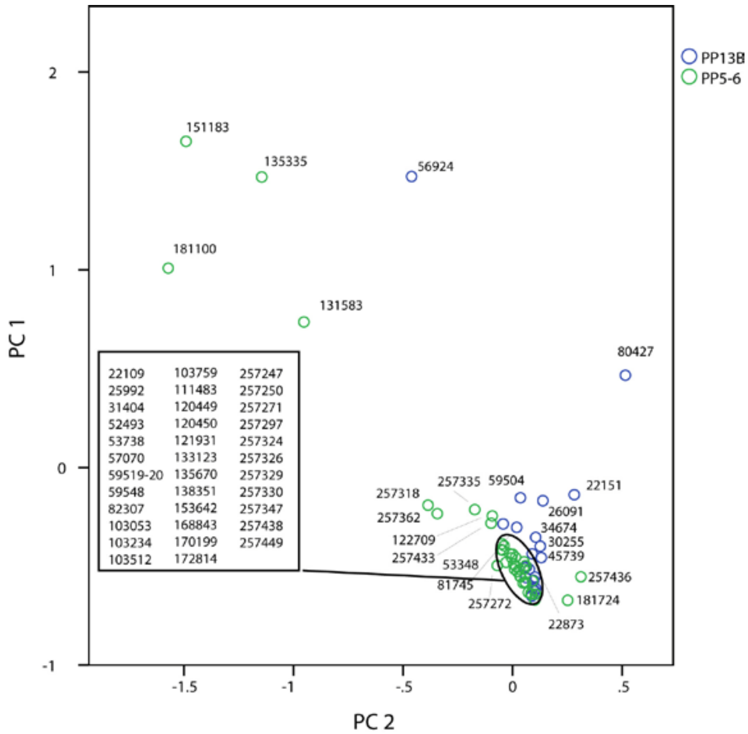

Fig. 6.1. PC 1 verses 2 for all geological and archaeological samples, only archaeological samples plotted

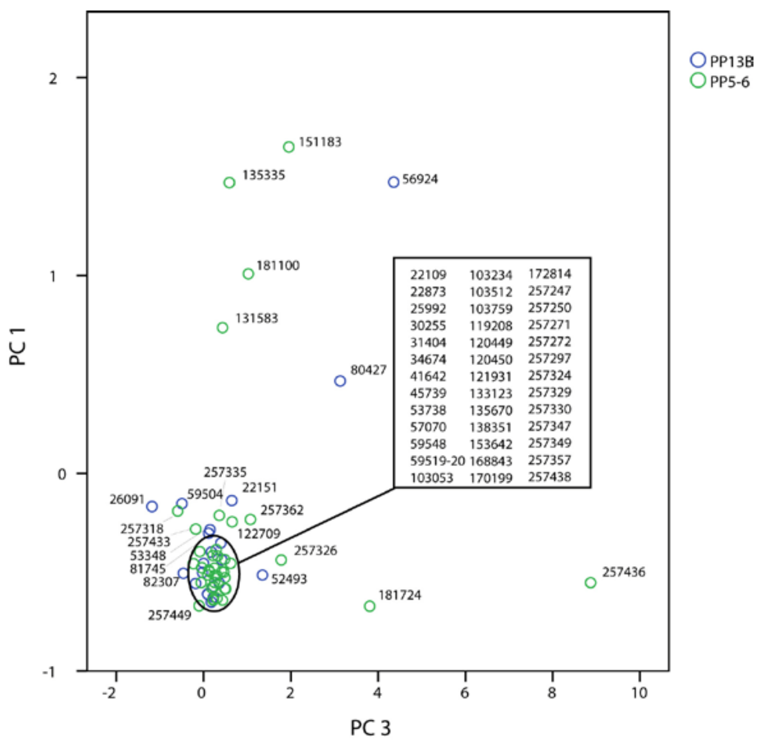

Fig. 6.2. PC 1 verses 3 for all geological and archaeological samples, only archaeological samples plotted

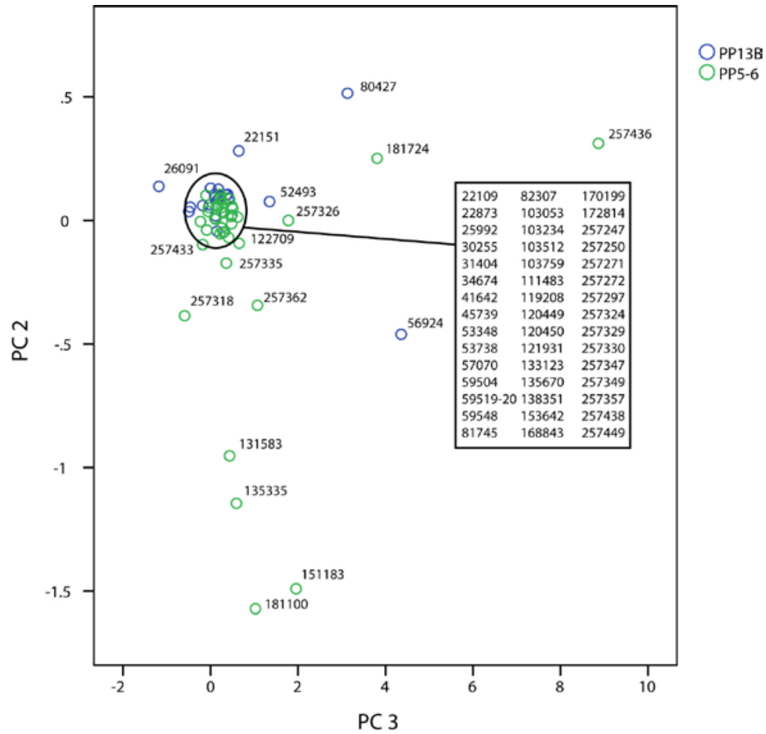

Fig. 6.3. PC 2 verses 3 for all geological and archaeological samples, only archaeological samples plotted

Geological sources were than classified based on their parent geology (taken from South African Geological Survey maps) and PCA was again used to see if distinctions could be made between groups of sources. This was used to further eliminate possibilities as matches for the main archaeological cluster. The sources occur on three different geological mapping units, shales belonging to the Bokkeveld group, Table Mountain Sandstone, and silcrete. PCA was run on sources classed by geological substrate and the archaeological samples. The first three principal components explain 63% of the variation in the dataset. Although there is still some overlap, the geological types do tend to cluster together (Fig. 6.4). The main archaeological cluster is associated with sources found within the silcrete geological mapping areas. This suggests the Albertinia B, Gondwana series, Matjesfontein, Rooikoppie, and Ruiterkraal as possible matches for the archaeological cluster.

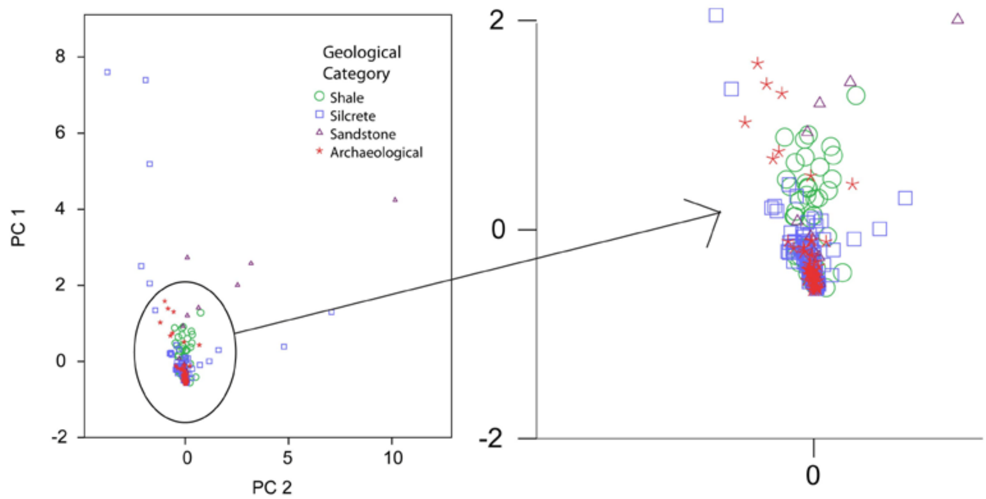

Fig. 6.4. PCA 1 verses 2 for geologically coded ochre samples and archaeological ochre samples

The archaeological material is plotted with each of these five sources separately (based on the PCA of all archaeological samples and geological samples) in Fig. 6.5 to Fig. 6.9. The archaeological cluster overlaps with each of these geological sources. However, the most likely fits for this cluster are the material from Rooikoppie or Ruiterskraal. The samples from Ruiterskraal plot within the archaeological cluster but have a more restricted range of variation than the archaeological samples. Also, the Ruiterskraal samples are soft compared to the archaeological samples. The material can be crushed between fingers and has a very clay like texture. Also, the XRD patterns from Ruiterskraal show a more significant clay component than the archaeological samples from this cluster. It is possible some of the samples come from Ruiterskraal but based on the geological properties of the Ruiterskraal material, Rooikoppie may be a better fit. The archaeological and Rooikoppie samples plot closely together and also show a similar range of variation. Further, the XRD data for the archaeological samples are consistent with the mineralogy identified at Rooikoppie, with a significant hematite and quartz component and minor to undetectable clay components.

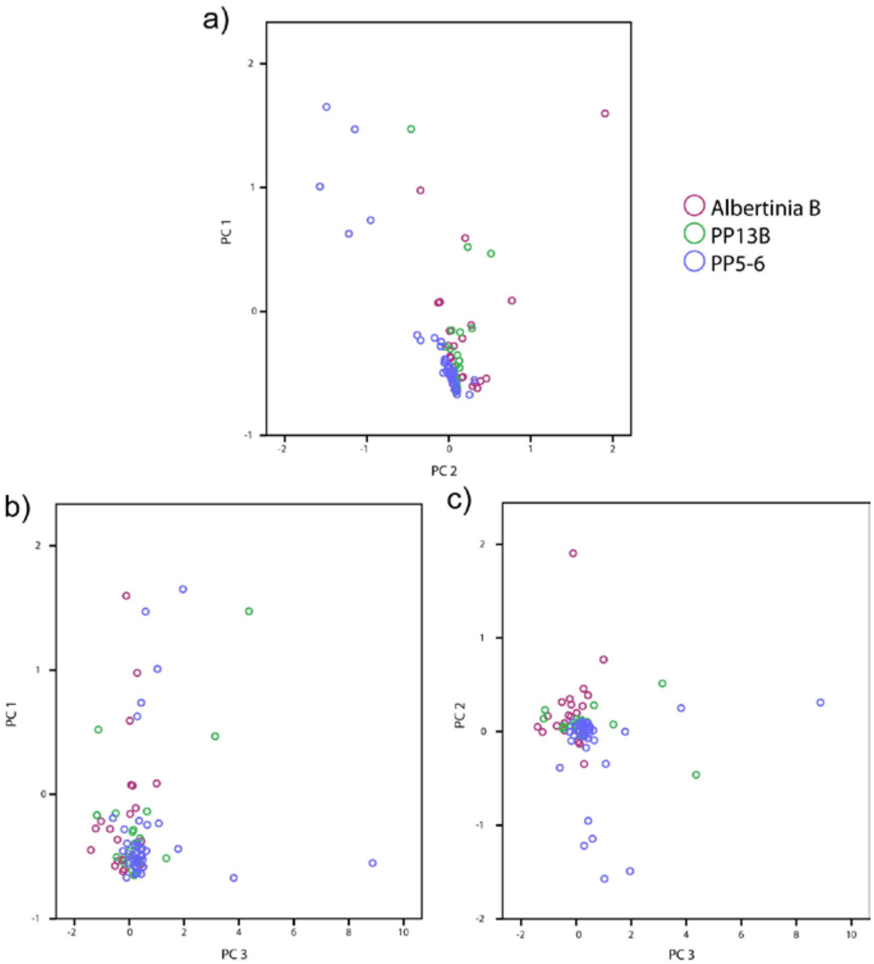

Fig. 6.5. Plots of principal components 1, 2 and 3 with only Albertinia B and the archaeological samples plotted

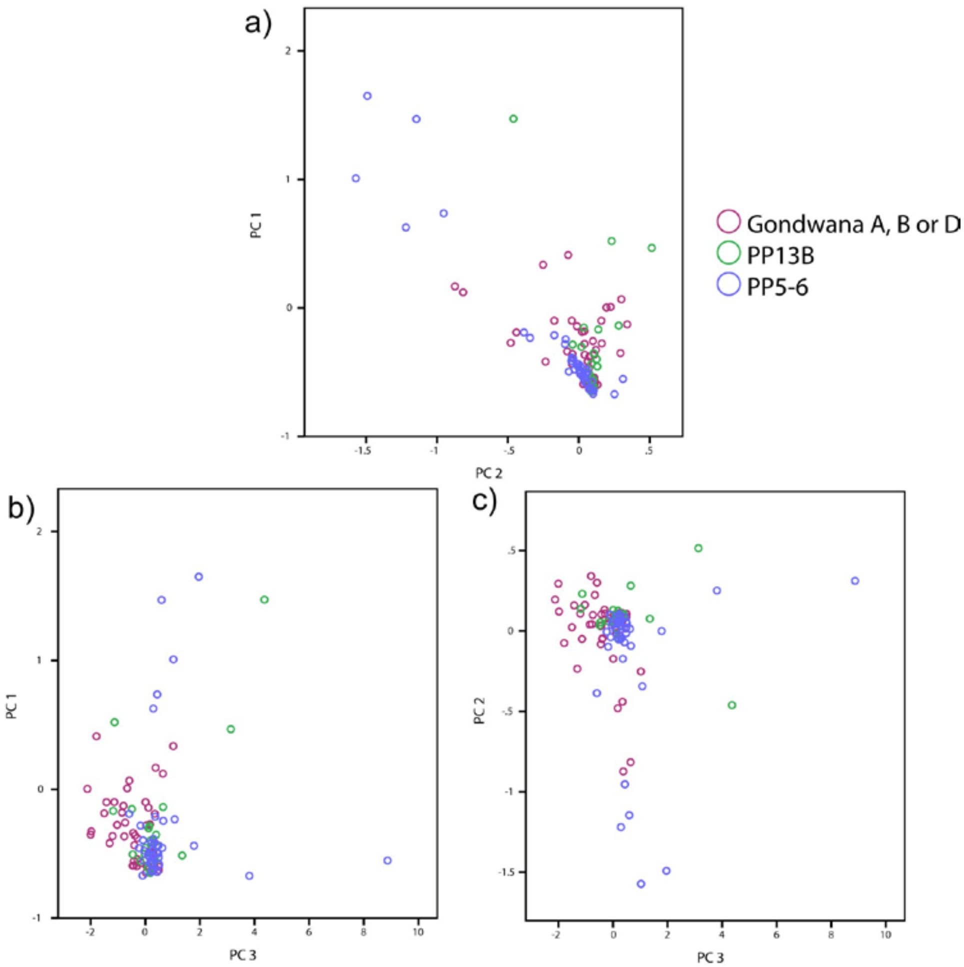

Fig. 6.6. Plots of principal components 1, 2 and 3 with only Gondwana A, B, D and the archaeological samples plotted

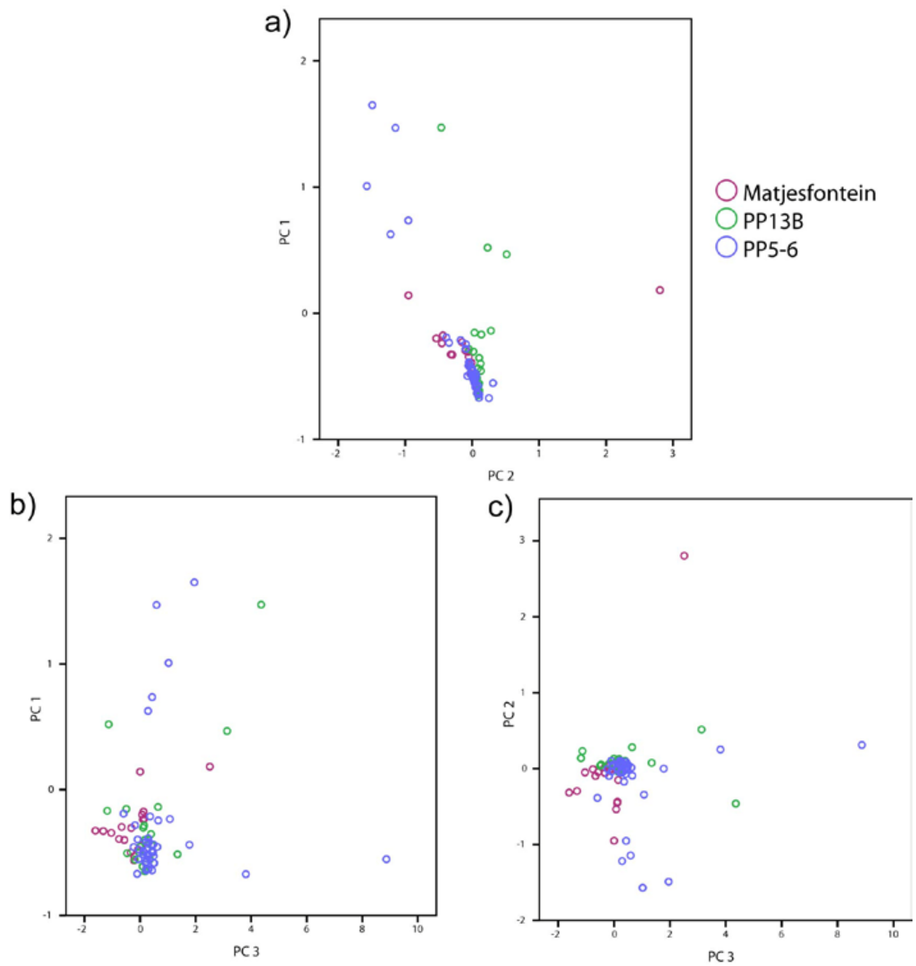

Fig. 6.7. Plots of principal components 1, 2 and 3 with only Matjesfontein and the archaeological samples plotted

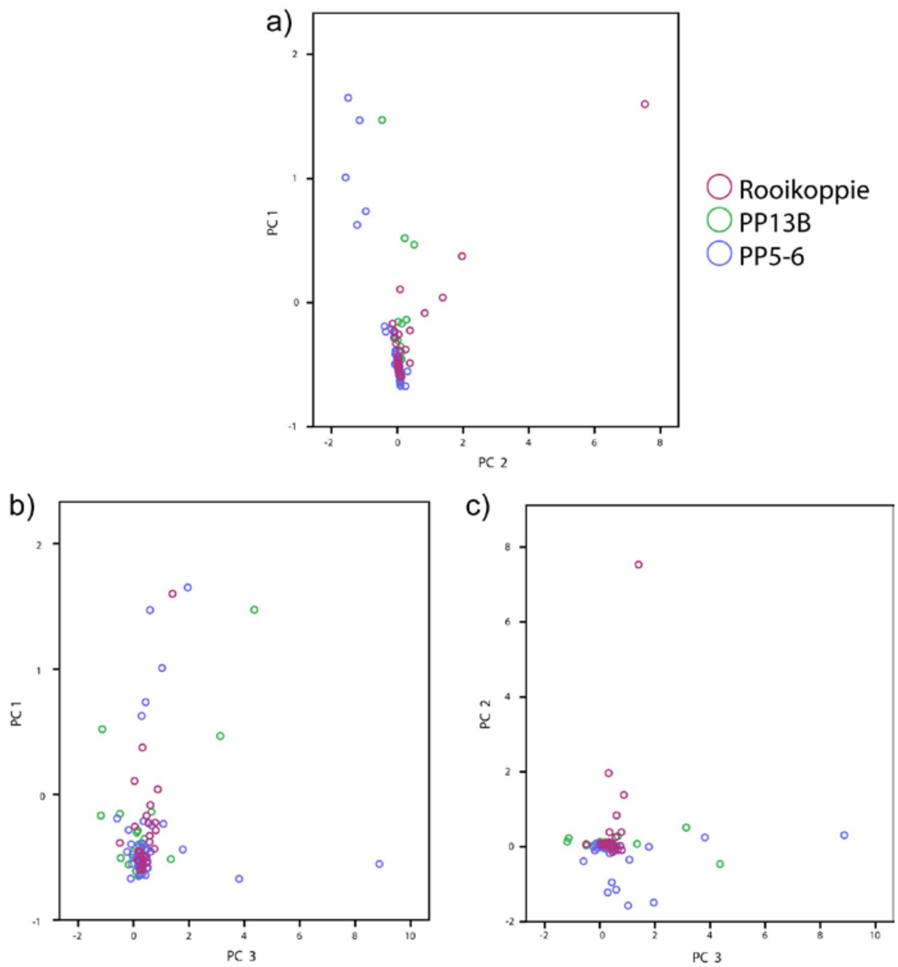

Fig. 6.8. Plots of principal components 1, 2 and 3 with only Rooikoppie and the archaeological samples plotted

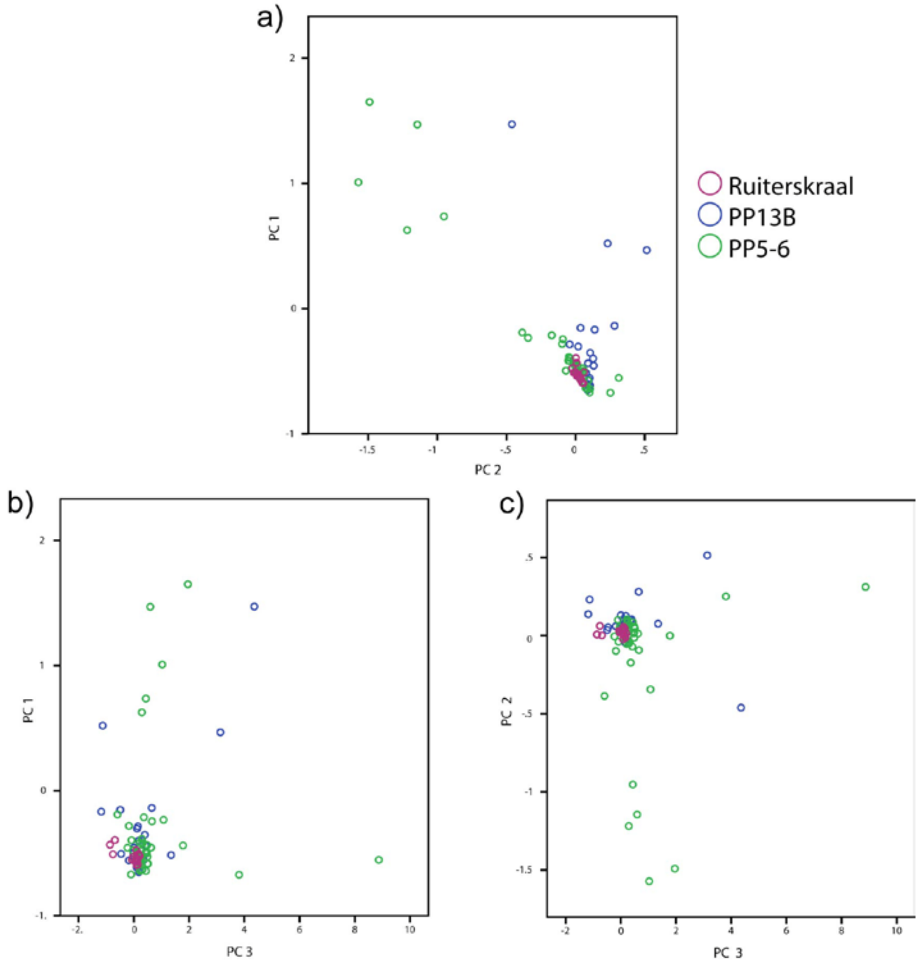

Fig. 6.9. Plots of principal components 1, 2 and 3 with only Ruiterskraal and the archaeological samples plotted

Tables 6.5 and 6.6 contain the likely source assignments for each sample. It was not possible to identify sources outside of the main cluster. For samples close to the cluster, there are multiple sources which could be a match. These samples are listed as unresolved. It is likely the source has been sampled but it was not possible to narrow down the possible matches with any certainty. Increased sampling or experimentation with different characterization techniques may be necessary to resolve these samples. The outlying samples (56924, 80427, 131583, 135335, 151183, 181100, 181724, 257436) do not correspond well to any of the sources identified during survey. This suggests an unknown source possibly outside the study area or variation within a known source that was not detected in the collected samples. These samples are labeled as unidentified. Further survey may help resolve these samples.

Table 6.5
Most likely source assignments for PP13B

Specimen	Excavation Area	StratAgg	Source
59504	Northeastern	LC-MSA Lower	Unresolved
80427	Northeastern	LC-MSA Lower	Unidentified
81745	Northeastern	LC-MSA Lower	Rooikoppie
59549	Eastern	Upper Roofspall	Not run
111483	Eastern	Upper Roofspall	Rooikoppie
52493	Eastern	Shelly Brown Sand	Unresolved
56924	Eastern	Shelly Brown Sand	Unidentified
57070	Eastern	Shelly Brown Sand	Rooikoppie
31404	Eastern	Truncation Fill	Rooikoppie
59548	Eastern	Truncation Fill	Rooikoppie
25992	Eastern	Redeposited Disturbance	Rooikoppie
30255	Eastern	Redeposited Disturbance	Rooikoppie
26091	Eastern	Surface	Unresolved
59519	Eastern	Surface	Rooikoppie
22873	Western	DB Sand 2	Rooikoppie
22109	Western	DB Sand 3	Rooikoppie
22151	Western	DB Sand 3	Rooikoppie
34674	Western	DB Sand 3	Rooikoppie
82307	Western	DB Sand 3	Rooikoppie
53348	Western	LBG Sand 1	Rooikoppie
53738	Western	LBG Sand 1	Rooikoppie
45739	Western	LB Sand 1	Rooikoppie

Table 6.6
Most likely source assignments for PP5-6

Specimen	Excavation Area	StratAgg	Source
103053	NWR	DBSS	Rooikoppie
103234	NWR	DBSS	Rooikoppie
103512	NWR	DBSS	Rooikoppie
103759	NWR	DBSS	Rooikoppie
257436	Long Section	BCSR	Unidentified
257438	Long Section	BCSR	Rooikoppie
153642	Long Section	RBSR	Rooikoppie
257250	Long Section	RBSR	Rooikoppie
257271	Long Section	RBSR	Rooikoppie
257297	Long Section	RBSR	Rooikoppie
257318	Long Section	RBSR	Unresolved
257324	Long Section	RBSR	Rooikoppie
257326	Long Section	RBSR	Unresolved
119208	Long Section	DBCS	Rooikoppie
120449	Long Section	DBCS	Rooikoppie
120450	Long Section	DBCS	Rooikoppie
121931	Long Section	DBCS	Rooikoppie
122709	Long Section	DBCS	Rooikoppie
133123	Long Section	DBCS	Rooikoppie
138351	Long Section	DBCS	Rooikoppie
168843	Long Section	DBCS	Rooikoppie
170199	Long Section	DBCS	Rooikoppie
181724	Long Section	DBCS	Unidentified
257335	Long Section	DBCS	Rooikoppie
257347	Long Section	SGS	Rooikoppie
257329	Long Section	OBS	Rooikoppie
257330	Long Section	OBS	Rooikoppie
257357	Long Section	OBS	Rooikoppie
131583	Long Section	SADBS	Unidentified
135335	Long Section	SADBS	Unidentified
135670	Long Section	SADBS	Rooikoppie
151183	Long Section	SADBS	Unidentified
257362	Long Section	SADBS	Unresolved
172814.2	Long Section	ALBS	Rooikoppie
181100.3	Long Section	ALBS	Unidentified
257247	Long Section	LBSR	Rooikoppie
257272	Long Section	LBSR	Rooikoppie
257349	Long Section	LBSR	Rooikoppie
257433	Long Section	LBSR	Rooikoppie
257449	Long Section	LBSR	Rooikoppie

Tables 6.7 and 6.8 provide the mineralogy for each of the samples tentatively assigned to the Rooikoppie source. With a few exceptions, the mineralogy is consistent with the Rooikoppie samples. A few samples contain halite but this is not surprising given the coastal location. Also, two samples contained possible maghemite which was not identified at Rooikoppie. However, this can easily be explained by intentional or unintentional burning of goethite in the presence of organic material.

Table 6.7
Mineralogy for PP13B samples attributed to the Rooikoppie source

Specimen	StratAgg	Mineralogy
81745	LC-MSA Lower	Hematite, quartz, illite, kaolinite
111483	Upper Roofspall	Hematite, quartz, kaolinite
57070	Shelly Brown Sand	Hematite, quartz
31404	Truncation Fill	Hematite, quartz, halite
59548	Truncation Fill	Hematite, quartz, goethite
25992	Redeposited Disturbance	Hematite, quartz
30255	Redeposited Disturbance	Hematite, quartz, illite, kaolinite
59519	Surface	Hematite, quartz, illite
22873	DB Sand 2	Hematite, quartz, goethite, halite
22109	DB Sand 3	Hematite, quartz
22151	DB Sand 3	Hematite, quartz, kaolinite, halite
34674	DB Sand 3	Hematite, quartz, illite, kaolinite
82307	DB Sand 3	Hematite, quartz, kaolinite
53348	LBG Sand 1	Hematite, quartz, illite, kaolinite
53738	LBG Sand 1	Hematite, quartz
45739	LB Sand 1	Hematite, quartz, illite

Table 6.8
Mineralogy for PP5-6 samples attributed to the Rooikoppie source

Specimen	StratAgg	Mineralogy
103053	DBSS	Hematite, quartz, illite, kaolinite
103234	DBSS	Goethite, quartz, feldspar
103512	DBSS	Hematite, quartz, illite, kaolinite
103759	DBSS	Hematite, quartz, illite, kaolinite
257438	BCSR	Hematite, quartz, illite, kaolinite
153642	RBSR	Hematite, quartz, illite, kaolinite
257250	RBSR	Hematite, quartz
257271	RBSR	Hematite, quartz, illite, kaolinite
257297	RBSR	Hematite, quartz, illite
257324	RBSR	Goethite, quartz, illite
119208	DBCS	Goethite, quartz
120449	DBCS	Hematite, quartz, illite, feldspar
120450	DBCS	Hematite, quartz, illite
121931	DBCS	Hematite, quartz
122709	DBCS	Hematite, quartz, illite
133123	DBCS	Hematite, quartz, illite
138351	DBCS	Hematite, quartz, maghemite
168843	DBCS	Hematite, quartz
170199	DBCS	Hematite, quartz
257335	DBCS	Hematite, quartz, illite, kaolinite
257347	SGS	Hematite, quartz
257329	OBS	Hematite, quartz, illite
257330	OBS	Goethite, quartz
257357	OBS	Hematite, quartz
135670	SADBS	Hematite, quartz
172814.2	ALBS	Hematite, quartz, illite, calcite
257247	LBSR	Goethite, quartz, illite
257272	LBSR	Goethite, quartz, kaolinite, illite
257349	LBSR	Hematite, quartz, maghemite
257433	LBSR	Hematite, quartz, illite, kaolinite
257449	LBSR	Hematite, quartz, goethite

Conclusion

Although not all samples could be identified to source, sixteen of the twenty two PP13B samples and thirty-one of the forty PP5-6 samples seem to have derived from the Rooikoppie ochre outcrop. Further work may be necessary to better support this conclusion but it appears that there is a preference for a particular source at both PP5-6 and PP13B. If this pattern remains true when more archaeological samples are tested it strongly supports symbolic overtones guiding the selection of ochre. There are numerous other sources within the study region, some a similar distance to PP that do not seem to be utilized at such a high frequency as the Rooikoppie material. Furthermore, if these source assignments prove correct, there is evidence for preferential ochre source exploitation covering a time span of over 100,000 years.

CHAPTER 7: TEST IMPLICATION 1B – COLOR PREFERENCES

Introduction

Watts has repeatedly argued that there is a distinct color preference in the ochre recovered from MSA sites (1998; 1999; 2002; 2010). He further argues that utilized pieces are among the most saturated red pieces. However, Watts uses a subjective system to classify color and his conclusions are based on his impressions of assemblages. This chapter investigates the color distributions of archaeological ochre from PP and geological ochre from the vicinity using more objective methods. Various shades of red, purple, and yellow ochre are available on the landscape and color should not necessarily dictate the usefulness of material for utilitarian purposes. If the PP sites show a restricted color distribution compared to the geological material available, this would be supporting evidence for symbolic behavior.

Methods

Color was recorded for all archaeological and geological (heated and unheated) ochre fragments. This was done using two methods. The first method involved measuring color from photographs. A small swatch was colored on a white ceramic plate for each archaeological sample and a full set of geological samples (Figure 7.1). All color swatches were then photographed in natural sunlight and color corrected to true white using a photographic scale as the white standard.

The L*a*b* values of these colors were then measured from the photographs using Photoshop. The center of each color swatch was cropped. These pixels were then averaged to obtain a uniform color. The L*a*b* values were then recorded from the info palate.

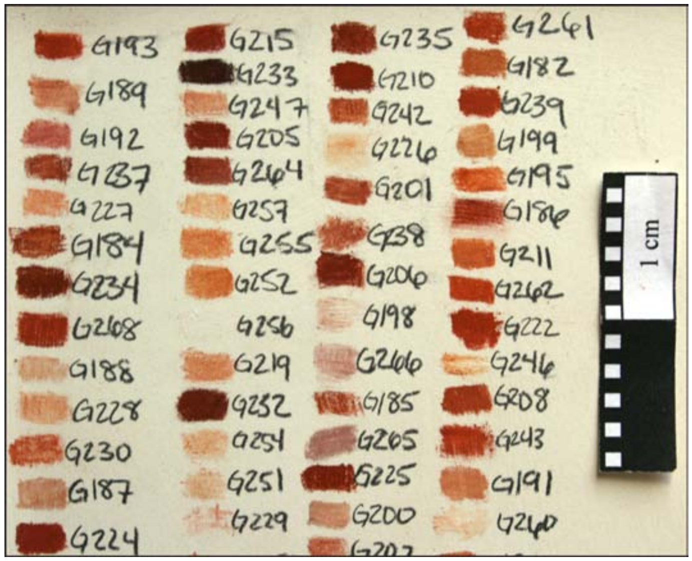

Fig. 7.1. Example of ceramic plate with ochre streaks

The CIELAB color space is a color-opponent space where L* is a measure of lightness and a* and b* are the color-opponent dimensions. a* is green to red and b* is blue to yellow. This color space includes all perceivable colors and is not device dependent like RGB or CYMK. This color space best approximates the range of human vision (Hunt 2011).

Digital readings of color were also taken directly from the samples. A Konica-Minolta CR400 series colorimeter was used. A color reading was taken for all whole archaeological fragments larger than 8mm. This restriction is based on the size of the aperture on the color meter. Taking a reading on anything smaller than this would average the color of the sample with the color of the surface behind it. Readings were taken on all original geological ochre fragments (before subdividing into smaller samples) and most heated geological samples (see Chapter 8 for heating experiments).

While the colorimeter is arguably the most accurate technique for obtaining color values, both methods were employed here. This allows a comparison of the more cost effective photographic method and the colorimeter to see if sufficient results can be achieved without acquiring an expensive piece of scientific equipment. Also, use of the photographic method allows better incorporation of archaeological pieces not being sampled, and therefore ground, for other analyses. The color swatches are more likely to capture the color of the sample as it would have been used. The solid fragments recovered archaeologically are often weathered and the outer color is not necessarily the best representation of the color when the pigment has been ground for use.

The data were then graphed to visually identify differences between the geological color distribution and the archaeological color distributions. Differences between the assemblages were then further described and tested using Pearson's r and Fisher's Z.

In the Lab color space perfect visual red is represented by equal values of a* and b*. A hypothetical assemblage of only red pieces would have a very high positive correlation. Fig. 7.2a depicts a sample distribution of only red values of different hues. The dataset has an r value of 1. A hypothetical assemblage of only yellow pieces would have a* values approaching zero and a range of positive b* values (Fig. 7.2b). A perfectly yellow assemblage would have an undefined r value but assemblages approaching this would be highly correlated. An assemblage with a range of yellow and red pieces, simulated in Fig. 7.2c, would have a range of a* and b* values resulting in a scatterplot with more spread. We would expect these datasets to have lower correlation values. Using Fisher's Z and the below hypotheses, it is possible to test if the r value for the geological data differs significantly from the r values for the archaeological data.

H_o = the r value of the geological material is the same as the archaeological material

H_a = the r value of the geological material differs from the archaeological material

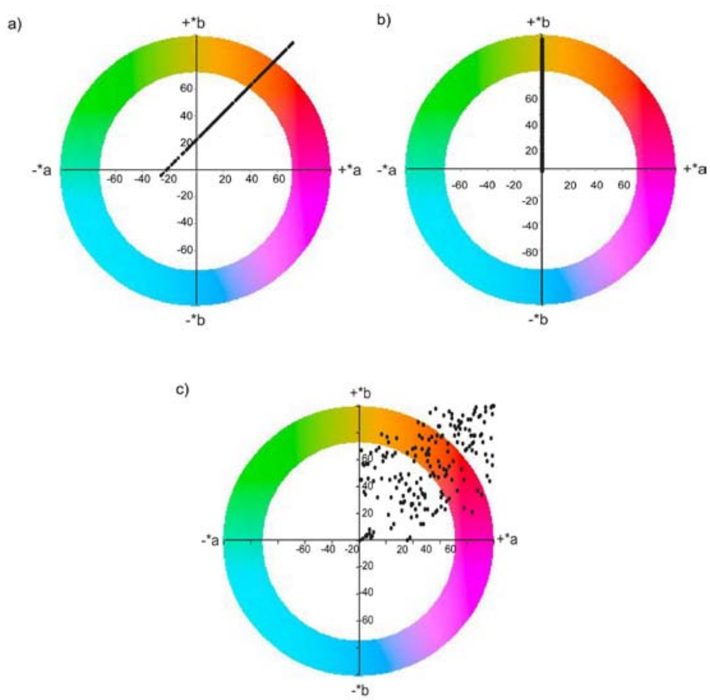

Fig. 7.2. Hypothetical ochre assemblages a) all red, b) all yellow, c) mixed red and yellow

Results

Photographic method

Figure 7.3 presents the graphical data for color distributions for all swatches taken. A total of 176 color swatch measurements were taken on raw untreated geological material. A total of 204 color measurements were taken on geological material that had been heat treated in campfires or furnaces (see Chapter 8). The PP13B swatches were drawn by Watts and photographed for this project. A total of 608 color measurements were possible. This includes material from the 3mm sieves as well. For PP5-6, only 315 measurements have been made. These do not include 3mm material. Sorting of material from the 3mm screens was not completed at the time of this analysis.

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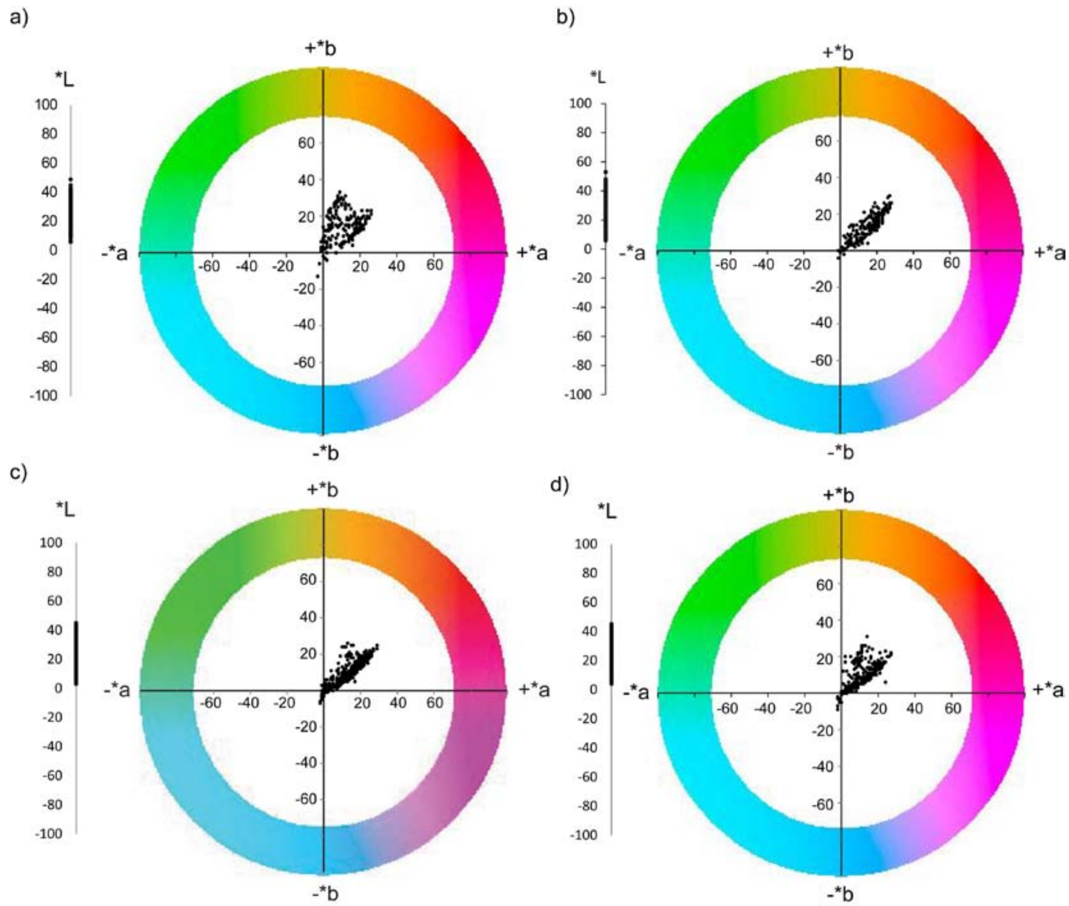

Fig. 7.3. Color distributions taken from photographs of color swatches drawn on white ceramic plates a) geological swatches, b) geological heated swatches, c) PP13B swatches, d) PP5-6 swatches

As expected from the graphs, the r values for the geological not heat treated material are much lower than the archaeological assemblages and the geological heated assemblage (Table 7.1). Using Fisher's Z, the differences between the geological material and the geological heated material and the both archaeological assemblages are statistically significant (Table 7.2).

Table 7.1
Pearson's r values for color values taken from photographs of color swatches

Assemblage	*N*	*r*
Geological	176	0.280
Geological heated	204	0.865
PP13B	608	0.875
PP5-6	315	0.637

Table 7.2
Fisher's Z test for color values taken from photographs of color swatches

Comparison	*Z*	*p*
Geological to geological heated	-9.89	0
Geological to PP13B	-12.37	0
Geological to PP5-6	-4.91	0

Colorimeter method

Figure 7.4 presents the graphical data for all color values taken from actual fragments with the colorimeter. A total of 97 measurements were taken on the original geological fragments (prior to subsampling). The geological heated color values (n=97) were taken from samples heated in campfires and furnaces prior to crushing for XRD and PIXE analyses. For the PP13B collection, 160 fragments were large enough to be measured by the colorimeter. 332 measurements were possible for PP5-6's collection.

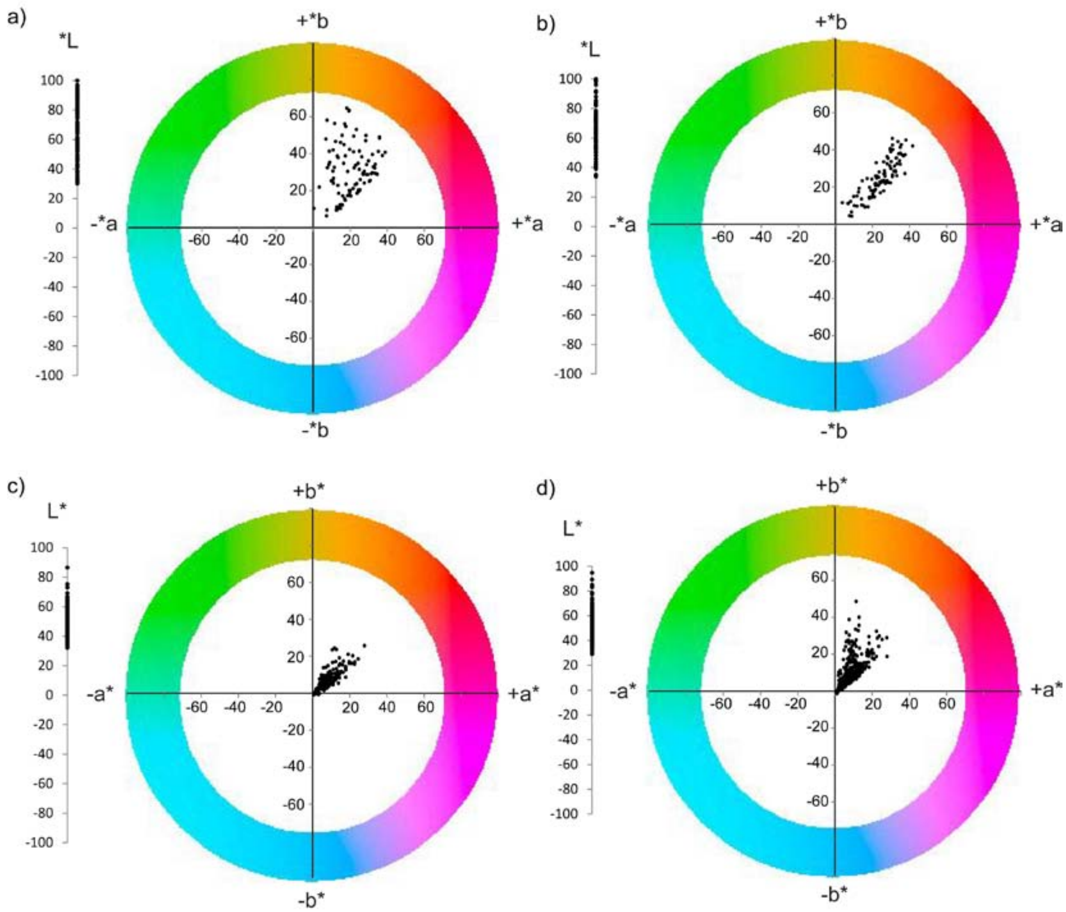

Fig. 7.4. Color distributions from ochre fragments taken with the colorimeter a) geological swatches, b) geological heated swatches, c) PP13B swatches, d) PP5-6 swatches

As expected from the graphs, the r values for the geological not heat treated material are much lower than the archaeological assemblages and the geological heated assemblage (Table 7.3). Using Fisher's Z, the differences between the geological material and the geological heated material and the both archaeological assemblages are statistically significant (Table 7.4).

Table 7.3
Pearson's r values for color values taken from ochre fragments

Assemblage	*N*	*r*
Geological	97	0.177
Geological heated	97	0.851
PP13B	160	0.785
PP5-6	332	0.626

Table 7.4
Fisher's Z test for color values taken from ochre fragments

Comparison	*Z*	*p*
Geological raw to geological heated	-7.41	0
Geological to PP13B	-6.74	0
Geological to PP5-6	-4.75	0

Discussion

Graphically there are clear differences between the archaeological color distributions and the geological color distributions which are evident using either data collection method. The geological raw swatches show a fairly even distribution along the yellow to red spectrum. The PP13B swatches are far more restricted, tending toward redder, and show a distribution that is more similar to that of the heated geological fragments than the raw fragments. The PP5-6 samples are more dispersed but still show a heavy concentration on the redder end of the distribution. These visual assessments are supported by the statistically significant differences between the Pearson's r values of the geological raw material and the heated and the archaeological material.

The measurements from the whole fragments give the same overall picture. The geological fragments that are untreated have the widest spread of color values. The PP13B fragments cluster towards the redder end of the spectrum. At PP5-6 the distribution is more varied but still shows a heavier concentration of redder pieces. Again, these visual assessments are supported by the statistically significant differences between the Pearson's r values of the geological raw material and the heated and the archaeological material.

Although measurements from the same sample do vary slightly between methods the overall results are similar and lead to the same conclusions. The photographic method is low cost and has the added benefit of testing actual color as opposed to potentially weathered surface color. In order to capture internal color with the colorimeter, samples would have to be broken open and this is not appropriate for archaeological collections. However, if multiple sites and regions are to be compared the photographic method may be limiting as it may be difficult to collect all photographic data under the same conditions. Each time new data was to be added, all streak plates would have to re-photographed under the same light and color values would have to be measured again. The best method for analyzing color may be a combination of the two. Streaks could be taken on ceramic and then these streak values could be measured with the colorimeter. However, this would require larger streaks to be taken, to accommodate the colorimeter aperture. When archaeological pieces are small this may not be ideal. An attachment for the colorimeter measuring head with a reduced aperture would be helpful but is currently not available.

Conclusion

This chapter is aimed at addressing Test Implication 1b, color preferences. It was argued that many colors of ochre are available locally and color should not necessarily dictate the usefulness of material for utilitarian purposes. These data show that there is in fact a restricted color representation in the PP sites as compared to the distribution of ochre colors on the landscape. There are two possible explanations for this. Either only red material is being selected for transport which would support a symbolic interpretation or yellow material is being collected and subsequently heated to change the material to red. This could also be in support of symbolic behavior but only if the intentionality of the heating can be demonstrated.

CHAPTER 8: TEST IMPLICATION 1C – HEAT TREATMENT

Introduction

There is now convincing evidence that MSA hominids heat treated silcrete to produce a more workable raw material (Brown *et al.* 2009). It is possible that ochre may also have been deliberately heat treated during this time period. This hypothesis is directly testable at PP due to the high quality data collection protocols in place. If it can be demonstrated that ochre is being deliberately heated it may be strong evidence for symbolic activity.

It is necessary to first determine if archaeological fragments have been subjected to heating. This can be done by identifying evidence for disordered hematite in XRD patterns. Disordered hematite forms primarily through the heating of goethite between 250˚C to 700˚C. Careful comparison of experimentally heated and unheated geological fragments was particularly informative when looking for evidence of heat treatment in the archaeological record.

It is further necessary to demonstrate that any evidence of heating is likely deliberate. This is done using magnetic susceptibility (MS) values for sediment bulk samples taken for each stratigraphic unit (small excavated lenses) excavated at the PP sites (Brown *et al.* 2009; Marean *et al.* 2004). MS has been shown to be a reliable proxy for burning of sediments in archaeological sites (Herries 2009; Herries and Fisher 2010). Using 3D spatial analysis (Herries and Fisher 2010), these data are used to determine if ochre pieces were possibly burnt unintentionally in a post depositional context.

Methods

Heat treatment experiments

All geological samples collected during survey were split into subsamples for heat treatment experiments (Fig. 8.1). Samples were either heated naturally in a campfire or in one of two furnace experiments.

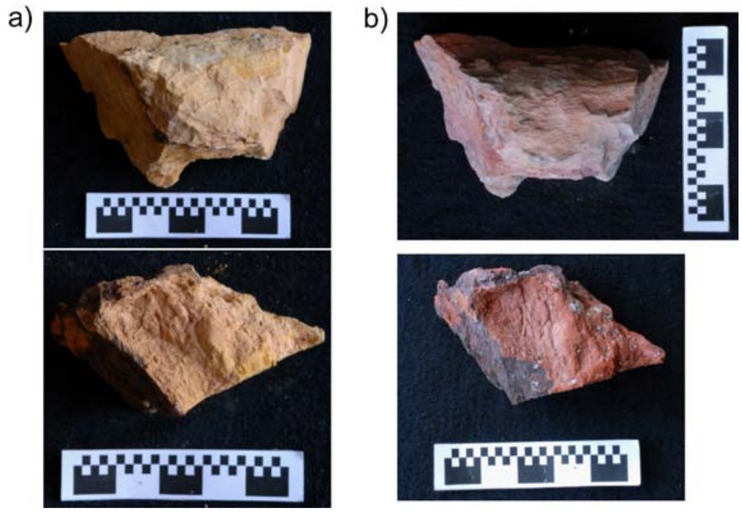

Fig. 8.1. Examples of geological specimens a) prior to heat treatment and b) after heat treatment

Actualistic heating methods included heating beneath, within and around campfires. In all cases, fires were made with locally available hardwoods and an electronic thermocouple was used to measure the heat of the fire over the course of the experiments. Most samples were heated beneath campfires. Samples were placed in local dune sand approximately five centimeters below the surface. For these experiments, one thermocouple probe was placed in the sand around the samples, while another was placed directly in the fire built above the samples.

This method of heating had the most success as samples were heated evenly. Some samples were placed directly in fires and others were placed adjacent to the fires. These samples tended to be unevenly heated, often being burnt in places while color was unaffected in others. Several of these samples also exploded during heating.

Samples were also heated in one of two furnace experiments. The first set of experiments were conducted on a furnace in South Africa. These were designed to mimic the heating profile of an actual fire. Samples were heated slowly, then held at temperature for several hours before being allowed to cool slowly over at least a 12 hour period. These experiments were successful but it was decided to run another heating on a portion of all samples taken in another furnace. The objective in these experiments was simply to create the conditions that should result in the production of disordered hematite. Samples were placed in the furnace and brought to 450ºC over an hour. The samples were then held at this temperature for two hours. They were then removed from the furnace and left to cool in air.

Identification of heated ochre

All geological heat treated material and all archaeological samples were subjected to XRD to investigate the possibility of heating in the MSA. The transformation of goethite to disordered hematite through heating is well documented and has been analyzed with various techniques (Francombe and Rooksby 1959; de Faria 1963; Watari *et al.* 1982; Koch *et al.* 1986; Goss 1987;

Béarat 1996; Gualtieri and Venturelli 1999; Pomiès *et al.* 1998; 1999; Ruan *et al.* 2002; Frost *et al.* 2003; de Faria and Lopes 2007). This transformation is detectable after heating to 250 ˚C. It is only after 700˚C that well crystallized hematite forms that would be difficult to distinguish from natural hematite. Campfires are unlikely to reach this temperature (Canti and Linford 2000; Herries 2009) and so the majority of heat treated material found in an archaeological site is likely to incorporate disordered hematite.

The XRD pattern of natural, well crystallized hematite has sharp peaks corresponding to all the major crystallographic planes and the peaks corresponding to (104) and (110) have an intensity ratio >1[1]. Disordered hematite has a general broadening of peaks with the exception of sharp and relatively intense peaks corresponding to the (110), (113), and (300) planes (Fig. 8.2). These planes are less disordered during transition because they are existing planes in the structure of goethite. This selective broadening is particularly evident when looking at two pairs of peaks (104) and (110) and (214) and (300). The (110) and (300) peaks remain narrow throughout the transition while the (104) and (214) peaks tend to be broad. An intensity ratio <1 for the peaks corresponding to (104) and (110) is also indicative of disordered hematite (Béarat 1996; Pomiés *et al.* 1998; 1999). The identification of the magnetic mineral maghemite would strengthen arguments of heat treatment. Maghemite is known to form through the heating of goethite when organic material is present, as would often be the case in a stone age hearth (Pomiés *et al.* 1998). The existence of disordered hematite in

[1] Parentheses enclose the Miller Index indicating a specific crystal face or crystallographic plane.

nature is very rare (Onoratini and Perinet 1985; Pomiés *et al.* 1999) although some examples have been put forward (Morin 1994; Pomiés 1997). Therefore, it is important to study the geologically available material before drawing conclusions about the intentionality of heating in archaeological sites. It must be demonstrated that disordered hematite is not locally available for collection.

Poorly crystallized hematite forms naturally and its XRD pattern is characterized by a (104) to (110) intensity ratio >1 (as in well crystallized hematite) but with a general broadening of all peaks (as opposed to the selective broadening seen in disordered hematite) (Béarat 1996).

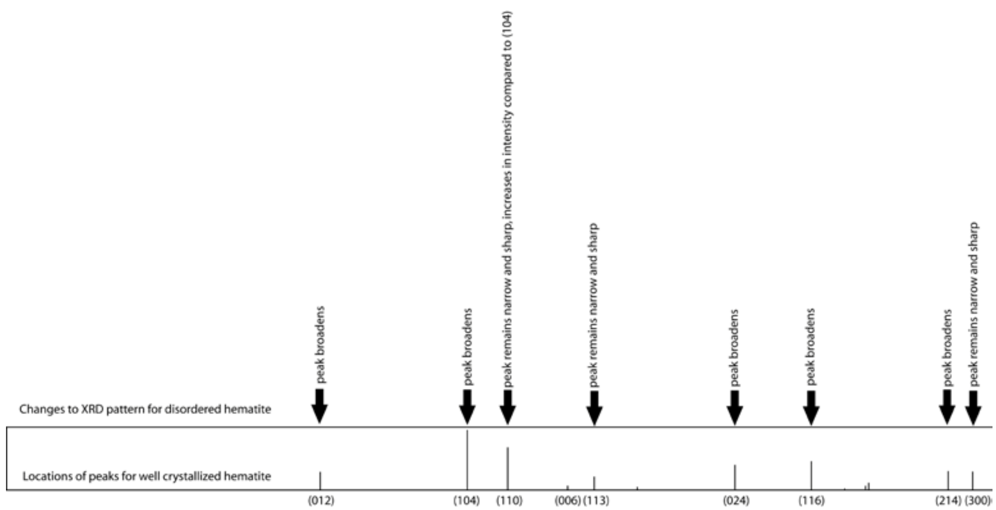

Fig. 8.2. XRD pattern of disordered hematite

The XRD patterns of all geological samples were carefully examined to determine that unheated geological material did not appear to have evidence for disordered hematite. All experimentally heated yellow material was examined to be sure disordered hematite was identifiable. Archaeological samples were then investigated and given a heat treatment classification of definite, probable, possible, or not likely. Three criteria were specifically looked for: 1) An intensity ratio <1 for the (104) and (110) peaks, 2) evidence of selective broadening of peaks (012), (104), (024), (116), and (214), 3) the presence of maghemite. A sample was deemed definite if at least the first two criteria were clearly met. All major peaks must be discernable in the pattern in order to make this judgment. The presence of maghemite in some samples further solidified these conclusions. A sample was deemed as probably heated if it met assumption one and had broadening of peak (104) and some of the other major peaks showed broadening or contained maghemite. In some cases not all of the peaks expected to show broadening were detectable on the samples. Samples meeting only criteria one were deemed as possible. In these cases, the other major peaks were usually not discernible and a judgment about peak broadening could not be assessed. All others samples were considered not likely to have been exposed to heat either because they displayed a well crystallized or poorly crystallized hematite pattern or because they contained goethite as the major color bearing mineral.

Classification of depositional burning context

Over 1200 sediment bulk samples have been taken from PP13B and PP5-6. These samples are all subjected to magnetic analyses including a measurement of magnetic susceptibility (MS). MS has been used as a proxy for archaeological burning with success (Herries and Fisher 2010). Values presented here are in units of $10^{-8}m^3kg^{-1}$. An MS value of larger than 50 is indicative of burnt sediments (Herries and Fisher 2010).

Archaeological samples with XRD evidence of heating were compared to field notes for archaeological evidence of burning. Samples were then also compared to the MS value from the bulk sample for the stratunit they were recovered from. Lastly, the location of ochre samples was plotted in a three-dimensional GIS in relation to all bulk and specialist samples having calculated MS values. It was then possible to assess if samples were not only in a burnt unit but close enough to one to have been exposed to heat in their post depositional environment. Wadley (2010b) has argued based on experimental results that color change (and presumably evidence through disordered hematite) can be achieved in ochre fragments buried up to 10cm away from the heat source. This was used as the distance benchmark for arguing that samples could or could not have been heated after deposition.

Results

Heat treatment experiments

XRD patterns for geological samples were presented in Chapter 5. 54 hematite bearing samples were identified from among this data set. No evidence for disordered hematite was identified among these samples. Most are cases of well crystallized hematite (Fig. 8.3). There are examples where the intensity ratio for peaks (104) and (110) is <1 but in these cases the peaks remain sharp and the increased intensity of peak (110) can be attributed to the inclusion of another mineral.

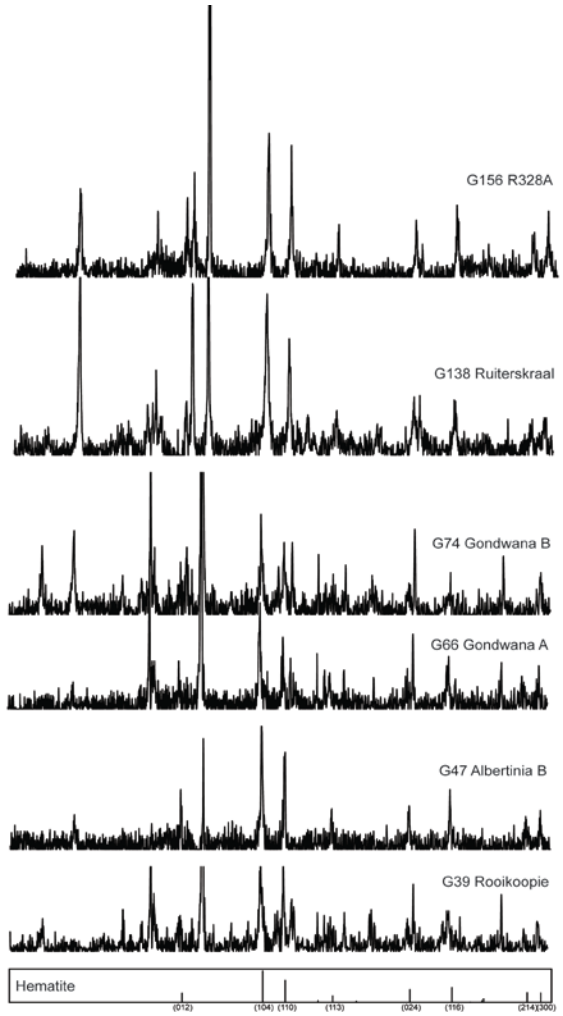

Fig. 8.3. Geological examples of well crystallized hematite from the study area.

All samples were heat treated regardless of color. However, it is only the goethite bearing samples that are of interest when looking for disordered hematite. Heating of hematite bearing samples will not result in disordered hematite. 39 geological goethite bearing samples were heat treated from 6 sources. These samples are presented below by source with a discussion of evidence for disordered hematite.

Albertinia B There are nine heat treated goethite bearing samples from Albertinia B (Fig. 8.4). Regardless of heat treatment method used these samples display XRD patterns for disordered hematite. The (104) and (110) intensity ratio is <1 and there is a selective broadening of peaks (012), (104), (024), (116), and (214) where they are detectable.

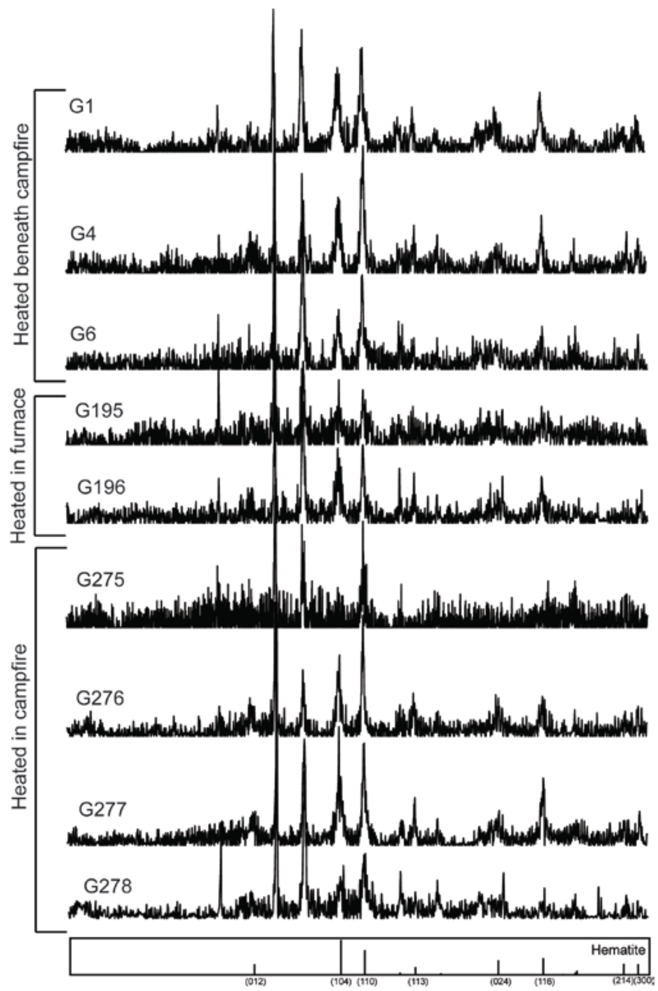

Fig. 8.4. XRD patterns of heated goethite bearing samples from Albertinia B

Gondwana B There are six heated yellow samples from Gondwana B. There is a reversed intensity ratio for the (104) and (110) peaks and there is a selective broadening of peaks (012), (104), (024), (116), and (214) where they are detectable.

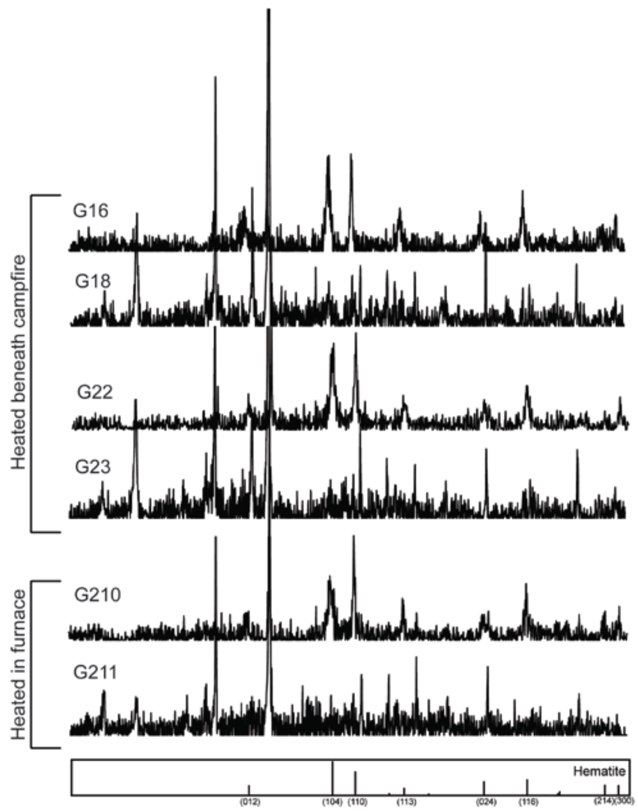

Fig. 8.5. XRD patterns of heated goethite bearing samples from Gondwana B

<u>Gondwana D</u> There are four heated yellow samples from Gondwana D. They show an intensity ratio <1 for the (104) and (110) peaks and there is a selective broadening of peaks (012), (104), (024), (116), and (214) where they are detectable.

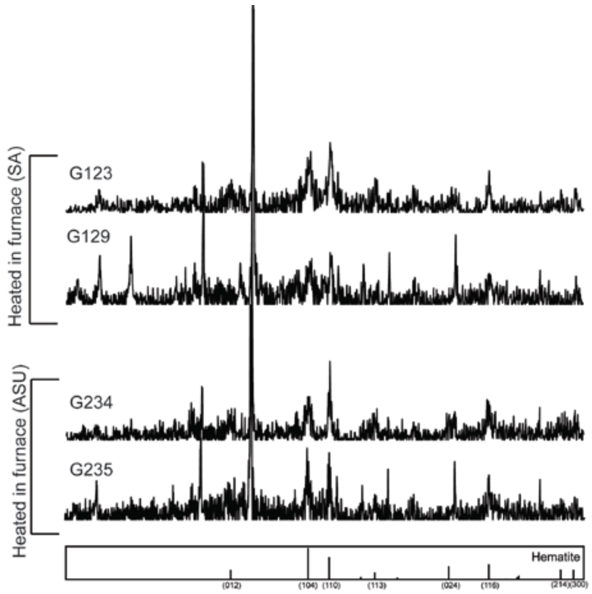

Fig. 8.6. XRD patterns of heated goethite bearing samples from Gondwana D

Rietvlei A There are four heated yellow samples from the Rietvlei A locality. These samples meet all the criteria of disordered hematite. The (104) and (110) intensity ratio is <1 and there is a selective broadening of peaks (012), (104), (024), (116), and (214).

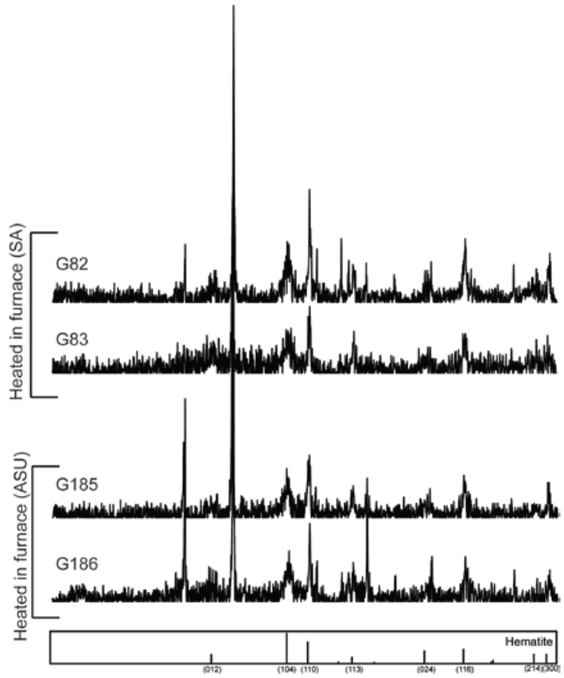

Fig. 8.7. XRD patterns of heated goethite bearing samples from Rietvlei A

<u>Rooikoppie</u> There are twelve heated yellow samples from Rooikoppie. Again the patterns show a reversed intensity ratio for the (104) and (110) along with selective broadening of peaks (012), (104), (024), (116), and (214) where they are detectable.

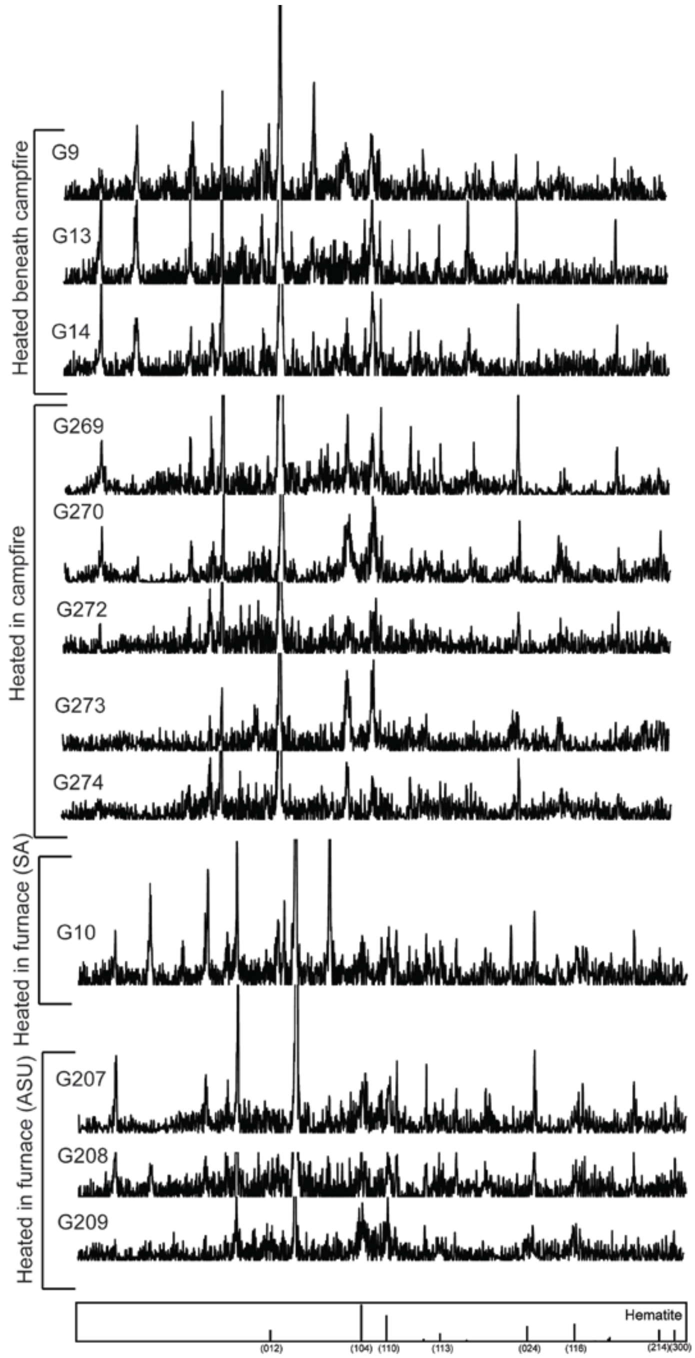

Fig. 8.8. XRD patterns of heated goethite bearing samples from Rooikoppie Ruiterskraal There are four heated originally goethite bearing samples from Ruiterskraal. Again, the (104) and (110) intensity ratio is <1 and there is a selective broadening of peaks (012), (104), (024), (116), and (214) where they are detectable.

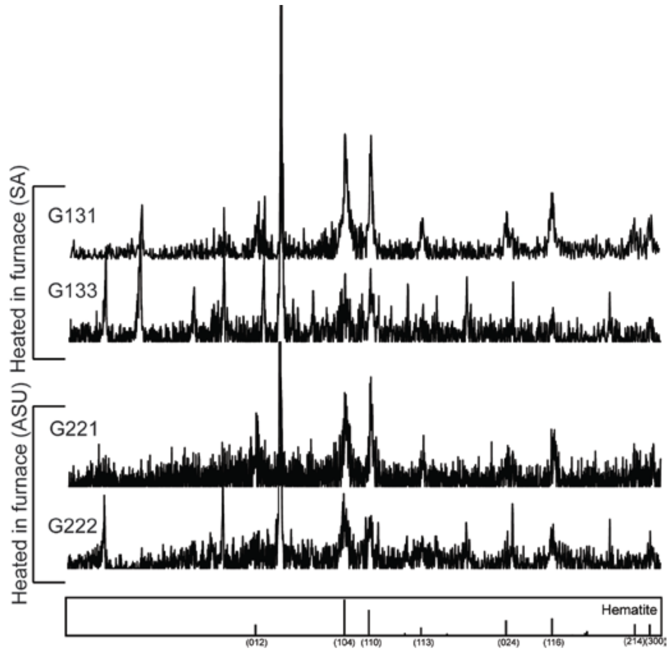

Fig. 8.9. XRD patterns of heated goethite bearing samples from Ruiterskraal

Evidence for disordered hematite is easily detectable in the experimental collection. It should be theoretically possible to determine if an archaeological hematite specimen was originally goethite that was heated treated to hematite.

Identification of heated ochre

All XRD patterns of samples taken from PP13 and PP5-6 were examined carefully for evidence of disordered hematite. Each sample was given a heat treatment classification of definite, probable, possible, or not likely based on the confidence of the hematite classification.

<u>PP13B</u> There are 22 samples from PP13B, the same samples used for sourcing analyses discussed in Chapter 6. The same XRD patterns presented earlier were used to identify evidence for heating through the presence of disordered hematite. Each sample is discussed individually.

Sample 59504 comes from the LC-MSA Lower in the Northeastern excavation area. This sample has hematite as the major color bearing mineral and has been classified as definitely heated (Fig. 8.10). The sample shows a (104) to (110) intensity <1, and there is broadening of the (024) and (116) peaks. The (214) peak is also broadened in comparison to the more narrow and sharp (300) peak. The presence of maghemite and the fact that the sample is partially magnetic further support the conclusion of heat treatment.

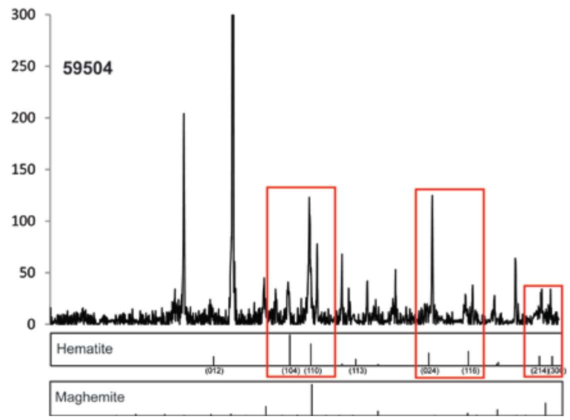

Fig. 8.10. 59504 XRD pattern and evidence of heating

Sample 80427 also comes from the LC-MSA Lower in the Northeastern excavation area. This sample has not been subjected to heating. The sample contains goethite as the main color bearing mineral.

Sample 81745 also comes from the LC-MSA Lower. This sample contains hematite as the major color bearing mineral. This sample was classified as possibly heated (Fig. 8.11). The (104) and (110) peaks have the appearance of disordered hematite. The intensity ratio is <1 and the (104) peak is broadened in comparison with the (110) peak. The other major peaks for hematite are not clear in this pattern however making it difficult to assess if further selective broadening is evident.

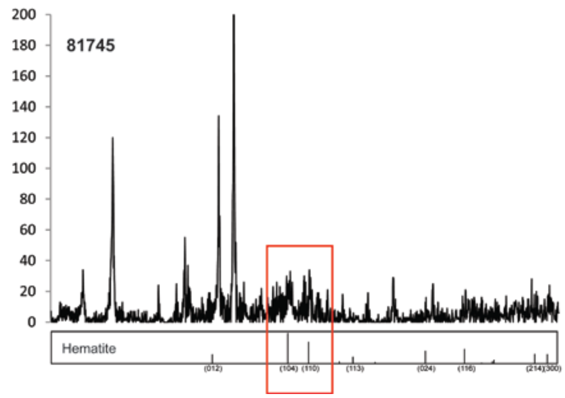

Fig. 8.11. 81745 XRD pattern and evidence of heating

Sample 59549 comes from the Upper Roofspall Facies of the Eastern excavation area. This sample contains hematite as the major color bearing mineral and has a heat treatment classification of definite (Fig.8.12). The sample shows a (104) to (110) intensity <1, and there is broadening of the (024) and (116) peaks. The (214) peak is also broadened in comparison to the more narrow and sharp (300) peak. The presence of maghemite and the fact that the sample is strongly magnetic further support the conclusion of heat treatment.

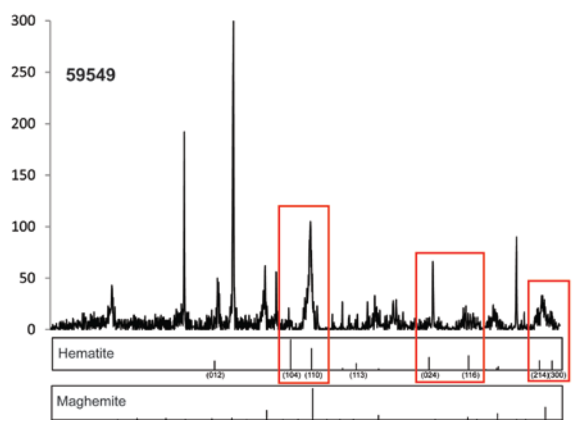

Fig. 8.12. 59549 XRD pattern and evidence of heating

Sample 111483 also comes from the Upper Roofspall Facies. This sample contains hematite as the major color bearing mineral and has been given a heat treatment classification of possible (Fig. 8.13). The (104) to (110) intensity ratio is <1 and the (104) peak is broad in comparison to the (110) peak. However, the remaining peaks that should show broadening are difficult to discern and cannot be reliably assessed.

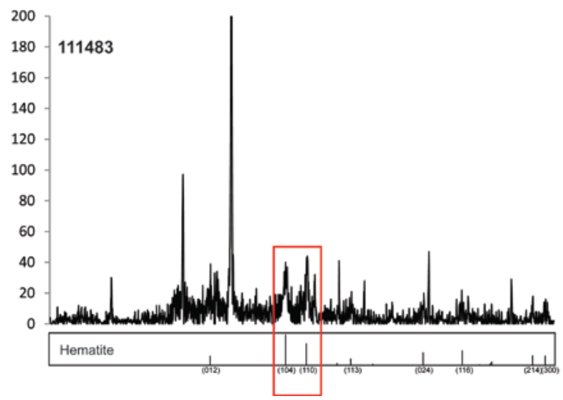

Fig. 8.13. 111483 XRD pattern and evidence of heating

Sample 52493 comes from the Shelly Brown Sand of the Eastern excavation area. The sample contains hematite as the color bearing mineral and has been given a heat treatment classification of definite (Fig. 8.14). The (104) to (110) intensity ratio is <1 and maghemite is present. The other peaks show some broadening although they are fairly sharp compared to other samples. This may suggest that the sample was heated to a higher temperature.

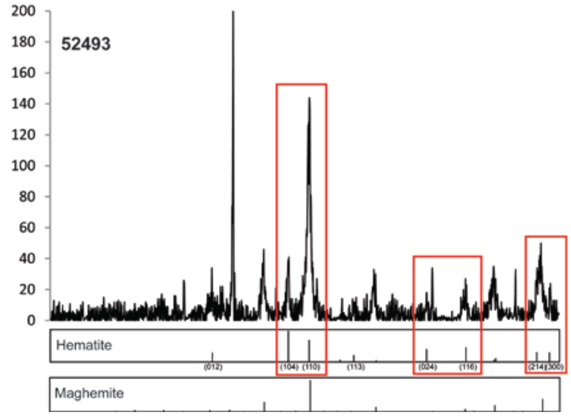

Fig. 8.14. 52493 XRD pattern and evidence of heating

Sample 56924 is also from the Shelly Brown Sand. The sample contains hematite as the major color bearing mineral and is classified as possibly heated (Fig. 8.15). The hematite signal is weak. The intensity ratio of (104) to (110) is <1 and the (104) peak is broad compared to the (110) peak. However, no other peaks are clear enough to make an assessment of broadening. It remains a possibility that this is an example of a naturally formed poorly crystallized hematite.

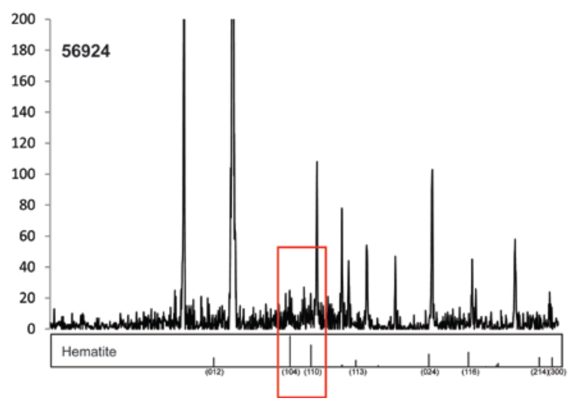

Fig. 8.15. 56924 XRD pattern and evidence of heating

Sample 57070 is also from the Shelly Brown Sand. The sample contains hematite as the color bearing mineral and it is not likely heated (Fig. 8.16). The intensity ratio for (104) to (110) is approximately one and most of the peaks are fairly sharp.

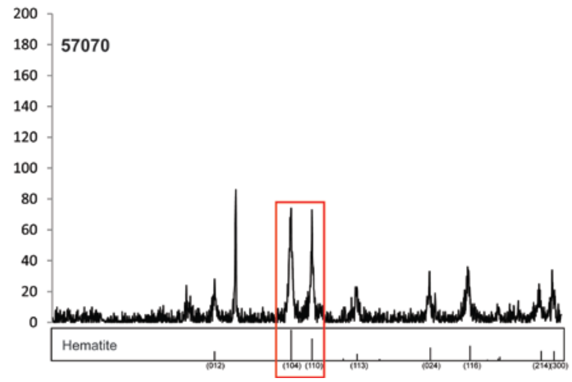

Fig. 8.16. 57070 XRD pattern and evidence of heating

Sample 31404 comes from the Truncation Fill in the Eastern excavation area. The sample contains hematite has the primary color bearing mineral but it does not show evidence that the hematite is disordered (Fig. 8.17). The sample has been classified as not likely heated. The (104) to (110) ratio is >1 and all peaks are sharp and narrow. This is indicative of well crystallized hematite.

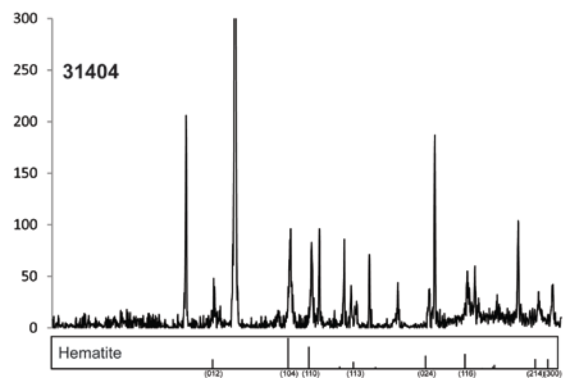

Fig. 8.17. 31404 XRD patterns

Sample 59548 also comes from the Truncation Fill. The sample has a mixture of hematite and goethite, suggesting that it has not been heated above 250ºC.

Sample 25992 comes from the Redeposited Disturbance in the Eastern excavation area. The sample is hematite bearing but is not likely heated (Fig. 8.18). The (104) to (110) intensity ratio is >1 and the peaks do not show selective broadening.

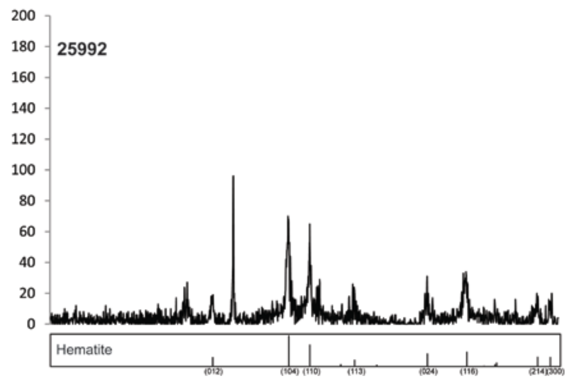

Fig. 8.18. 25992 XRD pattern with normal hematite

Sample 30255 also comes from the Redeposited Disturbance. It is hematite bearing, and it is not likely to have been heated (Fig. 8.19). The hematite XRD pattern is that of well crystallized hematite. The (104) to (110) ratio is >1 and there is no selective broadening of peaks.

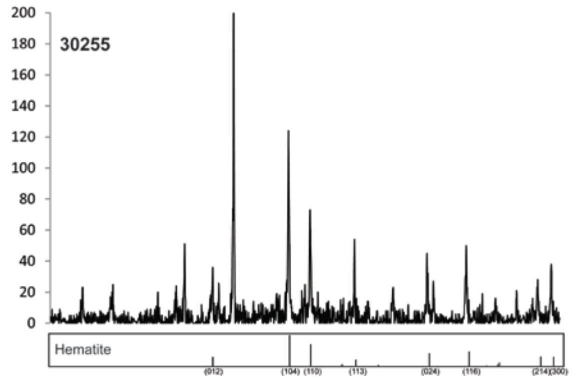

Fig. 8.19. 30255 XRD pattern with normal hematite

Sample 26091 comes from the Surface deposits in the Eastern excavation area. The sample is hematite bearing and is probably heated (Fig. 8.20). The sample has an intensity ratio of <1 for peaks (104) to (110) and maghemite was detected. The piece is also partially magnetic. There is also some broadening of the (024) and (116) peaks.

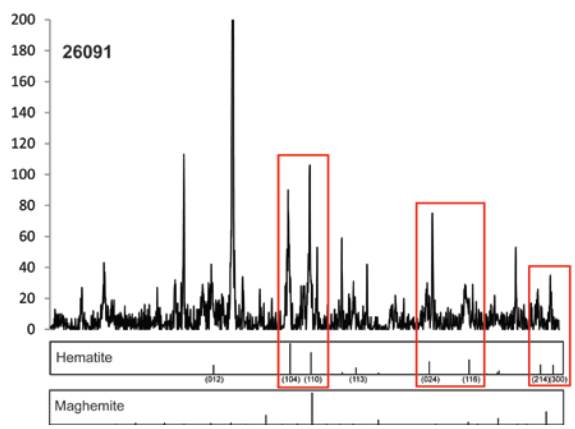

Fig. 8.20. 26091 XRD pattern and evidence of heating

Sample 59519/20 also comes from the Eastern Surface deposits. This sample is hematite bearing but is not likely heated (Fig. 8.21). The sample shows a normal >1 intensity ratio for peaks (104) and (110) and does not display selective broadening of other peaks.

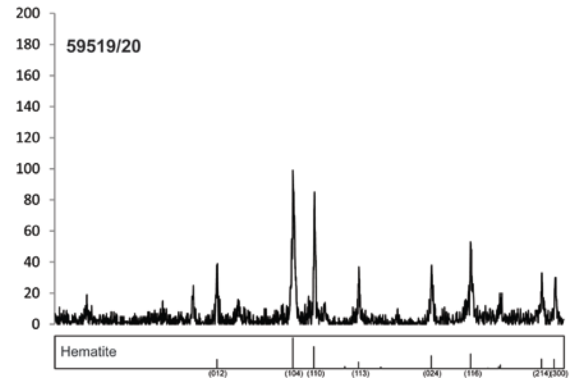

Fig. 8.21. 59519/20 XRD pattern with normal hematite signature

Sample 22873 comes from the DB Sand 2 in the Western excavation area. The sample is hematite bearing and probably heated (Fig. 8.22). The (104) to (110) intensity ratio is <1 and there is some selective broadening of peaks (116) and (214). There are also some goethite peaks remaining indicating that the sample was not heated to more than 270ºC (Pomiés *et al.* 1998).

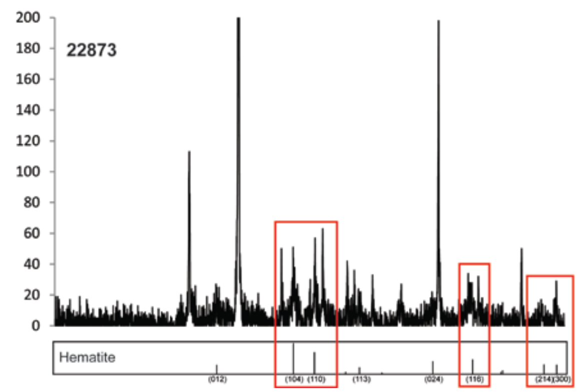

Fig. 8.22. 22873 XRD pattern and evidence of heating

Sample 22109 comes from the DB Sand 3 in the Western excavation area. The sample has hematite as the primary color bearing mineral and is possibly heated (Fig. 8.23). The (104) to (110) intensity ratio is <1 but the peaks are relatively sharp. There is possible maghemite detected accounting for the increase in the (110) peak. This is supported by the fact that the sample is partially magnetic.

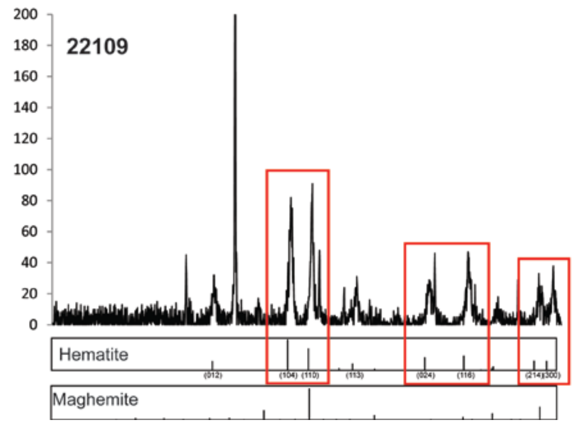

Fig. 8.23. 22109 XRD pattern and evidence of heating

Sample 22151 also comes from the DB Sand 3 and is hematite bearing. The sample is probably heated (Fig. 8.24). There is an intensity ratio <1 for (104) and (110) as well as some evidence for selective broadening.

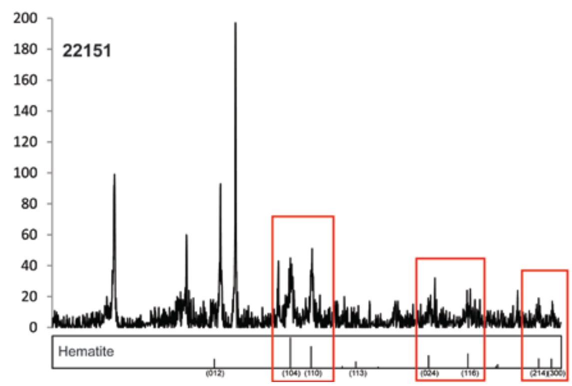

Fig. 8.24. 22151 XRD pattern and evidence of heating

Sample 34674 also comes from the DB Sand 3. The sample contains hematite and is not likely heated (Fig. 8.25). The hematite may be poorly crystallized however. The intensity ratio is >1 or close to 1 and all peaks are broad and not sharp.

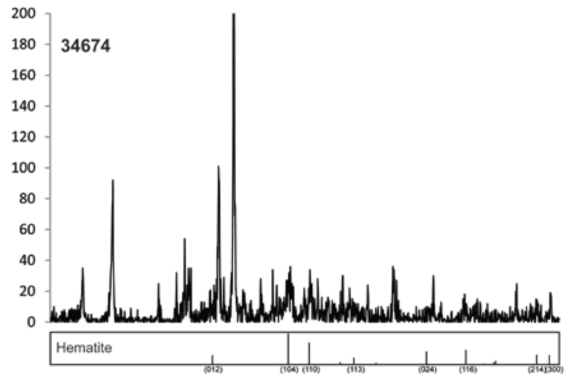

Fig. 8.25. 34674 XRD pattern with poorly crystallized hematite

Sample 82307 is also from the DB Sand 3 and contains hematite. The pattern is that of normal hematite and the sample is not likely to have been heated (Fig. 8.26). The intensity ratio of (104) and (110) is >1 or close to 1. The other major peaks are fairly narrow and well formed.

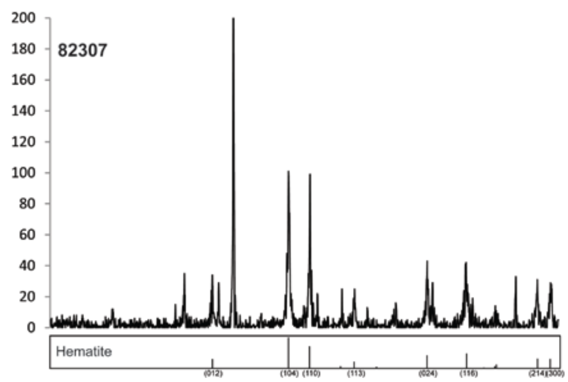

Fig. 8.26. 82307 XRD pattern with normal hematite

Sample 53348 comes from the LBG Sand 1 in the Western excavation area. The sample contains hematite with characteristics of disordered hematite (Fig. 8.27). It is classified as definitely heated. There is an intensity ratio <1 for peaks (104) to (110). Selective broadening is evident particularly for peaks (104), (024), (116), and (214) while peak (110), (113), and (300) stay relatively sharp and narrow.

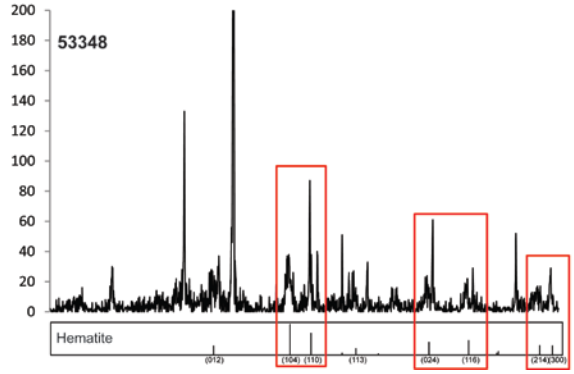

Fig. 8.27. 53348 XRD pattern with evidence of heating

Sample 53738 also comes from the LBG Sand 1 in the Western excavation area. The sample contains hematite that is clearly disordered (Fig. 8.28). It has been classified as definitely heated. The (104) to (110) intensity ratio is <1 and there is clear selective broadening of peaks (012), (104), (024), (116), and (214) while the remaining peaks are more narrow and sharp.

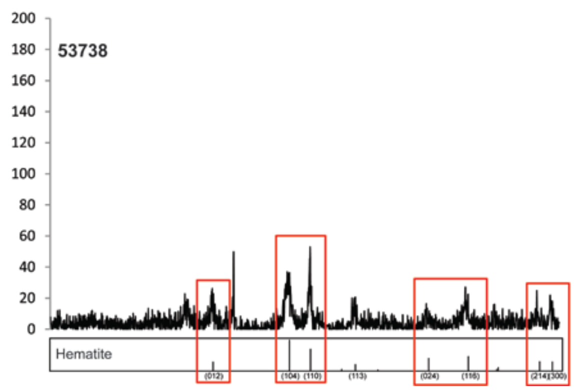

Fig. 8.28. 53738 XRD pattern and evidence of heating

Sample 45739 comes from the LB Sand 1. It is hematite bearing and is only possibly disordered (Fig. 8.29). The sample has a (104) to (110) intensity ratio of about 1. Some of the peaks show slight broadening.

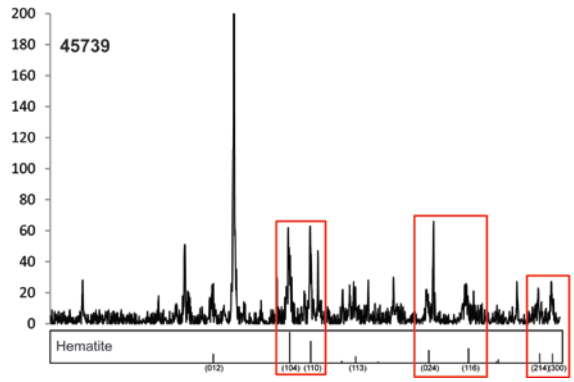

Fig. 8.29. 45739 XRD pattern and evidence of heating

Of the 22 samples tested from PP13B, there were five cases of clear exposure to heat, three probable cases, and five possible cases (Table 8.1). The remaining nine samples did not have sufficient evidence to suggest that the samples had been exposed to heating either intentionally or unintentionally.

Table 8.1
Summary of evidence for heating through disordered hematite at PP13B

StratAgg	Sample Number	Exposure to heating
LC-MSA Lower	59504	Definite
	80427	Not likely
	81745	Possible
Upper Roofspall	59549	Definite
	111483	Possible
Shelly Brown Sand	52493	Definite
	56924	Possible
	57070	Not likely
Truncation Fill	31404	Not likely
	59548	Not likely
Redeposited Disturbance	25992	Not likely
	30255	Not likely
Eastern Surface	26091	Probable
	59519/20	Not likely
DB Sand 2	22873	Probable
DB Sand 3	22109	Possible
	22151	Probable
	34674	Not likely
	82307	Not likely
LBG Sand 1	53348	Definite
	53738	Definite
LB Sand 1	45739	Possible

PP5-6 There are 40 samples from PP5-6, the same samples used for sourcing analyses discussed in Chapter 6. The same XRD patterns presented earlier were used to identify evidence for heating though the presence of disordered hematite. Each sample is discussed individually.

Sample 103053 is from the DBSS in the Northwest Remnant. The sample has probable evidence for disordered hematite and heating (Fig. 8.30). The (104) and (110) intensity ratio is about 1 and there is some possible selective broadening particularly of (012), (104), and (116).

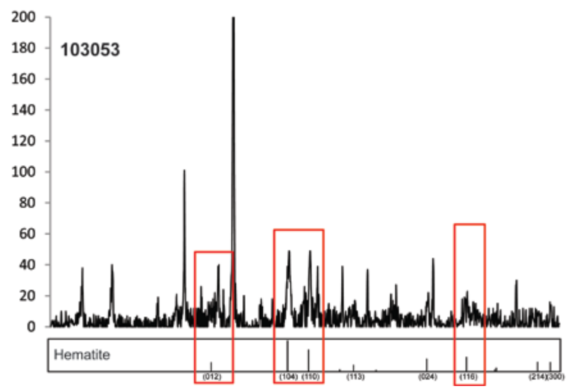

Fig. 8.30. 103053 XRD pattern and evidence of heating

Sample 103234 is from the DBSS. This sample has goethite as the color bearing mineral and so has not been heated.

Sample 103512 is also from the DBSS. This sample has hematite as the color bearing mineral and has been classified as definitely heated (Fig. 8.31). There is an intensity ratio <1 for peaks (104) and (110) and clear selective broadening. In this sample the broadening is most evident for peaks (104), (024) and (116).

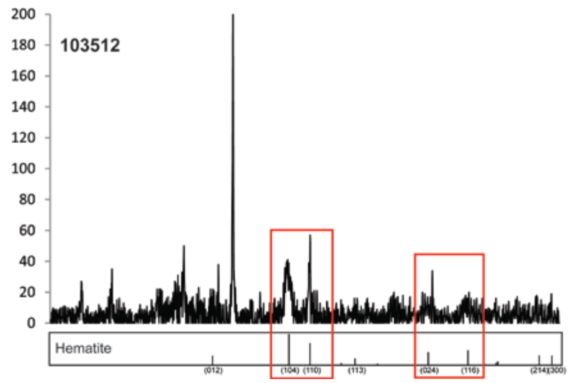

Fig. 8.31. 103512 XRD pattern and evidence of heating

Sample 103759 was also recovered from the DBSS. The sample contains hematite and has a heat treatment classification of not likely (Fig. 8.32). The (104) and (110) peaks have a normal intensity ratio of >1.

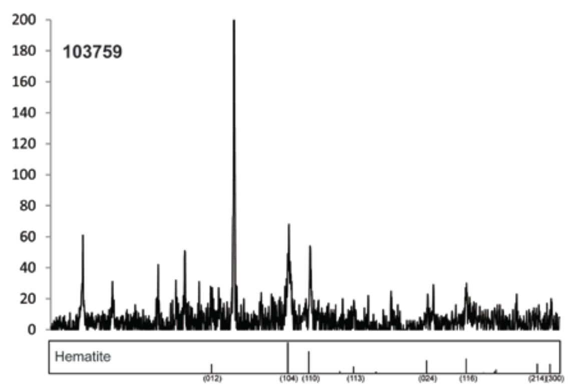

Fig. 8.32. 103759 XRD pattern

Sample 257436 comes from the BCSR. The sample is hematite bearing and has been given a heat treatment classification of possible (Fig. 8.33). The sample has an intensity ratio of <1 for the (104) and (110) peaks, however, there is broadening of all peaks suggesting the sample may in fact just be poorly crystallized. There may also be another unidentified mineral with a peak near the (110) location.

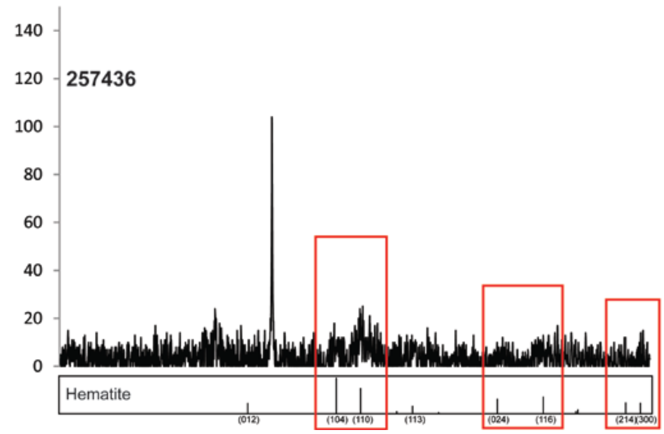

Fig. 8.33. 257436 XRD pattern and evidence of heating

Sample 257438 also comes from the BCSR. The sample is hematite bearing and has been assigned a heat treatment classification of possible (Fig. 8.34). The intensity ratio of the (104) to (110) peaks is <1 or about equal to 1. There is a general broadening of the other peaks that may actually suggest the sample is just poorly crystallized.

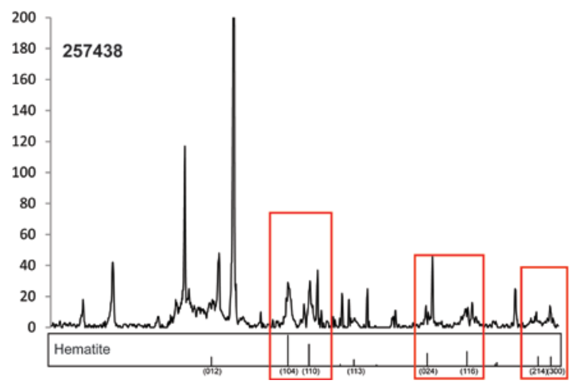

Fig. 8.34. 257438 XRD pattern and evidence of heating

Sample 153642 comes from the RBSR. This sample is hematite bearing and is not disordered (Fig. 8.35). The peaks are narrow and sharp and the (104) to (110) intensity ratio is >1.

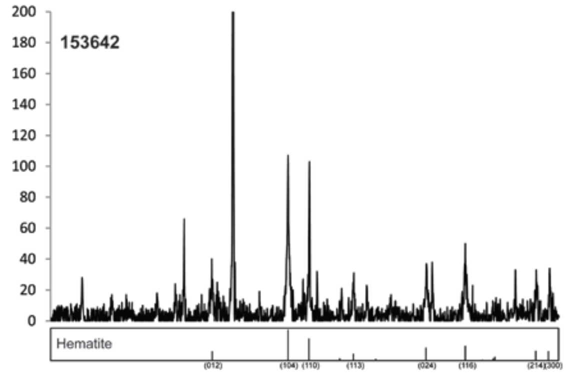

Fig. 8.35. 153642 with normal hematite XRD pattern

Sample 257250 also comes from the RBSR. This sample is hematite bearing and is not disordered (Fig. 8.36). The peaks are narrow and sharp and the (104) to (110) intensity ratio is >1.

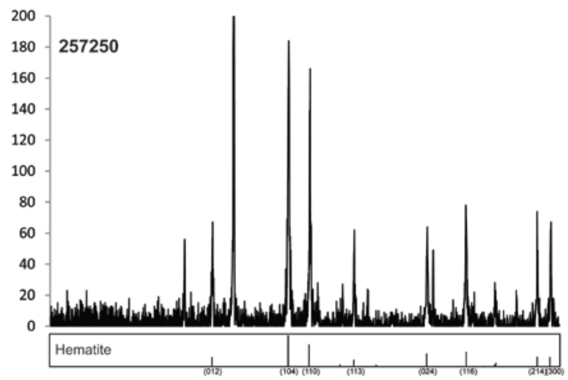

Fig. 8.36. 257250 with normal hematite XRD pattern

Sample 257271 also comes from the RBSR. The sample has been given a heat treatment classification of definite (Fig. 8.37). There is an intensity ratio <1 for peaks (104) and (110) as well as selective broadening of the (012), (104), (024), (116), and (214) peaks while (110), (113), and (300) peaks stay more narrow.

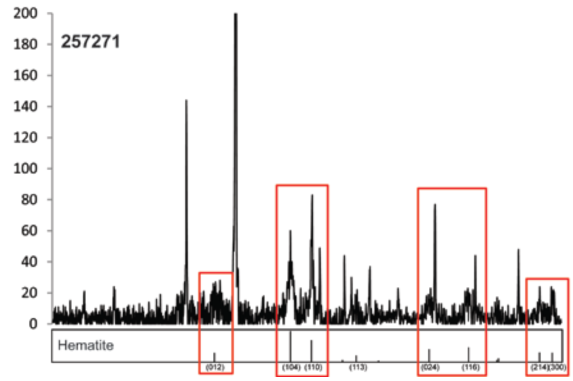

Fig. 8.37. 257271 XRD pattern with disordered hematite

Sample 257297 also comes from the RBSR. The sample contains hematite that is only possibly disordered (Fig. 8.38). The intensity ratio for peaks (104) and (110) is <1 but all the peaks are relatively sharp. It is possible that this sample is heated goethite that has been brought to a higher temperature. Or it is possible there is another unidentified mineral accounting for the increased intensity of the (110) peak.

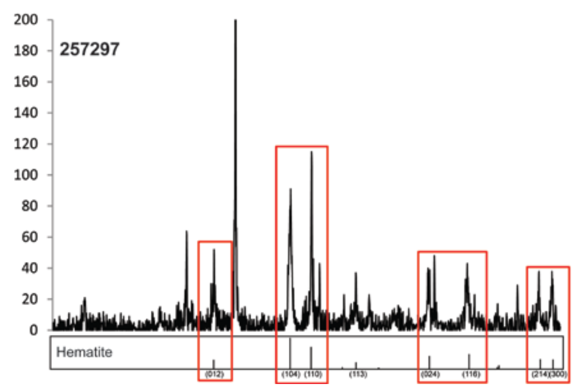

Fig. 8.38. 257297 XRD pattern with possible disordered hematite

Sample 257318 also comes from the RBSR. This sample contains hematite that is most likely poorly crystallized but not disordered (Fig. 8.39). The intensity ratio of the (104) to (110) peak is about equal to one and all peaks show broadening rather than only some.

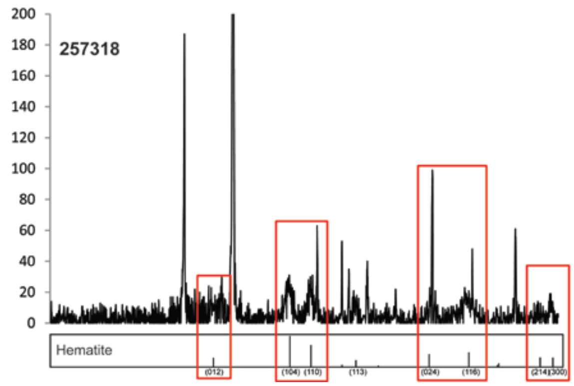

Fig. 8.39. 257318 XRD pattern and possibly poorly crystallized hematite

Samples 257324 and 257326 also come from the RBSR. These samples contains goethite as the primary color bearing mineral and therefore do not have evidence of heat treatment.

Sample 119208 comes from the DBCS. The sample contains goethite and does not have evidence of heat treatment.

Sample 120449 also comes from the DBCS. The sample contains normal well crystallized hematite with an intensity ratio of >1 for peaks (104) and (110) and narrow well defined peaks throughout (Fig. 8.40). The sample does not have evidence of heat treatment.

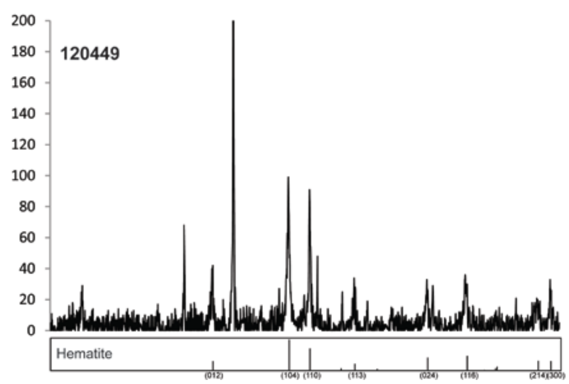

Fig. 8.40. 120449 XRD pattern with well crystallized hematite

Sample 120450 is also from the DBCS. The sample contains normal well crystallized hematite with an intensity ratio of >1 for peaks (104) and (110) and narrow well defined peaks throughout (Fig. 8.41). The sample does not have evidence of heat treatment.

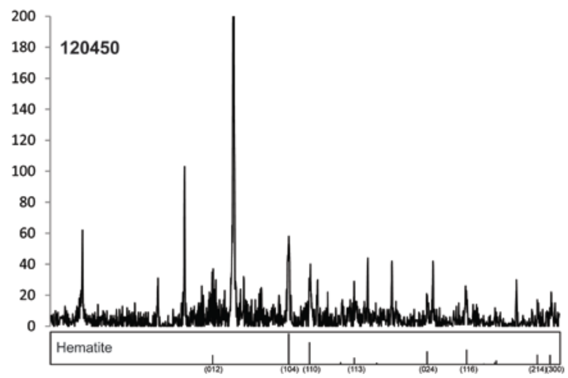

Fig. 8.41. 120450 XRD pattern with well crystallized hematite

Sample 121931 is also from the DBCS. The sample contains hematite that is disordered and has been given a heat treatment classification of definite (Fig. 8.42). The (104) to (110) peaks have an intensity ratio of <1 and there is selective broadening of the (012), (104), (024), and (116) peaks.

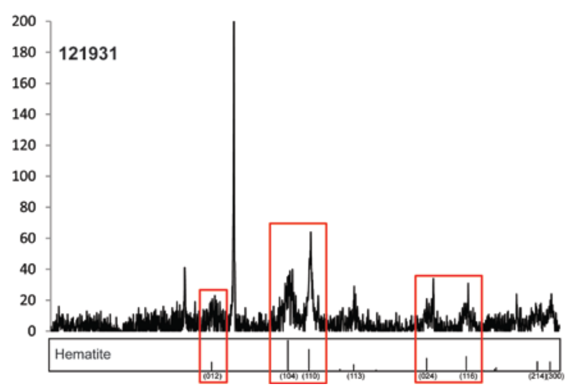

Fig. 8.42. 121931 XRD pattern with disordered hematite

Sample 122709 is also from the DBCS. The sample contains well crystallized hematite and does not provide evidence of heat treatment (Fig. 8.43).

There is a normal intensity ratio of >1 for peaks (104) to (110) and all peaks are narrow and sharp.

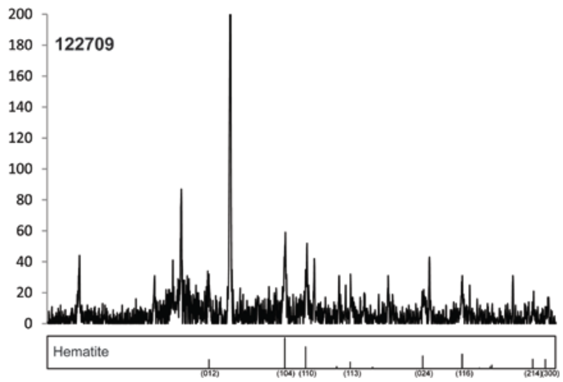

Fig. 8.43. 122709 XRD pattern with well crystallized hematite

Sample 133123 is also from the DBCS. The sample contains well crystallized hematite and does not provide evidence of heat treatment (Fig. 8.44). There is a normal intensity ratio of >1 for peaks (104) to (110) and all peaks are narrow and sharp.

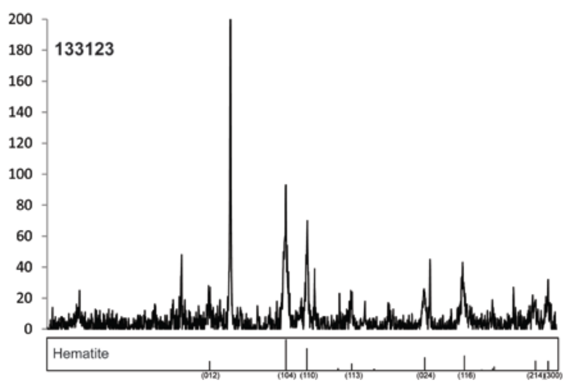

Fig. 8.44. 133123 XRD pattern with well-crystallized hematite

Sample 138351 is from the DBCS. The sample contains disordered hematite and maghemite. It has been given a heat treatment classification of definite (Fig. 8.45).

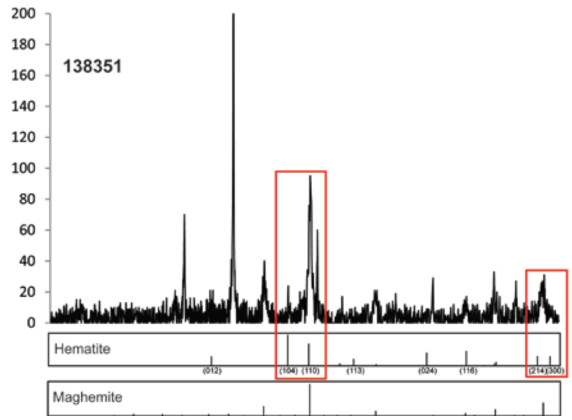

Fig. 8.45. 138351 XRD pattern with disordered hematite and maghemite

Sample 168843 also comes from the DBCS. The sample contains disordered hematite and has been given a heat treatment classification of definite (Fig. 8.46). The (104) to (110) intensity ratio is <1 and there is clear selective broadening of the (012), (104), (024), and (116) peaks.

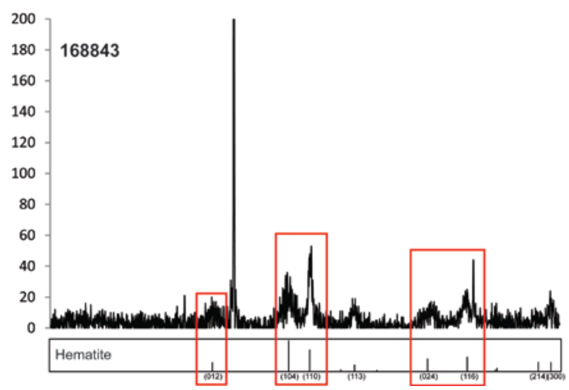

Fig. 8.46. 168843 XRD pattern with disordered hematite

Sample 170199 also comes from the DBCS. This sample contains probable disordered hematite and has been given a heat treatment classification of probable (Fig. 8.47). The (104) to (110) ratio is <1 or about equal to 1 and there is selective broadening of the (012), (024) and (116) peaks.

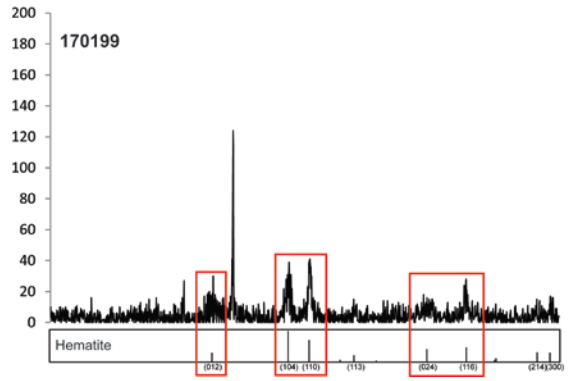

Fig. 8.47. 170199 XRD pattern with probable disordered hematite

Sample 181724 is also from the DBCS. The sample has been given a heat treatment classification of possible (Fig. 8.48). The intensity ratio of the (104) to (110) peaks is <1 but the (012), (104), (024), and (116) peaks are not as broad as would be expected for clearly disordered hematite.

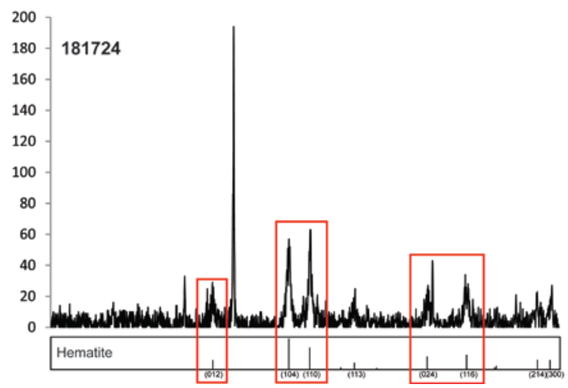

Fig. 8.48. 181724 XRD pattern with possible disordered hematite

Sample 257335 is also from the DBCS. The sample contains possibly disordered hematite or poorly crystallized hematite (Fig. 8.49). It is only given a heat treatment classification of possible. The intensity ratio of the (104) to (110) peaks is only just <1. There is a broadening of the (024) and (116) peaks but there is not a clear distinction between the broadening of (104) and (110). This could suggest poor crystallization rather than disordered hematite formed through heating of goethite.

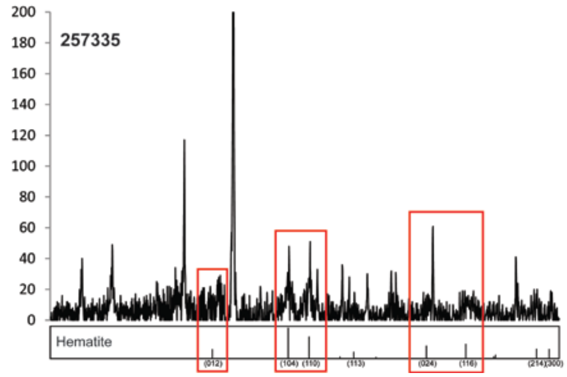

Fig. 8.49. 257335 XRD pattern and possible disordered hematite

Sample 257347 comes from the SGS. The sample contains evidence for disordered hematite and has been given a heat treatment classification of definite (Fig. 8.50). The intensity ratio for peaks (104) and (110) is <1 and there is broadening of peaks (012), (104), (024), (116), and (214).

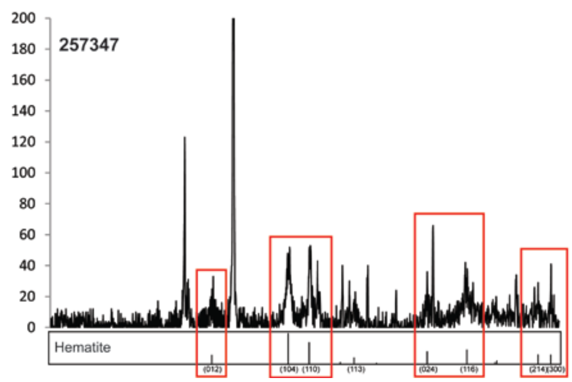

Fig. 8.50. 257347 XRD pattern with disordered hematite

Sample 257329 comes from the OBS. This sample is hematite bearing and has been given a heat treatment classification of probable (Fig. 8.51). The sample shows an intensity ratio of <1 for peaks (104) to (110) and some selective broadening. The (104) peak, however, is not particularly broadened leaving some doubt as to the assignment of disordered hematite.

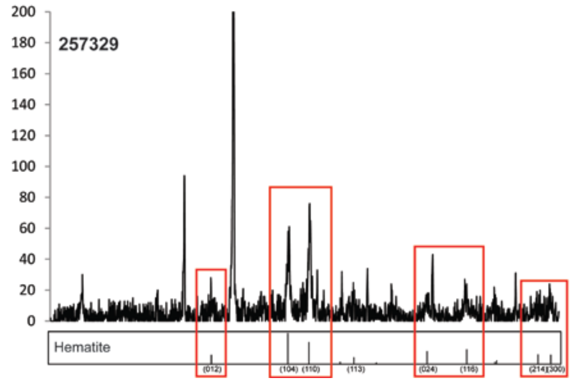

Fig. 8.51. 257329 XRD pattern with probable disordered hematite

Sample 257330 also comes from the OBS. The sample contains goethite as the color bearing mineral and has not been heat treated.

Sample 257357 also comes from the OBS. This sample contains hematite that appears to be normal and well crystallized (Fig. 8.52). The (104) to (110) intensity ratio is >1 and all peaks are fairly narrow and well formed.

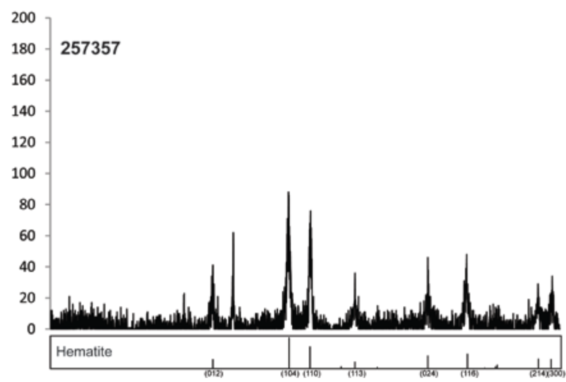

Fig. 8.52. 257357 XRD pattern with normal well crystallized hematite

Sample 131583 comes from the SADBS. The sample contains poorly crystallized hematite and is given a heat treatment classification of not likely (Fig. 8.53). The (104) to (110) intensity ratio is approximately equal to one and there is a general broadening of all peaks including the (110) peak which would be sharp in a disordered or well crystallized hematite pattern.

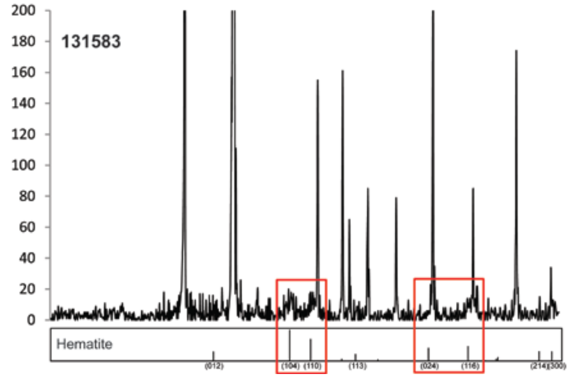

Fig. 8.53. 131583 XRD pattern with poorly crystallized hematite

Sample 135335 comes from the SADBS. The sample is orange in color and neither hematite nor goethite was identifiable over the quartz and clay patterns. The sample's heat treatment status is therefore classified as "not likely".

Sample 135670 comes from the SADBS. The sample does not have a normal hematite pattern and has been classified as possibly heated (Fig. 8.54). There is an intensity ratio <1 for peaks (104) to (110) and possible broadening particularly of (024), (116), and (214). The (104) peak, however, is not broadened leaving some doubt. It is possible that this sample has been heated to a higher temperature.

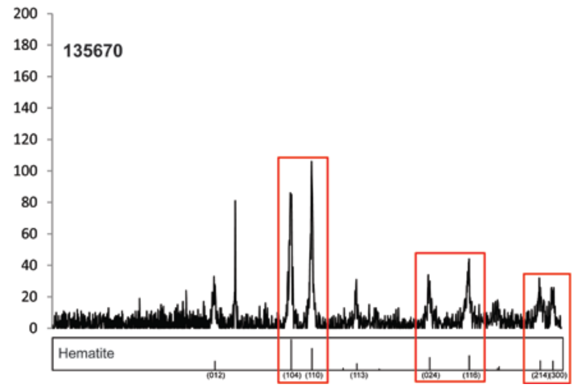

Fig. 8.54. 135670 XRD pattern with possibly disordered hematite

Sample 151183 also comes from the SADBS. This sample is primarily quartz; no other minerals were identified. The sample is therefore deemed as not likely heated due to lack of evidence.

Sample 257362 also comes from the SADBS. This sample contains goethite as the major color bearing mineral and therefore has not been heated to more than 200ºC.

Sample 172814.2 comes from the ALBS and contains well crystallized hematite with sharp peaks and an intensity ratio >1 for peaks (104) and (110) (Fig. 8.55). The sample is classified as not likely heat treated.

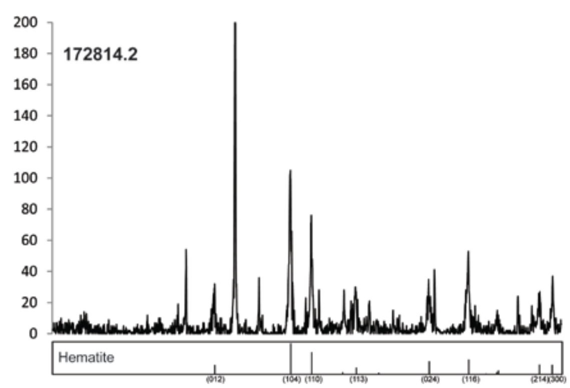

Fig. 8.55. 172814.2 XRD pattern with well-crystallized hematite

Sample 181100.3 is also from the ALBS. This sample contains goethite as the major color bearing mineral and therefore has not been heat treated.

Sample 257247 and 257272 both come from the LBSR. These samples contain goethite as the major color bearing mineral and have not been exposed to heat above 200ºC.

Sample 257349 also comes from the LBSR. This sample contains hematite that is disordered and also contains maghemite. The sample has been given a heat treatment classification of definite (Fig. 8.56).

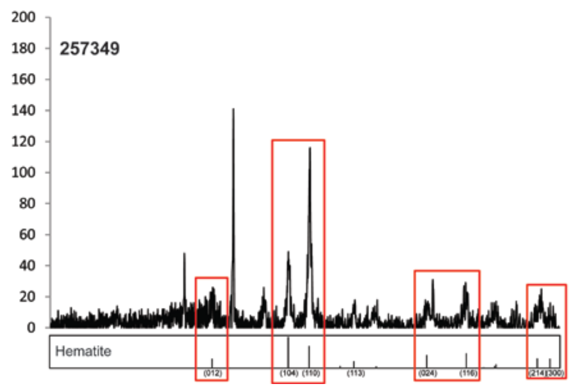

Fig. 8.56. 257439 XRD pattern with disordered hematite and maghemite

Sample 257433 comes from the LBSR. The sample contains disordered hematite and has been given a heat treatment classification of definite (Fig. 8.57). There is an intensity ratio of <1 for peaks (104) and (110) as well as selective broadening.

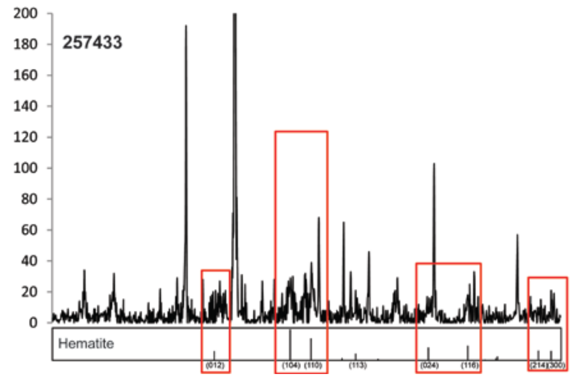

Fig. 8.57. 257433 XRD pattern with disordered hematite

Sample 257449 also comes from the LBSR. The sample displays a normal hematite pattern and it has been given a heat treatment classification of not likely (Fig. 8.58).

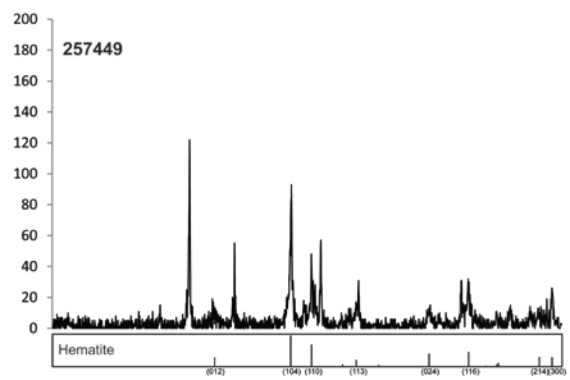

Fig. 8.58. 257449 XRD pattern with normal hematite

Of the 40 samples subjected to XRD analysis from PP5-6 there are eight samples that have definitely been exposed to temperatures above 200ºC, three that probably have been, and six that possibly have been (Table 8.2). The remaining twenty-three samples did not have sufficient evidence to argue that they have been exposed to heat either intentionally or unintentionally.

Table 8.2
Summary of evidence for heating through disordered hematite at PP5-6

StratAgg	Sample Number	Exposure to heat
DBSS	103234	Probable
	103234	Not likely
	103512	Definite
	103759	Not likely
BCSR	257436	Possible
	257438	Possible
RBSR	153642	Not likely
	257250	Not likely
	257271	Definite
	257297	Possible
	257318	Not likely
	257324	Not likely
	257326	Not likely
DBCS	119208	Not likely
	120449	Not likely
	120450	Not likely
	121931	Definite
	122709	Not likely
	133123	Not likely
	138351	Definite
	168843	Definite
	170199	Probable
	181724	Possible
	257335	Possible
SGS	257347	Definite
OBS	257329	Probable
	257330	Not likely
	257357	Not likely
SADBS	131583	Not likely
	135335	Not likely
	135670	Possible
	151183	Not likely
	257362	Not likely
ALBS	172814.2	Not likely
	181100.3	Not likely
LBSR	257247	Not likely
	257272	Not likely
	257349	Definite
	257433	Definite
	257449	Not likely

Classification of depositional burning context

The depositional context of all samples with definite, probable, or possible exposure to heat was further explored to determine if the heating could have been post-depositional. If there is no evidence of heating within 10cm of the samples location, the likelihood that the sample was heated before being deposited at its final location increases. The more samples that meet this criteria the stronger an argument of intentional heat treatment becomes.

<u>PP13B</u> At PP13B, thirteen of the tested samples showed possible to definite evidence of exposure to heat. Table 8.3 presents each sample with field identifications of burning as noted by excavators and the MS values for the corresponding bulk sample from the same stratunit as the ochre sample.

Table 8.3
PP13B contextual and MS evidence of heating compared to XRD determinations of exposure to heat

StratAgg	Sample #	Lot #	XRD heat evidence	Field identified heating	Bulk MS
LC-MSA Lower	59504	3	Definite	Burnt feature	47.92
	81745	2519	Possible	No	32.71
Upper Roofspall	59549	1115	Definite	No	98.26
	111483	1597	Possible	No, layer above	64.63
Shelly Brown Sand	52493	1109	Definite	No	53.55
	56924	1520	Possible	No	32.45
Eastern Surface	26091	367	Probable	Modern hearth	27.53
DB Sand 2	22873	743	Probable	No	13.70
DB Sand 3	22109	676	Possible	Possible hearth	97.35
	22151	680	Probable	Possible hearth	20.81
LBG Sand 1	53348	1471	Definite	No	26.32
	53738	1491	Definite	No	6.17
LB Sand 1	45739	1441	Possible	No	1.68

Sample 59504 from the LC-MSA was deemed definitely heated based on XRD evidence. However, the sample comes from a unit that was described as burnt by excavators and has an MS value of 47.92, borderline for a burnt signature. The sample may have been intentionally heated but based on the depositional context we cannot conclusively rule out post-depositional exposure to heat.

Sample 81745, also from the LC-MSA, showed possible evidence of heating in the XRD pattern. Excavators did not note any direct evidence of burning and the MS value is only 32.71. It is further necessary to check for burning in units within ten centimeters. It is possible the piece could have been exposed to heat from an overlaying fire. Fig. 8.59 is a horizontal plan of all MS values within 10cm elevation of the ochre sample. The sample lies beneath an MS hotspot and the goethite to hematite transition could have taken place post-depositionally.

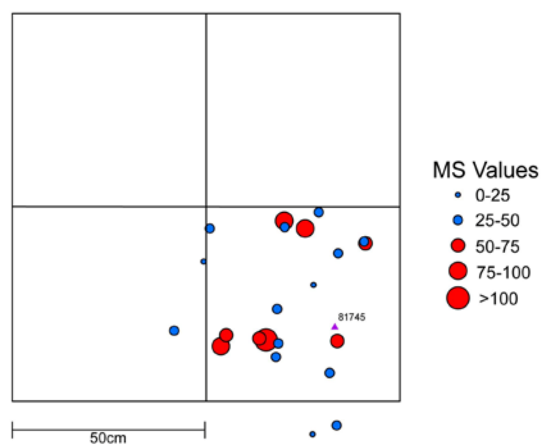

Fig. 8.59. MS values within 10cm elevation of ochre sample 81745

Sample 59549, from the Upper Roofspall, had definite evidence of heating based on the XRD pattern. Although the excavators did not note evidence of heating, the MS signature of 98.26 suggests otherwise. It cannot be argued that this sample was intentionally heated.

Sample 111483, from the Upper Roofspall, had possible evidence of heat exposure based on the XRD pattern. Excavators did not note evidence of burning in this stratunit but did identify it in the layer directly above. The MS value of 64.63 also indicates potential post-depositional exposure to heat. An argument of intentional heat treatment cannot be made for this sample.

Sample 52493 comes from the Shelly Brown Sand and was definitely exposed to heat based on the XRD pattern. Excavators did not note evidence of burning but the MS value of 53.55 suggests exposure to heat and a post-depositional explanation for the ochre's heated signature cannot be ruled out.

Sample 56924 also comes from the Shelly Brown Sand but has only possible evidence of heating based on its XRD pattern. Burning was not identified during excavation and the MS value is only 32.45 for this unit. The sample is far enough away from the closest MS hotspot that is may not have been burned *in situ*.

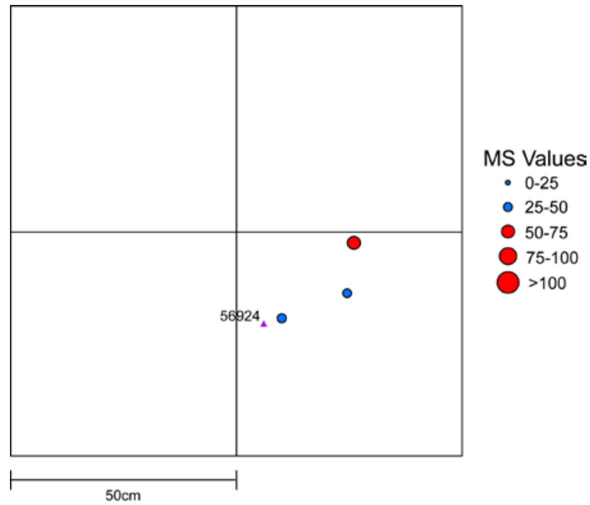

Fig. 8.60. MS values within 10cm elevation of ochre sample 56924

Sample 26091 comes from the surface of the Eastern excavation area and has probable evidence for exposure to heat. It is unlikely that this piece is in primary context but according to excavation notes was in association with a modern hearth. The MS value is low, only 27.53, but this piece could easily have been heated post-depositionally especially since it was found on the surface and is likely to have moved around considerably.

Sample 22873 comes from the DB Sand 2 and was identified as probably heated based on the XRD evidence. Excavators did not note evidence of heating and the MS value of 13.70 indicates that these sediments have not been exposed to heat. The sample does not have evidence of burning near it (Fig. 8.61) and was not likely heated post-depositionally.

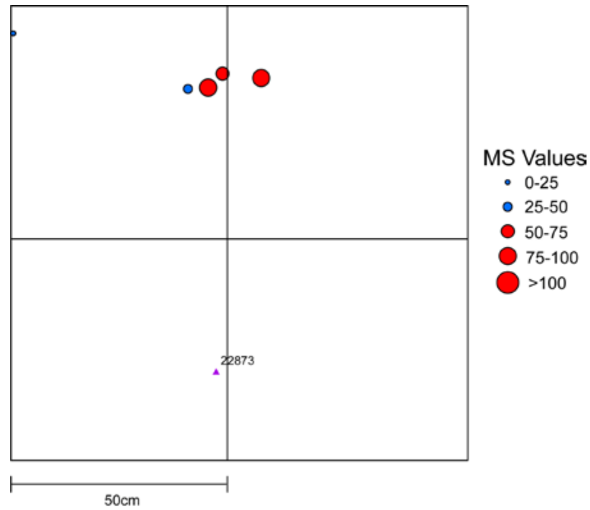

Fig. 8.61. MS values within 10cm elevation of ochre sample 22873

Sample 22109 was found in the DB Sand 3 and has possible evidence of heating identified in the XRD pattern. Excavators identified this unit as a possible hearth and the MS value of 97.35 supports this conclusion. We cannot conclusively argue that this sample was intentionally heated based on the depositional context.

Sample 22151 also comes from the DB Sand 3 and is probably heated based on the XRD pattern. Although excavators mentioned possible burning the MS value of 20.81 suggests these sediments have not been heated. The sediments above the sample, however, have been heated (Fig. 8.63) close enough to the sample to cause a goethite to hematite transition.

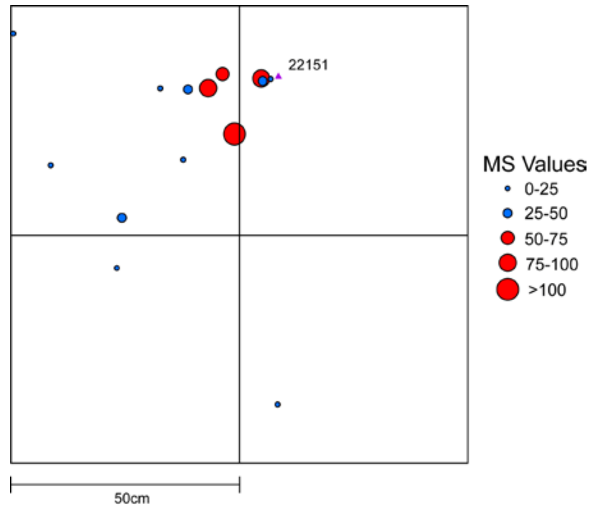

Fig. 8.63. MS values within 10cm elevation of ochre sample 22151

Sample 53348 comes from the LBG Sand 1 and was classified as definitely heated based on the XRD pattern. The excavators did not note any evidence of heating for this unit and the MS value is low at 26.32. It is possible that this piece was intentionally heated. There are no high MS values within the vicinity of this piece that could have caused a post-depositional goethite to hematite transition (Fig. 8.64).

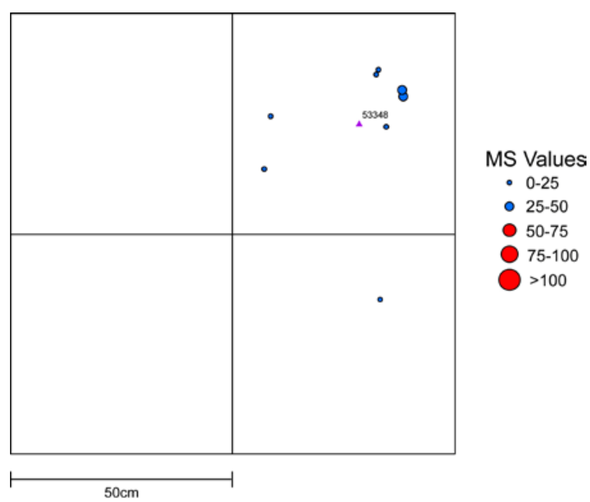

Fig. 8.64. MS values within 10cm elevation of ochre sample 53348

Sample 53738 also comes from the LBG Sand 1 and was classified as definitely heated based on the XRD pattern. The excavators did not note any evidence of burning and the MS value of 6.17 supports their conclusions. This sample could be intentionally heated as the surrounding and overlaying sediments also show no evidence for heating (Fig. 8.65).

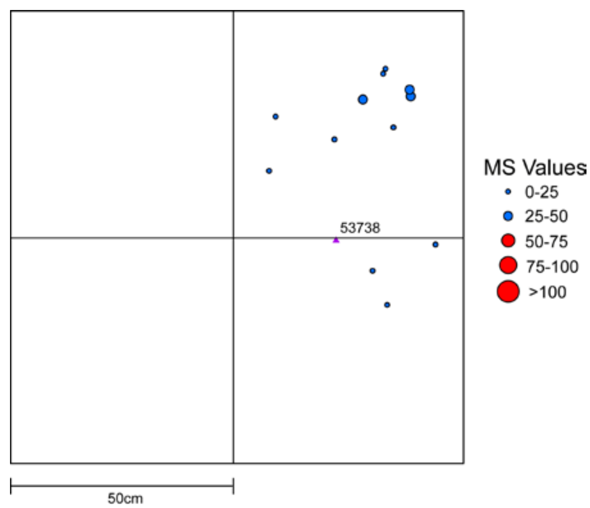

Fig. 8.65. MS values within 10cm elevation of ochre sample 53738

Sample 45739 comes from the LB Sand 1 and had possible evidence of heating identified in its XRD pattern. Excavators did not identify evidence of fire and the MS value is extremely low at 1.68. There is no evidence of heating in any of the surrounding or overlying sediments that is close enough to have caused a goethite to hematite transition (Fig. 8.66)

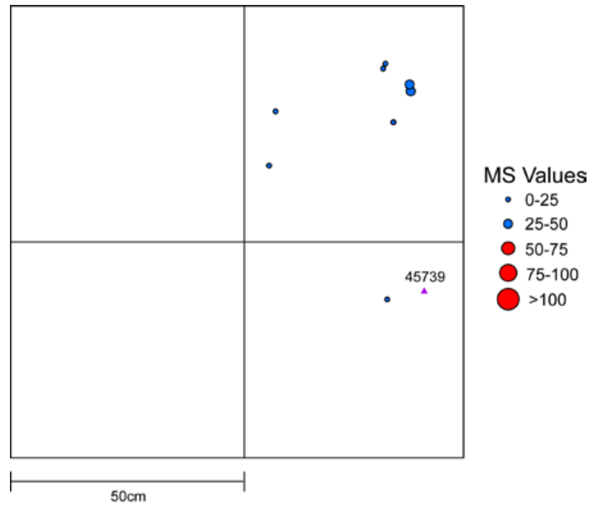

Fig. 8.66. MS values within 10cm elevation of ochre sample 45739

Of the thirteen tested samples with definite, probable or possible classifications for heating based on their XRD patterns, five cannot be explained by post-depositional heating of the surrounding or overlying sediments. Two of these samples have only possibly been heated, 56924 and 45739. One has been probably heated, 22873, and two have been definitely heated 53348 and 53738.

PP5-6 At PP5-6, seventeen of the tested samples showed possible to definite evidence of exposure to heat. Table 8.4 presents each sample with field identifications of burning as noted by excavators and the MS values for the corresponding bulk sample from the same stratunit as the ochre sample.

Table 8.4
PP5-6 contextual and MS evidence of heating compared to XRD determinations of exposure to heat

StratAgg	Sample #	Lot #	XRD heat evidence	Field identified heating	Bulk MS
DBSS	103234	3336	Probable	No	80.00
	103512	3337	Definite	No	53.06
BCSR	257436	8532	Possible	No	None
	257438	8532	Possible	No	None
RBSR	257271	3220	Definite	No	25.44
	257297	5268	Possible	No	None
DBCS	121931	3296	Definite	No	69.52
	138351	1283	Definite	Possible hearth	156.21
	168843	7998	Definite	No	137.62
	170199	7998	Probable	No	137.62
	181724	8206	Possible	No	65.06
	257335	7998	Possible	No	137.62
SGS	257347	8054	Definite	No	31.12
OBS	257329	7979	Probable	No	31.44
SADBS	135670	1214	Possible	Possible hearth	92.02
LBSR	257349	8068	Definite	No	96.40
	257433	8520	Definite	Possible hearth	50.89

Sample 103234 comes from the Dark Brown Silty Sands in the Northwest Remnant. The sample had probable evidence for exposure to heat. No field identification of burning was made by the excavators but the MS value of 80 suggests that these sediments have been exposed to heat. It is possible that this sample was heated unintentionally after deposition.

Sample 103512 also comes from the Dark Brown Silty Sands and had definite evidence of exposure to heat based on the XRD pattern. Again there was no identification of burning in the excavation notes but the MS value of 53.06 suggests the sediments may have been heated. Again, it is possible that the sample was heated unintentionally after deposition.

Sample 257436 and 257438 come from the same unit in the Black Compact Sand and Roofspall and both samples had possible evidence of exposure to heat. There were no field identifications of burning for this unit but MS values have also not been calculated. The unit is close to the surface and may be disturbed. The MS value for the unit directly beneath is 153.92.

Sample 257271 comes from the RBSR and has definite evidence of burning. Excavators did not identify evidence of heating and the MS value is low at 25.44. However, there is concern that parts of the RBSR are not in primary context. While this sample may be evidence of intentional heating, the lack of confidence in the context casts doubt. Sample 257297 also comes from the RBSR but had only possible evidence for heating. There was no evidence for burning for this unit during excavation but here is no MS value associated with the unit. Again, because of issues with context we cannot say if this sample was likely heated intentionally.

Three samples (121931, 138351, and 168843) from the Dark Brown Compact Sand had definite evidence of heating in their XRD patterns. The stratunits that these samples came from all have MS values indicative of heated sediments (69.52, 156.21 and 137.62 respectively). The unit with the highest MS value, corresponding to sample 138351, was also identified as a possible hearth during excavation. Because these samples were recovered from clearly heated sediments we cannot argue that they were intentionally exposed to heat. They could easily have been heated after deposition. Three other samples were tested from the DBCS. Samples 170199 (probably heated) and 257335 (possibly heated) come from a unit with an MS value of 137.62 and also could have been exposed to heat in a post depositional context. The last sample, 181724, had possible evidence of exposure to heat and is associated with a bulk sample MS value of 65.06 again suggesting the sample could have been heated unintentionally.

Sample 257347 comes from the Shelly Gray Sand and has definite evidence of heating in its XRD pattern. There was no evidence of heating noted by excavators and the MS value for the units bulk sample is 31.12. It is possible that this sample was heated intentionally. However, Fig. 8.67 shows this sample was recovered near heated sediments which could explain the evidence for disordered hematite.

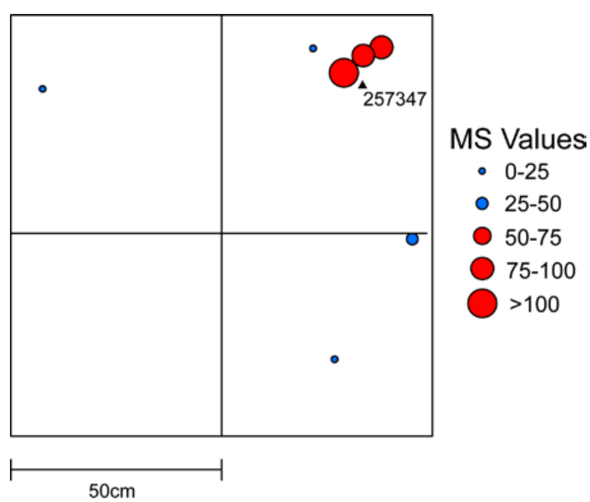

Fig. 8.67. MS values within 10cm elevation of ochre sample 257347, as the sample is from the 10mm screen it is plotted as the centroid of all shots from the same unit

Sample 257329 comes from the Orange Brown Sand and has probable evidence of exposure to heat based on its XRD pattern. Excavators did not note any evidence of heating for this unit and the MS value is only 31.44. It is possible that this sample was heated intentionally elsewhere before being deposited. The centroid of the unit that this sample comes from is not close to an MS hotspot (Fig. 8.68). However, it is possible that this 10mm screen sample comes from close to the hotspot and could have been heated post-depositionally.

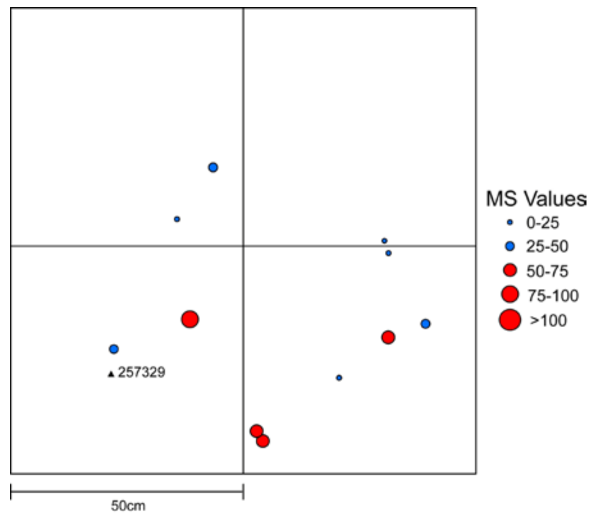

Fig. 8.68. MS values within 10cm elevation of ochre sample 257329, as the sample is from the 10mm screen it is plotted as the centroid of all shots from the same unit

Sample 135670 comes from the Shelly Ashy Dark Brown Sand and had possible evidence of heating identified in its XRD pattern. The unit was identified by excavators as a possible combustion feature or hearth. The MS value of 92.02 supports this conclusion. This sample could have been heated post-depositionally.

Sample 257349 comes from the Light Brown Sand and Roofspall. It has definite evidence for heating based on XRD. Excavators did not identify the unit as heated but the MS value of 96.40 suggests it was heated. This sample could have been heated after deposition. Sample 257433 also comes from the LBSR and was definitely heated. The unit was identified as a possible hearth layer and has an MS value of 50.89 suggesting the sediments probably have been exposed to heat. Again, we cannot argue that this sample was intentionally heated prior to deposition.

There are no samples from PP5-6 with XRD evidence of heating which cannot be explained by exposure to post-depositional heat.

Conclusion

There is only minimal evidence for intentional heat treatment at the PP sites. Seventeen samples from PP 5-6 showed evidence of exposure to heat, however, all of these samples were found in contexts with high MS values indicative of heated sediments. It is not possible to determine if these samples were heated by the site inhabitants to change yellow ochre to red ochre or if they were heated accidently after being deposited. At PP13B there are five samples with some evidence of heating which cannot be explained by their post-depositional context. It is possible that these samples are disturbed and were heated post-depositionally elsewhere. However, previous work suggests that these deposits are intact (Bernatchez 2010; Marean *et al.* 2010; Karkanas and Goldberg 2010).

The PP13B data suggest that there is the possibility that ochre was being intentionally heated. This warrants further study with more focused sampling. For this study samples were used that were chosen for sourcing analysis. They were chosen randomly from throughout the sites in an attempt to capture the diversity within the assemblages. Samples were chosen without regard for the heating context of the surrounding sediments. It would be useful to target samples from unburned sediments specifically to look for further evidence of intentional heat treatment. Ongoing micromorphology analysis may also be helpful in determining if sediments are heated *in situ* or if high MS values are resulting from the inclusion of burnt material from elsewhere in the site.

CHAPTER 9: TEST IMPLICATION 2 – RESIN AND HAFTING EXPERIMENTATION

Introduction

Use of ochre in mastic recipes for binding stone tools to wooden hafts is the most commonly proposed utilitarian hypothesis for the presence of ochre in MSA archaeological sites. This hypothesis is supported by evidence for ochre residue on stone tools from several sites, most notably Rose Cottage Cave and Sibudu Cave (Tomlinson 2001; Wadley 2001b; Lombard 2004; Wadley *et al.*2004a; Lombard 2005; Wadley 2005b; Lombard 2007). Despite some experimental work (Allain and Rigaud 1986; Wadley *et al.*2004a; Wadley 2005b; Hodgskiss 2006; Wadley *et al.*2009), several questions remain unanswered. First, does the inclusion of ochre actually provide a longer lasting haft? Second, is there a functional advantage to the use of red ochre as opposed to yellow ochre or any other more readily available additive such as sand?

A two fold approach was applied here to address these questions. The first was an actualistic study in which replicated spears with different resin recipes were fired with controlled force at two different substances. The second approach attempted to apply mechanical testing methods to different resin recipes. These data are used to assess the usefulness of ochre in strengthening hafts. If the hafts with ochre do not have a clear advantage then the utilitarian hafting hypothesis must be rejected.

Methods

Actualistic experiments

MSA stone tools were replicated using local raw materials and hafted. A total of 75 Howieson's Poort style backed crescents were knapped by Kyle Brown using locally collected and heat treated silcrete (Fig. 9.1). These replicas are similar to tools found in the HP layers (the DBCS) at PP5-6. All the crescents were weighed and length, width, and thickness (at thickest point) were measured (Table 9.1). The crescents were then separated into three groups (Groups A, B, and C) based on size so that each group had a range of sizes. This was done to minimize the effects of tool size on the outcome of the experiments, since it is impossible to knap 75 identical crescents. Fig. 9.2 compares the range of length to width ratios for each of the three groups. A Kruskal-Wallis test supports the null hypothesis that these samples have statistically similar distributions ($H=0.06$, $p=0.97$).

Fig. 9.1: Examples of HP crescent replicas knapped for these experiments

Table 9.1
Measurements and groupings of experimental crescents

Group	Lithic #	Length (mm)	Width (mm)	Thickness (mm)	Weight (g)
A	4	38.30	19.6	4.27	3.9
A	16	42.19	17.29	4.86	4.2
A	20	44.03	15.49	3.54	2.8
A	26	40.12	12.46	3.7	2.1
A	29	43.53	16.15	3.83	2.9
A	30	35.77	16.17	2.56	1.9
A	32	41.15	19.12	4.42	3.5
A	34	32.78	13.45	2.84	1.4
A	35	30.68	16.09	2.49	1.3
A	36	33.15	17.32	2.21	1.5
A	37	33.55	14.41	2.87	1.7
A	39	38.94	20.19	5.88	4.4
A	40	37.80	17.52	2.91	2.4
A	41	34.39	14.55	4.11	2.1
A	43	36.42	14.81	4.61	2.5
A	57	38.57	15.53	4.83	3.1
A	58	29.75	16.64	3.47	1.7
A	62	32.15	11.45	2.92	1.2
A	63	41.19	13.86	3.6	1.9
A	65	38.13	15.44	3.81	2.3
A	67	33.69	18.08	3.67	2.7
A	75	35.20	15.3	3.04	1.8
A	76	40.62	18.47	3.38	3.3
A	78	42.43	17.76	2.88	3.1
A	80	38.12	14.64	3.97	2.2
B	2	27.57	16.42	4.14	2.1
B	3	39.03	18.56	4.72	3.6
B	11	31.12	17.63	4.54	2.3
B	12	44.16	14.23	3.46	1.9
B	14	36.02	18.01	3.88	3.1
B	17	39.34	18.16	3.91	3.3
B	19	43.68	18.59	4.78	4
B	21	39.46	18.55	5.15	4.2
B	23	31.30	17.29	4.14	2.7
B	27	44.72	15.89	2.87	2.2
B	50	35.04	14.03	3.21	1.5
B	52	30.59	12.86	3.74	1.4
B	55	43.18	18.19	3.92	3.1
B	56	31.27	14.03	4.05	1.8
B	60	39.76	18.73	2.9	2.9
B	64	38.20	14.8	4.29	2.4
B	69	32.03	13.44	3.97	1.9
B	70	36.47	15.21	3.28	1.7
B	71	38.35	14.83	4.72	2.2
B	72	41.53	16.89	3.4	2.6

Table 9.1 Con't
Measurements and groupings of experimental crescents

Group	Lithic #	Length (mm)	Width (mm)	Thickness (mm)	Weight (g)
B	73	40.30	16.95	4.23	2.9
B	74	40.18	19	6.56	4.6
B	79	34.53	13.86	3.26	1.7
B	81	30.06	12.57	2.97	1.2
B	84	34.69	11.97	3.14	1.3
C	6	42.36	20.61	4.91	4.7
C	8	30.40	15.72	4.72	2.9
C	22	36.76	16.55	3.02	2.4
C	24	40.20	19.45	4.61	3.1
C	28	32.66	14.31	4.15	1.8
C	31	43.05	20.45	3.61	4.2
C	33	40.31	15.94	5.05	3.7
C	38	36.80	12.31	2.68	1.7
C	42	30.24	13.67	2.74	1.2
C	44	38.08	16.61	3.38	2.5
C	45	28.76	14.35	3.72	1.8
C	46	35.42	11.96	3.92	2
C	47	34.13	19.34	3.99	3.1
C	48	34.35	17.85	3.42	2.8
C	49	25.10	13.47	3.7	1.4
C	51	36.22	12.1	3.92	1.9
C	53	35.53	13.66	4.12	2.1
C	54	41.60	12.91	3.47	2.3
C	59	38.97	19.42	7.23	4.3
C	61	30.69	15.6	3.51	1.7
C	66	30.72	12.88	3.74	1.4
C	68	39.24	13.74	3.83	2.2
C	77	40.11	14.88	3.05	2.7
C	82	44.33	15.61	5.43	3.4
C	83	34.72	17.26	4.22	3

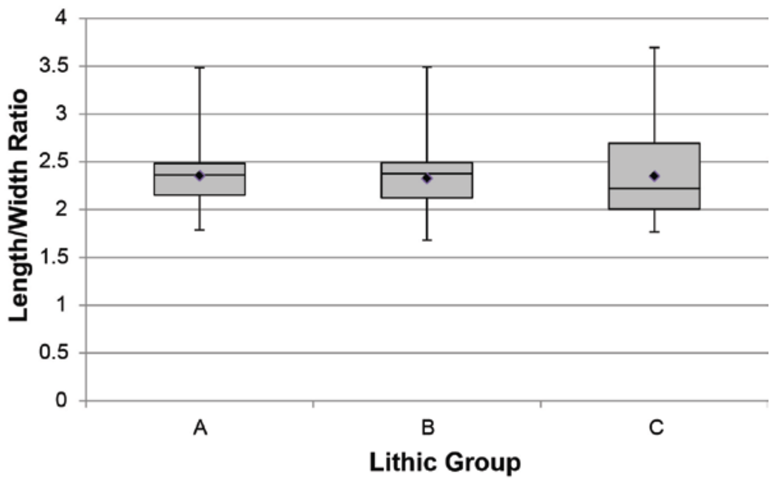

Fig. 9.2. Box plots of lithic groupings showing mean markers

Acacia resin was chosen as the adhesive for these experiments because it has been used in previous ochre hafting studies (Hodgskiss 2006; Wadley 2005b; Wadley *et al.*2009) and it is widely used in Africa as an adhesive (van Wyk and Gericke 2000). Acacia is wide spread in the area today and it thrives in the summer rainfall regime (Palmer and Pitman 1972). Isotope data from PP speleothem research suggests summer rainfall during the 72 to 60 ka glacial period (Bar-Matthews *et al.*2010). It is likely that acacia species would have been available in the area during this period. Phytolith and pollen analysis from PP sediments would be helpful in determine what other species of resinous plants may have been available throughout the MSA.

Acacia karoo resin was collected from acacia stands located in Die Hell. The resin from numerous trees was mixed together to create one homogenous mixture that was used for all subsequent experiments. Therefore, the resin used is identical for all replicated tools and for all mechanical testing (see below). Small amounts of water were added to the resin so that it would flow. The material was then passed through a 1.5mm geological sieve to eliminate as much plant matter and other debris as possible. A small amount of cinnamon oil was added to the resin to inhibit mold growth over the course of the experiments.

Resin mixtures were then created. Group A used plain resin with no additives. Group B resin was one part red ochre powder and two parts resin. This recipe was chosen as it has been argued to be the most successful in previous research (*e.g*. Wadley *et al.*2009). Very little ochre powder was needed to turn the dark brown resin to bright red (Fig. 9.3). The red ochre was collected from the Rooikoopie source. At the time of the experiments it was believed to be a highly likely match for archaeological ochre from both PP13B and PP5-6. The ochre was hand ground on a locally collected quartzite slab. The piece of ochre was ground on multiple facets until it was not possible to hold and grind. Sometimes the striations on older facets were rubbed away while the piece to grind other facets. Group C resin was one part local dune sand and two parts resin.

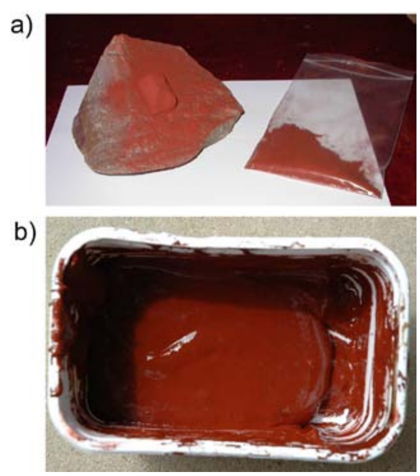

Fig. 9.3. a) Red ochre powder and b) resin mixture

Wooden dowels were used for the hafts. The dowels were cut to 30cm and a notch was cut into one end. The notched end was then softened in fire and ground to a point. This was done so that the force would be absorbed by the hafted stone tool and not the blunt end of the wooden dowel. Resin was applied to the notch and the tool was inserted (Fig. 9.4). The tool was then held over a fire for 1-2 minutes to begin drying the resin. It was necessary to keep a close watch so as not to let the resin burn. The tools were then left to air dry for two weeks. No sinew was used to bind the hafts so that only the strength of the resin would be tested. It is likely that binding the tools would have made the strength of the resin insignificant. All completed replicated tools were photographed prior to carrying out the experiments.

Fig. 9.4. Replicated tools drying

The experiment consisted of two phases. The replicated spears were each fired using a calibrated crossbow (Shea *et al.*2001; 2002) at two different substances, a ballistics gel block used by ballistics specialists to test firearms (Jussila 2004) and a wooden board suspended in sand. The goal was to fire each tool at a flesh like substance (the gel block) and a harder bone like substance (the wood). This guaranteed that every tool was shot with the same force from the crossbow and impacted the exact same material as opposed to firing at an actual carcass where some points would strike bone and others only flesh. Allowing for controlled force and controlled impact helped to minimize variability between tools and resin groups.

The ballistics gel block measured 12x12x20 inches and was made up of 9 pounds of gelatin and 9 gallons of water. The gelatin was mixed with water and then chilled allowing the gelatin to bloom. The mixture was then heated to no more than 130 degrees Fahrenheit until melted. It was then placed in a plastic mold and cooled in an ice bath until solid. The result was a block with the consistency and density of flesh (Jussila 2004). The block was wrapped in a fresh sheep skin donated by a local slaughter house. All tools were fired at this block from the calibrated crossbow at 20cm. Tools were then removed from the block and the hafts were inspected for damage. All tools that were intact then progressed to the second phase.

The second phase consisted of firing the tools at the sand and wood block. This block was contained in a cardboard box. This phase of the experiment insured that all tools impacted a hard substance more like hitting bone. Tools were then removed from the block and inspected for damage.

Mechanical testing

Four different resin recipes, plain resin, red ochre and resin, yellow ochre and resin, and dune sand and resin, were also tested mechanically at the Arizona

State University's Mechanical Testing Laboratory in the College of Technology and Innovation. A series of tests were designed and executed. These tests were Rockwell hardness, compression testing, tensile strength, and a simple mechanical test involving pulling hooks from dried resin. The Mechanical Testing Laboratory requires that a trained lab employee run all experiments. The lab analyst then reported back results when they were available.

Resin cubes were used for the hardness and compression testing. Ten cubes were made using plastic molds for each of the four resin groups. There was some difficulty in generating these cubes. The plant resin is largely made of water and shrinks considerably as it dries. It does not, however, shrink in a consistent manner. As the cubes dried fresh resin was added to fill the molds. Once shrinking had stopped and the mold was full, the samples were left to dry for several months. Efforts were made to minimize air pockets within the cubes but they could not be avoided entirely.

A PTC Type A Durometer Model 306L was used for measuring hardness. A Rockwell Hardness reading was taken at twelve locations on each of the ten cubes resulting in 120 hardness readings for each resin group.

For compression testing, force is applied to the resin cube until it cracks (Callister 2003). A Deepak Hydraulics (I) Pvt. Ltd manual 2 Pillar Compression testing machine was used for compression testing. Because the cubes would not dry evenly and had air pockets it was not possible to distinguish the point of failure from cracking heard as voids collapsed. No results were reported from the lab as the analysts did not believe they were reliable.

Testing tensile strength involves pulling the resin from both ends until it breaks (Davis 2004). In order to measure tensile strength a metal mold was machined. Resin samples for each group were set in the mold and allowed to dry for several weeks. A Cometech QC-505A1 Universal Material Testing Machine was used for the attempted tensile strength test. Resin samples would not dry flat and all samples broke at the attachment points when they were put into the machine for testing.

The fourth test involved inserting metal hooks into resin cubes while wet. These cubes were allowed to dry for several months. The experiment design involved testing how much weight or force was required to pull the hooks free from the resin. However, as the resin cubes dried the resin consistently pulled away from the hooks leaving large air pockets around them. The samples were reset three times with the same results before the experiment was abandoned.

Results

Actualistic results

A summary of the results is presented in Table 9.2. After each tool was fired, a damage assessment was made. Tools fell into one of three categories, either the lithic was damaged, the haft failed, or the tool was declared undamaged. If both the haft and the lithic were damaged it was considered a haft failure. For the research question of interest, the failure of the tool along with the haft is inconsequential.

Table 9.2

Summary of crossbow experiment results

		Haft failure	Lithic damage	No damage
Round 1	Group A	1	1	23
	Group B	1	1	23
	Group C	0	0	25
Round 2	Group A	3	15	5
	Group B	3	14	6
	Group C	4	19	2

Group A (tools hafted with plain resin) had one haft failure and one tool failure during round one. All other tools were undamaged and were used in round two. After round two, five tools remained undamaged, fifteen showed lithic damage, and three had haft failures.

Group B (tools hafted with resin and red ochre) also had one haft failure and one tool failure during round one. All other tools were undamaged and were used in round two. After round two, six tools remained undamaged, fourteen showed lithic damage, and three had haft failures.

Group C (tools hafted with resin and dune sand) had no tool or haft failures during round one. All tools were used in round two. After round two, two tools remained undamaged, nineteen showed lithic damage, and four had haft failures.

These data were evaluated using a Fisher's Exact Test. The null hypothesis for the test is that the relative proportions of the outcomes are independent of the treatment. This test uses the hypogeometric distribution to determine the probability of getting the observed data set and more extreme data sets. In this case, the null hypothesis is that the proportions of haft failures, tool failures, and no damage are independent of the resin recipe. If the null is rejected (significance level of 0.05) we can conclude that there is a relationship between the resin recipe and the outcome of haft/tool failures.

For Round 1, firing tools into the ballistics gel, the sum of the probabilities of "unusual" tables is p = 0.691 (Tables 9.3 and 9.4). The null hypothesis is not rejected. The proportions of haft failure, tool failure, and no damage are statistically the same for the three resin recipes.

Table 9.3
Round 1 data contingency table

	Haft failure	Lithic damage	No damage	*Total*
Group A	1	1	23	*25*
Group B	1	1	23	*25*
Group C	0	0	25	*25*
Total	*2*	*2*	*71*	*75*

Table 9.4
Round 1 expected contingency table

	Haft failure	Lithic damage	No damage
Group A	0.667	0.667	23.7
Group B	0.667	0.667	23.7
Group C	0.667	0.667	23.7

For Round 2, firing the undamaged tools into wood, the sum of the probabilities of "unusual" tables is p = 0.564 (Tables 9.5 and 9.6). Again the null hypothesis is not rejected, and the proportions of haft failure, tool failure, and no damage are statistically the same for the three resin recipes.

Table 9.5
Round 2 data contingency table

	Haft failure	Lithic damage	No damage	*Total*
Group A	3	15	5	*23*
Group B	3	14	6	*23*
Group C	4	19	2	*25*
Total	*10*	*48*	*13*	*71*

Table 9.6
Round 2 expected contingency table

	Haft failure	Lithic damage	No damage
Group A	3.24	15.5	4.21
Group B	3.24	15.5	4.21
Group C	3.52	16.9	4.58

Mechanical testing results

The tests were largely unsuccessful due to the nature of the resin. The material will not dry with enough consistency to obtain accurate results. Hardness values were the only successful data collected, and they are presented in Tables 9.7 to 9.10.

Table 9.7
Rockwell hardness values for red ochre resin

Cube	1	2	3	4	5	6	7	8	9	10	11	12	Average
1	92	92.5	94	95	92.5	93	92	92.5	93	95	94.5	92	93.17
2	94.5	93	92.5	95	95	94	92.5	93	95	95	94.5	93.5	93.96
3	95	96.5	95	96	93	97	96.5	95	95.5	94	95	96.5	95.42
4	97	96	93.5	97	96.5	97.5	96	95	95.5	95	96.5	97	96.04
5	96.5	97	95.5	97	95	95	98	95.5	96.5	95	97.5	97	96.29
6	98	97.5	96	96	96.5	98	99	97.5	98.5	97	96	96	97.17
7	97	93	96	96.5	96	97	97.5	96	95.5	95.5	95.5	96	95.96
8	97.5	98	98	96.5	97.5	97	98	98.5	97	98	97.5	97.5	97.58
9	97	97.5	99	98	97.5	97.5	98	98	97.5	96	97.5	98	97.63
10	94.5	94	95	94.5	96	94	97	94.5	96	96	95.5	94	95.08
													95.83

Table 9.8

Rockwell hardness values for yellow ochre resin

Cube	1	2	3	4	5	6	7	8	9	10	11	12	Average
1	88	89.5	88.5	87.5	87	88.5	87.5	88	86	89	86.5	89	87.92
2	93	93.5	93	92.5	94	93.5	93	93.5	94	93	93.5	94	93.38
3	96	99	97	99	98.5	98.5	99	98.5	97	98.5	98.5	99	98.21
4	93	93	93.5	93	93	94	92.5	93	93.5	93	94	93	93.21
5	97	98	96.5	99	100	98.5	97	97	98.5	98	97	98.5	97.92
6	93.5	93	93.5	94	94	93	92	95	93.5	93	94	94.5	93.58
7	90	88.5	88.5	89.5	89	89	88.5	88.5	87	88.5	89	89	88.75
8	87	90	88.5	87.5	90	90	89.5	88	87.5	90	90	89.5	88.96
9	94	95	94	94	96	94.5	94	95.5	95	95	92	95	94.50
10	94.5	94	93.5	94	95	93.5	94	94	96	95.5	94.5	93	94.29
													92.74

Table 9.9

Rockwell hardness values for sand resin

Cube	1	2	3	4	5	6	7	8	9	10	11	12	Average
1	98	98	98.5	98	97.5	97.5	98	99	99	98.5	98	99	98.25
2	97	97	96.5	98	99	98.5	98.5	98	99	97	97	99	97.88
3	96	95	96.5	96	95	95.5	96	96	96	95.5	96	97	95.88
4	97.5	98	98	97.5	95	96.5	96	97	99	98	98	98	97.38
5	97	97	98	97.5	97	96.5	98	98	99	98	97.5	97	97.54
6	98	98	97	97	97.5	96	97.5	97	99	98	98	97	97.50
7	97.5	97	97	97.5	98	96	99	98.5	98.5	98	99	97	97.75
8	96	98	98	97.5	98	97	97	96	98	97	97.5	98	97.33
9	97	97	97.5	98	98.5	98	97	97.5	96	95	98.5	97	97.25
10	99	97	98.5	98	98	97.5	97	98.5	99	97	98	99	98.04
													97.48

Table 9.10
Rockwell hardness values for plain resin

Cube	1	2	3	4	5	6	7	8	9	10	11	12	Average
1	86	86.5	89	90	87.5	87.5	89.5	90	90	87	88	90	88.42
2	88	88.5	88	90	89	89	89	89.5	89	88	90	90	89.00
3	88	91	90.5	88	90	90.5	91	89	89	88	90	90.5	89.63
4	87	85.5	86	89	87	87	85.5	89	88	89	85.5	89	87.29
5	89	88	88.5	88	88	88.5	87	89	90	87.5	87	88	88.21
6	90	91	90	88	89.5	88	87	89	87.5	88	88.5	90	88.88
7	91	90	90	88.5	89	89	87	88	89.5	87.5	88	89	88.88
8	90	88	87.5	91	91	89	89.5	89.5	88	89	89	88.5	89.17
9	88	88	89	88	87.5	88.5	88	88	89	88	87.5	89	88.21
10	89	90	90	90	89.5	89.5	87	88	89	89	90	90	89.25
													88.69

The plain resin had the lowest average Rockwell Hardness value followed by the yellow ochre resin, the red ochre resin and the sand resin. These data do not meet the assumptions of single factor ANOVA or a Kruskal-Wallis test as the variances are unequal. A series of t-tests assuming unequal variance were performed for each possible pairing of resins. The differences between the means are statistically significant. All p-values were extremely small. The lab analyst voiced some concern, however, about the accuracy of the results. It is possible that the uneven drying and air pockets in the resin are affecting the hardness readings.

Wadley *et al.*(2009) argued that harder resins seemed more likely to fail. If this is the case, the plain resin would actually be a better choice. This requires more testing but if this observation holds it may suggest a less than functional reason for adding red ochre to plant resin for hafting.

Conclusion

The actualistic experiments suggest that there is no difference between the functionality of tools hafted with plain resin, red ochre resin, or sand resin. In fact, the results suggest that failure of the haft may not be of primary concern as the tool is more likely to fail first. If tools were also bound with sinew after hafting the resin recipe may be even less of a concern. This suggests that adding red ochre to resin may be unnecessary from a strictly functional point of view at least for the type of tool tested. More tool types and resin recipes need to be tested but these data suggest that a utilitarian interpretation of ochre hafting is too simplistic.

The mechanical testing results were inconclusive largely due to lack of data. The materials testing machines are designed for use mainly with synthesized materials that are extremely homogeneous. Plant resin, unfortunately, is extremely heterogenous. This made setting the resin into the shapes necessary for testing difficult to impossible. The resin shrinks considerably while drying leaving air pockets and uneven surfaces. Although the material adhered well to the stone and wood used for the actualistic experiments, it pulled away from the metal and plastic molds and the metal hooks as it dried.

A follow-up experiment is planned that will build off the success of the actualistic experiments while incorporating more rigorous variable control that mechanical testing can provide. Small standardized stone blocks will be cut with a rock saw. These will be inserted into notches cut into wooden planks using a measured amount of resin mixture with different ochre and non-ochre additives. These will then be allowed to dry. Hopefully the resin mixtures will adhere well to the stone and wood as it did in the actualistic experiments. The amount of pressure needed to cause the resin to fail will then be tested by hanging weight from the stone inserts. This experiment is designed to circumvent the observation that stone tools tend to break on impact before the resin haft can fail.

CHAPTER 10 – OCHRE AND THE LARGER CONTEXT

Introduction

This study has presented multiple aspects of the ochre record in the MSA archaeological sites at PP, South Africa. Ochre from PP13B and PP5-6 has now been fully described. Based on comparison with ochre available in the TMS, it is clear that the majority of the material recovered from these sites has originated from elsewhere. Use wear modification has been detected on a large proportion of the assemblages; forty-eight percent of the PP13B collection has definite modification and twenty-four percent of the PP5-6 collection has definite modification. It is clear from this descriptive groundwork that ochre is being brought to these sites and utilized, possibly in a variety of tasks.

The research question, hypotheses, and test implications

Within these MSA sites, was ochre used as a pigment for symbolic activities or was it used for more utilitarian activities? Symbolism or artistic expression and a utilitarian use in hafting were specifically investigated using a series of test implications.

Test implication 1a involved ochre exploitation strategies. Based on the fact that ethnographic peoples around the world have highly ritualized ochre exploitation strategies, it was argued that an exploitation strategy focusing primarily on distant sources rather than closer sources or a pattern focused on a few deposits when many are available may be suggestive of some symbolic meaning.

Survey and sourcing attempts were carried out to address this test implication. A total of 22 ochre sources were identified; the majority within 30km of PP. This resulted in mineralogical and elemental dataset of 260 ochre samples. This is the first large scale ochre survey reported for southern Africa and is also the largest ochre characterization dataset available. Twenty-two ochre samples from PP13B and 40 ochre samples from PP5-6 were subjected to the same characterization techniques (XRD and PIXE) as the geological dataset. These data were used to match archaeological samples to the most likely geological source on the landscape. Sixteen samples from PP13B and thirty-one from PP5-6 had similar mineralogy and elemental concentrations suggesting they derived from the same source. More work will need to be done to solidify these conclusions given the high level of variability in the geological dataset, but it does appears there is a long term preference (> 100,000 years) for ochre from the Rooikoppie locality.

A least cost path analysis based on slope generated from SRTM DEM data generates a walking path distance of 20km from PP to Rooikoppie (Fig. 10.1). The straight line distance is 19km. Given an average human walking speed of 5km an hour this is an 8 hour round trip. Marlowe (2005) gives maximum daily foraging ranges of 9.5 to 14.1km for ethnographically known foragers and a yearly home range median of 175 square km. Marlowe (2005) also notes a decrease in mobility were aquatic resources make up a large part of the diet as it does in most periods at PP. Little is known about the yearly ranges or patterns of mobility in this region during the MSA. Our excavated sample is focused on coastal caves and rockshelters with large deposits. There remains the possibility that ochre is being collected prior to moving camp to PP but given the amounts seen in the sites this seems unlikely. Specific ochre collecting trips may have been taking place. These trips could have been paired with collection of other raw materials such as silcrete, and future SACP4 sourcing work will address this.

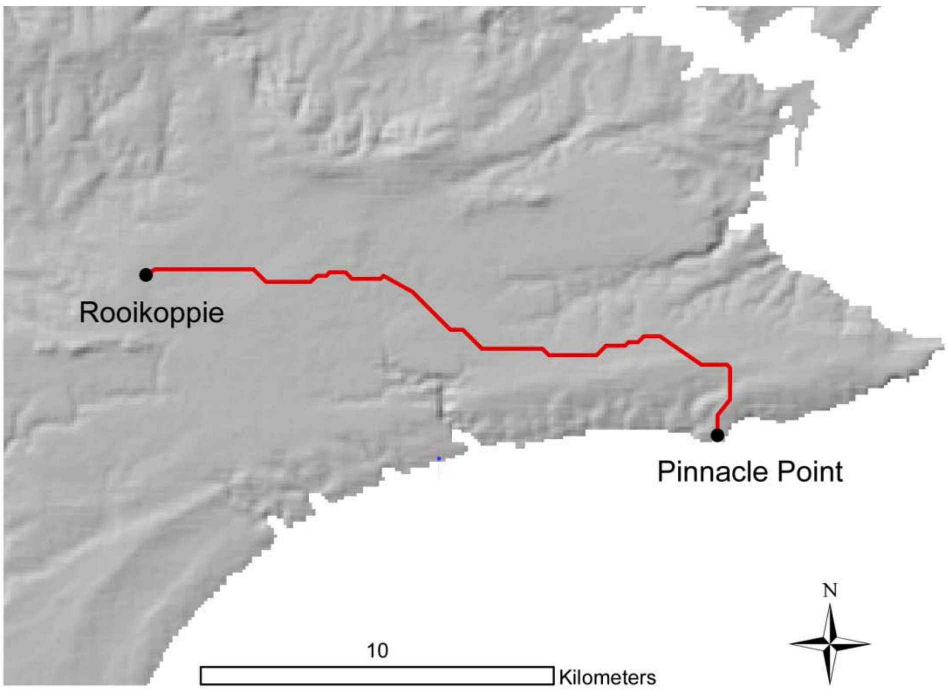

Fig. 10.1. Least cost walking path from PP to the Rooikoppie ochre source

There are ochreous Bokkeveld outcrops within 5 km of PP where high quality material can be obtained, and the proposed walking path would pass quite close to these deposits. In fact, Watts initially identified these nearby deposits as the most likely source of the PP ochre (Watts 2010). It now appears that this material was largely passed up in order to more exclusively exploit the Rooikoppie material. Should these conclusions hold up to further characterization and sourcing analyses, it is powerful evidence for symbolic behavior.

Test implication 1b dealt with the color distributions of ochre in archaeological sites. Many colors of ochre are available on the landscape and color should not necessarily dictate the usefulness of material for utilitarian purposes. It was argued that a restricted color representation in the PP sites as compared to the distribution of ochre colors on the landscape would be a strong indication of symbolic behavior.

Color data were collected for the archaeological and the geological collections using a photographic method and using a colorimeter. With both techniques, a color preference was identified at PP13B and at PP5-6. Graphs of the color distributions and comparisons of Pearson's r values showed that while the geological material ranges from red to yellow there is a tendency towards redder material in the archaeological sites. These color preferences in the archaeological record may suggest ochre collection that is not consistent with strictly utilitarian uses. It is also possible that yellow material is being removed from the archaeological assemblages due to intentional or unintentional heating.

Test implication 1c dealt with the potential heat treatment of ochre in the PP sites. There is no evidence yet to suggest that red ochre is more functional than yellow for the utilitarian tasks that have been presented in the literature, or that heated ochre is somehow more functional for the utilitarian tasks. Therefore, it was argued that evidence of deliberate ochre heat treatment in MSA sites would lend strong support to symbolic and artistic interpretations of use.

Experimental heat treatment was carried out on all geological samples collected during survey. These experiments confirmed that it is possible to identify a heated signature from the XRD pattern.

All archaeological samples that were taken for sourcing analyses were also investigated for evidence of heat treatment. Thirteen samples from PP13B and seventeen samples from PP5-6 had definite to possible heated XRD signatures. The depositional context of these samples was used to determine if heating could have taken place accidentally after the ochre was discarded. Unfortunately, the majority of the heated pieces do come from sediments with high MS values suggestive of some exposure to heat. The results are currently inconclusive. Material has been heated but post-depositional heating cannot be ruled out. Further study will require testing of more archaeological samples chosen specifically for their lack of association with heated units. Ongoing micromorphology studies should also be helpful in determining which units are intact burning features and which units have high MS values resulting from the mixing of relocated burnt sediment and ash.

Test implication 2 was directed at the second hypothesis that ochre was used in utilitarian tasks, namely for hafting of stone tools. In order for a strictly utilitarian interpretation to hold up, it must be possible to demonstrate a functional advantage to adding red ochre to mastic when hafting MSA stone tools. It is important that the geological ochre that is identified as occurring in the MSA sites is used in experimentation as ochre is so variable. It may be that some ochre has a functional advantage but this is only significant if that specific ochre is recovered archaeologically.

A series of actualistic experiments were carried out to test the usefulness of red ochre in resin hafting. Three sets of tools were hafted using plain resin, red ochre resin, and dune sand resin. All tools were fired at two substances, a ballistics gel block and a wooden block, using controlled force. For both experiments there was no statistically significant difference between the three groups of tools in terms of resin performance. In fact, it was far more likely for the stone tool to break before the haft failed. This suggests that the inclusion of red ochre from Rooikoppie does not provide a functional advantage over no additive or a sand additive.

A series of mechanical tests were also devised for plain resin, red ochre resin, yellow ochre resin, and sand resin. These tests were largely unsuccessful due to unforeseen problems with setting natural resin samples. Future experiments will hopefully address these issues and allow for testing with as few variables as possible. These tests will incorporate various colors of ochre as well as heated verses unheated material. Based on the initial experiments, however, a strictly utilitarian explanation for the presence of ochre at PP does not seem likely.

One other test implication for the utilitarian hafting hypothesis, the patterning of ochre residues on stone tools, was not studied here. Select units have been carefully excavated at PP5-6 with residue analysis in mind. This material awaits analysis and will be crucial in further unraveling the implications of the hafting hypothesis at PP. If no functional advantage can be demonstrated for ochre in hafts but ochre residues are evident as at Sibudu Cave and Rose Cottage Cave there must be some other explanation. The most parsimonious choice would be some symbolic meaning attached to the color red.

Ochre in context

Research from the larger SACP4 project provides a rich environmental and behavioral backdrop for ochre use at PP. Work is ongoing that will continue to contribute insight to the role ochre played in the larger MSA context. It is possible to investigate the ochre record overtime at PP and discuss how trends in ochre occurrence and use relate to other factors such as climatic fluctuations, sea level changes, and lithic raw material usage (Fig. 10.2).

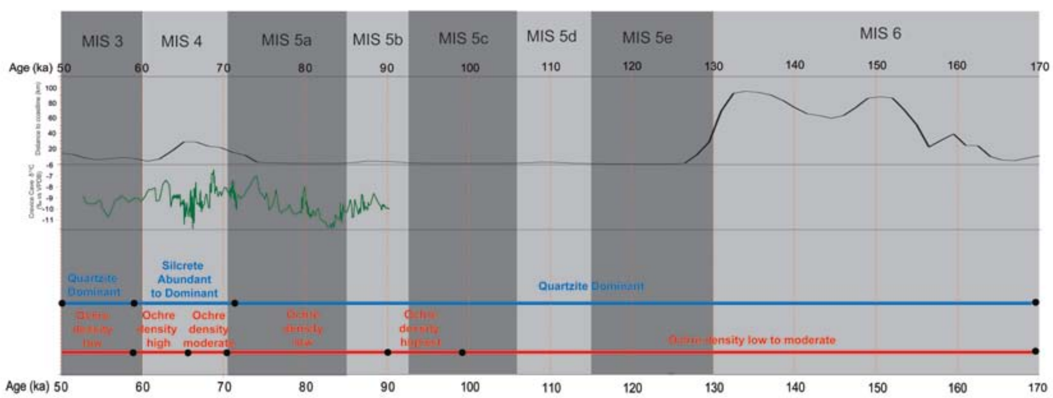

Fig. 10.2. Comparison of ochre usage at PP to other SACP4 datasets (Isotope curve Bar-Matthews *et al*. 2010; Sea level curve Fisher *et al*. 2010)

MIS 6 (~190 ka to 130 ka)

The early part of MIS 6 is represented at PP13B by the LC-MSA Lower deposits and the DB Sand 4 deposits. MIS 6 is thought to be a period of relative climatic instability. There are fluctuations but the period is largely glacial. Africa is expected to be cooler and drier during this period (Marean 2010). There is a hypothesized C4 grassland expansion replacing local fynbos habitats during the lowered glacial sea levels. However, paleoecological reconstructions may suggest a mosaic or ecotone habitat and imply that resources may have been somewhat unpredictable (Rector and Reed 2010). The early systematic exploitation of shellfish around 164 ka has been proposed as a possible response to difficult environmental conditions (Marean *et al.* 2007; Marean 2010).

The lithic assemblages for this time period are similar to those recovered from other MSA sites prior to the Still Bay. They are dominated by locally available quartzite and retouch is rare. The PP13B assemblage as a whole lacks any evidence for temporal change (Marean 2010; Thompson *et al*. 2010).

The LC-MSA Lower has a moderate level of occupation based on artifact densities and average MS values. The coastline is projected to be within 5 to 6 km of the cave (Marean 2010; Fisher *et al.* 2010). These deposits contain the earliest securely dated ochre in southern Africa. The calculated ochre density is approximately 230g/m^3. Thirty-seven percent of the LC-MSA ochre assemblage by mass has definitely been modified.

The DB Sand 4 deposits have a low occupation intensity and a projected coastline further than 10 km from the cave (Marean 2010; Fisher *et al.* 2010). This is supported by the low shellfish densities in these layers (Jerardino and Marean 2010). The calculated ochre density for the DB Sand 4b is approximately 15g/m^3 and for the DB Sand 4c is approximately 139g/m^3. The DB Sand 4b has only two pieces of ochre and one is definitely modified. The DB Sand 4c has no modification on six fragments of ochre.

MIS 5e (~130 ka to 115 ka)

MIS 5e is represented by the LC-MSA Middle (transitional MIS 6 to MIS 5e) and Upper and the first occupation within the LBG Sand. Occupation intensity is moderate to low perhaps due to relative inaccessibility of the cave during the rapid rise in sea level to +5 msl (Marean 2010). The LC-MSA Middle ochre density is approximately 8 g/m^3, the Upper is about 9 g/m^3, and the LBG Sand is approximately 120 g/m^3, although this includes both occupations.

MIS 5d (~115 ka to 106 ka)

The Lower Roofspall and the second occupation of the LBG Sand fall within MIS 5d. Occupation for the LBG Sand is thought to be low but the Lower Roofspall has the highest estimated occupation levels based on artifact densities and average MS values for the entire excavated deposit, and the coastline is projected to within 1 km of the site (Marean 2010; Fisher *et al.* 2010). Ochre density (~80 g/m^3) for the Lower Roofspall, however, is low compared to other aggregates with high to moderate levels of occupational intensity. Less than 2% of the ochre by mass shows evidence of modification.

MIS 5c (~106 ka to 93 ka)

MIS 5c is represented by the Upper Roofspall/Shelly Brown Sand deposits in the eastern excavation area of PP13B. The occupation in these layers is dense and the coastline is 1 to 2 km from the cave (Marean 2010; Fisher *et al.* 2010).

The ochre density, however, is moderate to low with 421 g/m^3 for the Upper Roofspall and 38 g/m^3 for the Shelly Brown Sand. Sample sizes were low, but ecological reconstructions for these layers suggest a habitat that is more open and drier than other periods of occupation (Rector and Reed 2010).

The DB Sand 2 and 3 and the LB Sand 1 and 2 layers were deposited near the transition of MIS 5c and 5b. These layers may sample a transitional period from warmer to cooler climate (Rector and Reed 2010). Occupation intensity is moderate and the coastline is projected to be within 2 to 3 km from the cave (Marean 2010; Fisher *et al.* 2010). Ochre density is highest in the DB Sand 2 and 3 aggregates. The DB Sand 2 has a density of approximately 2267 g/m^3 and the DB Sand 3 has a density of 939 g/m^3. For the DB Sand 2, 69% of the ochre by mass is definitely modified. For the DB Sand 3, 43% is definitely modified. Densities are far lower in LB Sand 1 (244 g/m^3) but 55% by mass is definitely modified. In the LB Sand 2 the ochre density is even lower at 33 g/m^3 and there is no modification.

MIS 5b(~93 ka to 85 ka)

Starting at approximately 90 ka, cave PP13B is sealed by dune deposits and no longer available for occupation (Marean 2010; Bar-Matthews *et al.* 2010). The archaeological sequence for the region continues at PP5-6. MIS 5b is represented by the LBSR deposits. The sea level model puts the average coastline within 5km of PP (Fisher *et al.* 2010), and isotope data from the Crevice Cave speleothem record suggest a C3 grass dominant ecosystem with increased winter rainfall. This has been interpreted as a fynbos ecosystem similar to that in the area today (Bar-Matthews *et al.* 2010). Shellfish are common in these layers and rocky intertidal species of mussels and limpets appear to dominate (shellfish analysis is currently ongoing). The lithic assemblage is dominated by local grey quartzite with only a small percentage of silcrete. Ochre was recovered but density is fairly low, approximately 62g/m^3. Only about 13% of the ochre by mass is definitely modified.

MIS 5a (~85 ka to 74 or 71 ka)

MIS 5a is represented by the ALBS. The speleothem record indicates a continued dominance of C3 grasses and winter rainfall until about 75ka when there is a shift to cooler conditions with more C4 grasses and increased summer rainfall (Bar-Matthews *et al.* 2010). During MIS 5a, the sea level remains close to the site until about 75 ka when it begins to retreat. Artifact densities are moderate for these levels but do include shellfish. The lithic assemblage is transitional in nature with silcrete increasing in frequency to about 20% (by count). Ochre density is low at 95g/m^3 and about 43% of the ochre by mass is definitely modified.

MIS 4 (~74 ka or 71 ka to 60 ka)

MIS 4 is represented by the SADBS, the OBS1, the SGS, and the DBCS. It is a period of extreme climatic fluctuation. The ratio of C3 to C4 grasses and the pattern of winter verses summer rainfall regularly changes with the period between 73 ka and 65 ka being particularly variable. Following this period, C4 grasses dominate until about 60 ka (Bar-Matthews *et al.* 2010). These changes would have caused a shifting and at times unpredictable resource base. During MIS 4 we see several distinct changes in the archaeology suggesting a more complex behavioral package perhaps in response to this instability.

The SADBS (~70 ka) has dense occupation with high frequencies of plotted finds and a unique microlithic technology. Silcrete is the dominant raw material and makes up approximately 80% of the assemblage and gloss analysis demonstrated that this material was routinely heat treated (Brown *et al.* 2009). Shellfish remains were recovered suggesting the coastline is within 8km of the site. Ochre density is fairly low at 226 g/m^3 and only 11% of the ochre by mass is definitely modified.

The OBS1 (~66 ka) dune accumulated rapidly. The dune is largely sterile but does have occasional thin lenses of occupation. Silcrete makes up approximately 23% of the lithic collection, and ochre density is low at 125 g/m^3. Less than 3% of the ochre by mass is definitely modified.

Occupation intensity increases with the overlying SGS. Shellfish is abundant suggesting a nearby coastline. Silcrete usage climbs to about 55% of the lithics collection. Ochre density increases significantly to 724 g/m^3. Fifty-eight percent of the ochre by mass is definitely modified.

The DBCS (~58 ka to 65 ka) deposits include a Howieson’s Poort occupation. The isotope record suggests the beginning of this period is climatically unstable and is followed by a period dominated by summer rain and

C4 grasses (Bar-Matthews *et al.* 2010). This aggregate is quite dense with archaeological material but lacks shellfish. Silcrete is again dominant making up 71% of the lithic assemblage and gloss analysis demonstrated that the majority of this material has been heat treated (Brown *et al.* 2009). Ochre density is highest in this aggregate at 1755 g/m^3. Only about 5% of the assemblage by mass is definitely modified. However, the DBCS ochre assemblage is extremely fragmented and many of the pieces were too small to positively identify evidence of use. Also, ochre powder was recovered throughout the aggregate. These two facts may suggest that ochre modification in the DBCS is actually much higher than other aggregates. Ochre fragments are being used to exhaustion and all that remains are smaller pieces and powder. Even though much of the finds are small, the DBCS has the largest cumulative mass of ochre recovered in any aggregate at PP5-6.

Discussion

This study of ochre spanning a period of over 100,000 years has begun to answer questions about the significance of ochre in the MSA. There are clear periods of time where ochre use intensifies. There is an earlier intensification at PP13B in the DB Sand 2 and DB Sand 3 deposits during the MIS 5c to 5b transition and a later intensification at PP5-6 in the DBCS deposits during the more recent portion of MIS 4. The cumulative masses of ochre and the densities in these aggregates are the highest identified in the PP sequence. Also, ochre in both periods is interpreted as heavily utilized. In the DB Sand deposits, a large percentage of the pieces had clear evidence of modification. In the DBCS, clear evidence of grinding and scraping was more restricted but the extreme fragmentation of the assemblage coupled with the presence of powder suggests intense processing. These time periods are both reconstructed as climatically and environmentally unstable.

There are two plausible explanations for increased ochre use linked to changing environmental conditions. First, there may be a rapid technological change in response to uncertain conditions that involves the use of ochre in some functional application such as in hafting. Alternatively, stresses from an unpredictable resource base and/or population pressure related to climate change and restricting habitat could be leading to increased investment in symbolic or ritual behaviors linked to ochre. The lithic record at PP13B has been shown to be remarkably static even compared to other MSA assemblages of similar age (Thompson *et al.* 2010). There is no technological shift documented during the DB Sand that would explain the sudden increase in ochre use.

The DBCS, however, does have a technological shift with the Howieson's Poort characterized by its focus on heat treated silcrete and small backed blade segments. The increase in ochre use in this case could be argued to be part of this technological shift. It could also be argued that because silcrete and ochre often co-occur on the landscape, an increase in ochre collection is simply a function of increased silcrete collection. While searching for silcrete, MSA people have increased exposure to ochre deposits.

Research presented here has shown both these explanations for the DBCS are lacking. First, the incorporation of the type of ochre recovered from the DBCS does not improve the performance of hafts. Secondly, the earlier SADBS also has a lithic industry dominated by bladelet products made from heat treated silcrete but does not have a similar increase in ochre use. These blade products would have been hafted as part of composite tools and we might expect to see an increase in ochre as a hafting agent. SADBS inhabitants must have also been in regular contact with ochre sources as they collected silcrete, yet they do not transport large quantities back to PP5-6. Lastly, sourcing results suggest that all but one of the DBCS sampled ochre pieces originates from the Rooikoppie source. Silcrete was not found in direct association with ochre at Rooikoppie as it is at several other localities. Poor quality silcrete outcrops approximately 200m north of the Rooikoppie hill. Higher quality material can be found about a kilometer away.

Based on these considerations, an interpretation invoking increasing symbolic behavior or ritual involving ochre may be the most parsimonious explanation for both the DB Sand and the DBCS ochre intensifications. This conclusion is further supported by the preferential source exploitation and dominance of the color red at both sites demonstrated in this study.

Watt's, among others, has presented the "Female Cosmetics Coalitions" (FCC) model as an explanation for early ochre use (Knight *et al.* 1995; Power and Aiello 1997; Power 1999; Watts 2002; 2009). This theory posits the use of red pigments to falsely signal menstruation and upcoming fertility. The practice is intended to allow females to attract and/or retain potential mates. This theory is based heavily on Khoisan female menarcheal initiation rituals where red pigments figure prominently. Several archaeological predictions accompany this theory. First, the earliest identified pigments should be red. Second, pigment use cannot predate the mid-Middle Pleistocene increase in encephalization. Third, in the time frame following encephalization (500 ka to 150 ka) red pigment use should go from sporadic to regular. Lastly, blood-red pigments will be procured even if this requires incurring heavy costs (Watts 2009).

Watt's has argued that the PP13B and the MSA record in general meet the predictions of the FCC model. The data presented here do support the conclusion that these predictions are met at PP. However, other types of rituals such as the ethnographically well-documented use of red pigment in hunting ritual and in male initiation ritual would all have similar archaeological predictions. Trying to project a specific type of ritual into the MSA is well beyond the current scope of the archaeological method and theory. The strongest conclusion that can be drawn is that ochre use in the MSA seems to have surpassed pure function. There is some significance attached to ochre and the color red and this may be evidence for the beginnings of habitual collective ritual.

Conclusion

Of the two overarching hypotheses for MSA ochre occurrences, symbolic behavior or utilitarian use, the PP record and the data presented here lend far more support to symbolic or even ritualistic overtones. Similar focused studies need to be carried out at other sites to determine the robusticity of this conclusion. Further work with the PP ochre will also be beneficial. In particular more work needs to be done on characterization and sourcing to better demonstrate the preferential exploitation pattern proposed here and on identifying ways to separate unintentional from intentional heat treatment of ochre. A detailed hide working experimental study is warranted as well as further experimentation with ochre in hafting. Lastly, residue analysis will be crucial in better understanding what other artifacts ochre may have been used in conjunction with.

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APPENDIX A

GEOLOGICAL SAMPLES XRD PATTERNS

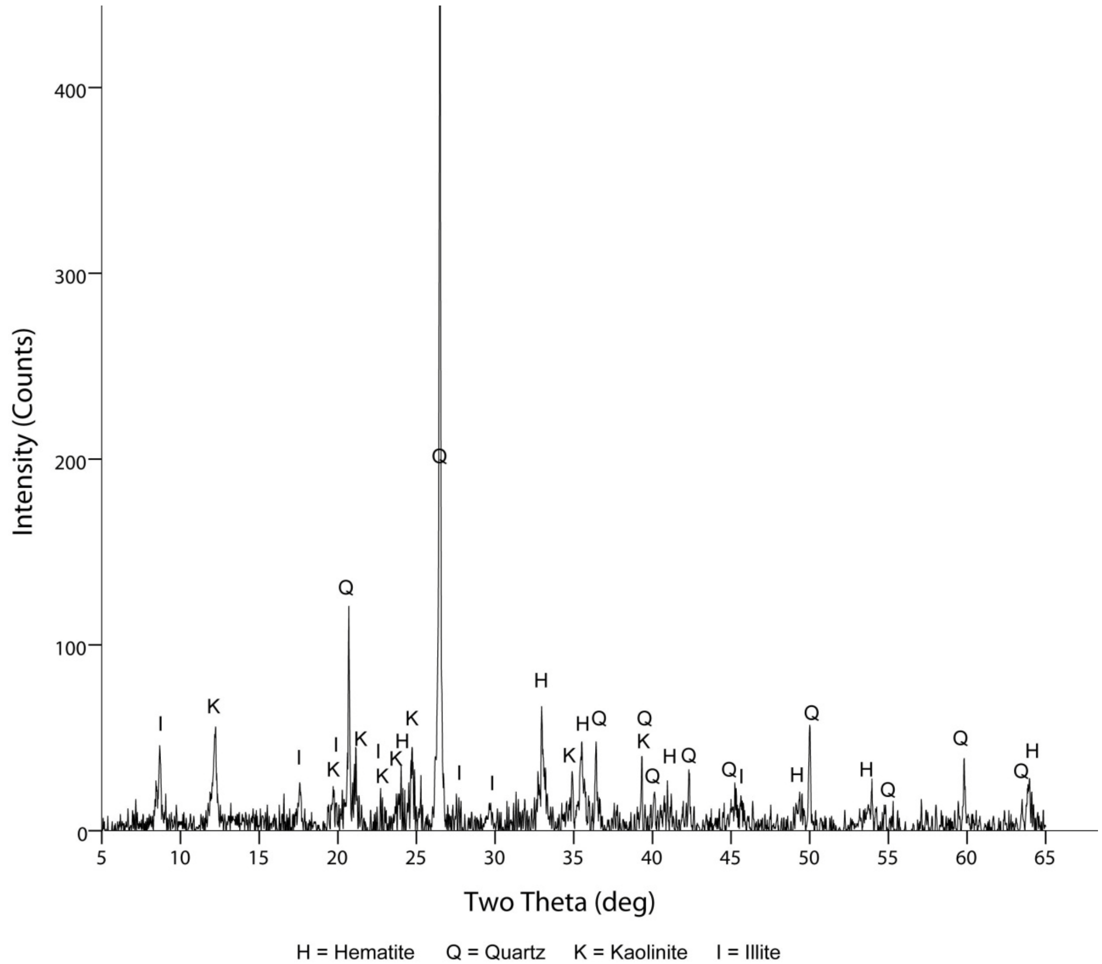


Fig. A.1. G47 Albertinia B red

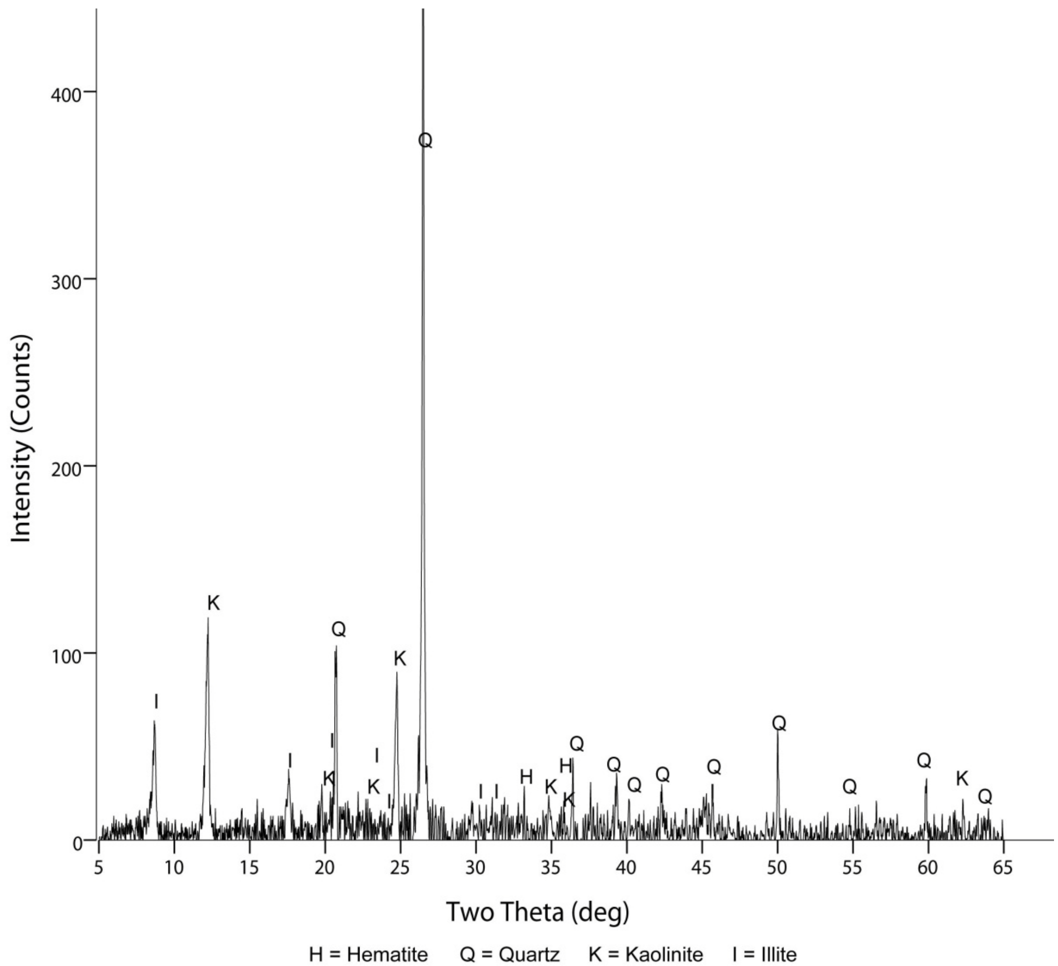
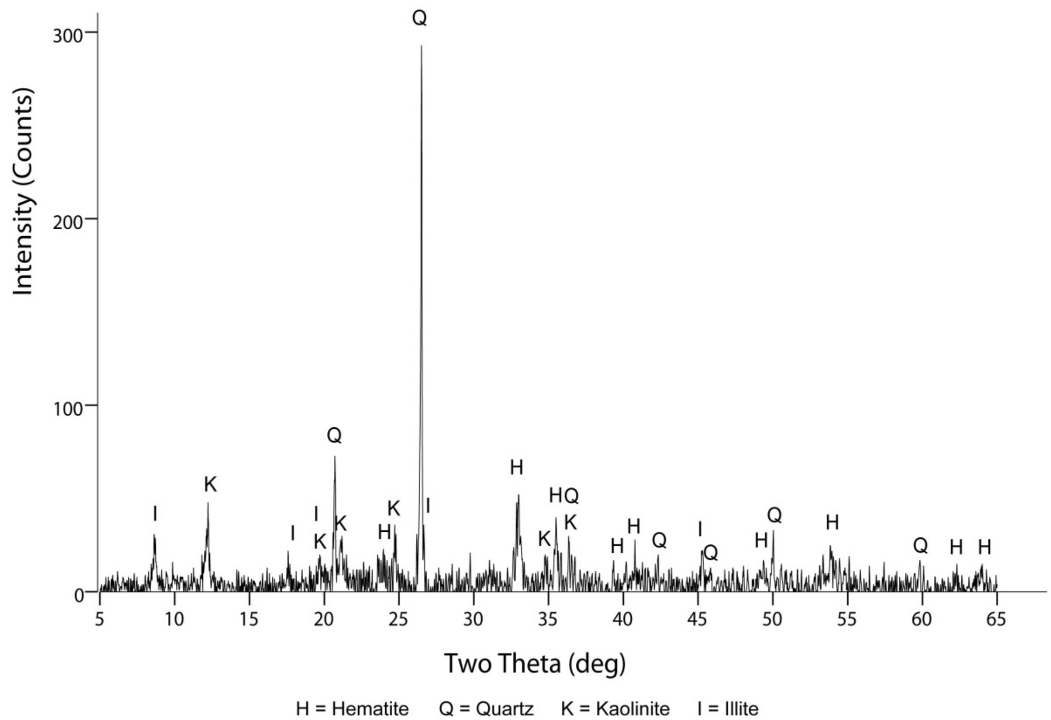


Fig. A.2. G48 Albertinia B red



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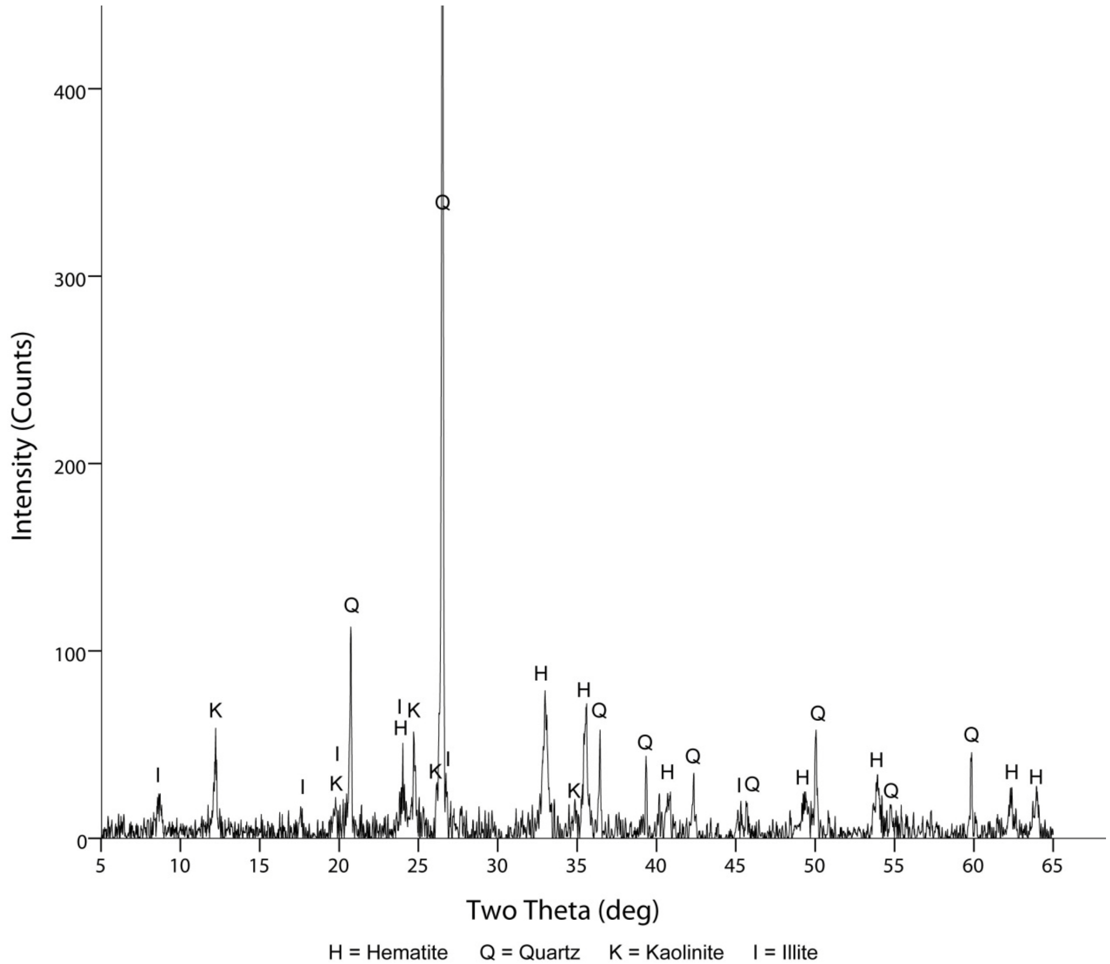

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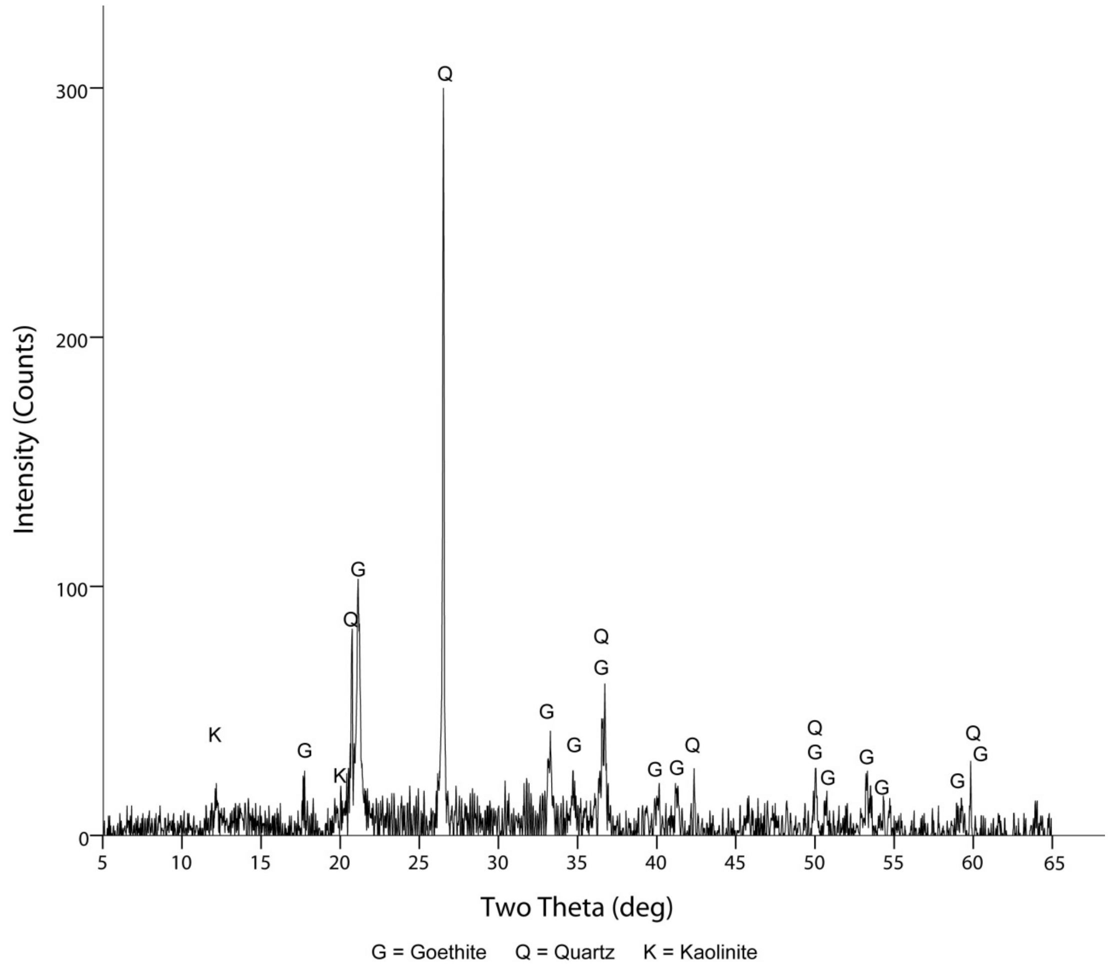


Fig. A.5. G46 Albertinia B yellow

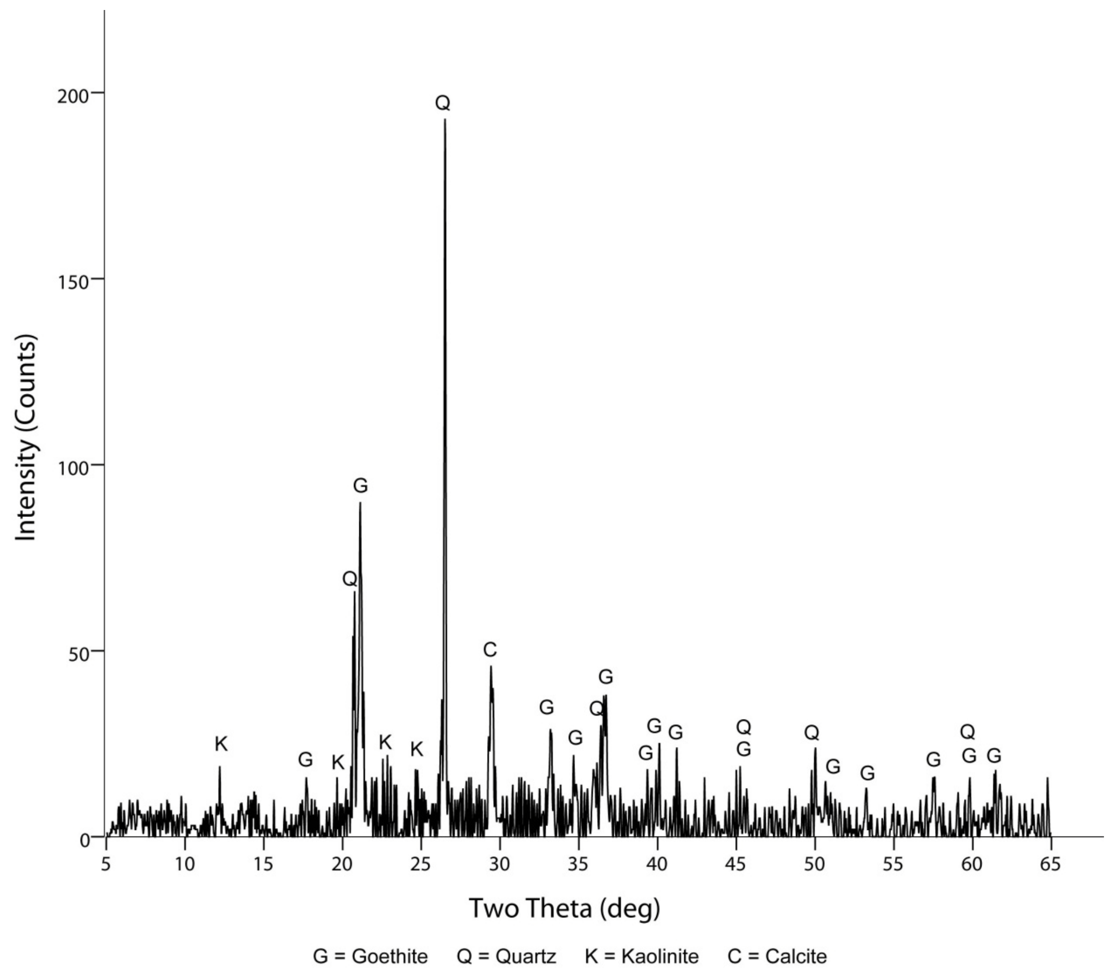


Fig. A.6. G50 Albertinia B yellow

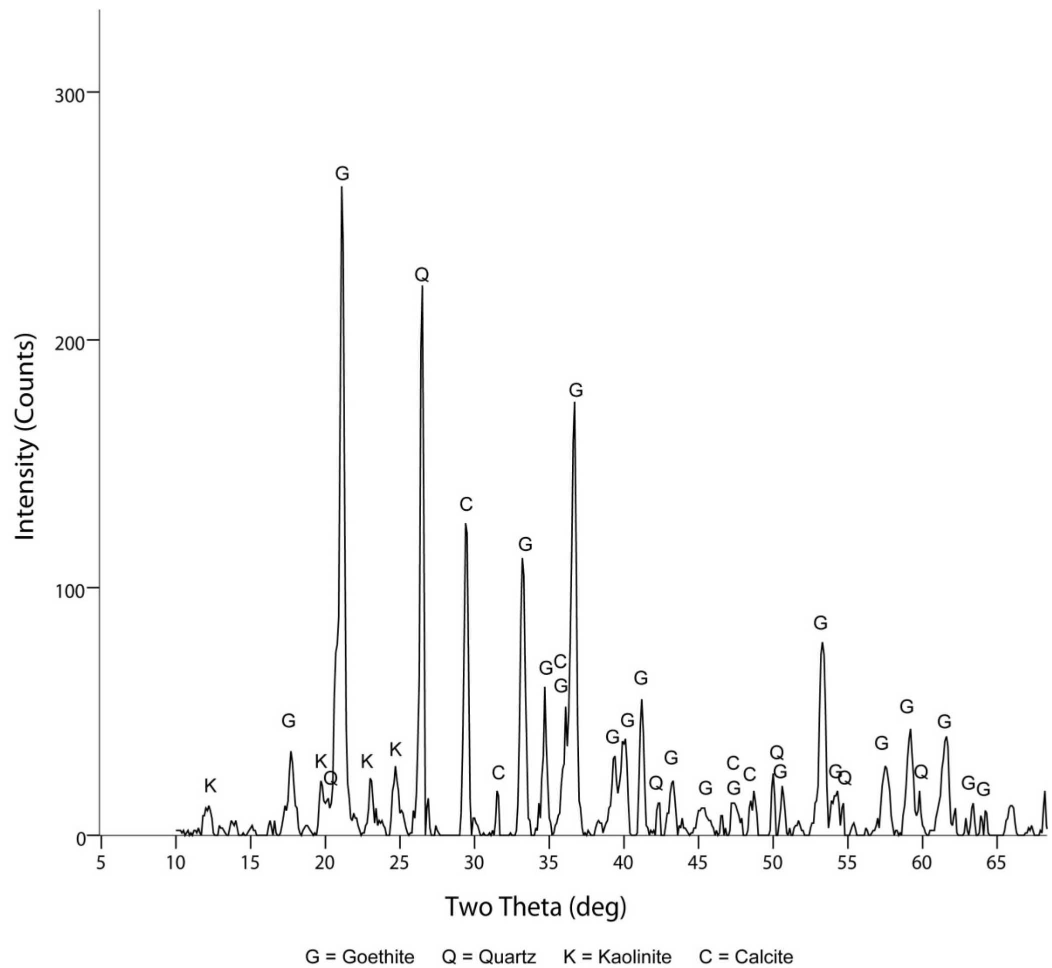


Fig. A.7. G51 Albertinia B yellow

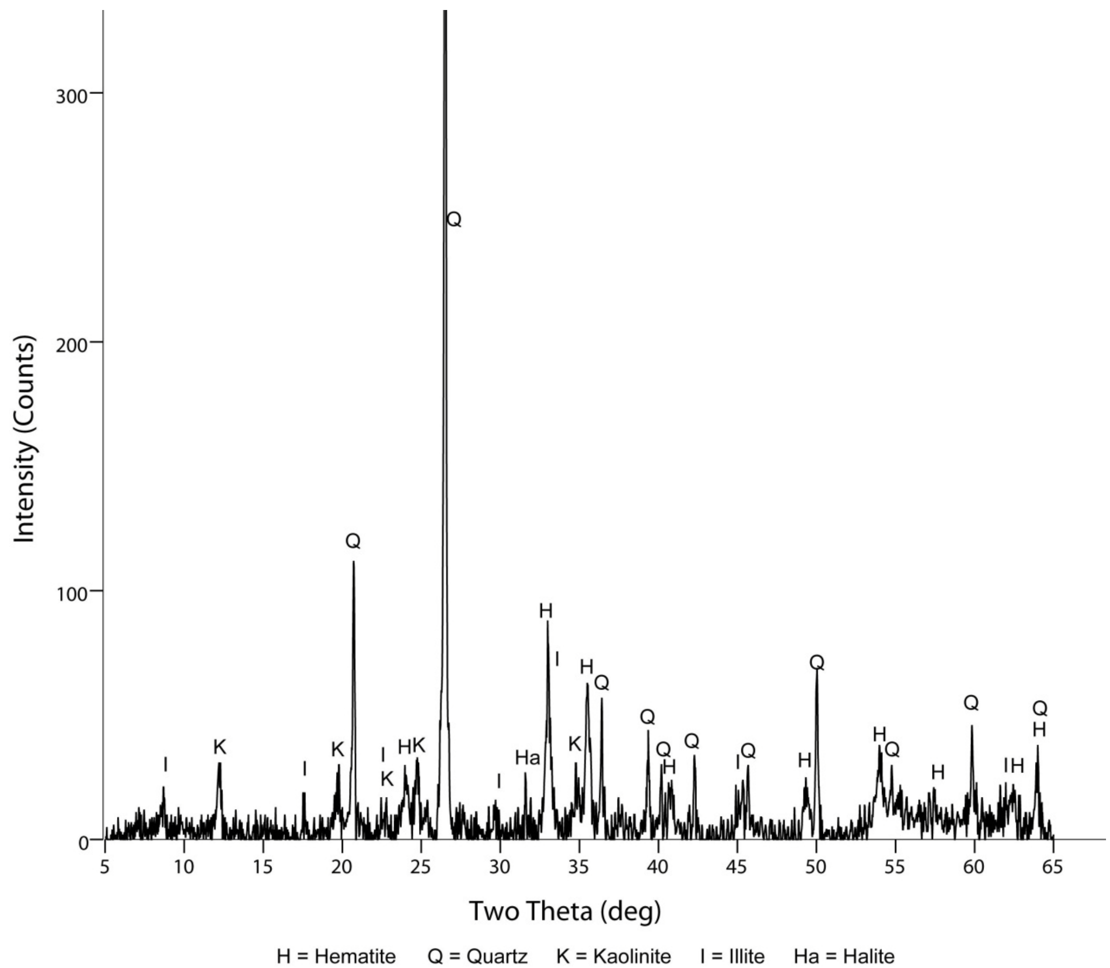


Fig. A.8. G2 Albertinia B red heated

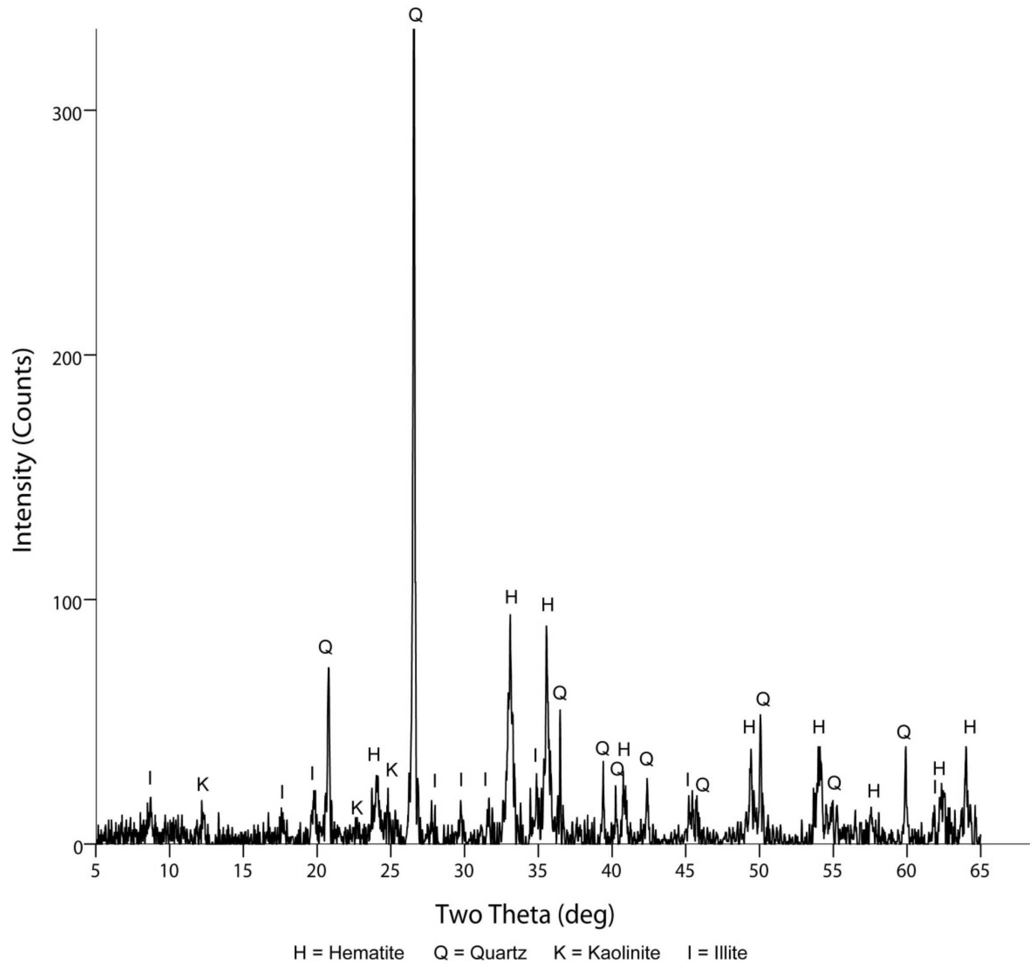


Fig. A.9. G3 Albertinia B red heated

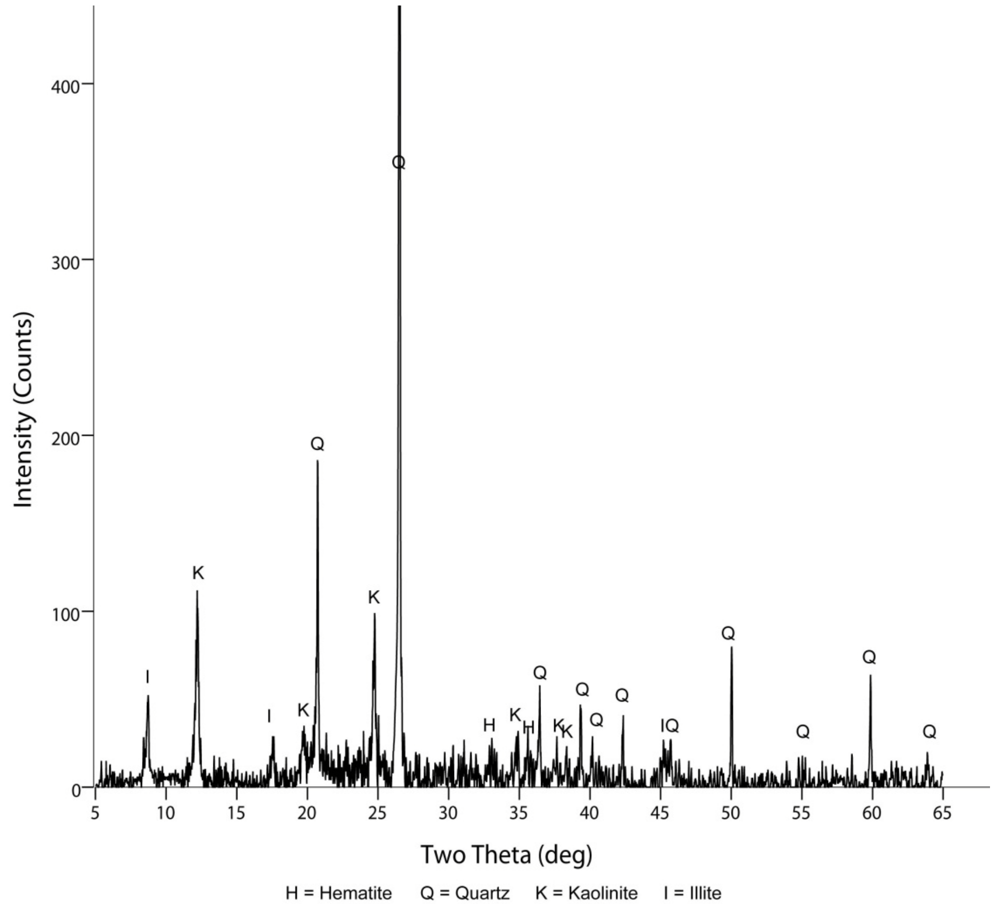


Fig. A.10. G5 Albertinia red heated

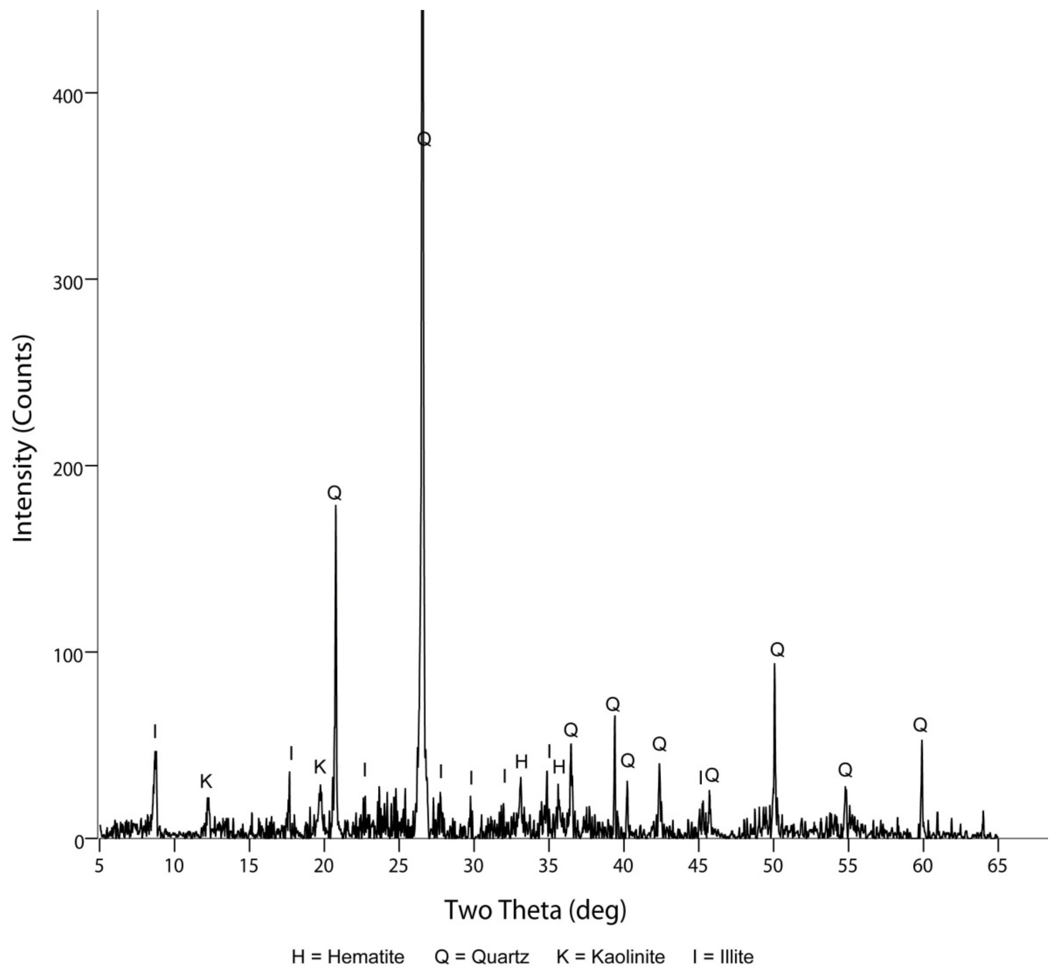


Fig. A.11. G192 Albertinia B red heated

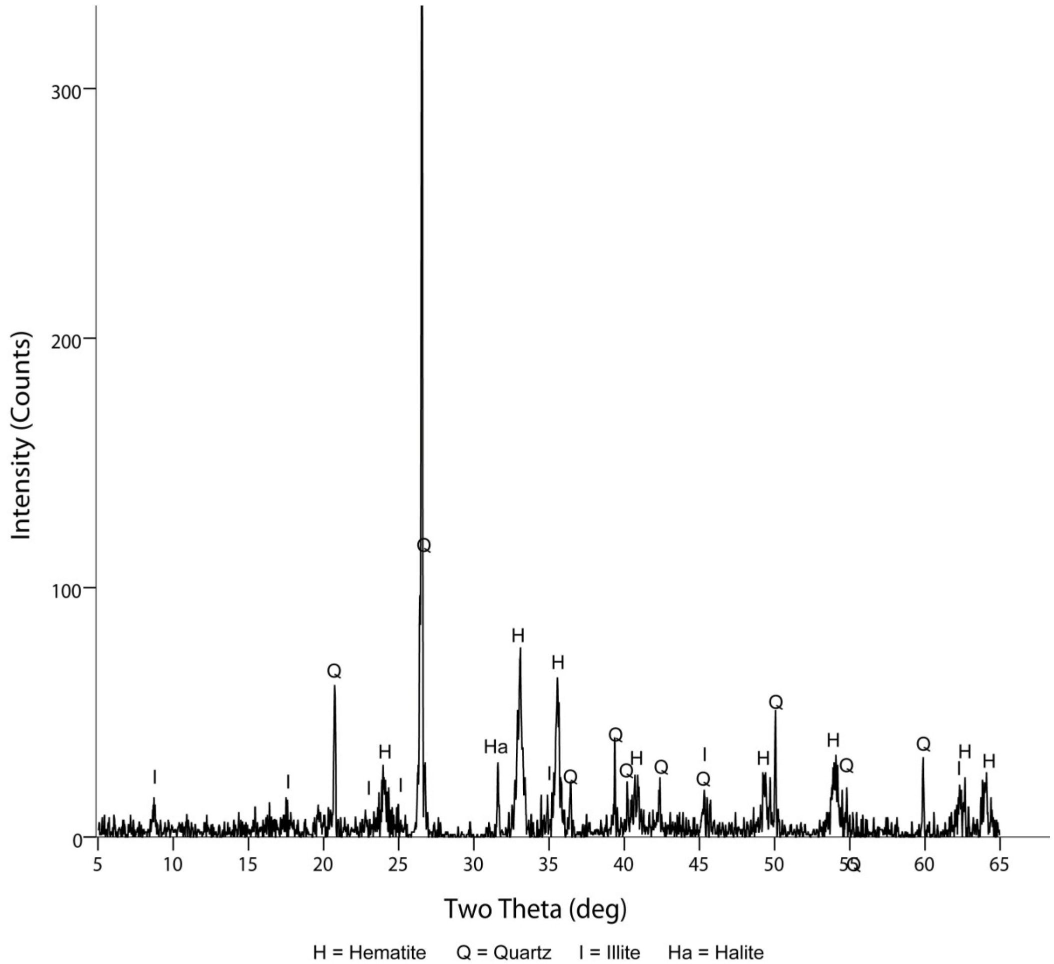


Fig. A.12. G193 Albertinia B red heated

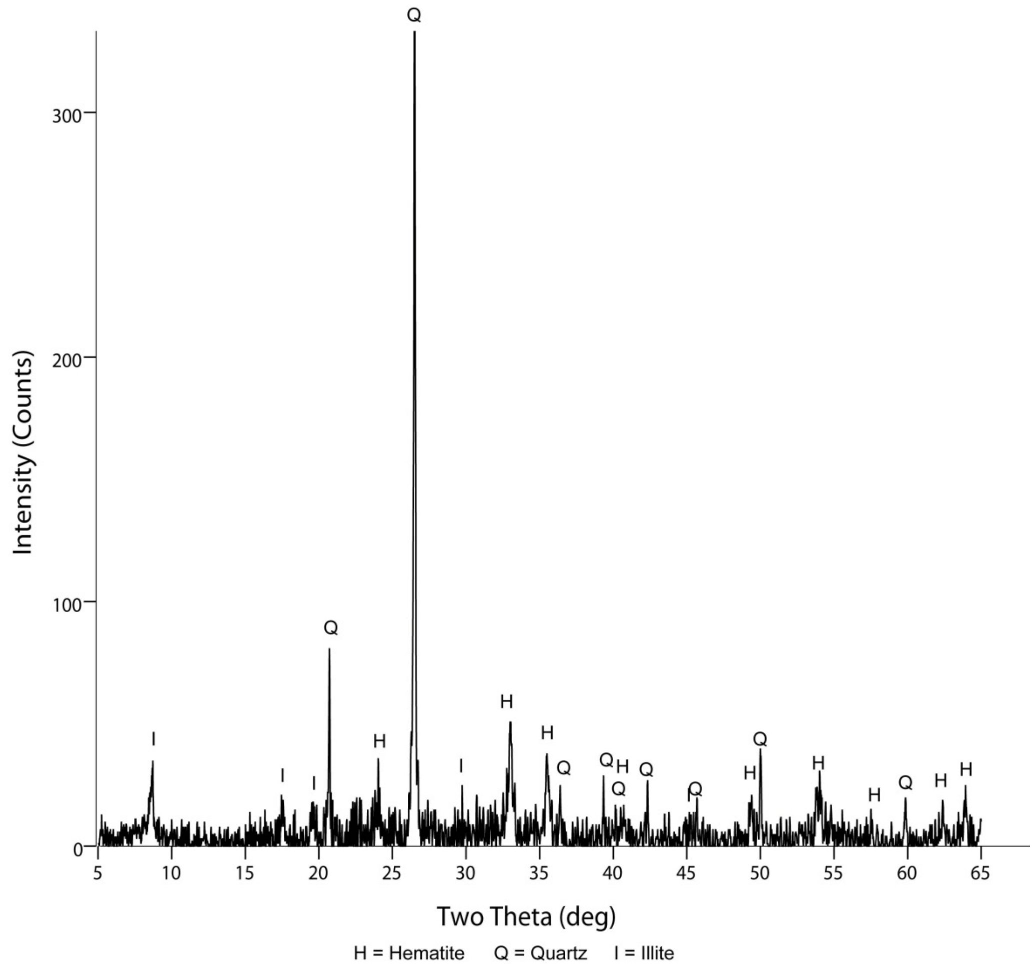


Fig. A.13. G194 Albertinia B red heated

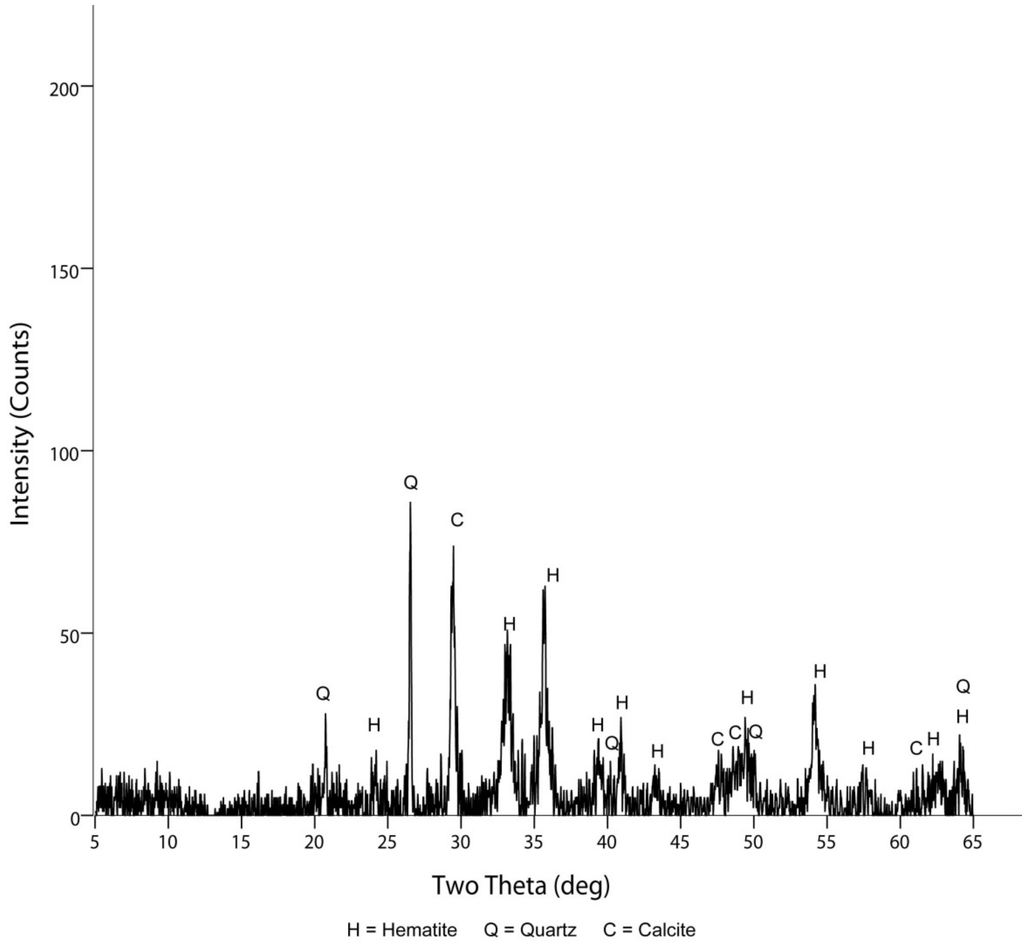


Fig. A.14. G1 Albertinia B yellow heated

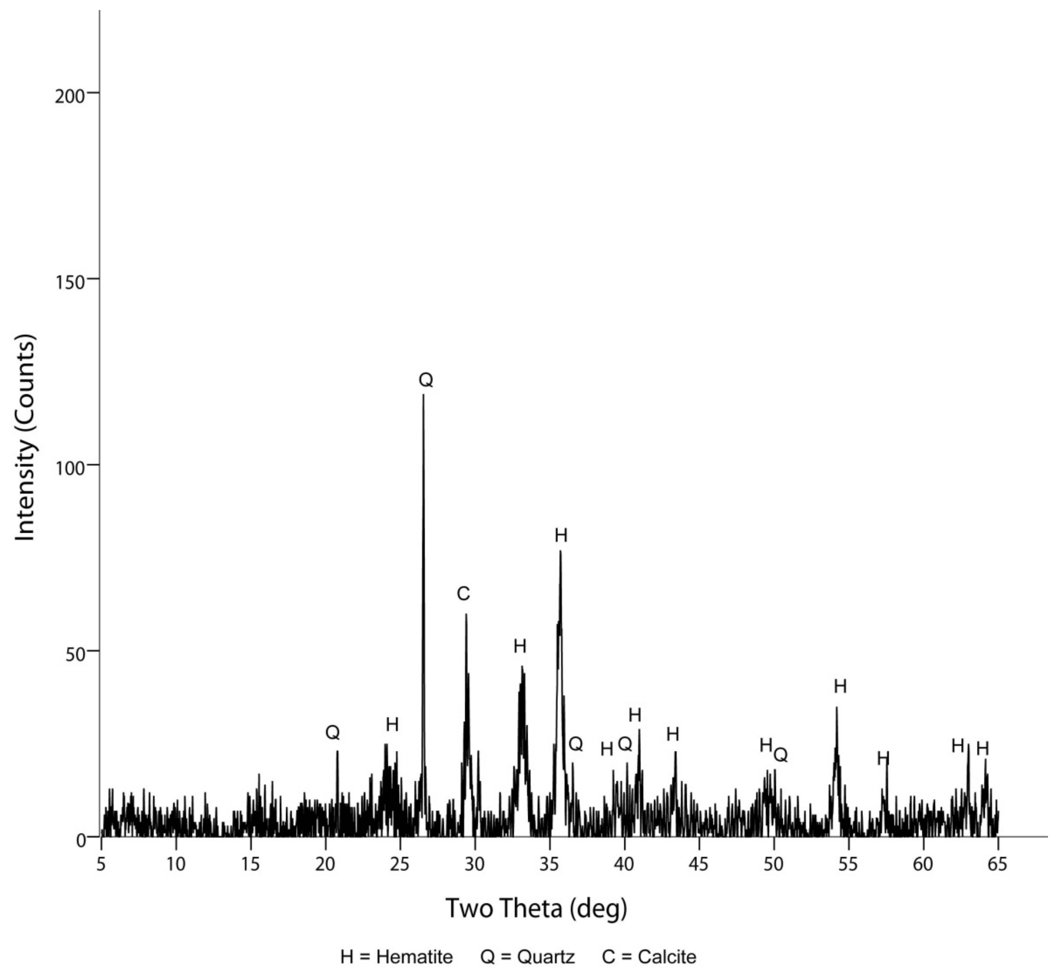
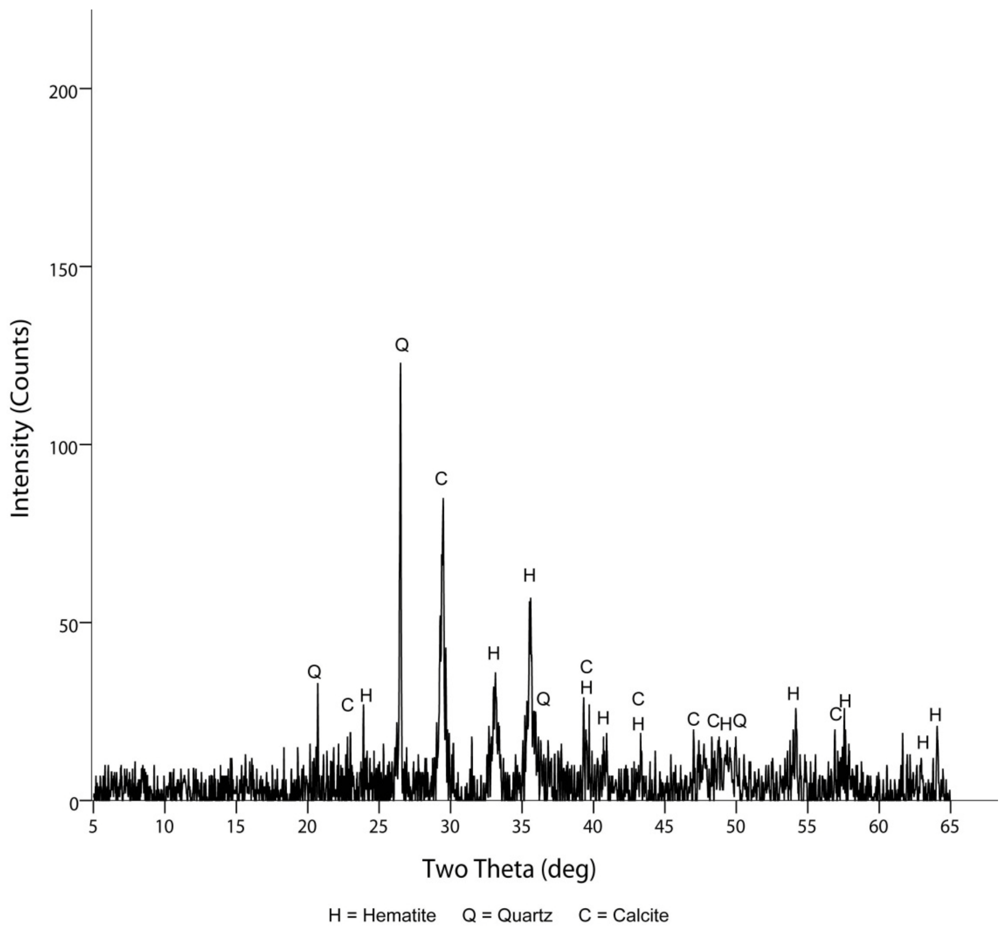


Fig. A.15. G4 Albertinia B yellow heated



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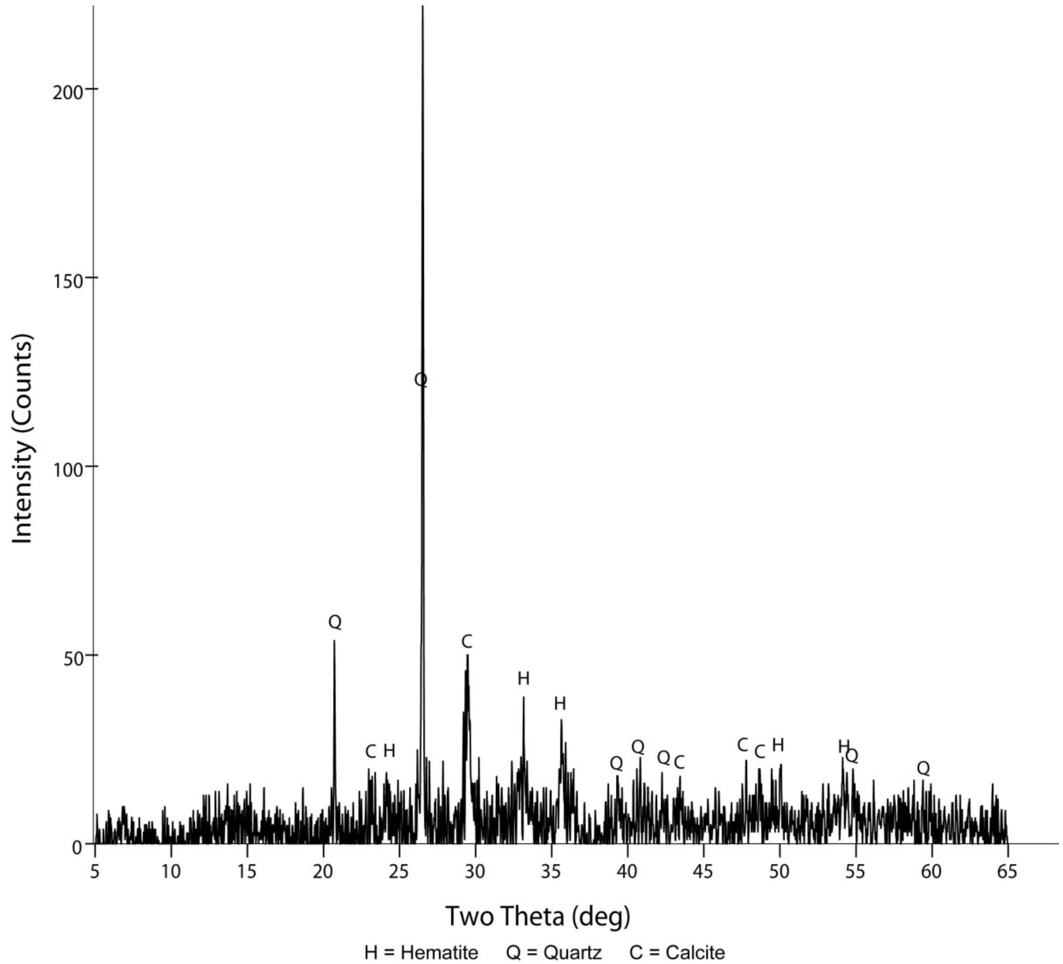

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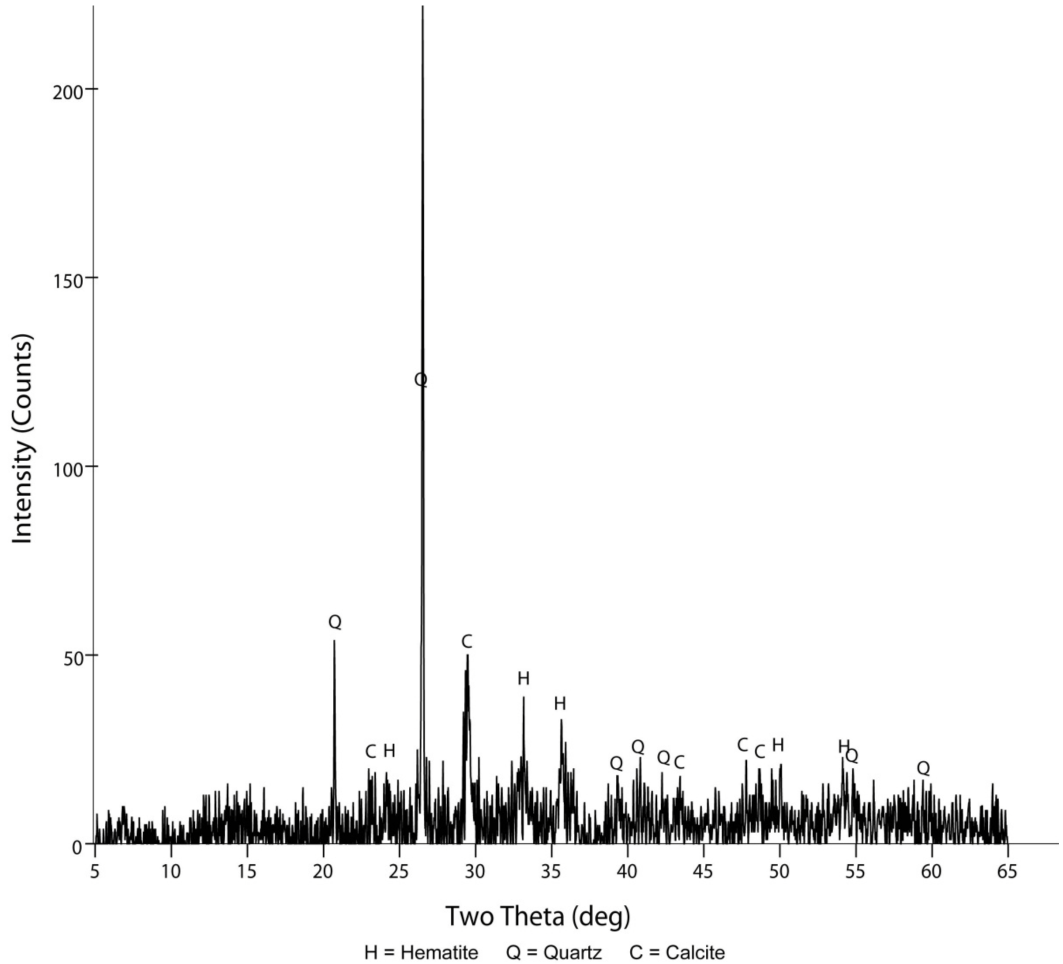
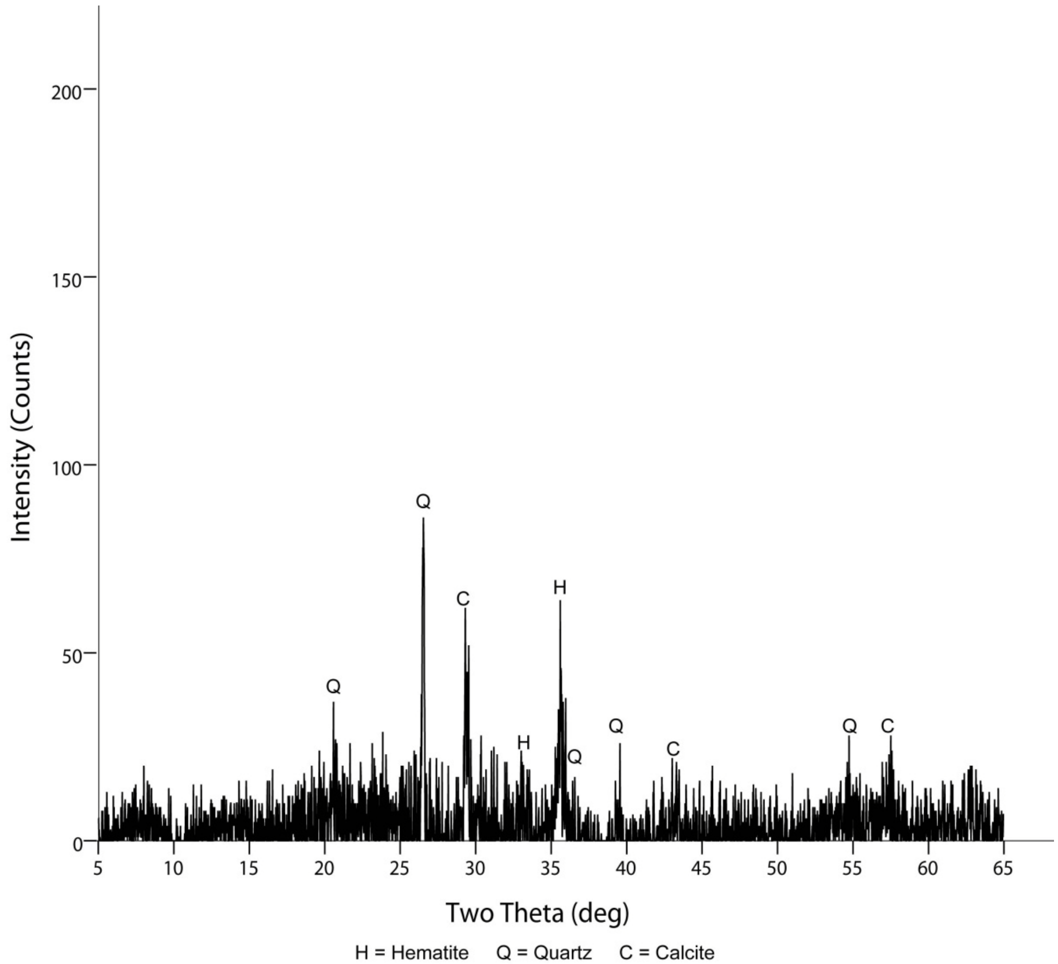


Fig. A.18. G196 Albertinia B yellow heated



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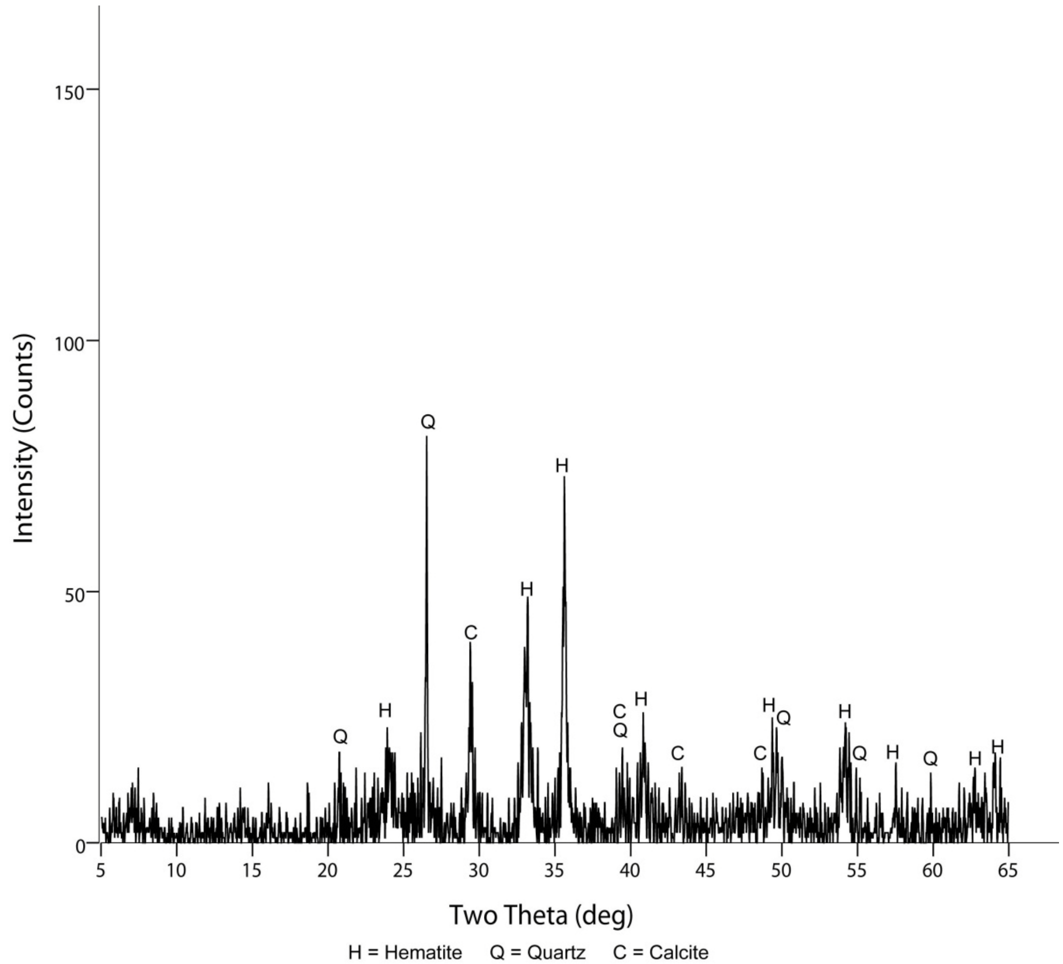
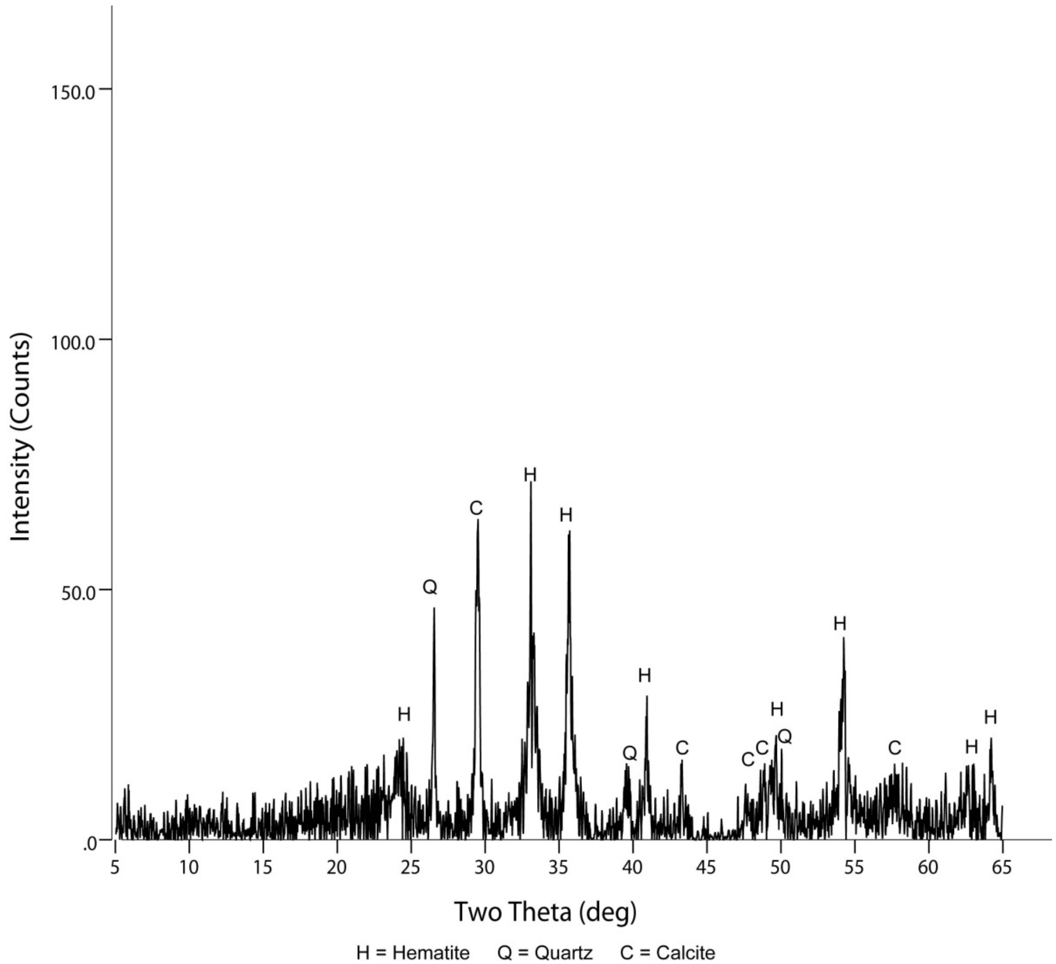


Fig. A.20. G276 Albertinia B yellow heated



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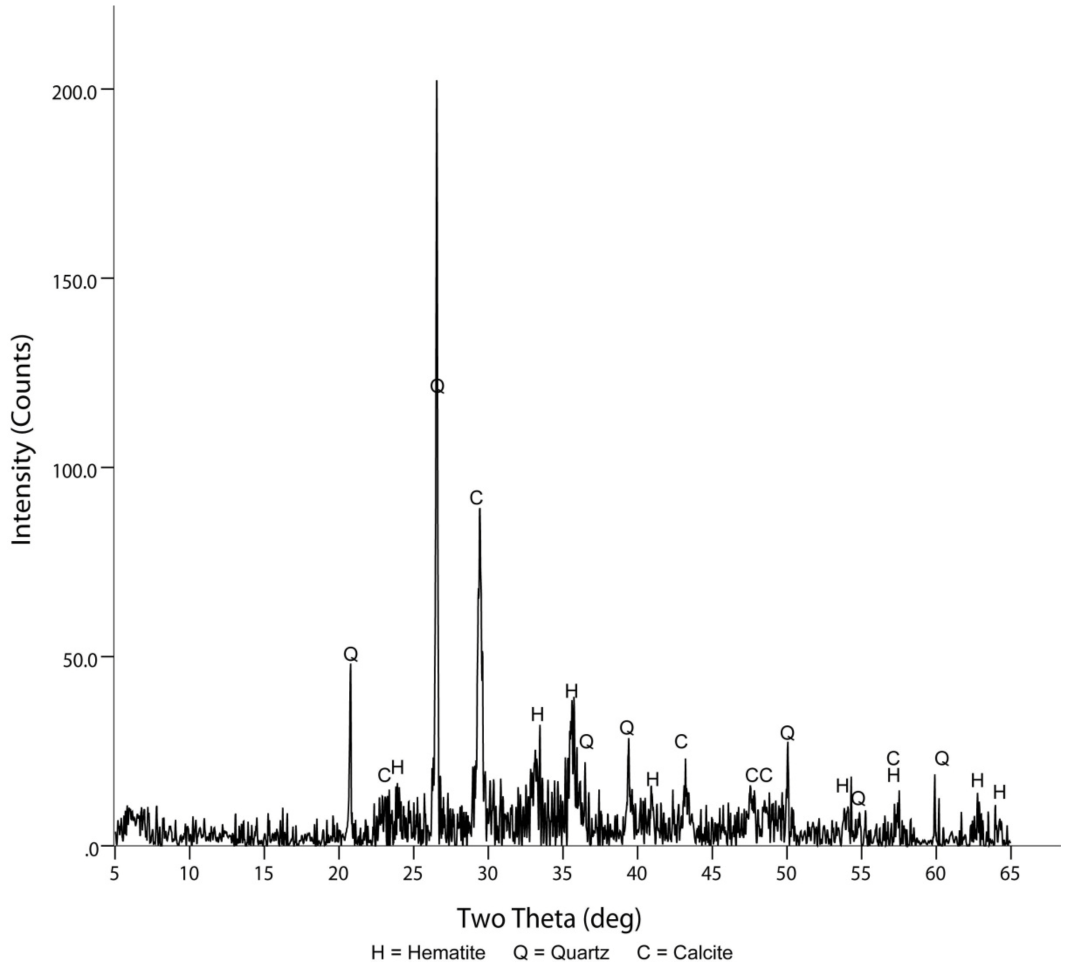

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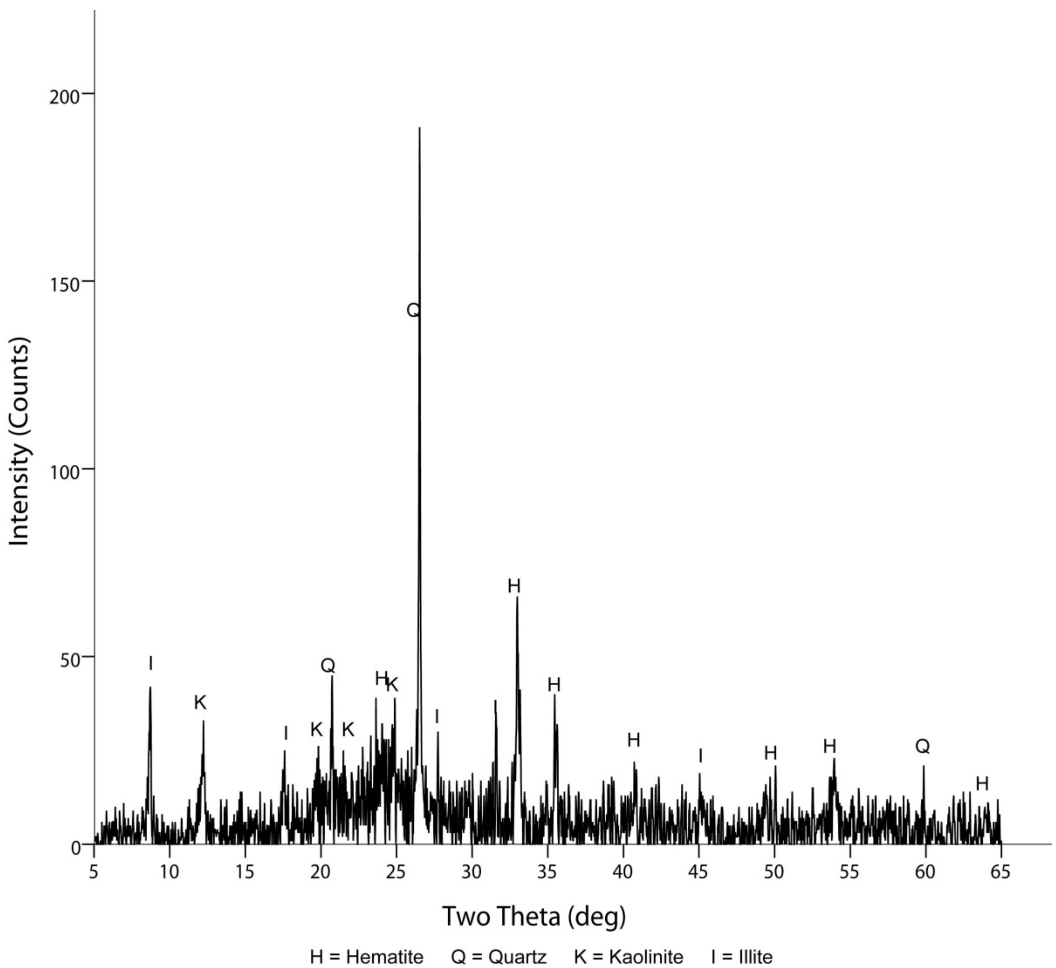
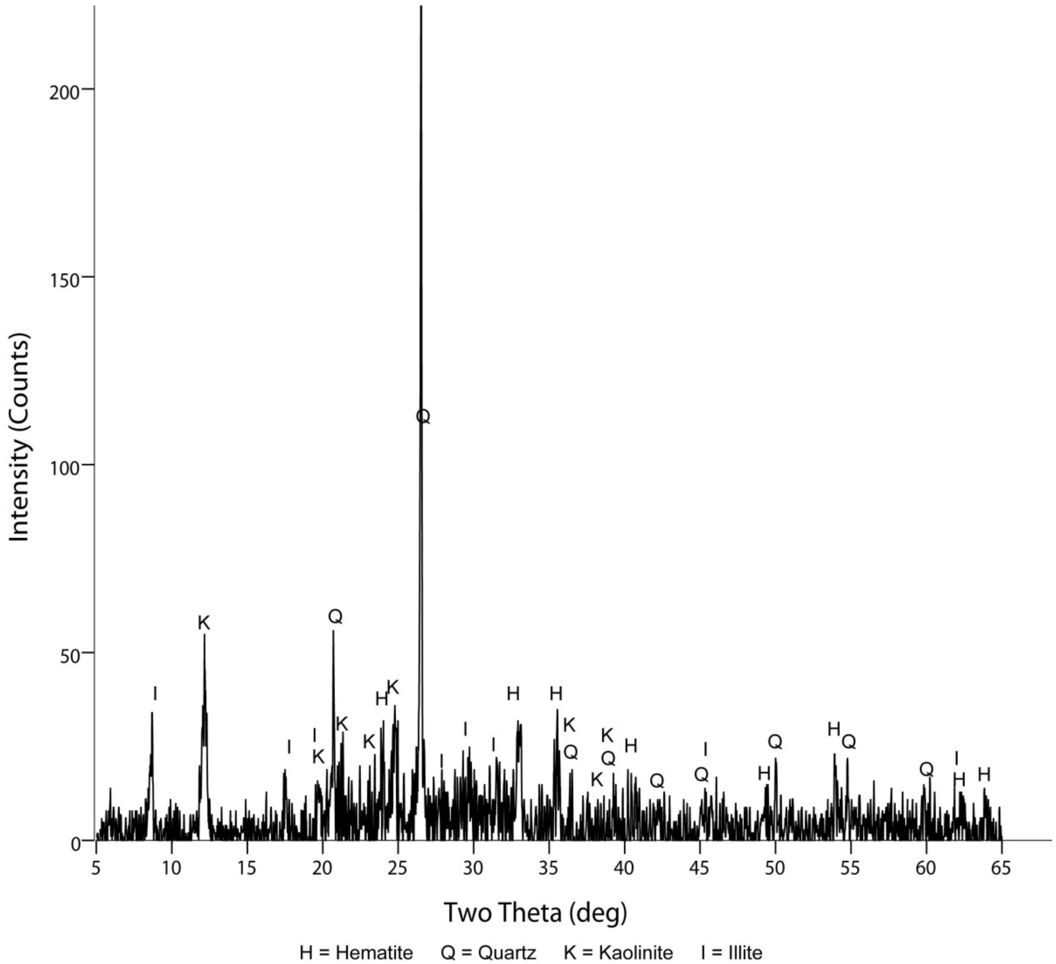


Fig. A.23. G263 Albertinia C red



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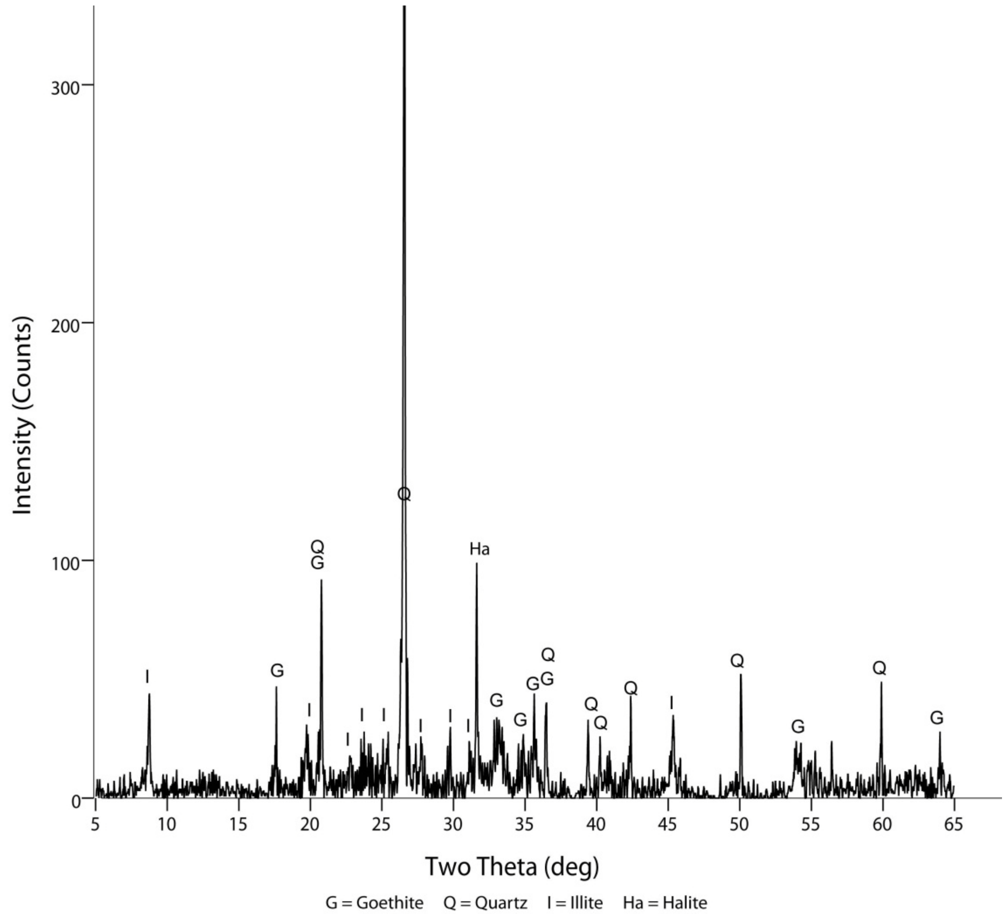

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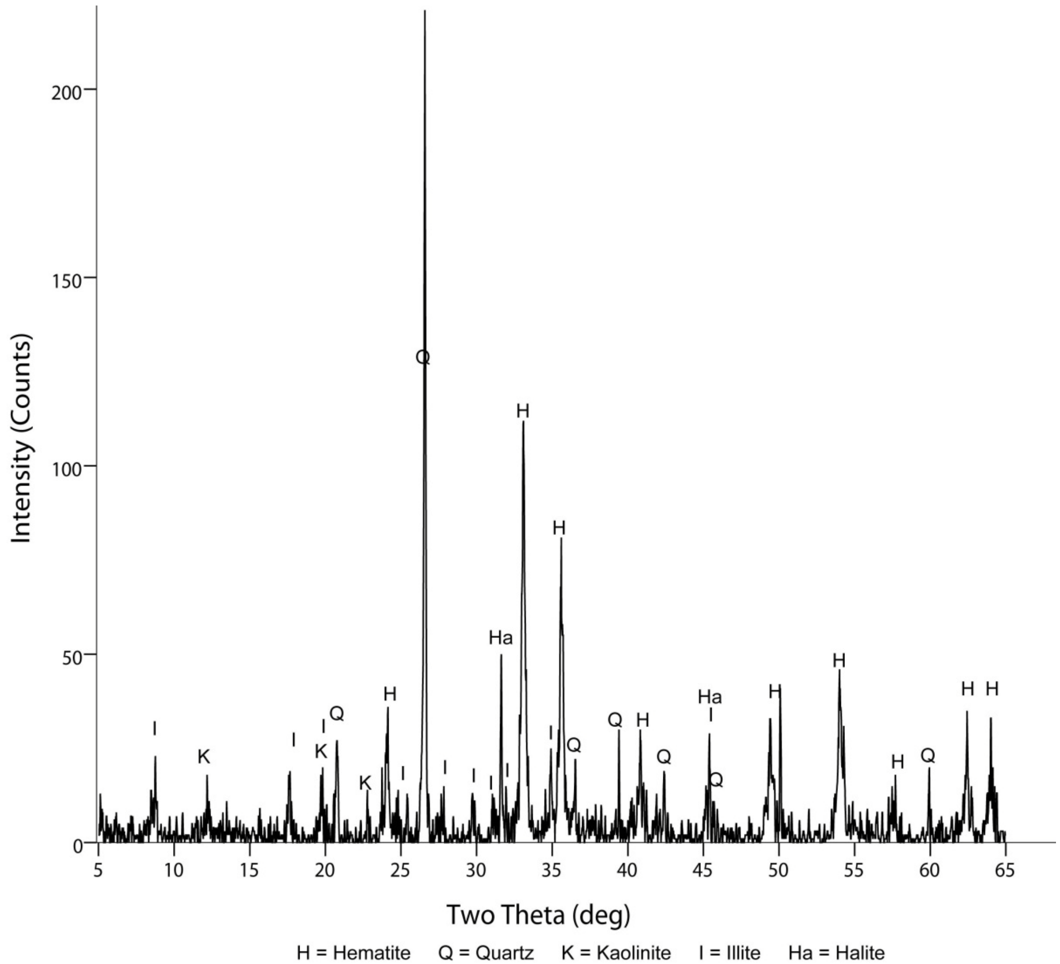
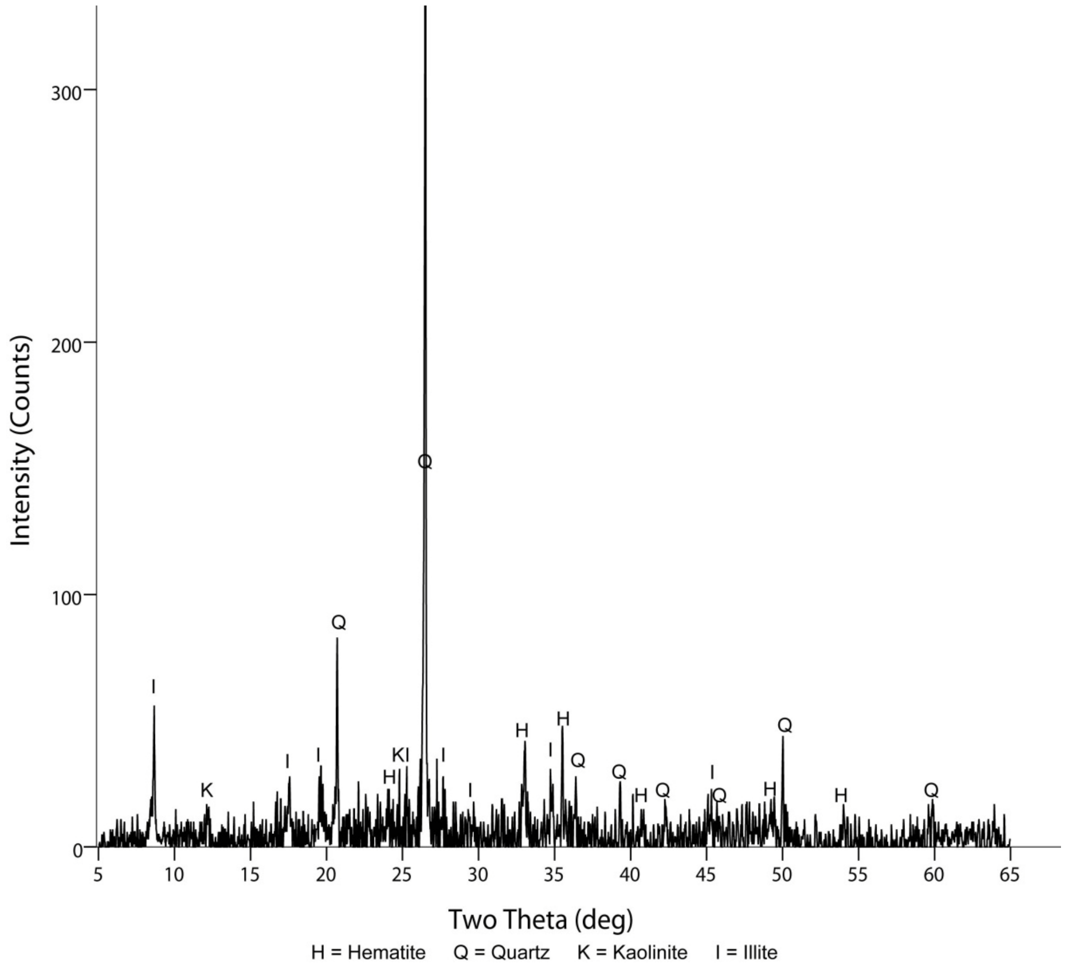


Fig A.26. G264 Albertinia C red heated



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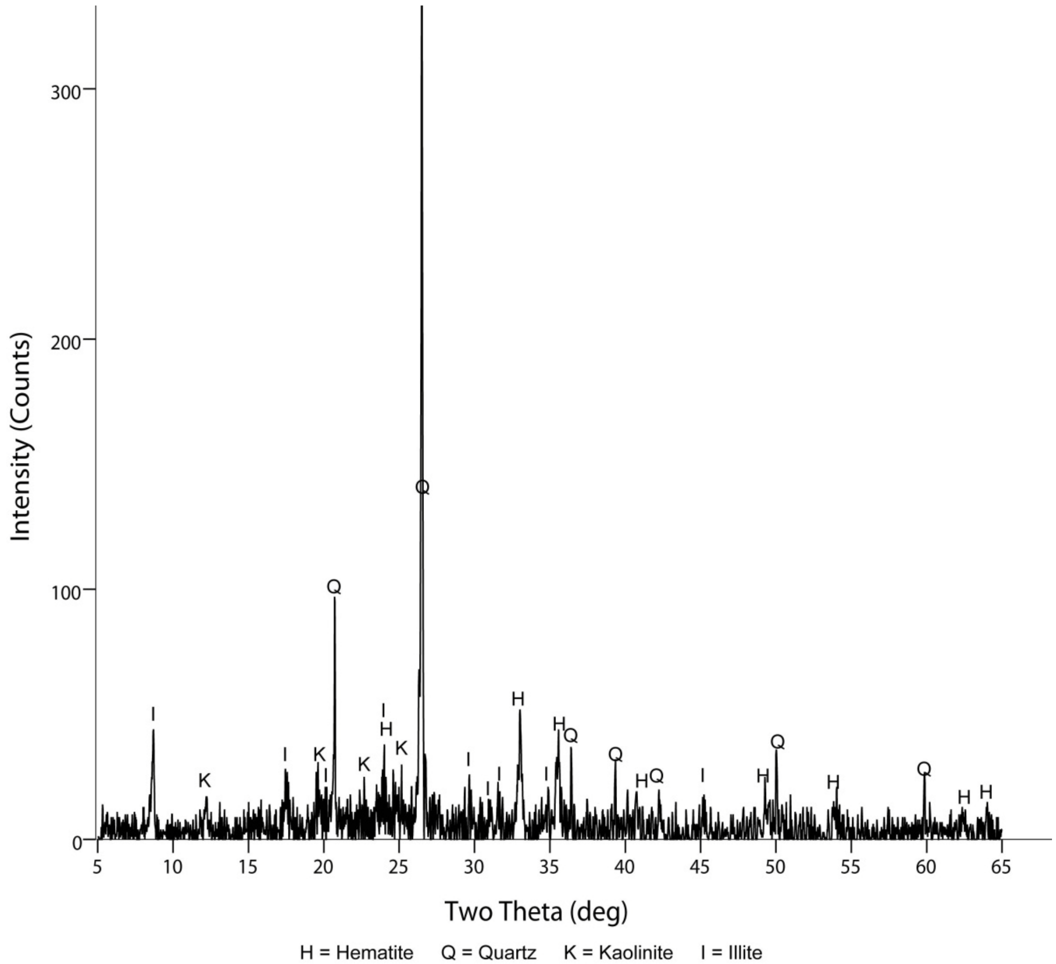

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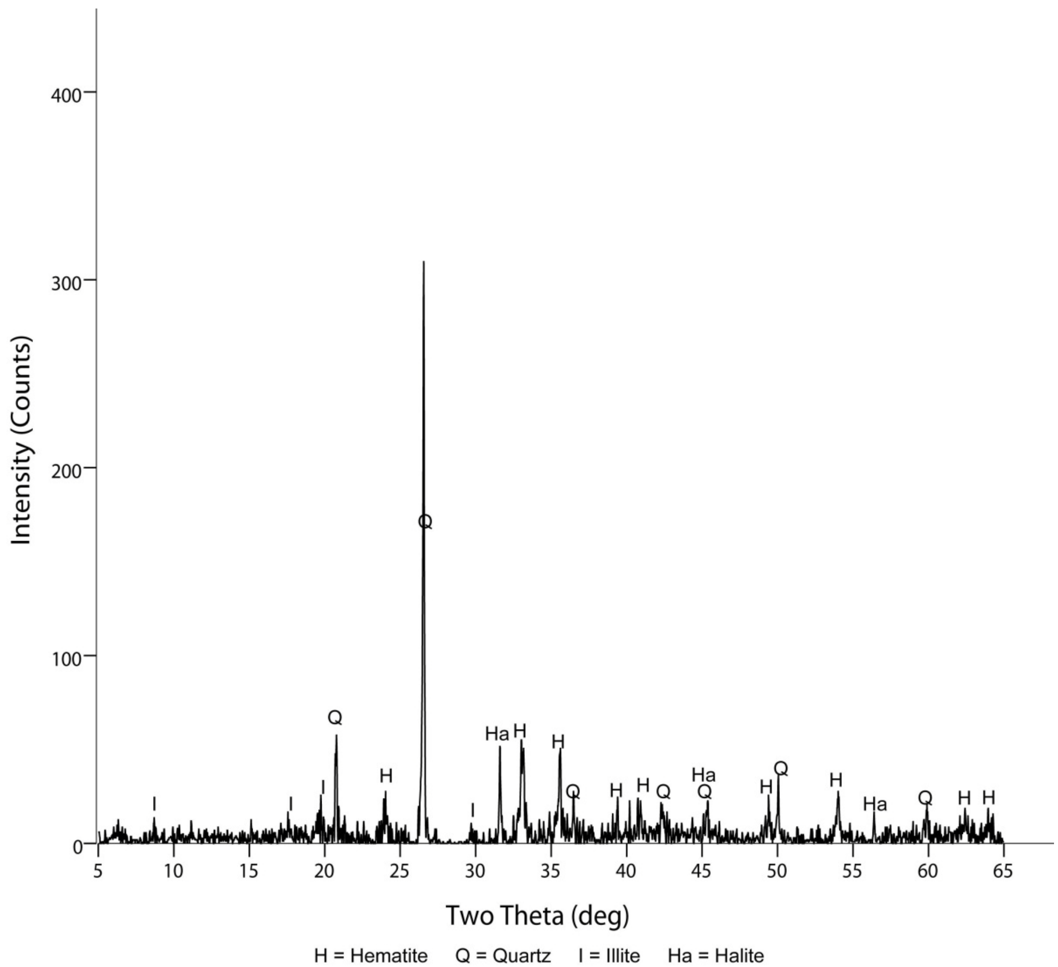

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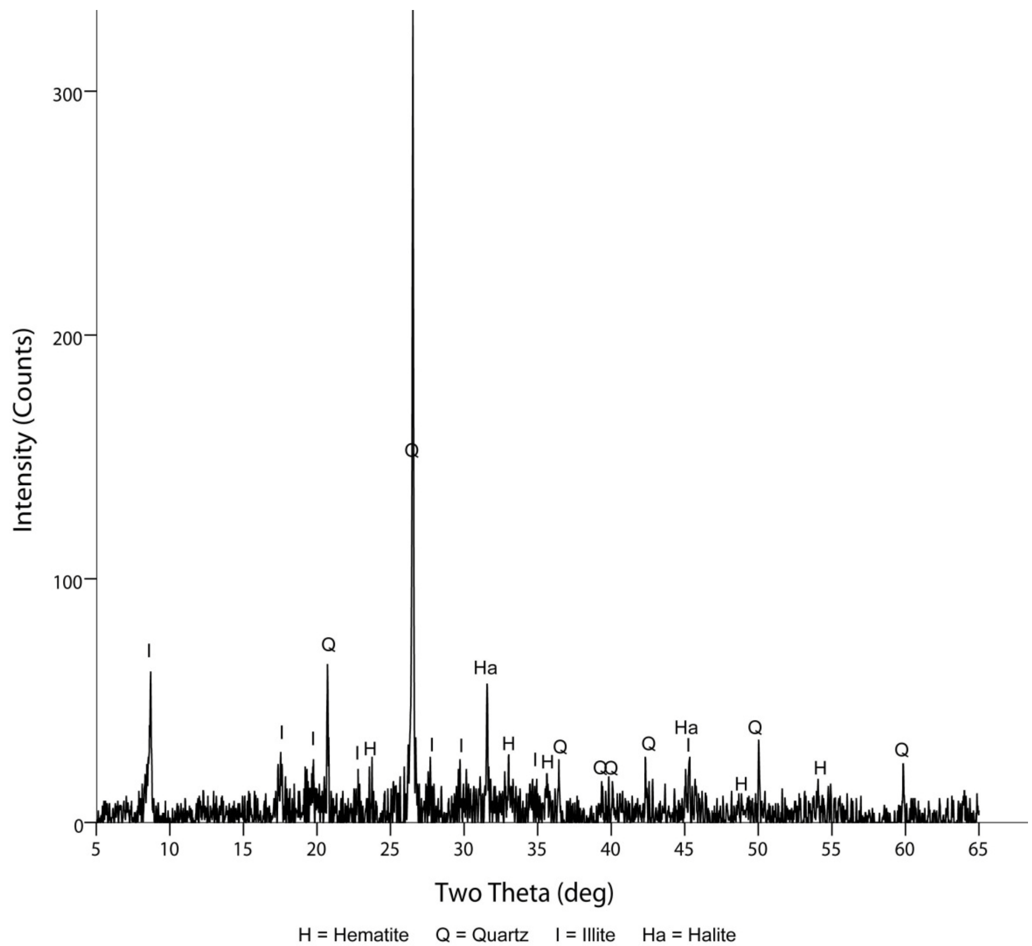

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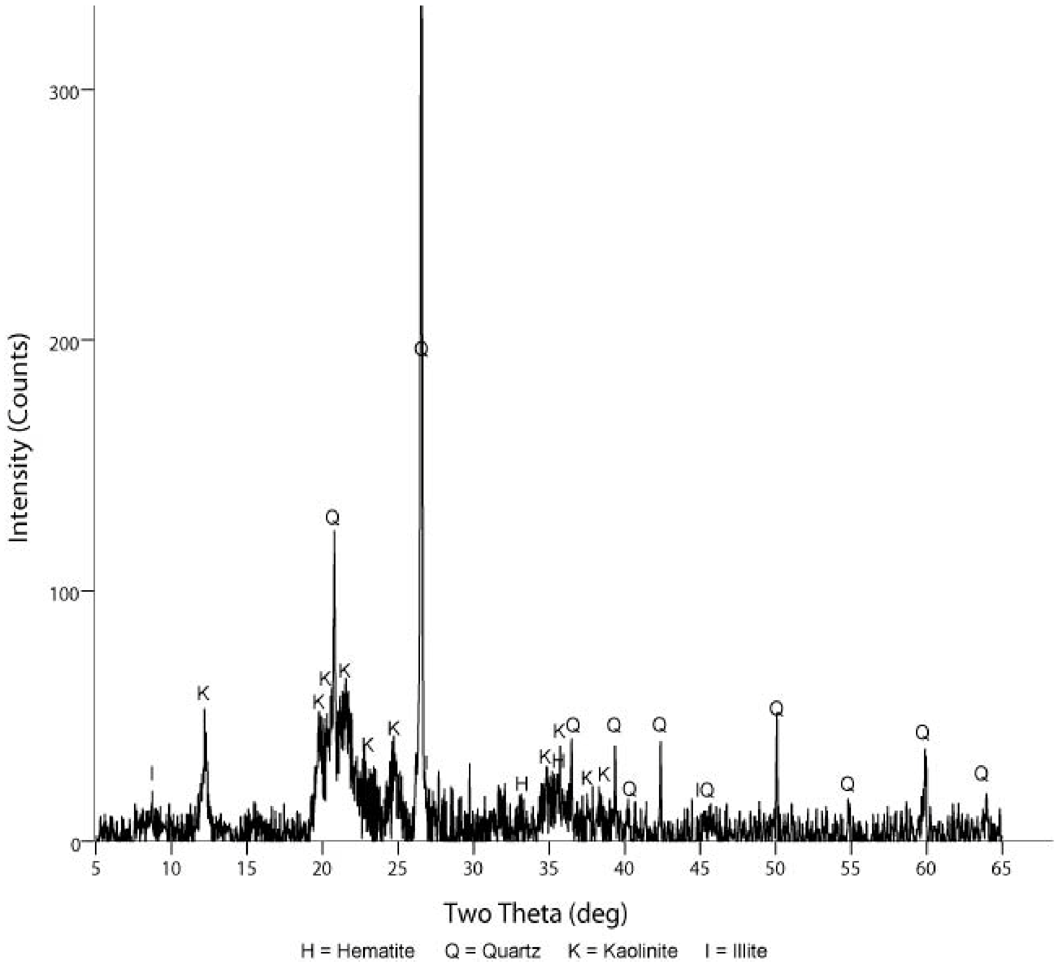


Fig. A.31. G65 Glentana orange

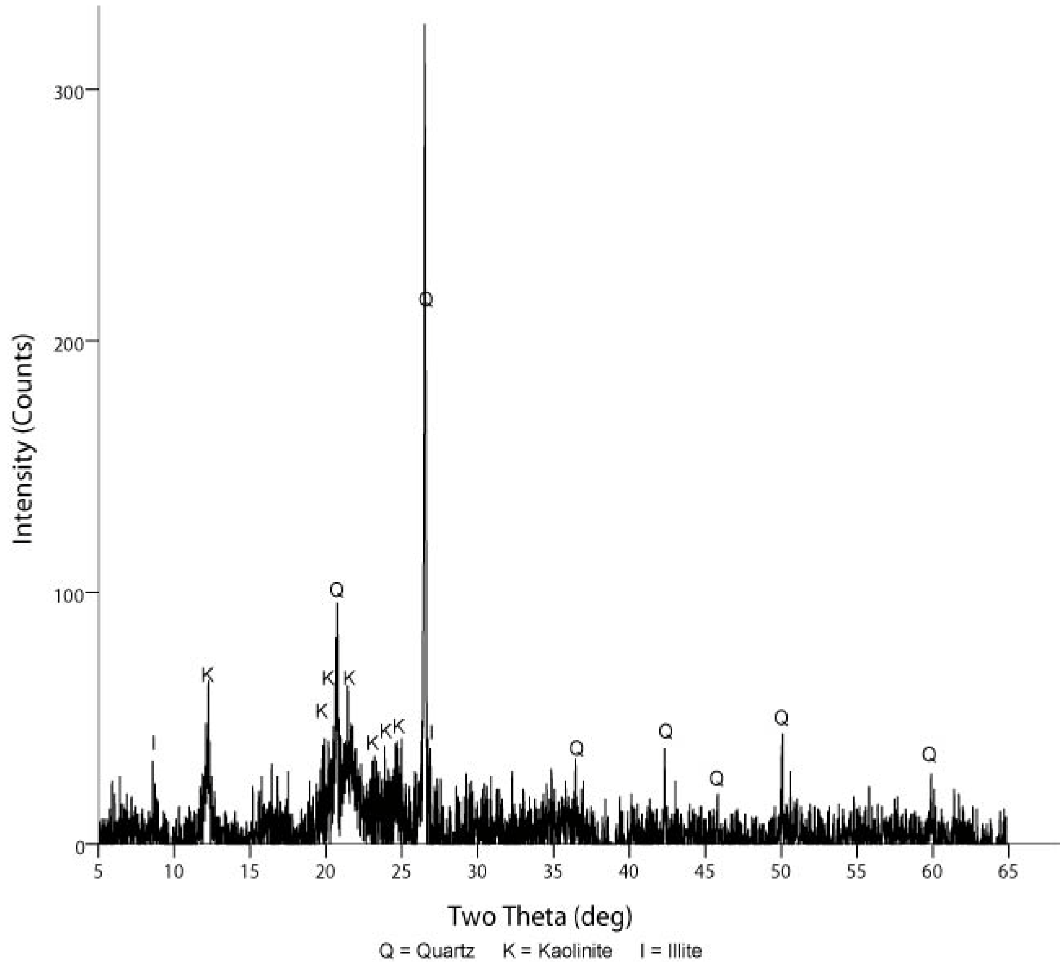


Fig. A.32. G34 Glentana orange heated

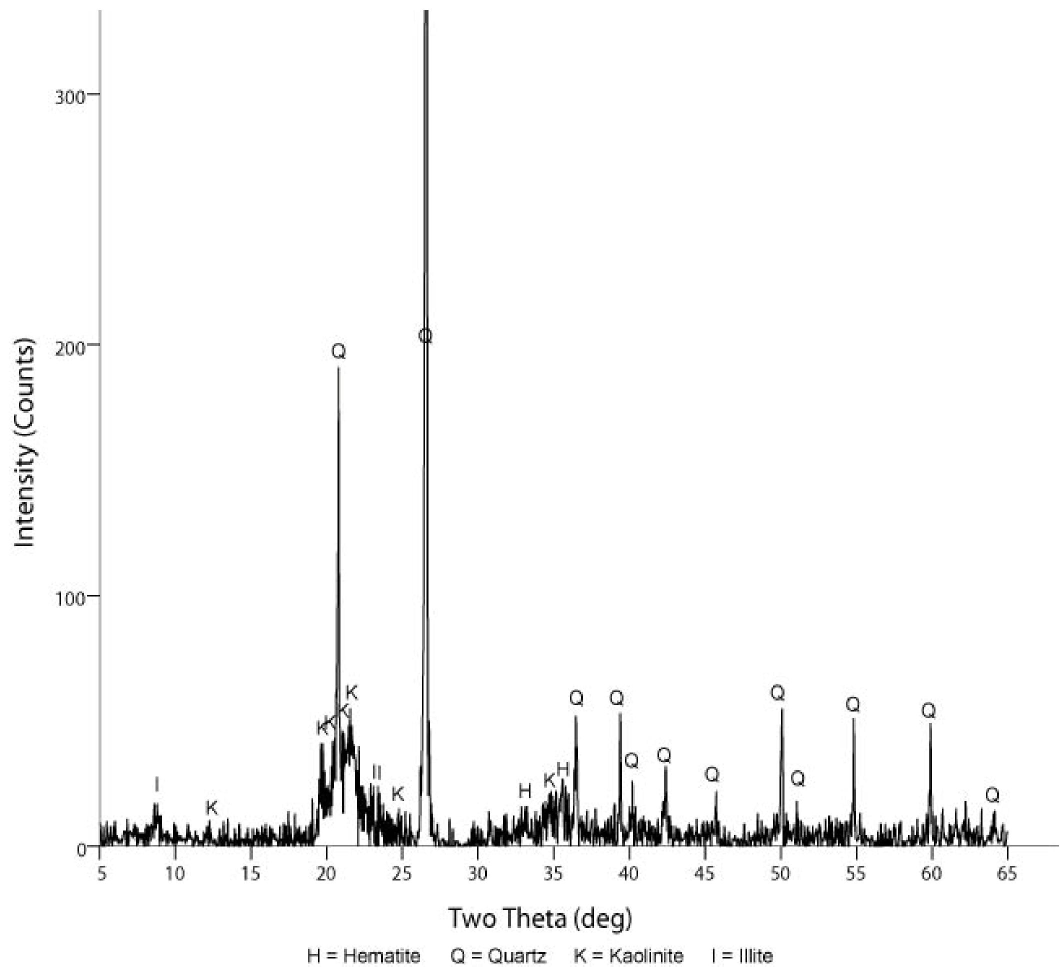


Fig. A.33. G257 Glentana orange heated

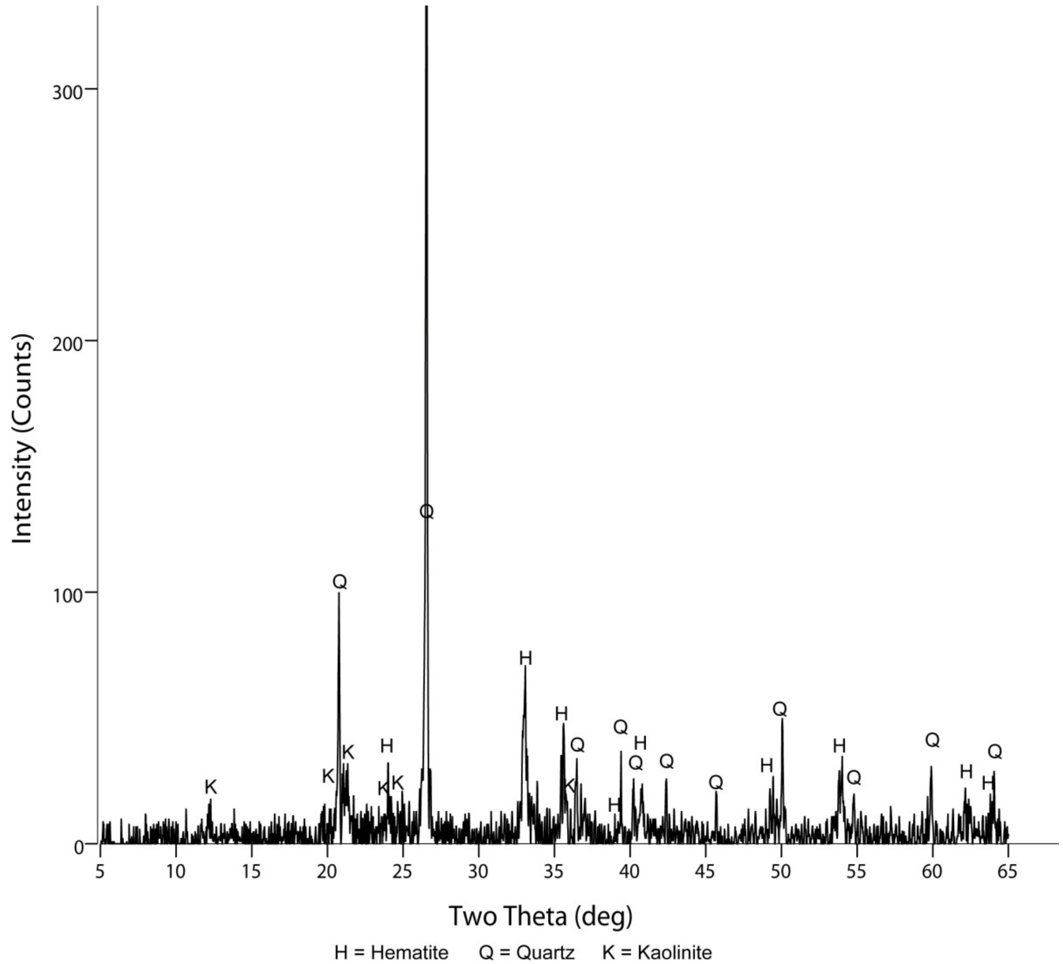


Fig. A.34. G66 Gondwana A red

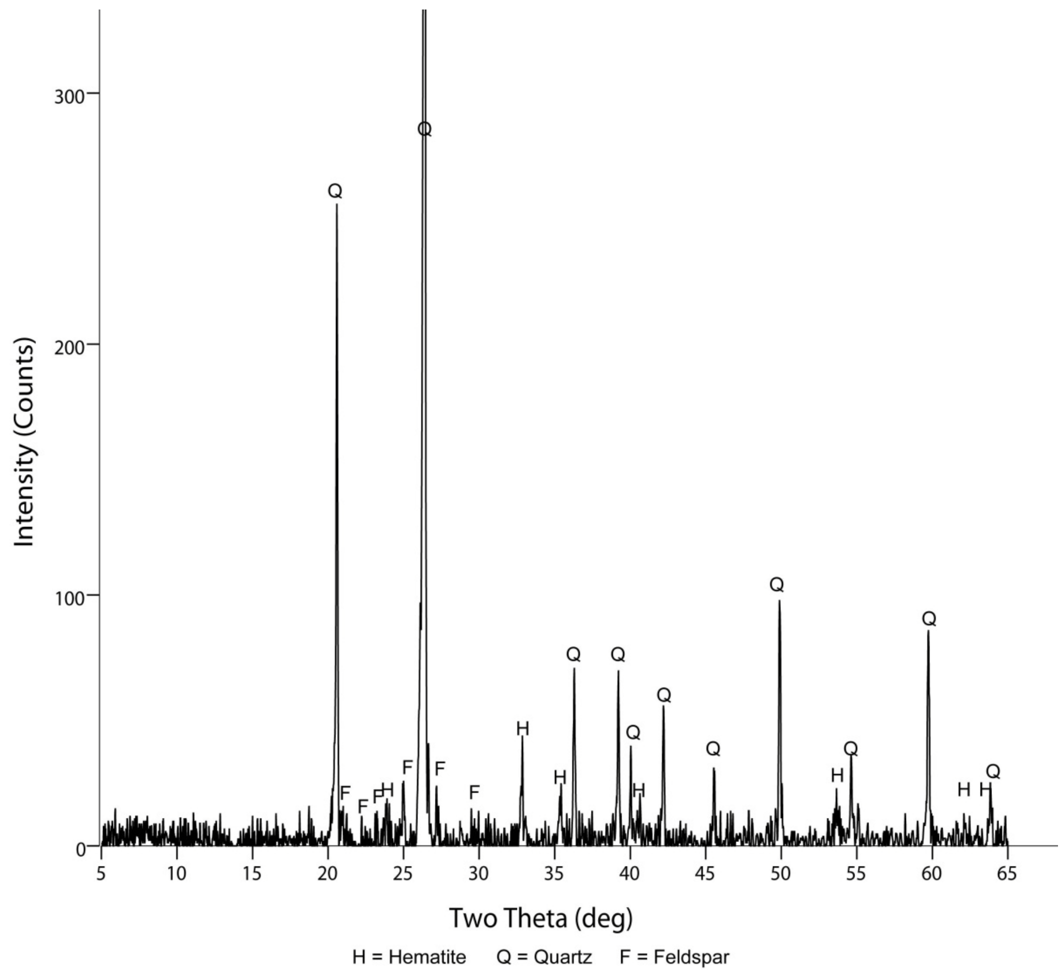


Fig. A.35. G68 Gondwana A red

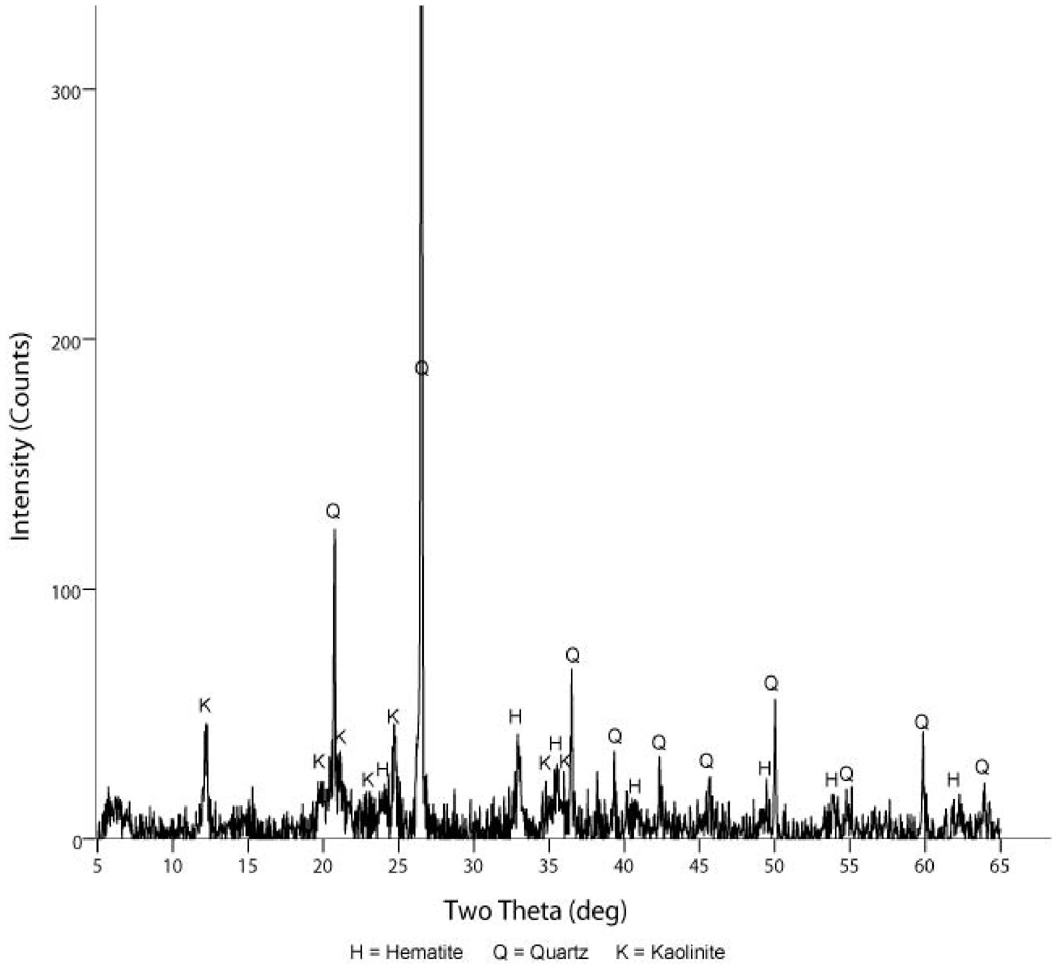


Fig. A.36. G70 Gondwana A red

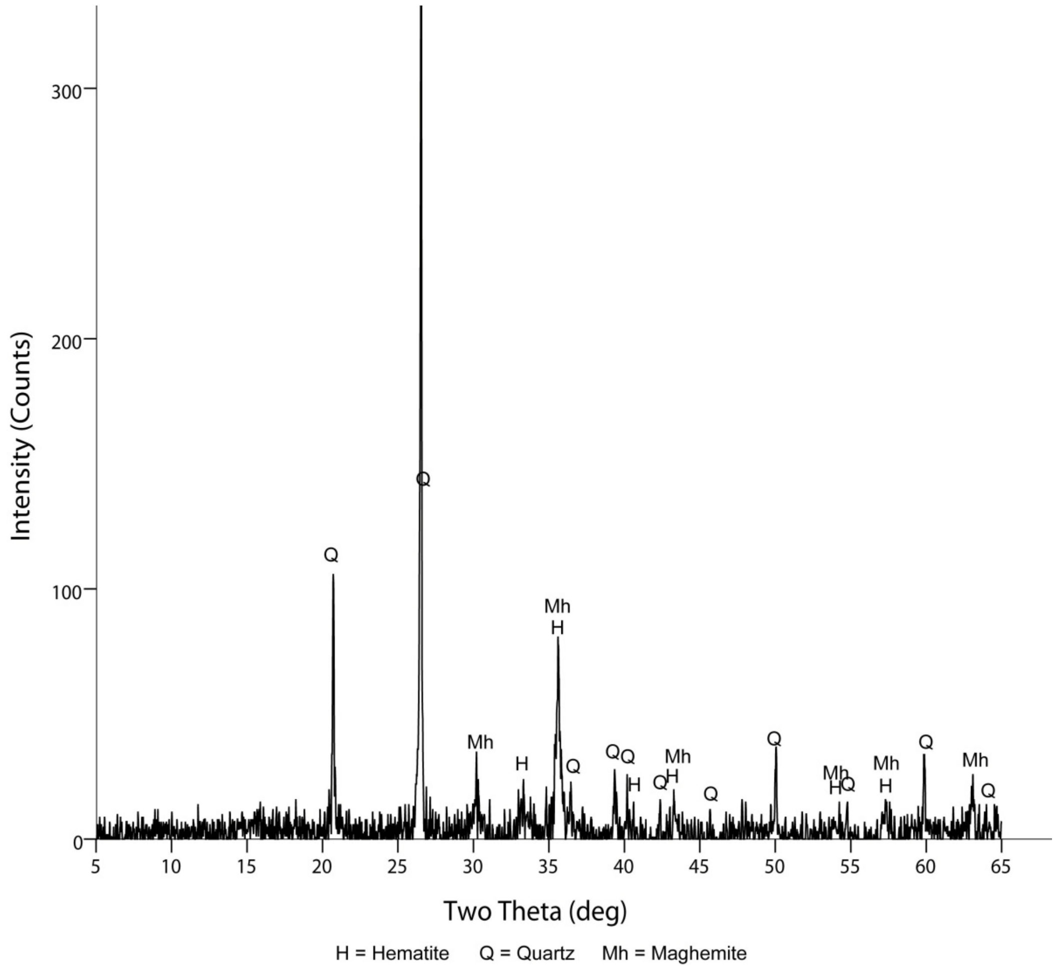


Fig. A.37. G26 Gondwana A red heated

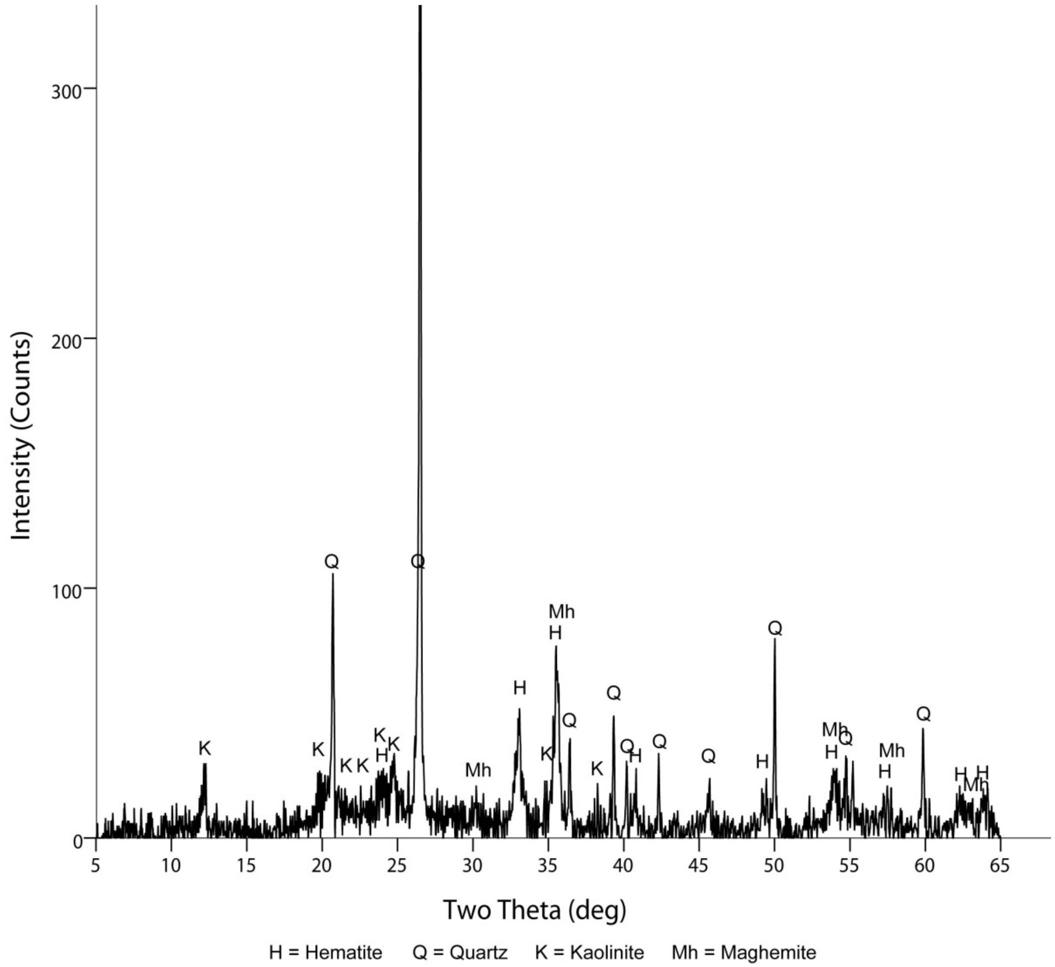


Fig. A.38. G27 Gondwana A red heated

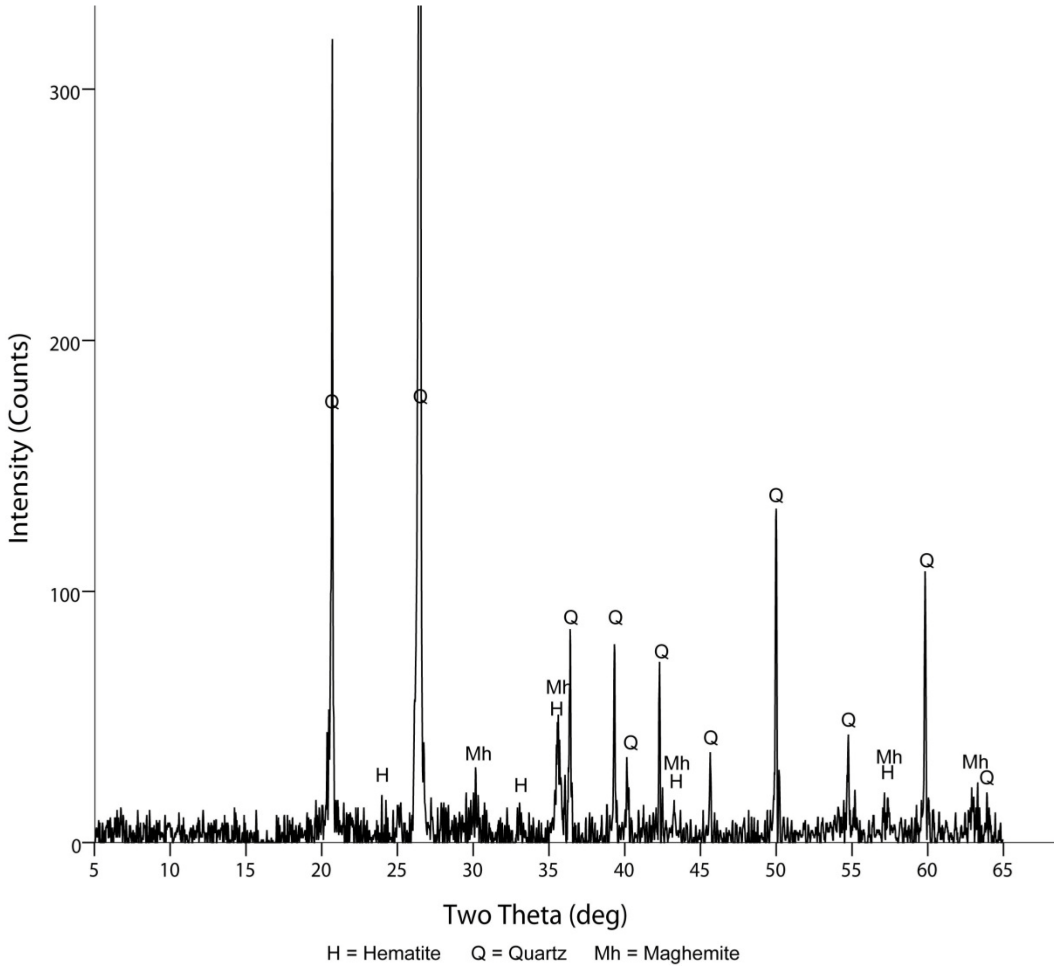


Fig. A.39. G28 Gondwana A red heated

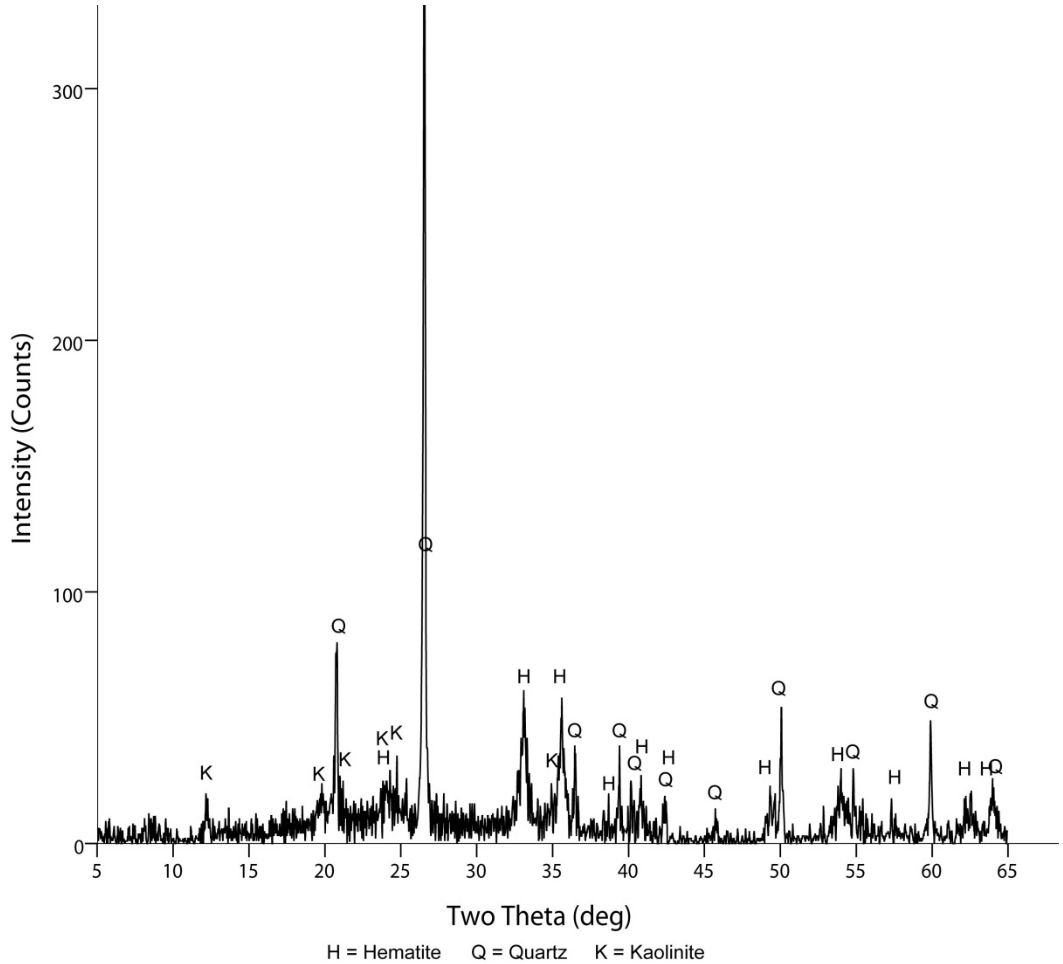


Fig. A.40. G201 Gondwana A red heated

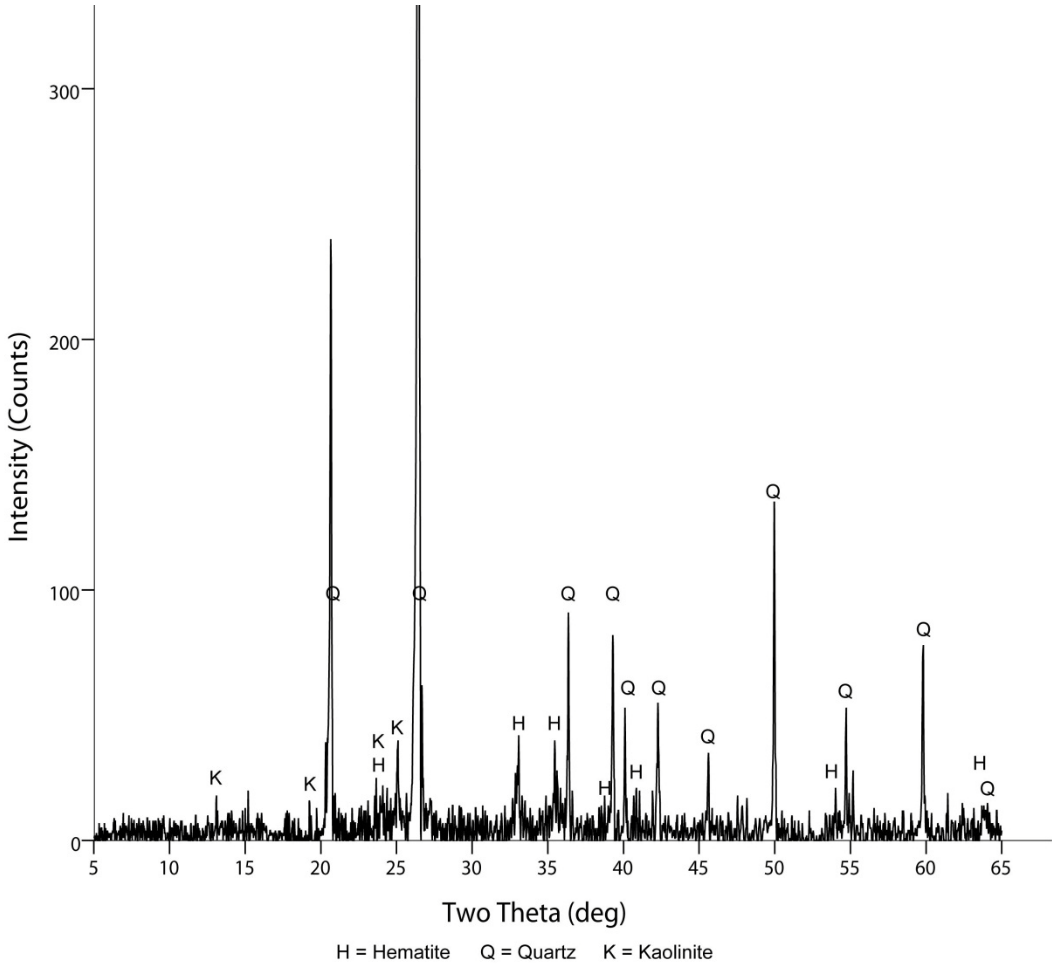


Fig. A.41. G202 Gondwana A red heated

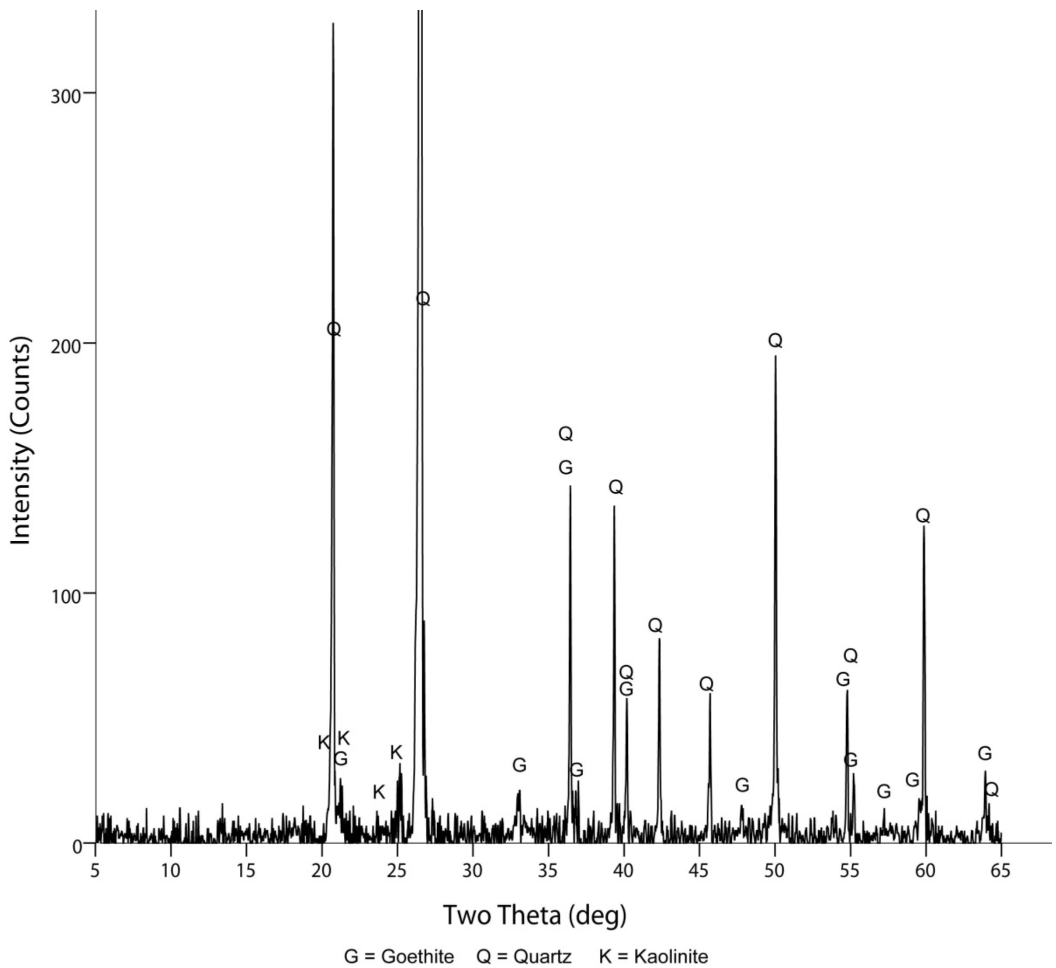


Fig. A.42. G67 Gondwana A yellow

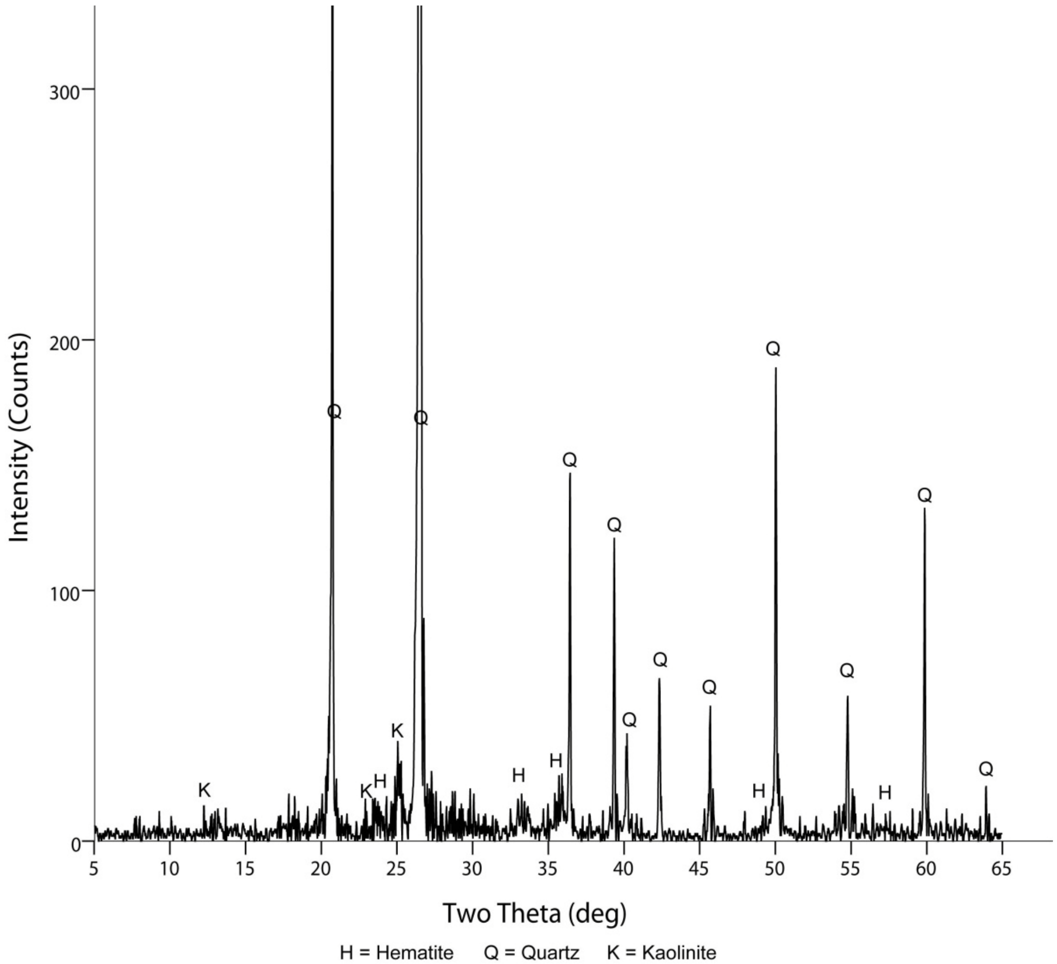


Fig. A.43. G29 Gondwana A yellow heated

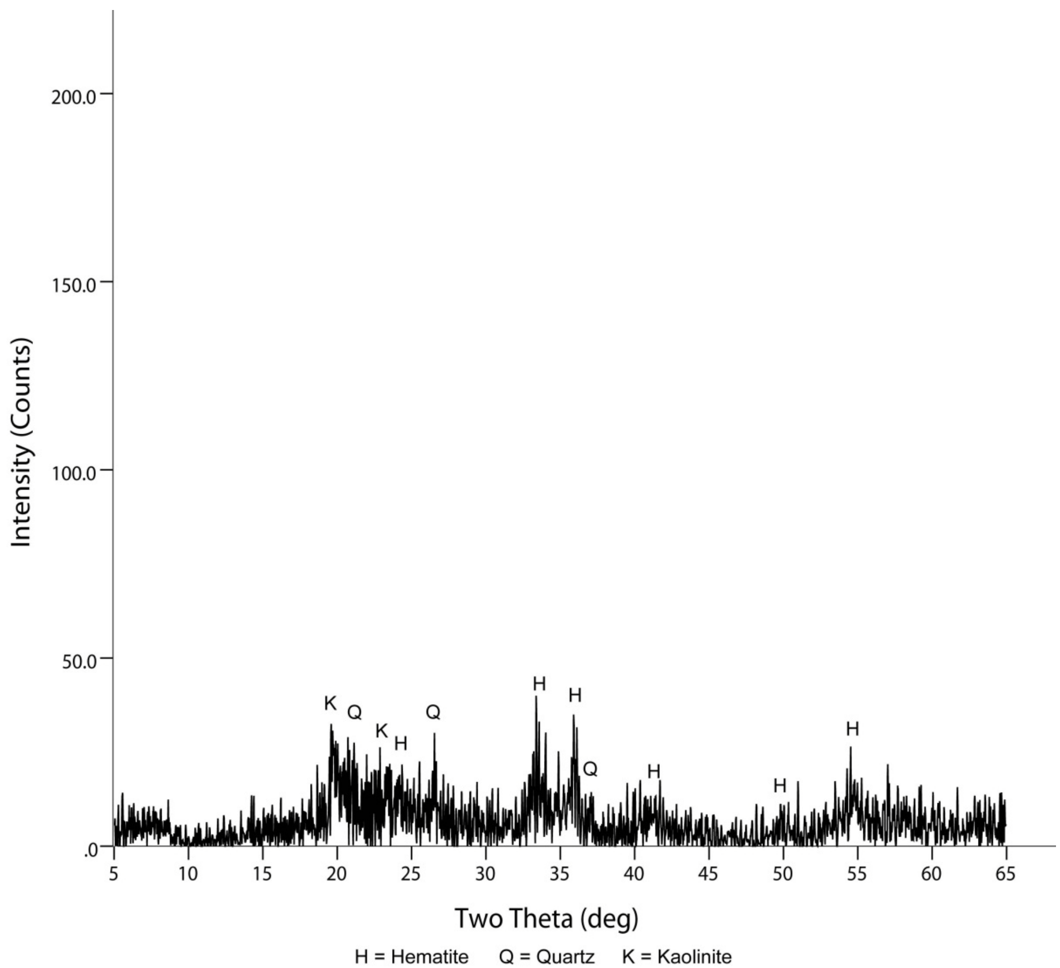


Fig. A.44. G203 Gondwana A yellow heated

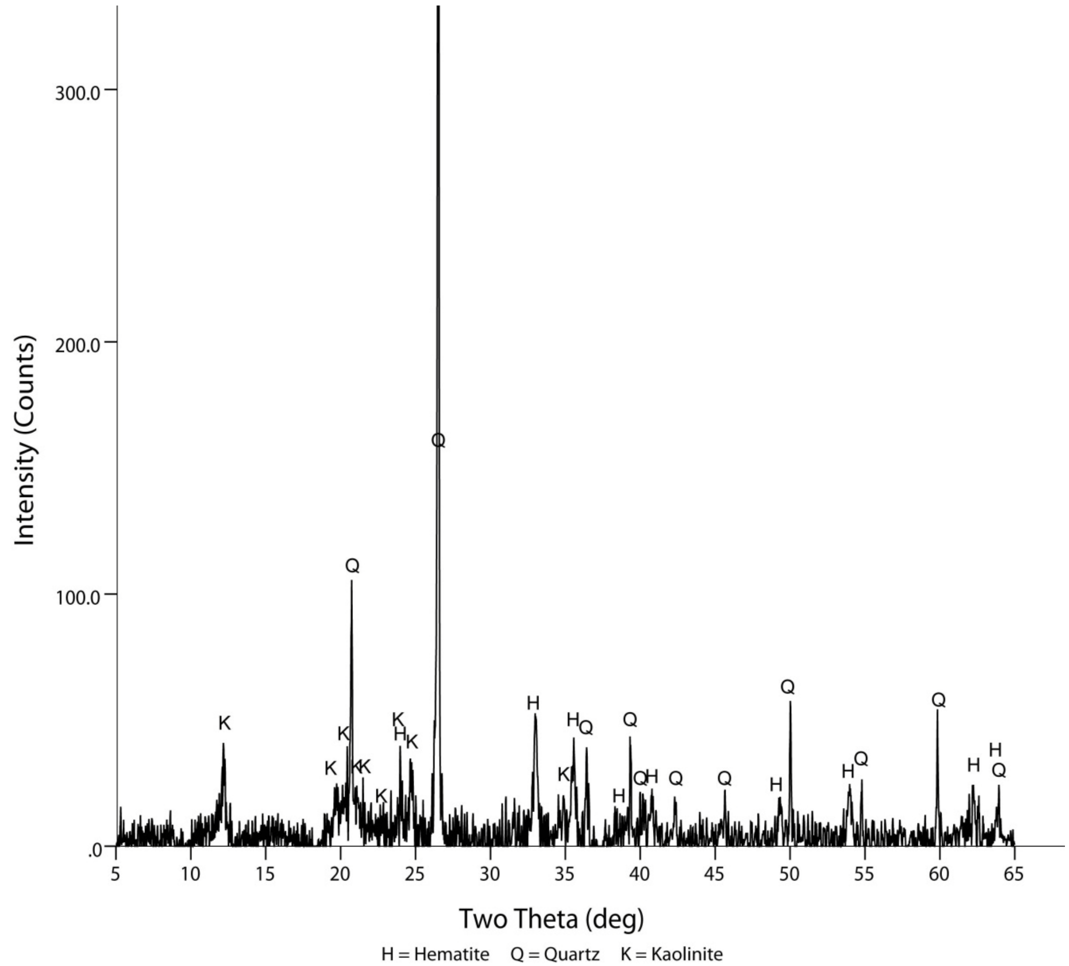


Fig. A.45. G71 Gondwana B red

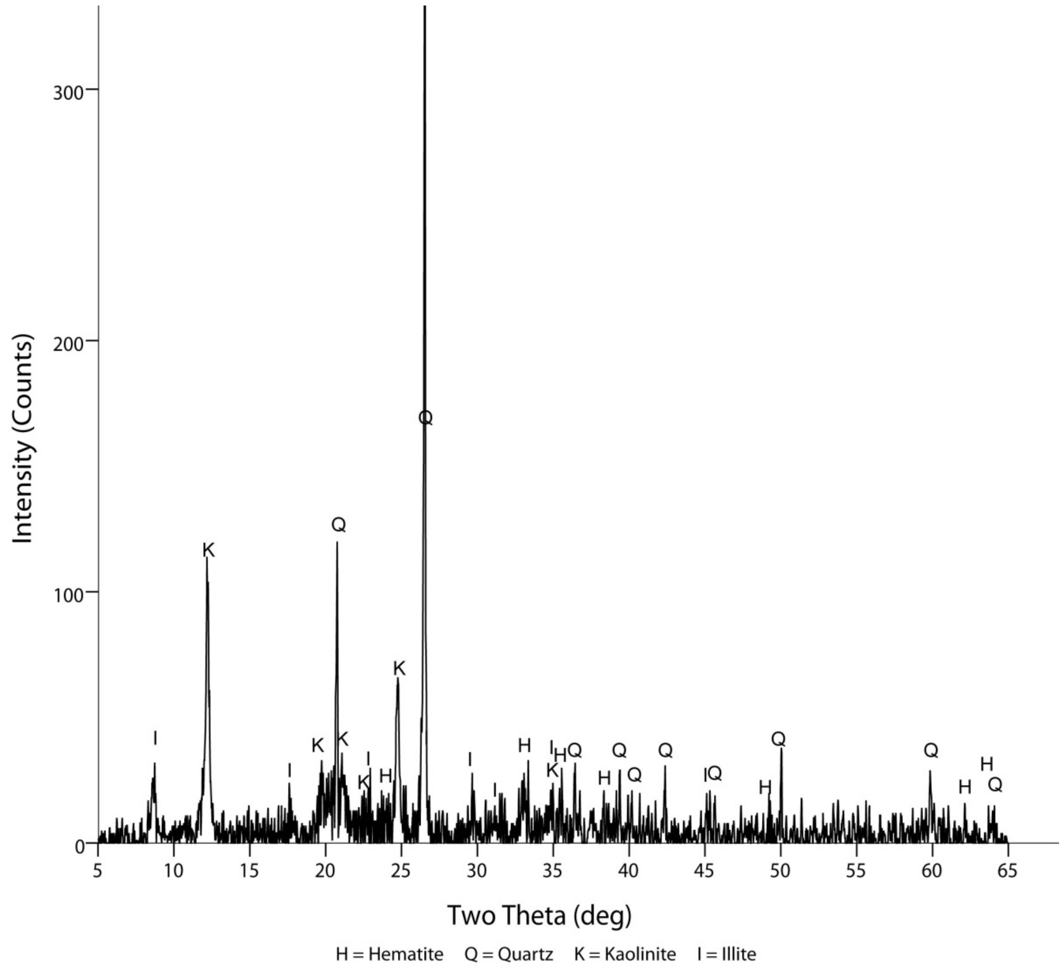


Fig. A.46. G73 Gondwana B red

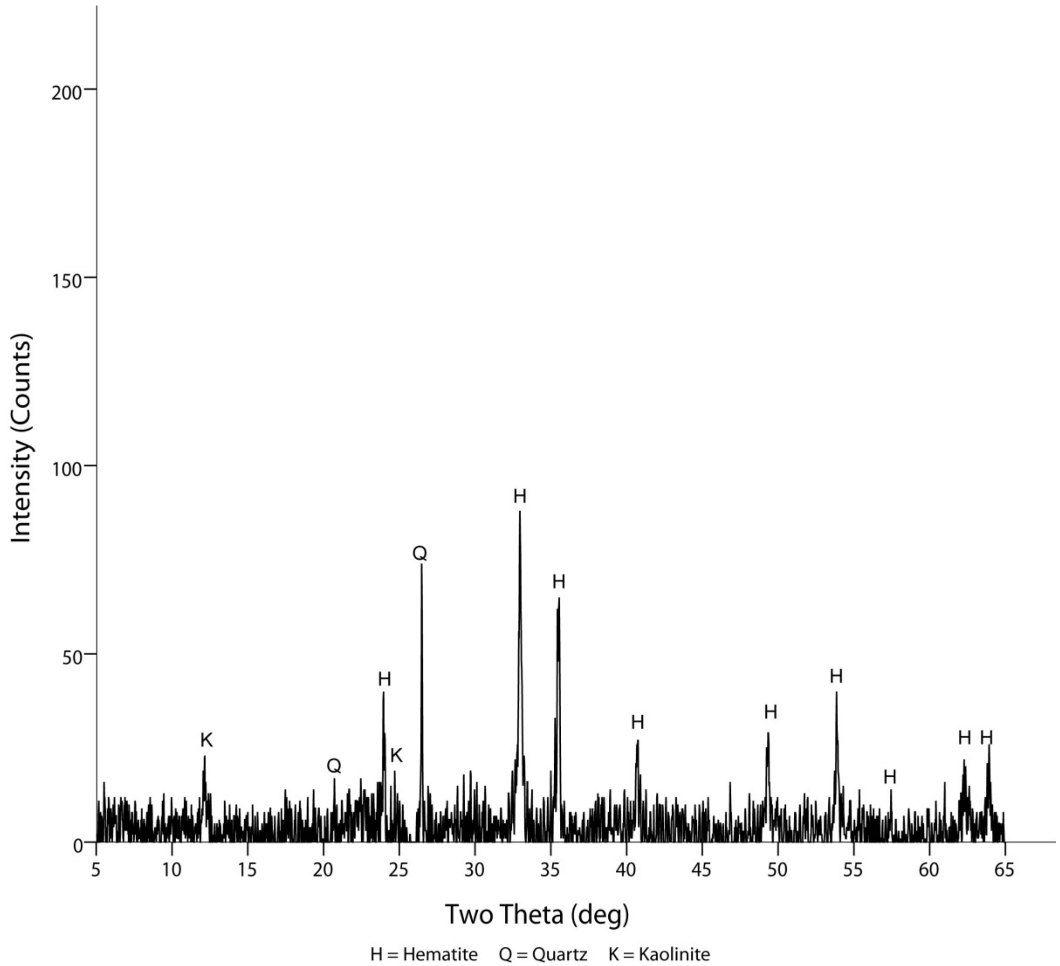


Fig. A.47. G74 Gondwana B red

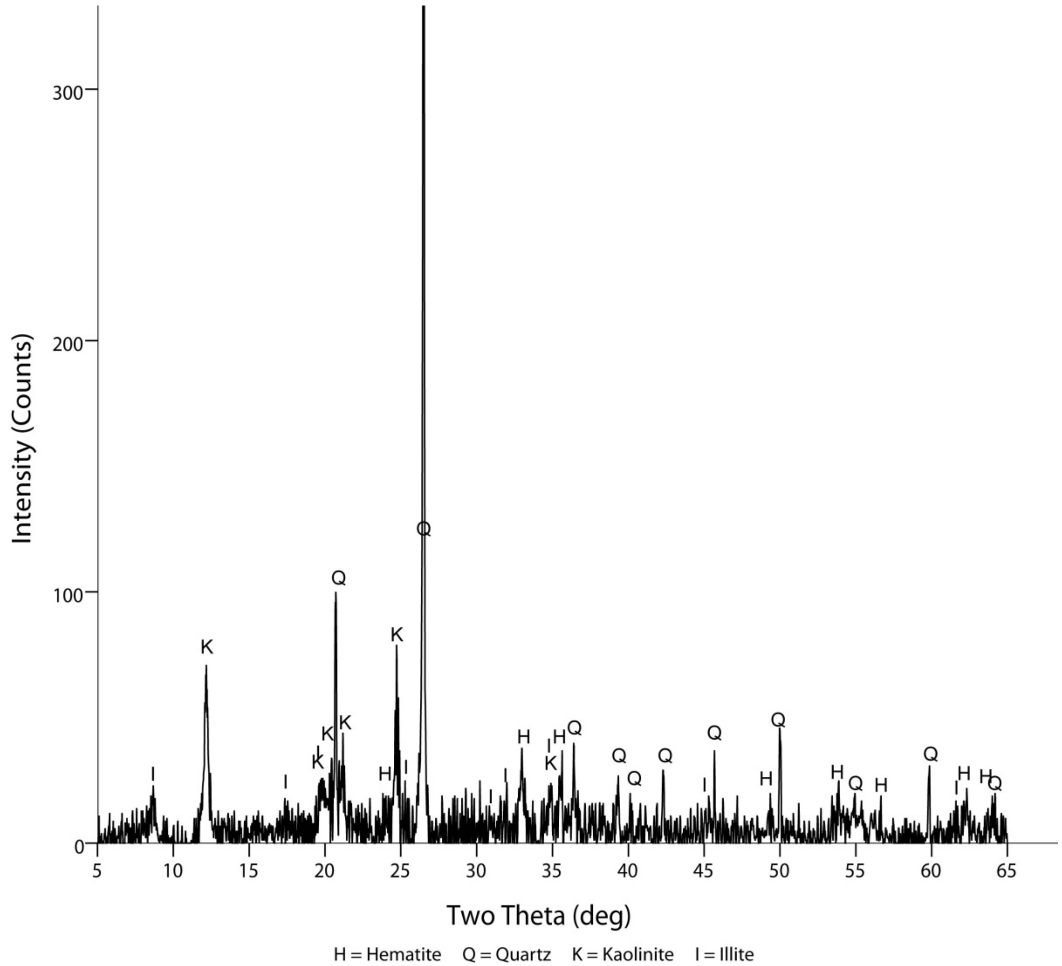


Fig. A.48. G75 Gondwana B red

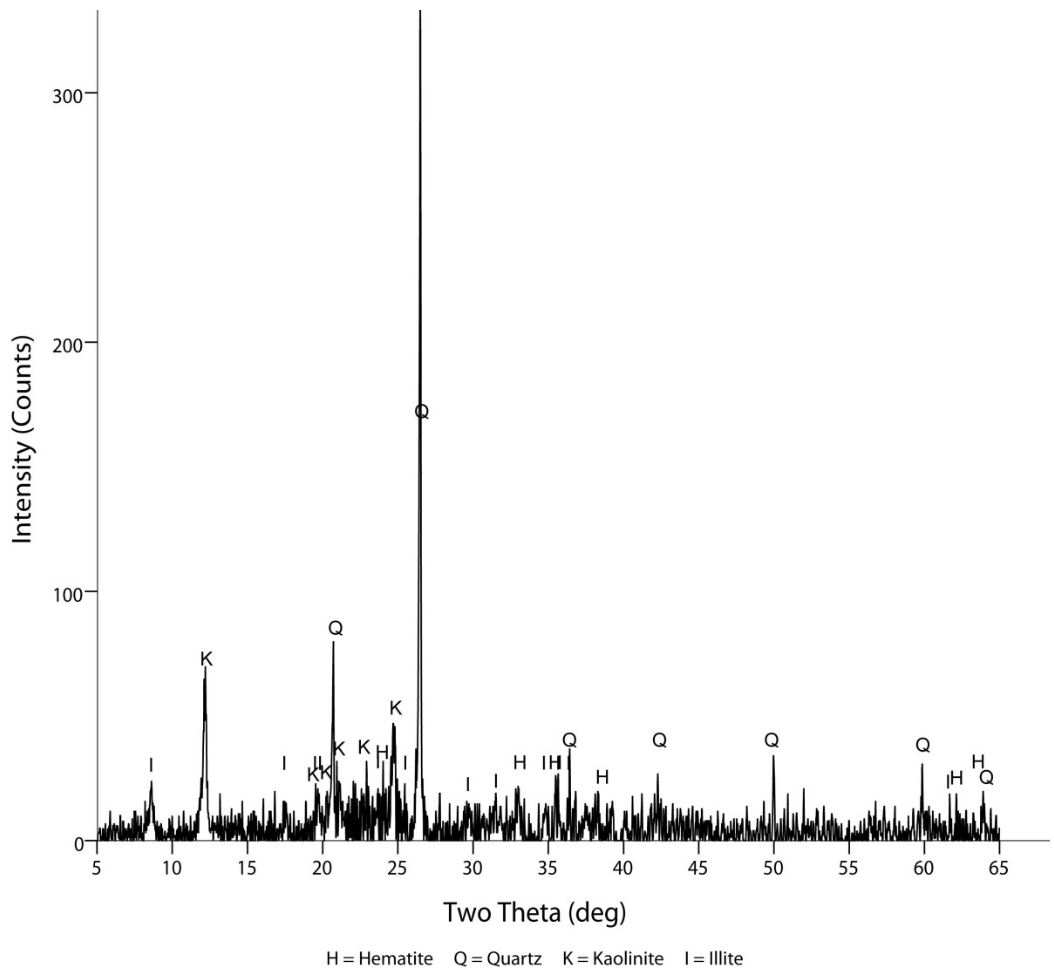


Fig. A.49. G77 Gondwana B red

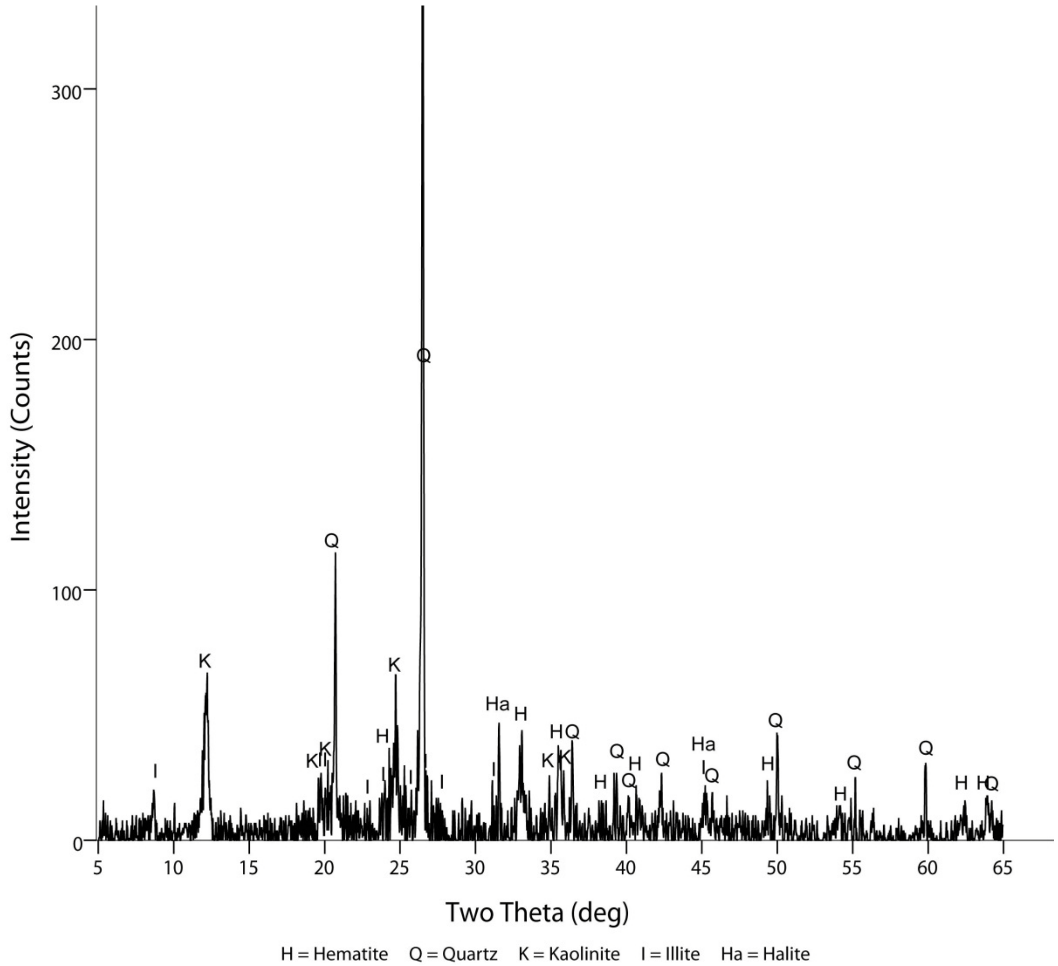


Fig. A.50. G15 Gondwana B red heated

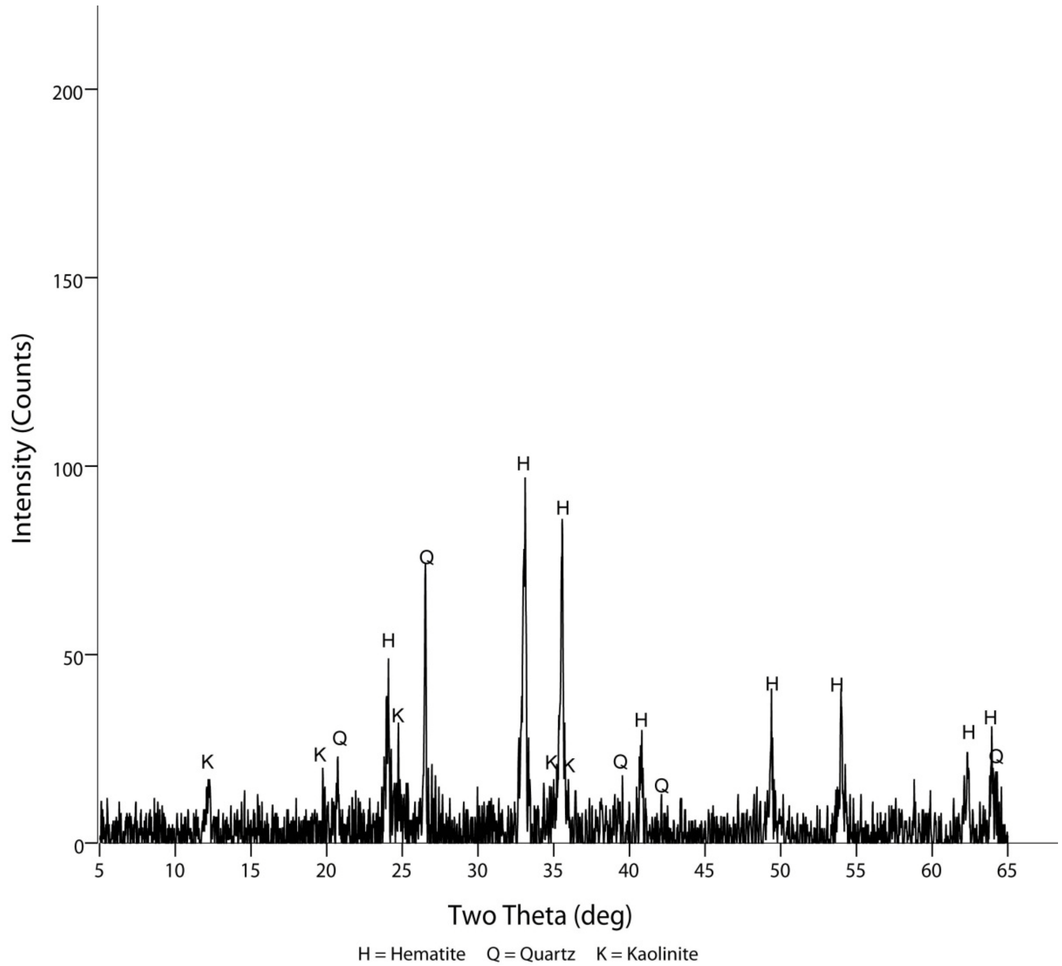


Fig. A.51. G17 Gondwana B red heated

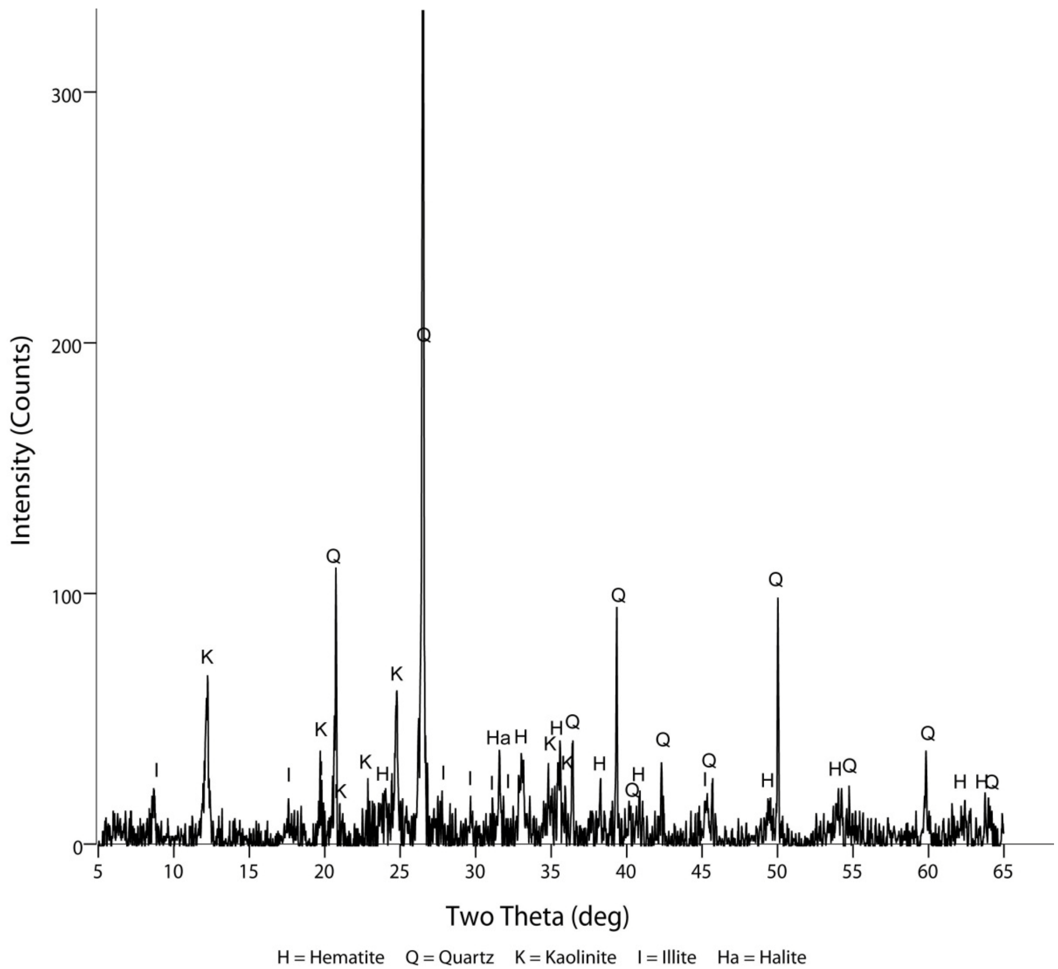


Fig. A.52. G19 Gondwana B red heated

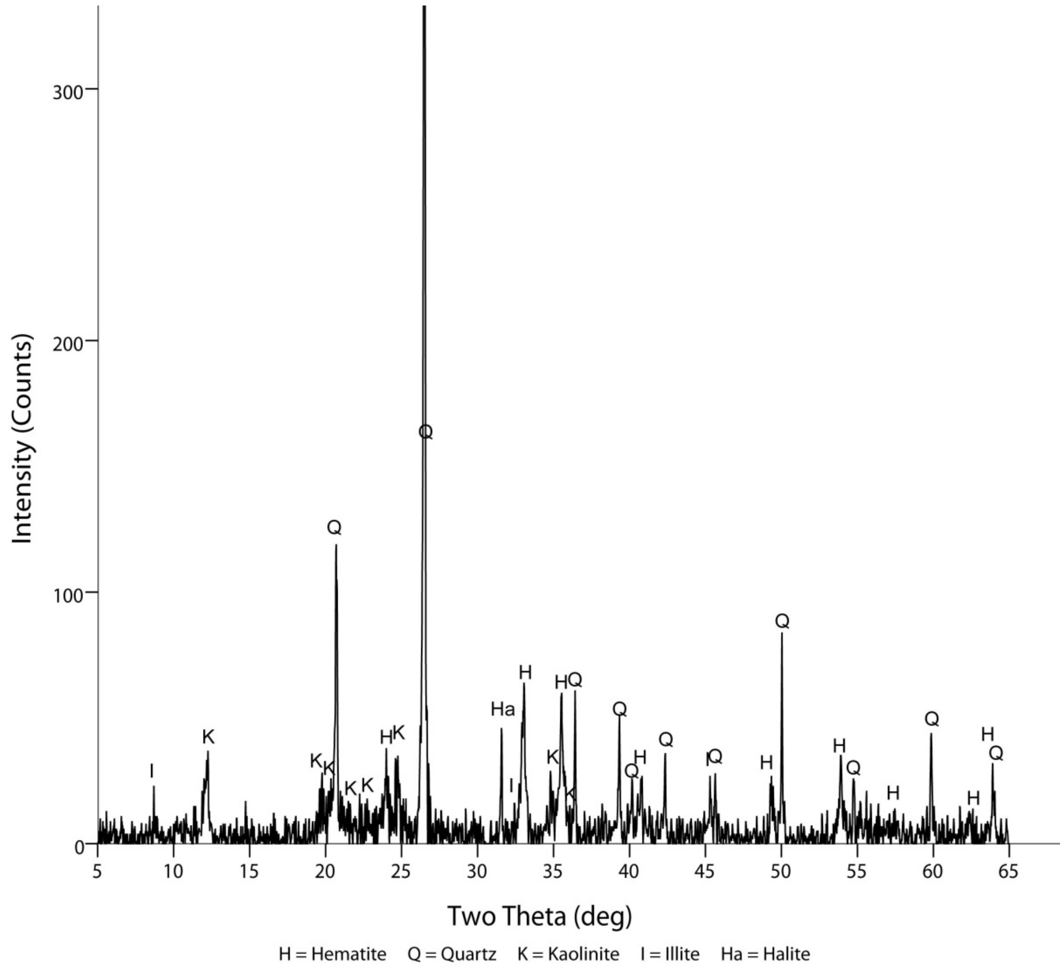


Fig. A.53. G20 Gondwana B red heated

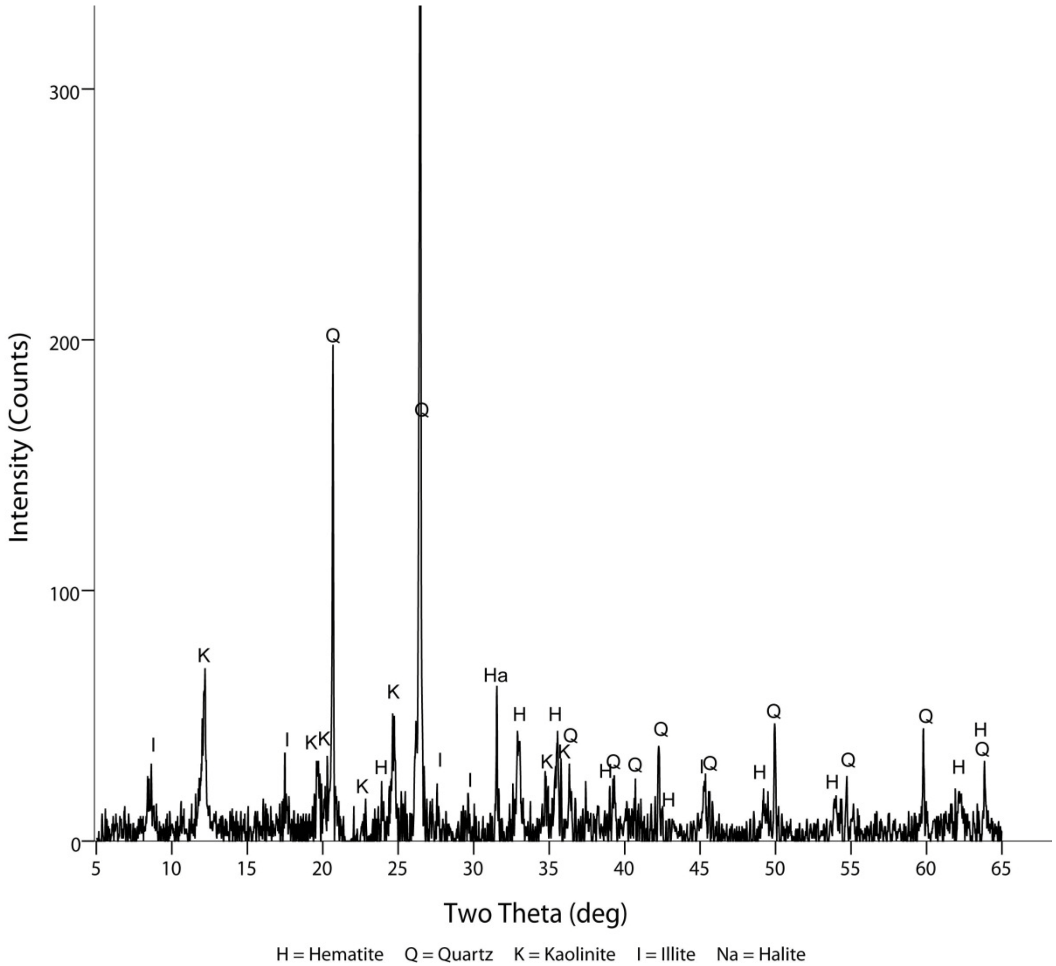


Fig. A.54. G21 Gondwana B red heated

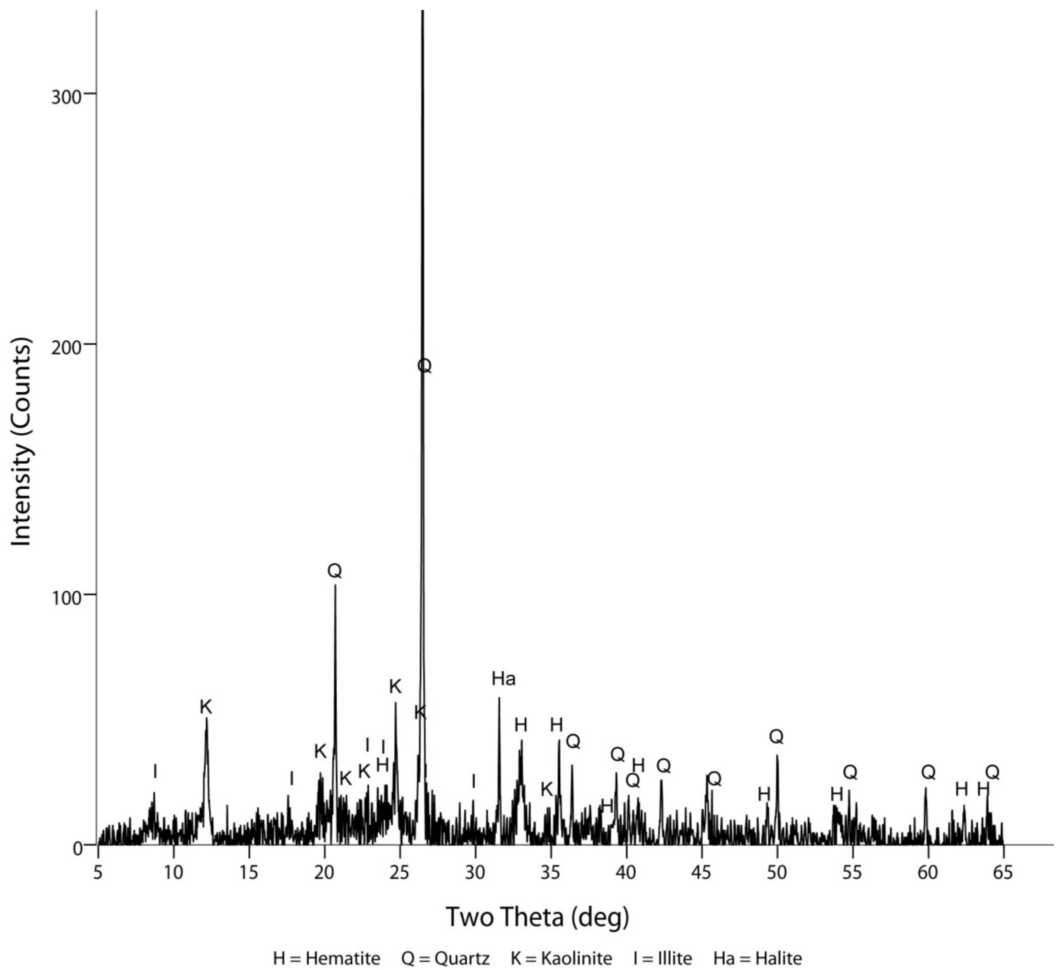


Fig. A.55. G24 Gondwana B red heated

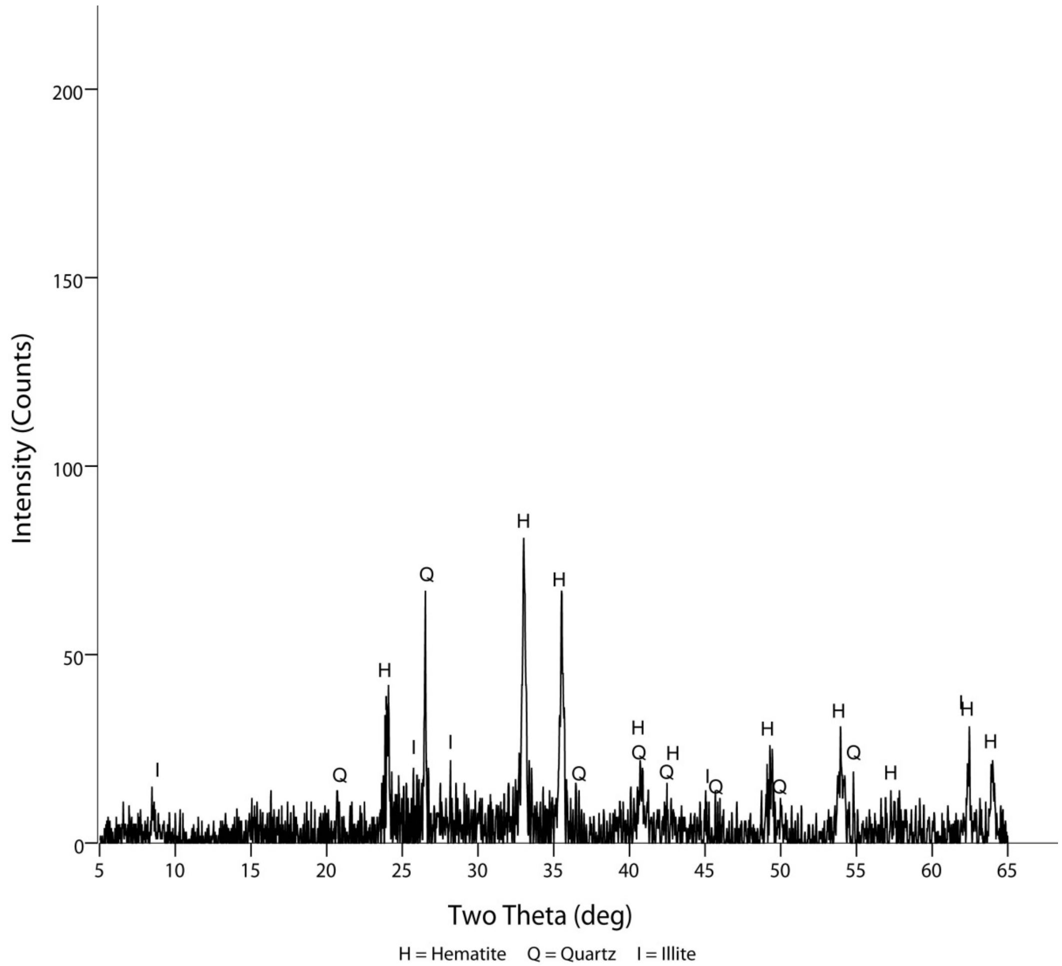


Fig. A.56. G212 Gondwana B red heated

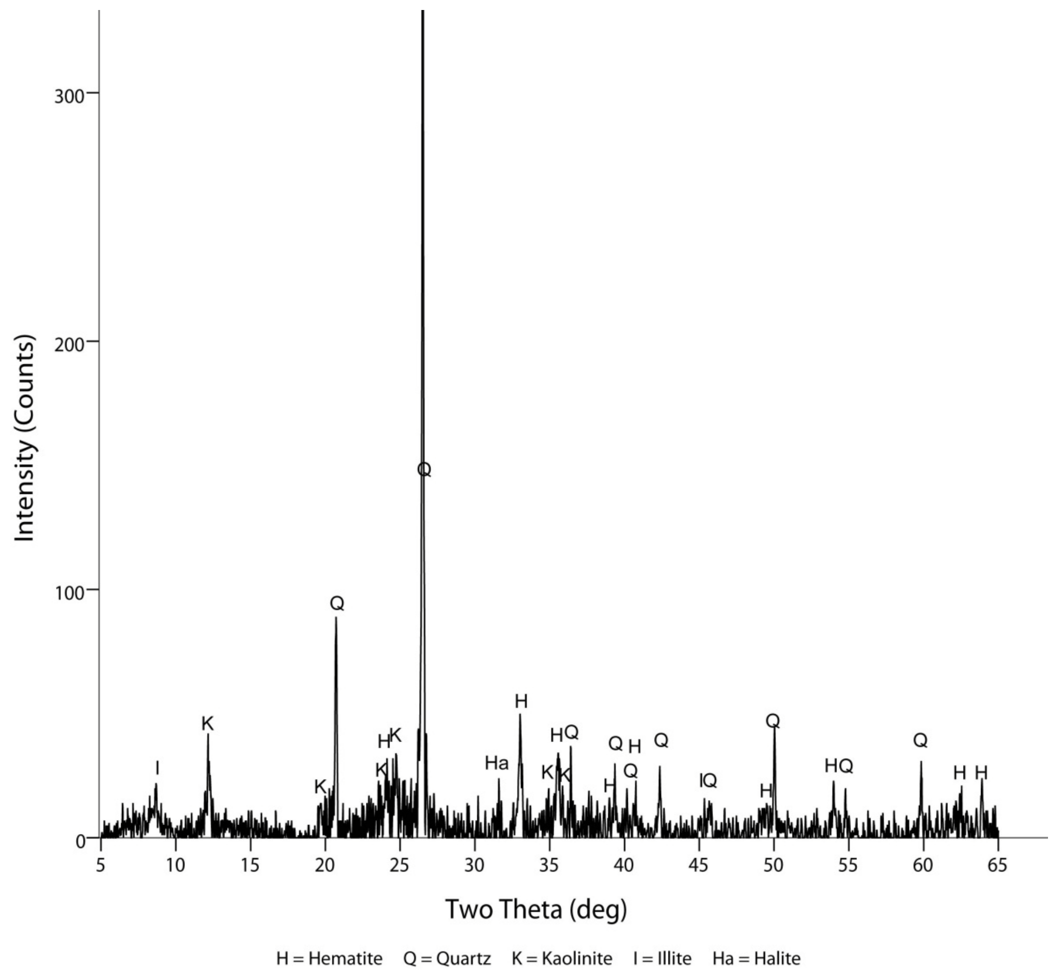


Fig. A.57. G213 Gondwana B red heated

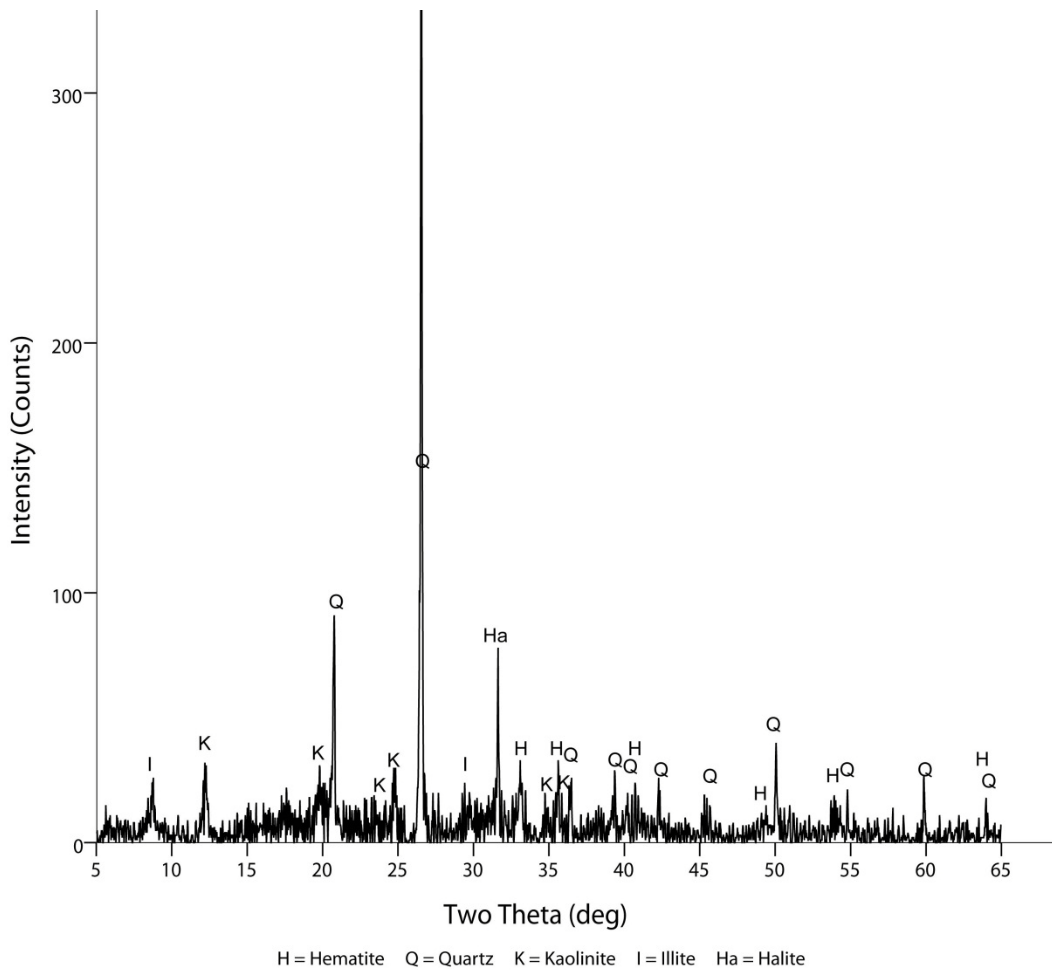


Fig. A.58. G214 Gondwana B red heated

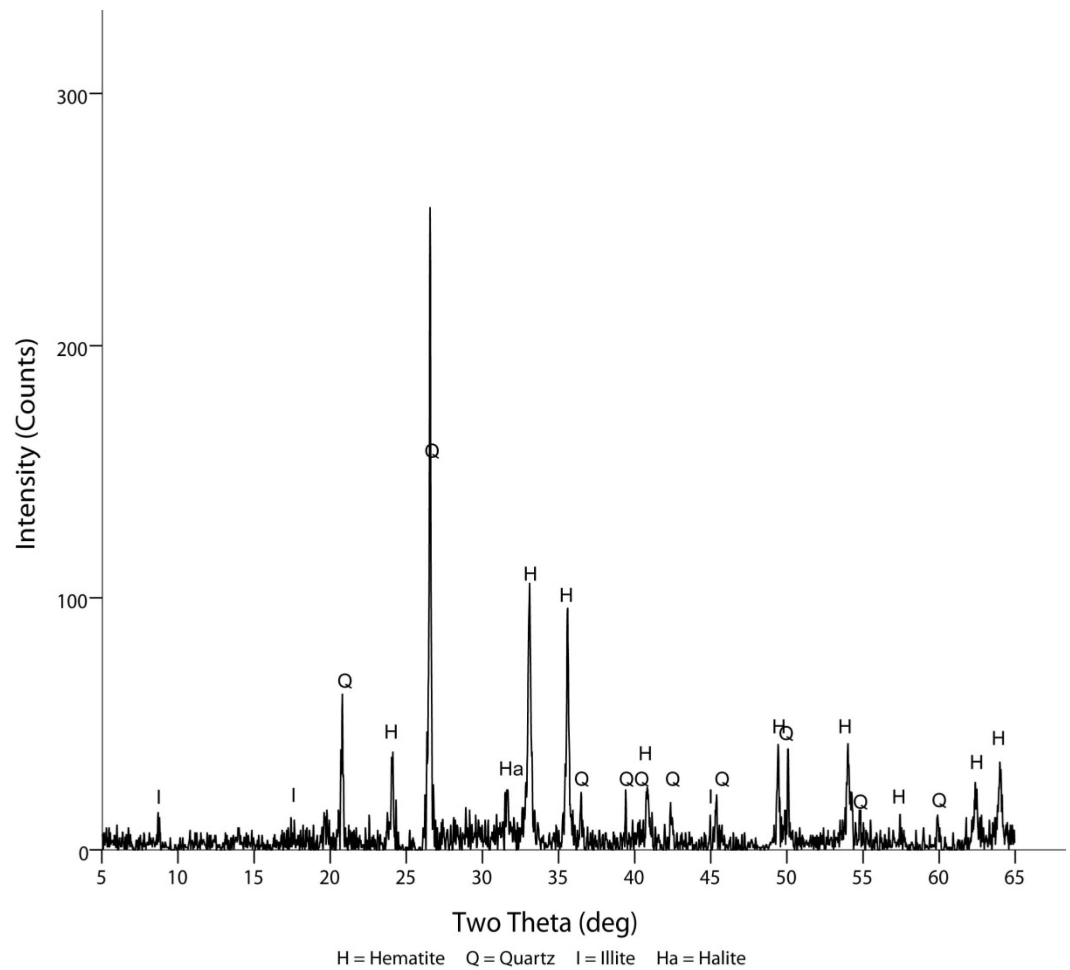


Fig. A.59. G215 Gondwana B red heated

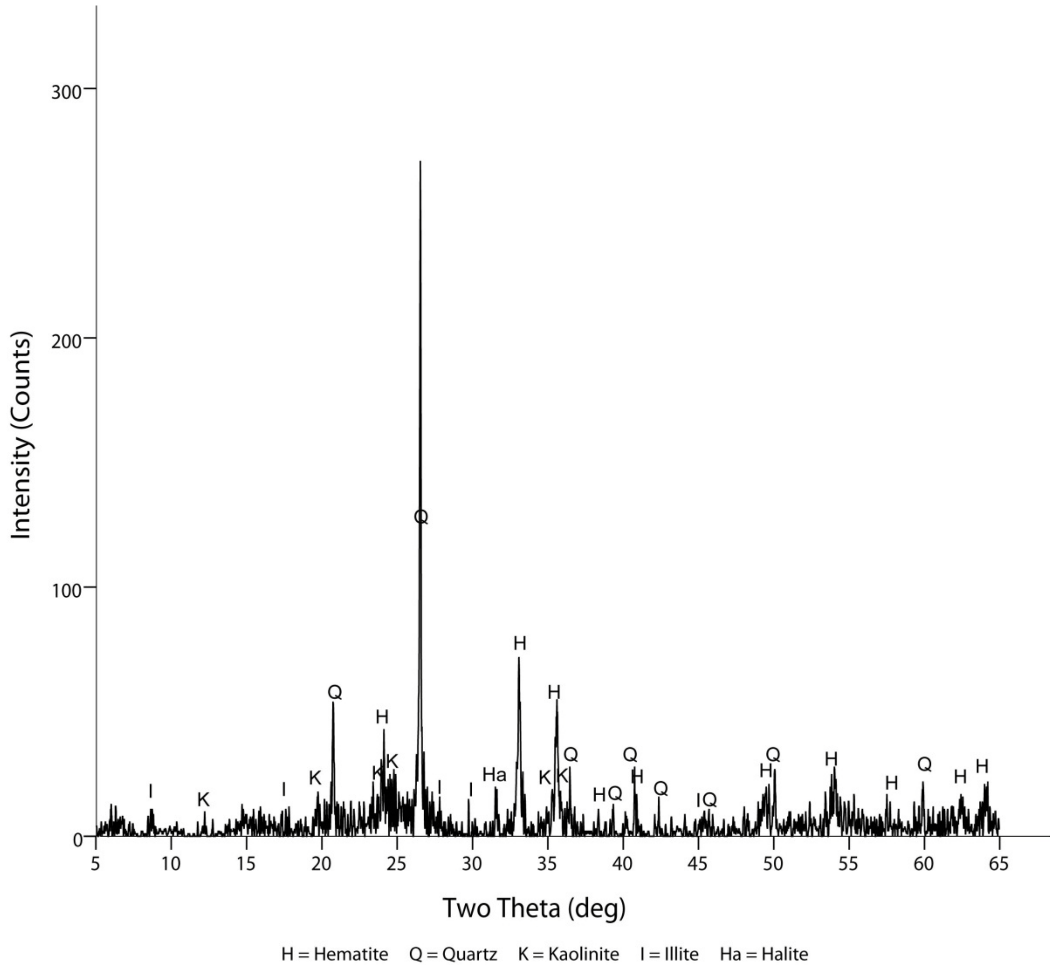


Fig. A.60. G216 Gondwana B red heated

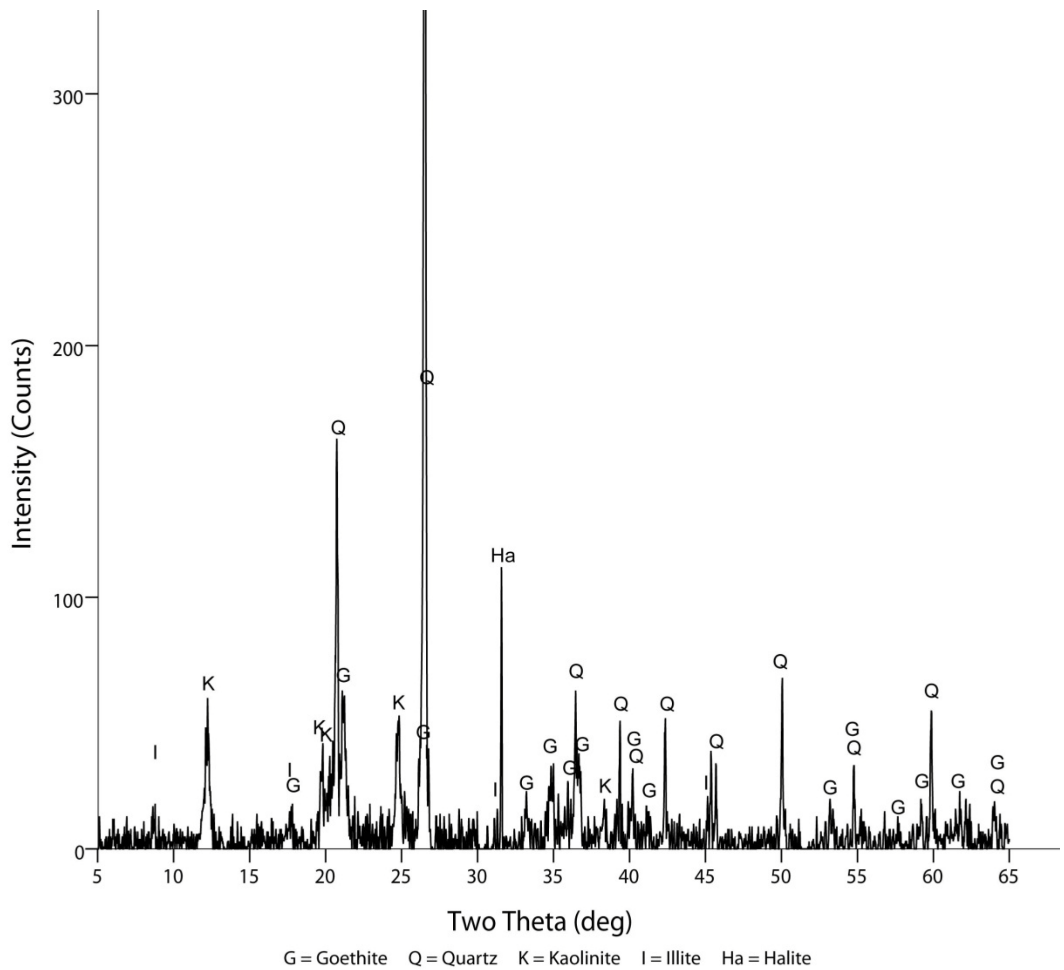


Fig. A.61. G72 Gondwana B yellow

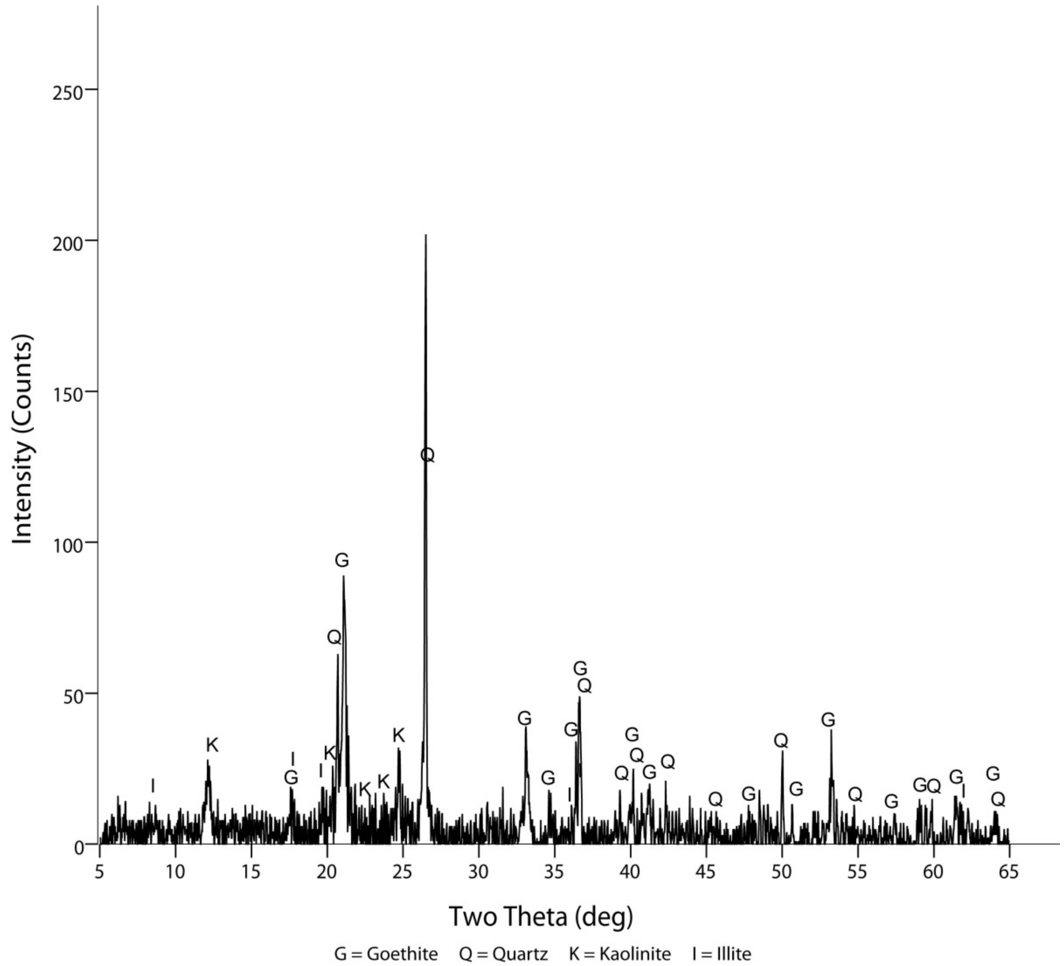


Fig. A.62. G76 Gondwana B yellow

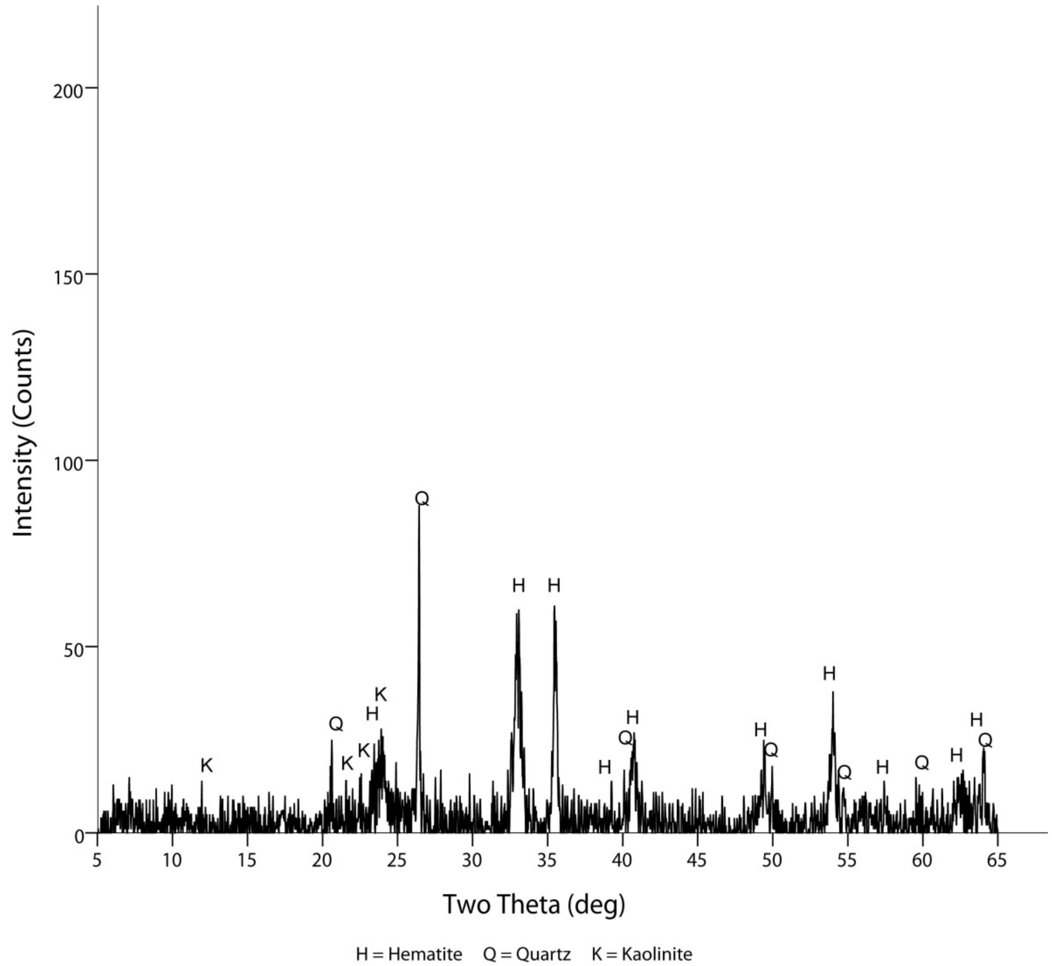


Fig. A.63. G16 Gondwana B yellow heated

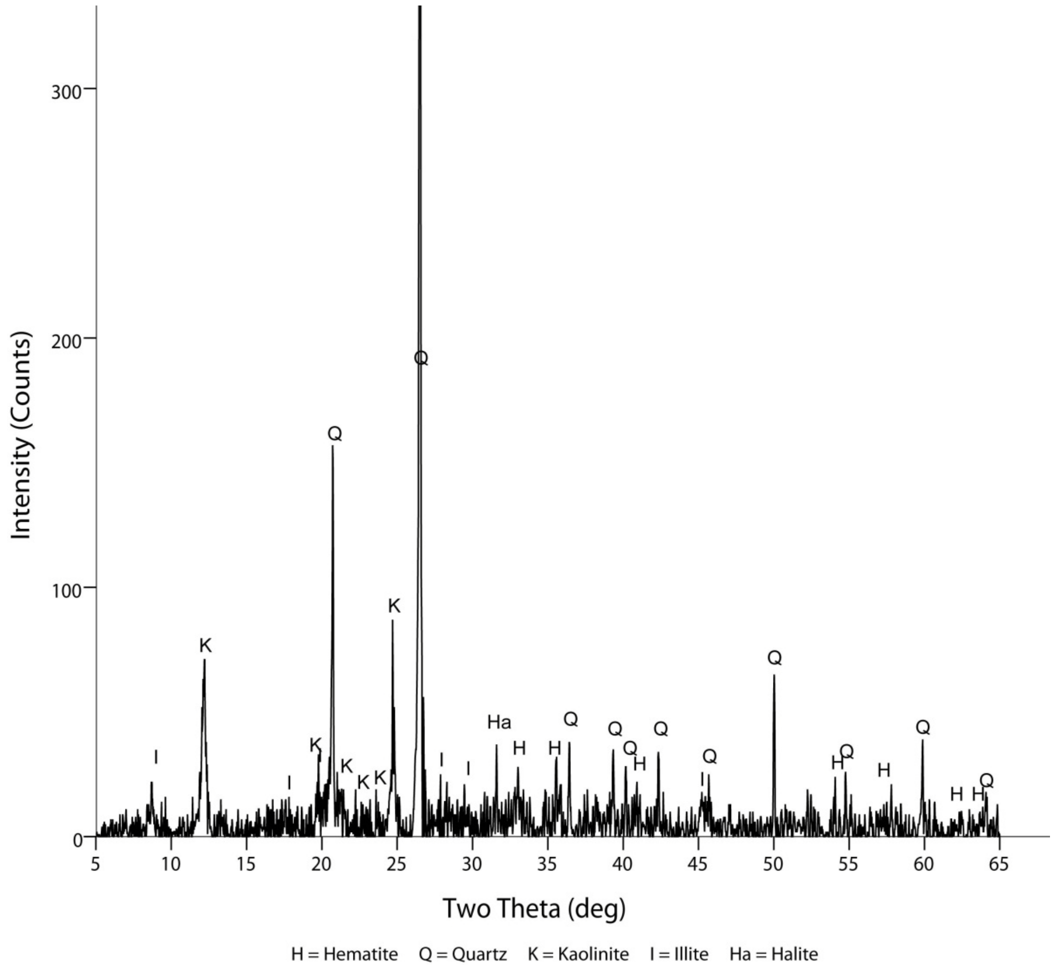


Fig. A.64. G18 Gondwana B yellow heated

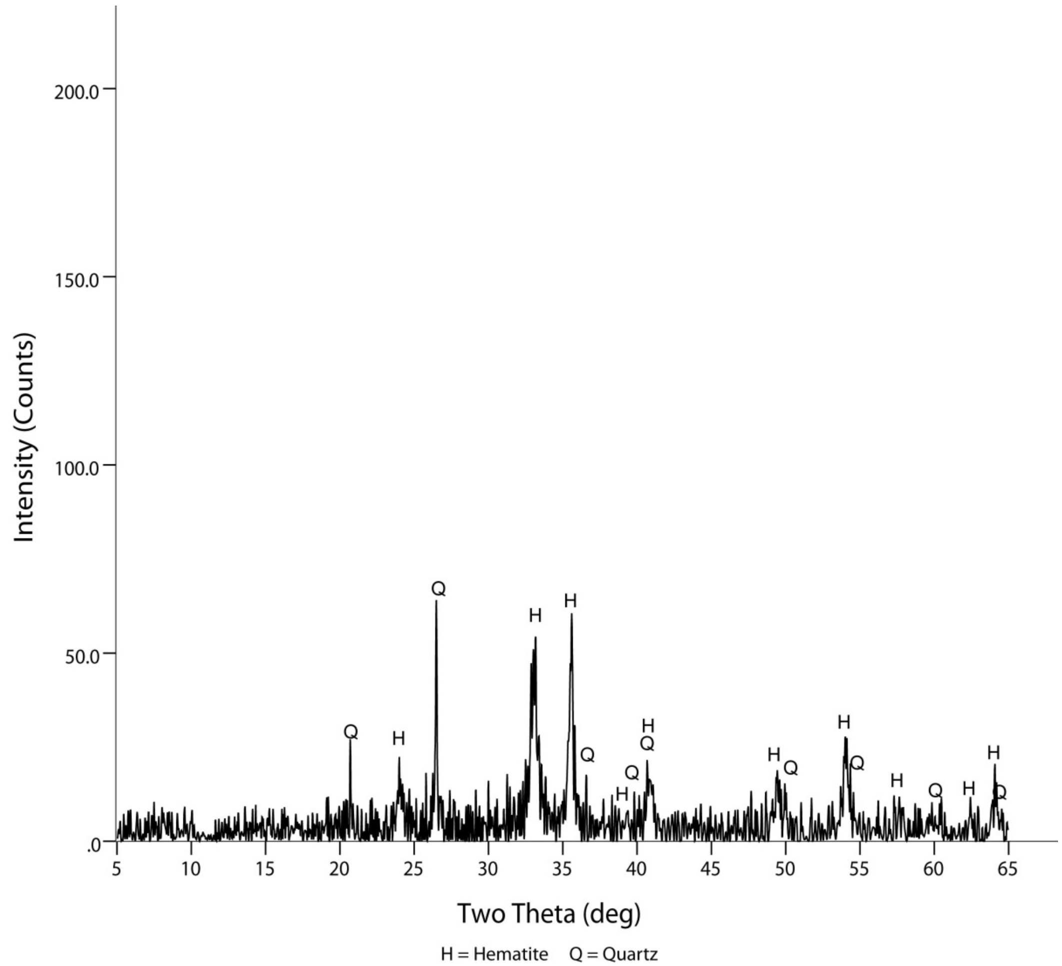


Fig. A.65. G22 Gondwana B yellow heated

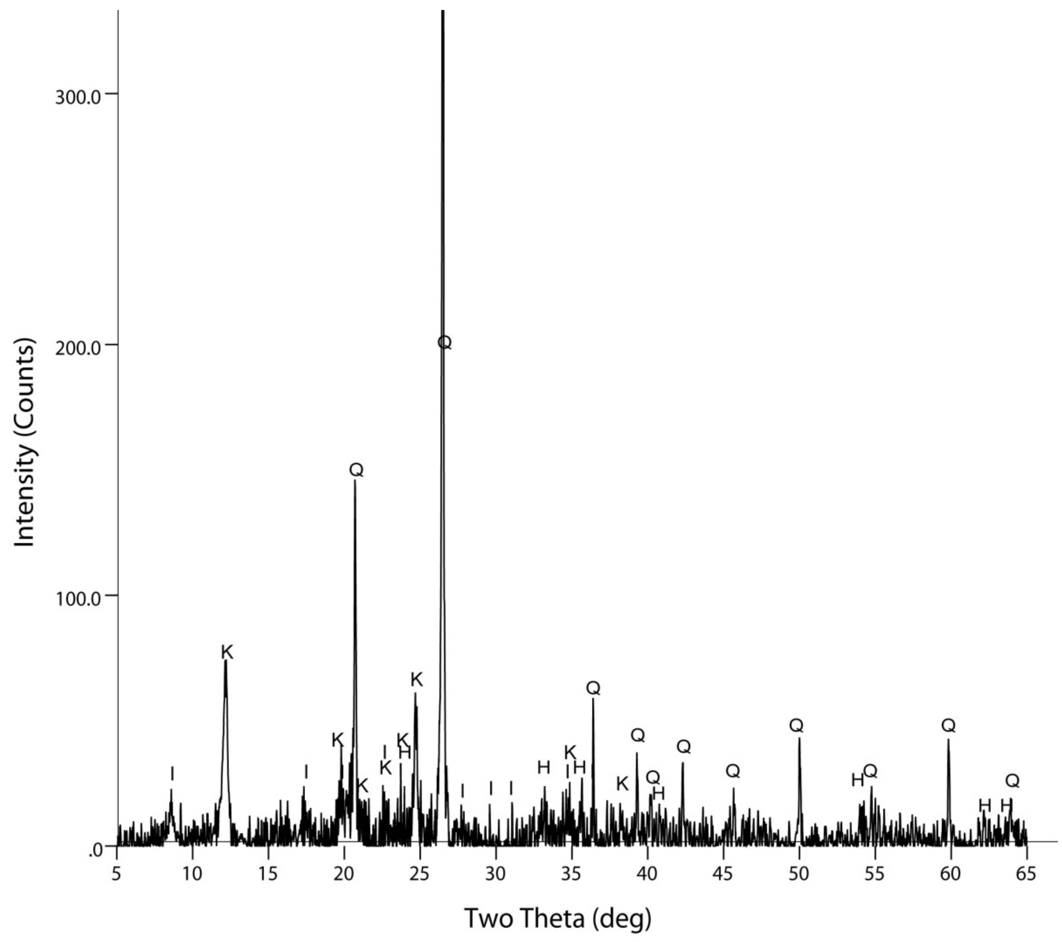


Fig. A.66. G23 Gondwana B yellow heated

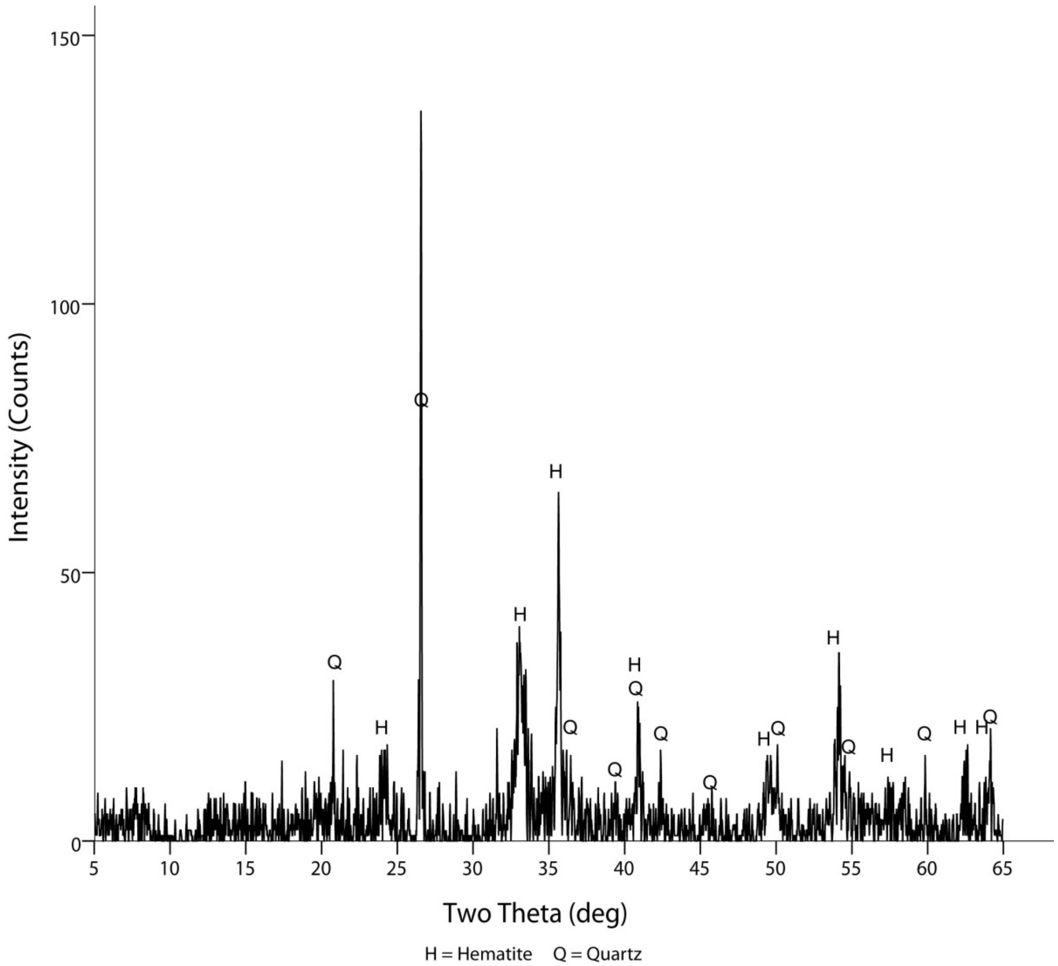


Fig. A.67. G210 Gondwana B yellow heated

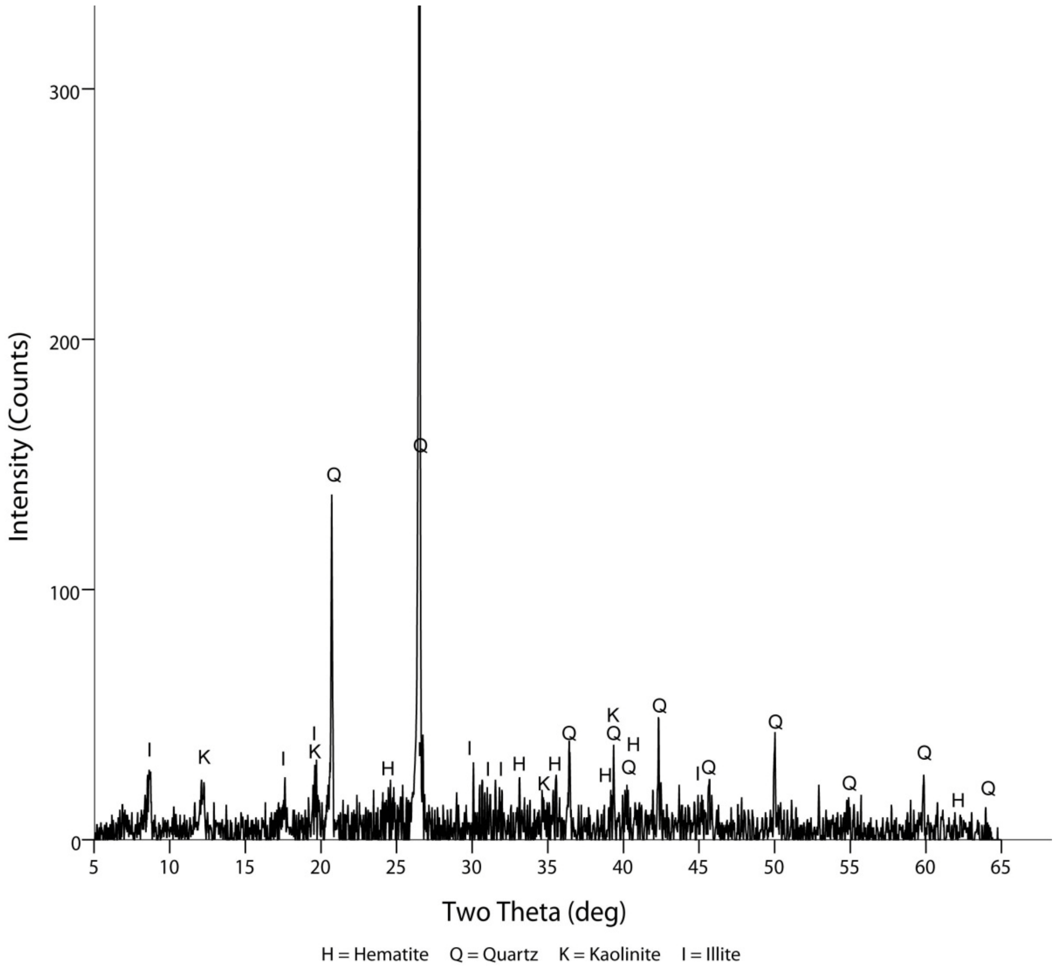


Fig. A.68. G211 Gondwana B yellow heated

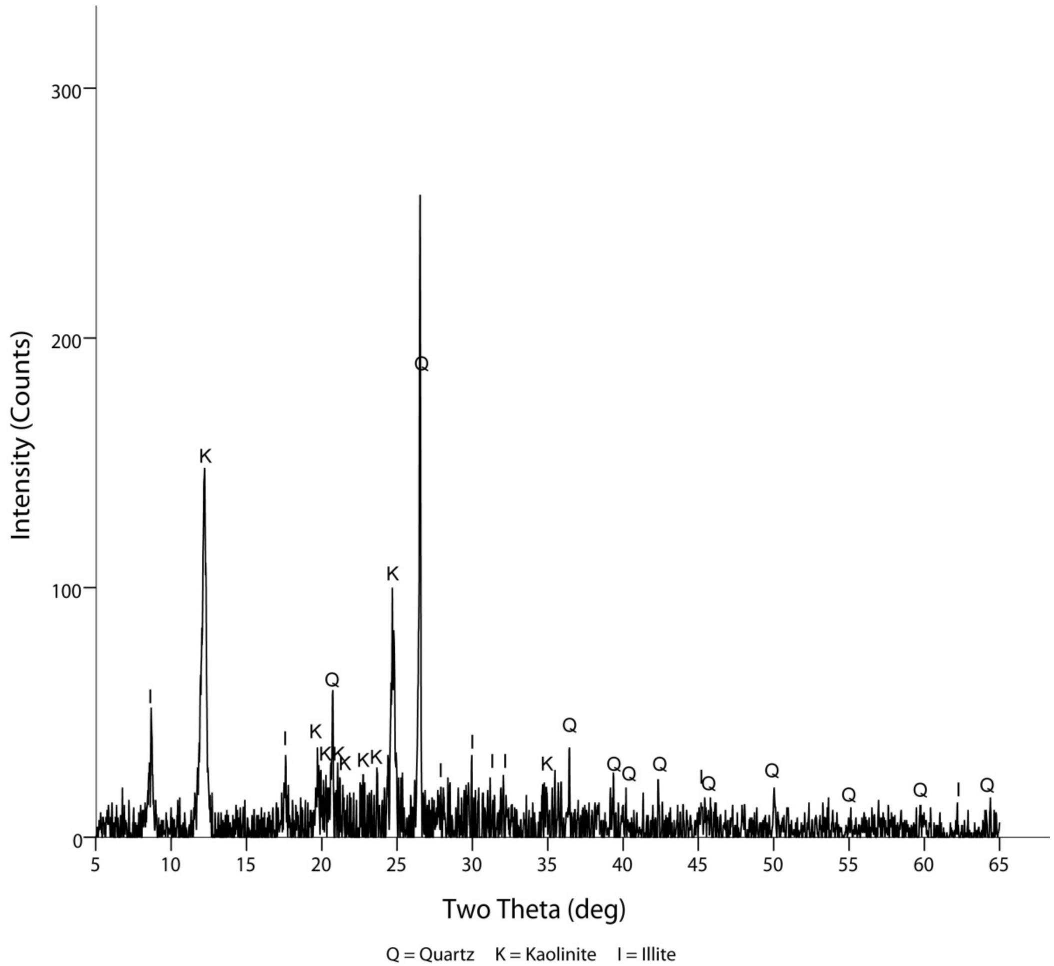


Fig. A.69. G78 Gondwana C white

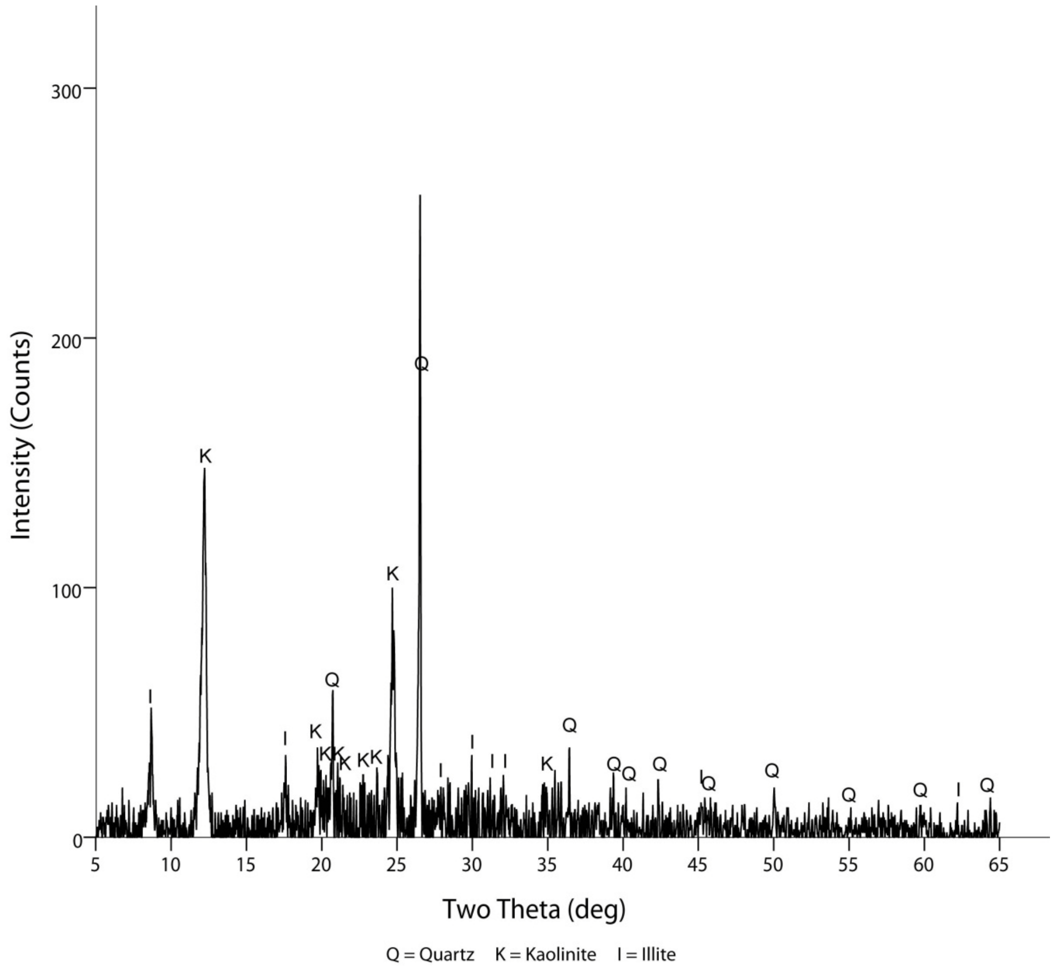


Fig. A.70. G25 Gondwana C white heated

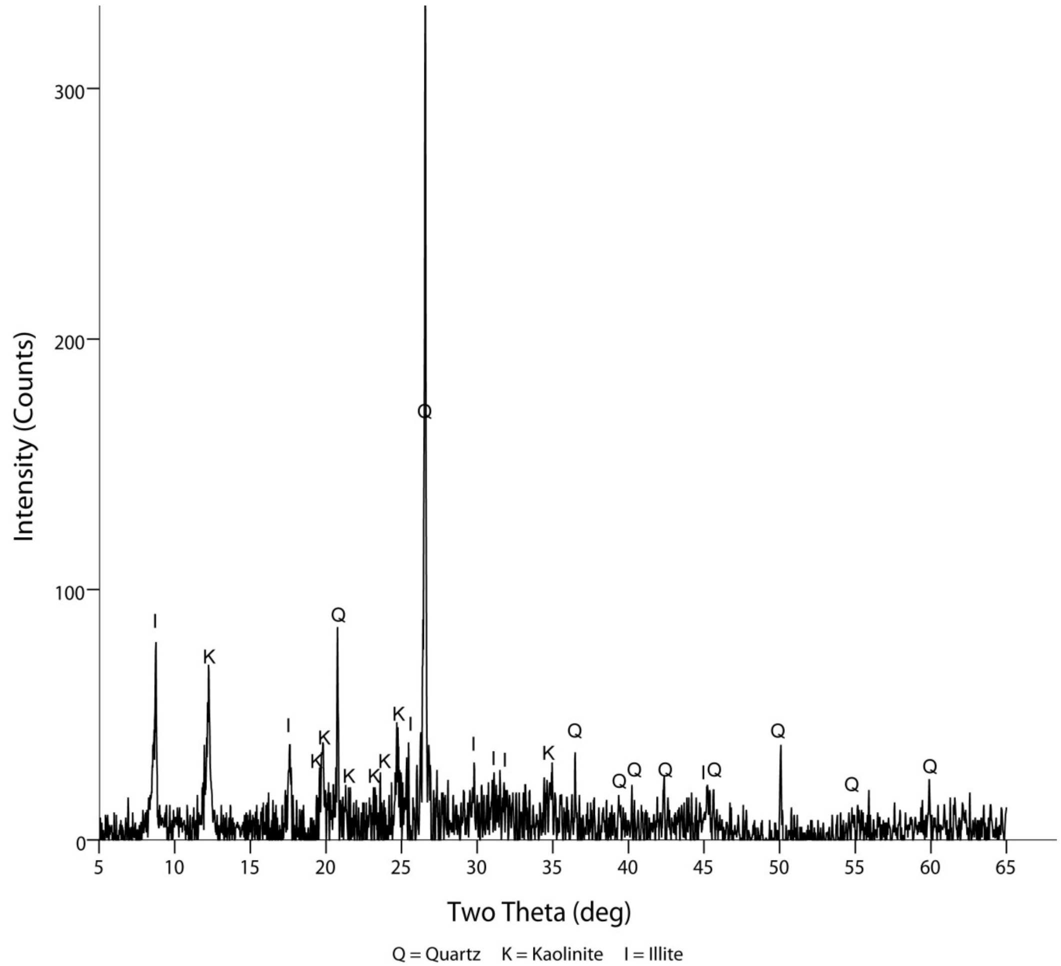


Fig. A.71. G256 Gondwana C white heated

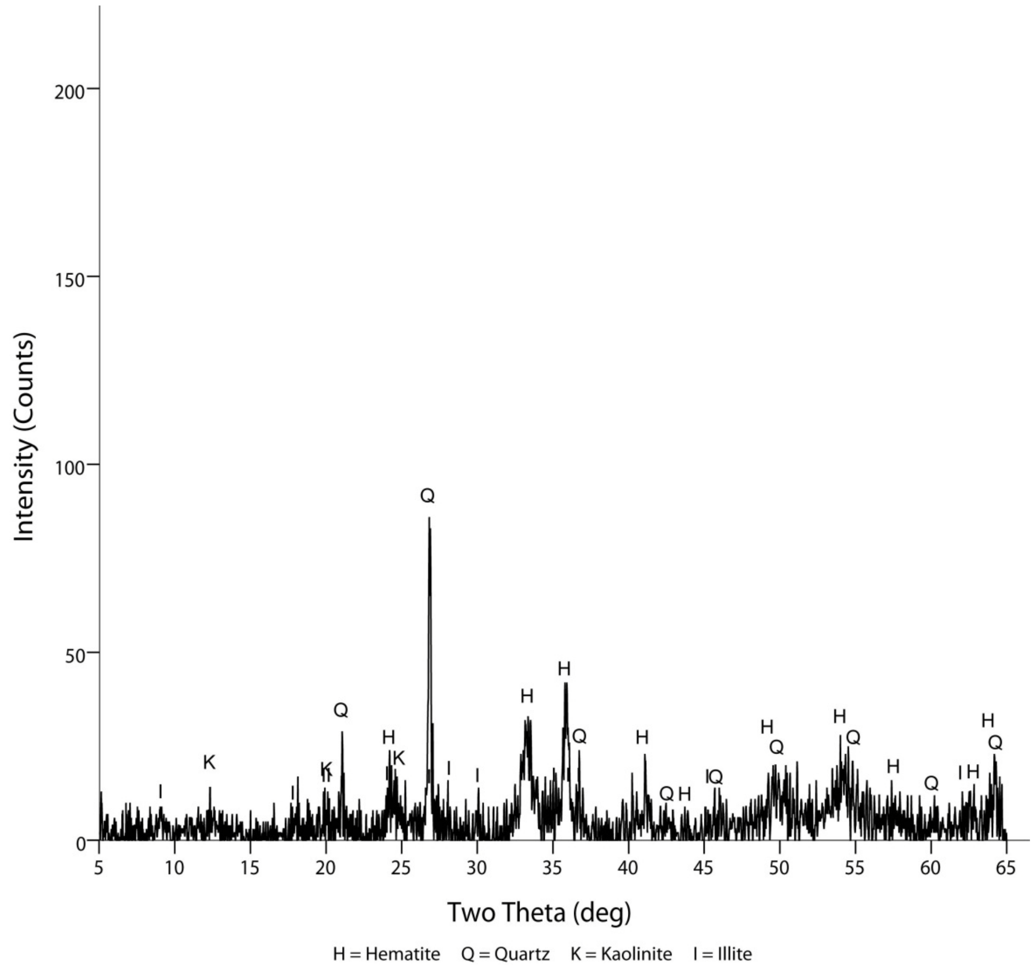


Fig. A.72. G124 Gondwana D red

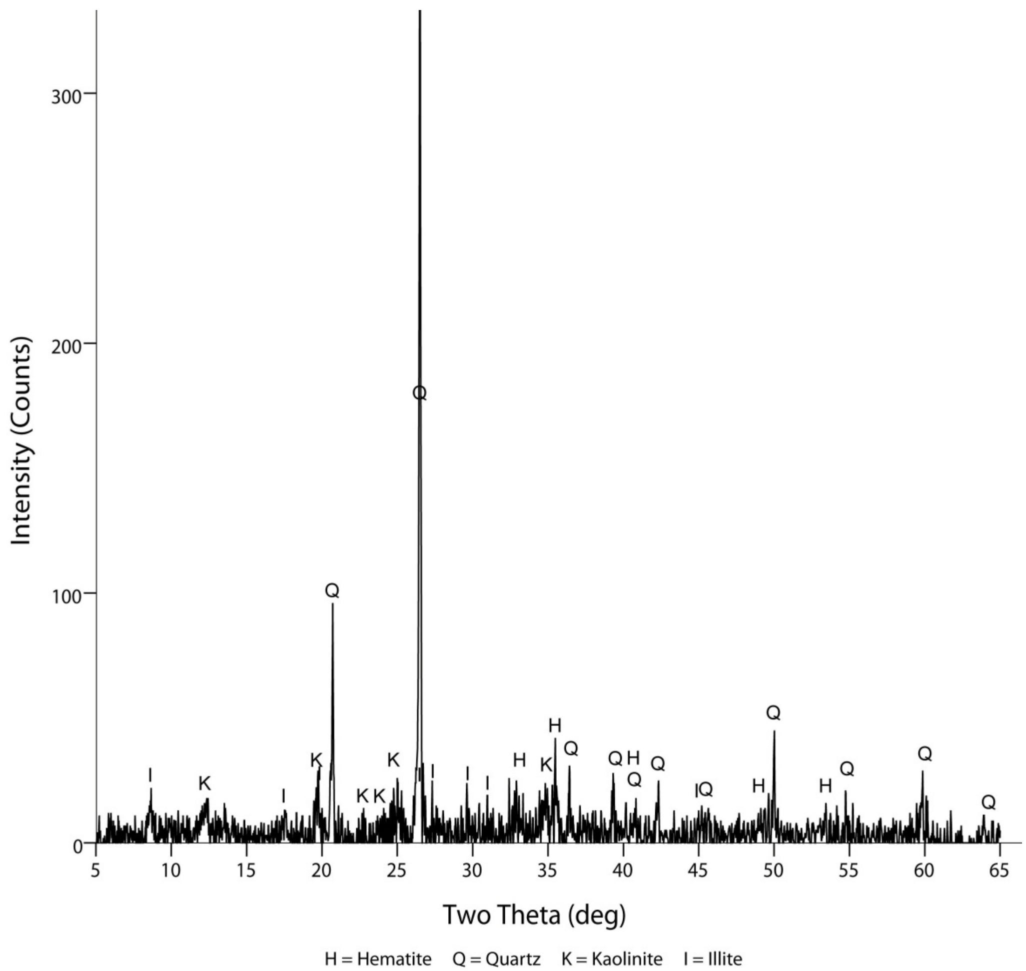


Fig. A.73. G126 Gondwana D red

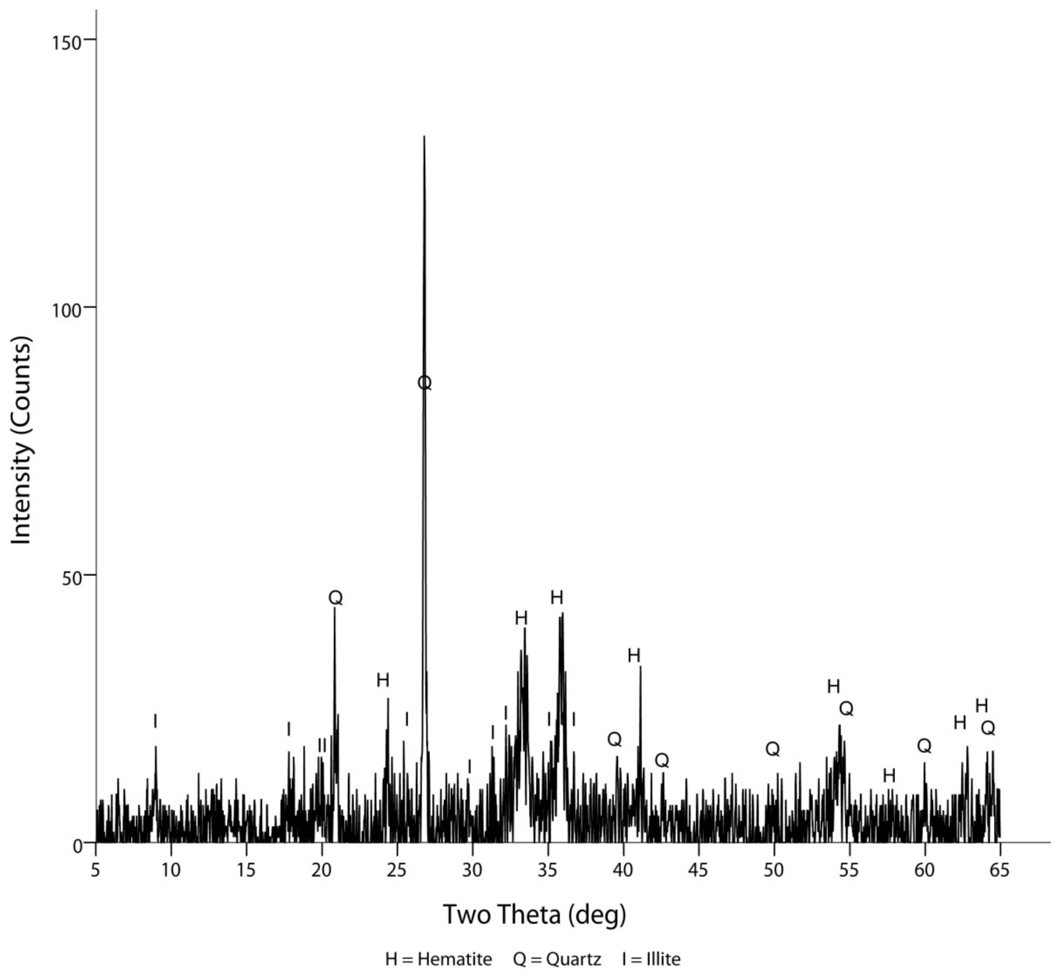


Fig. A.74. G125 Gondwana D red heated

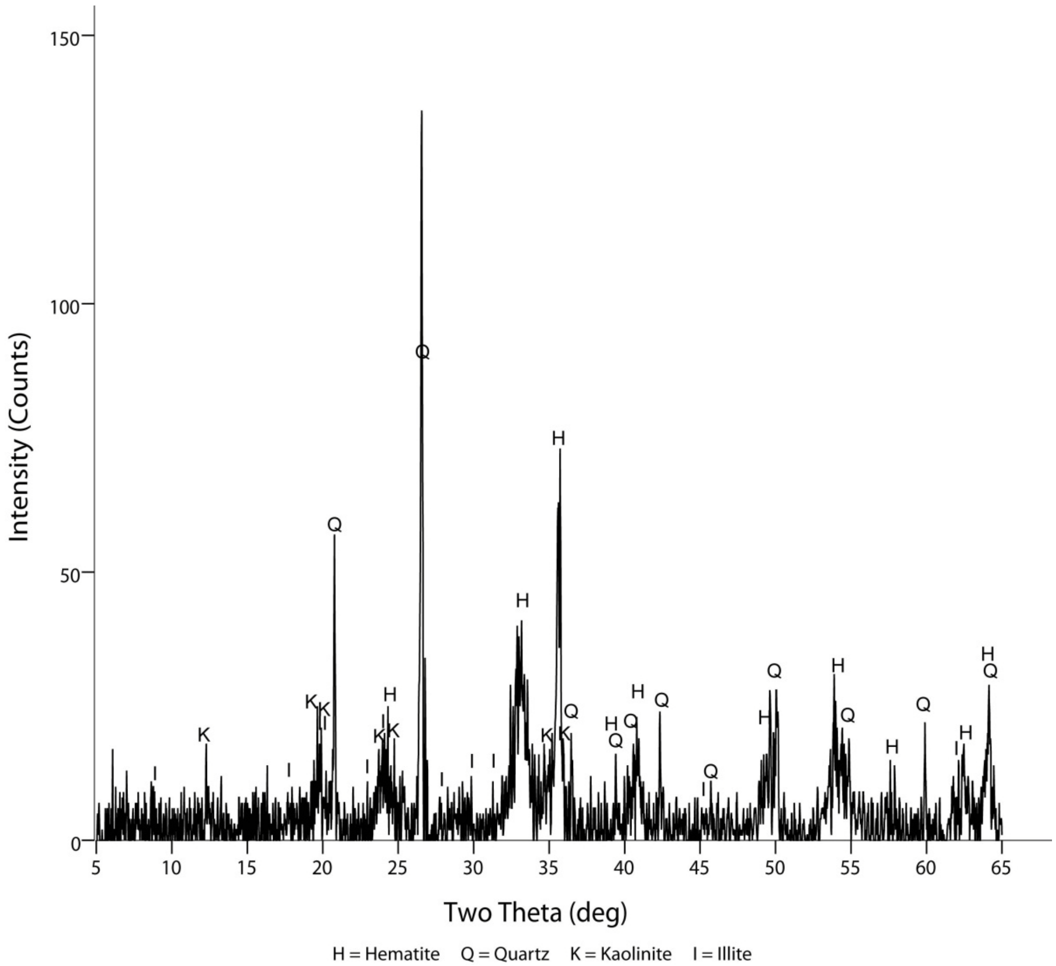


Fig. A.75. G127 Gondwana D red heated

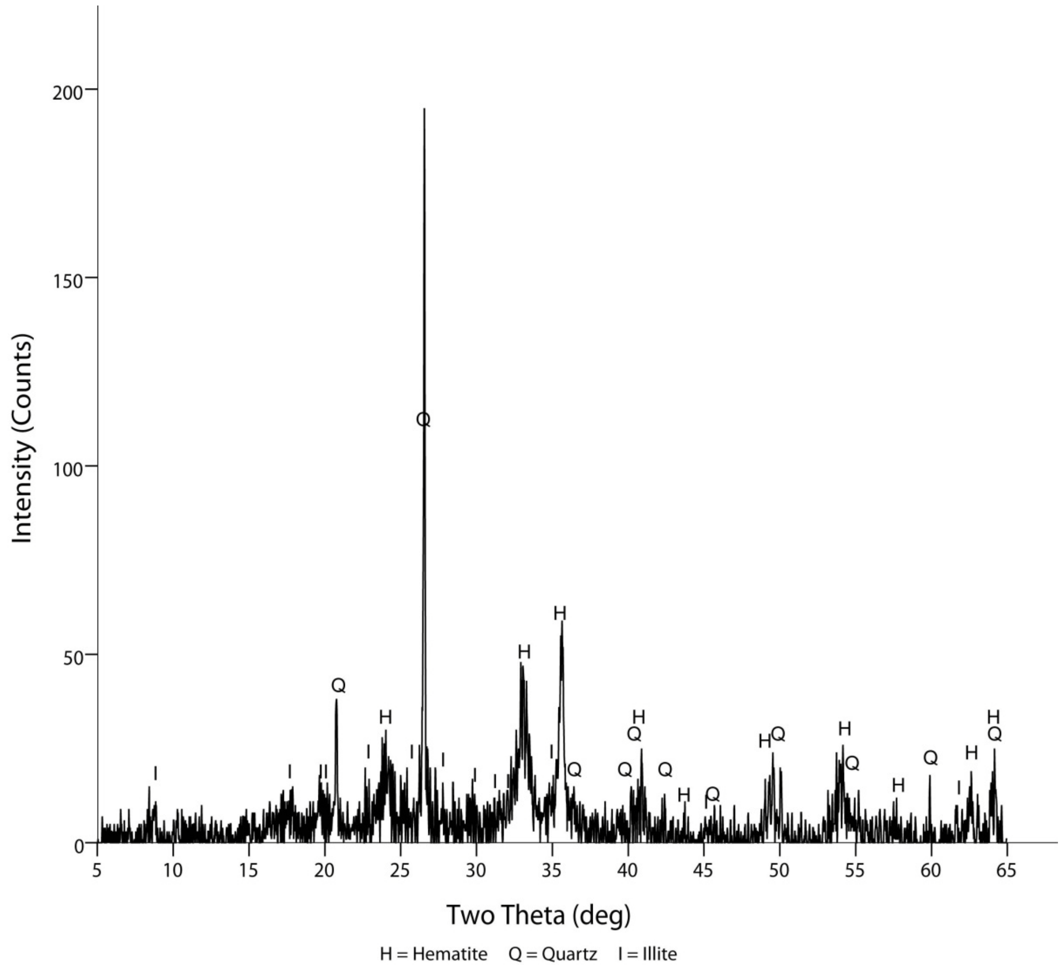


Fig. A.76. G232 Gondwana D red heated

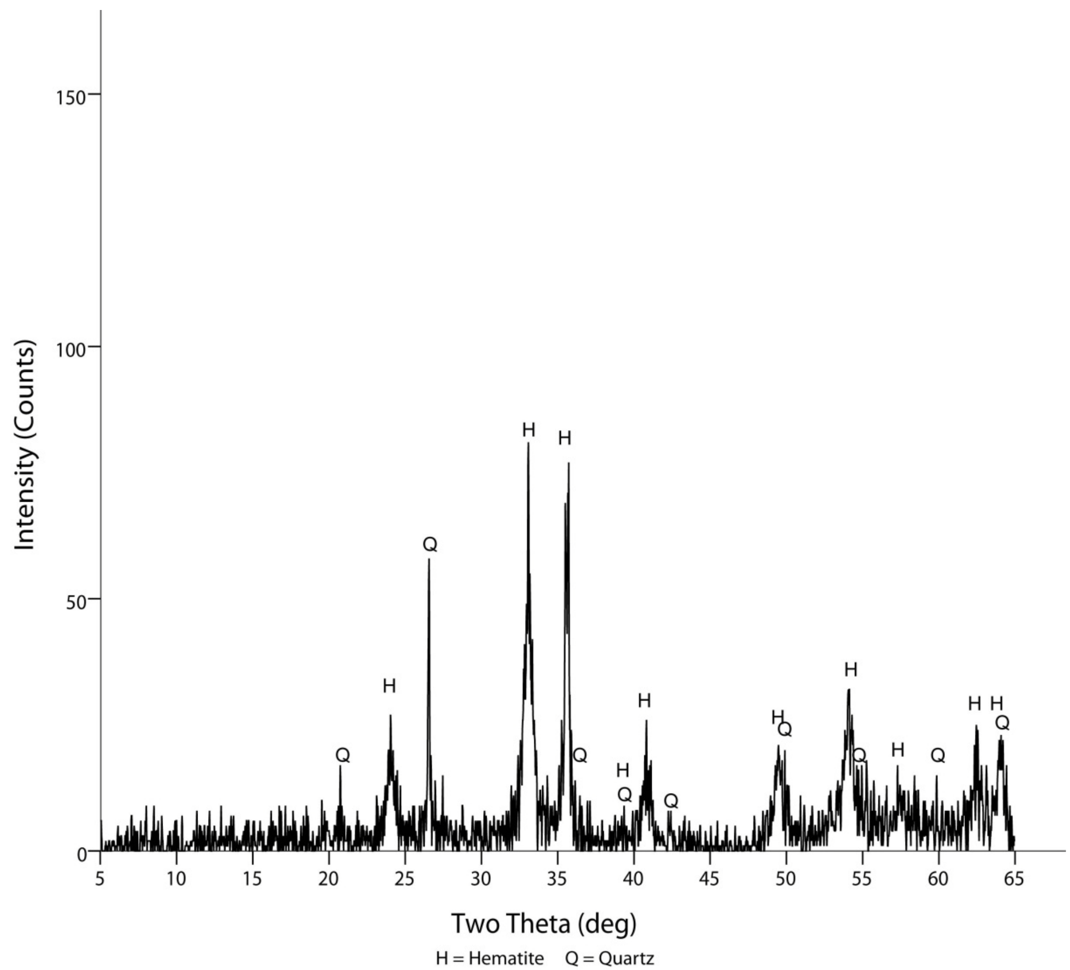


Fig. A.77. G233 Gondwana D red heated

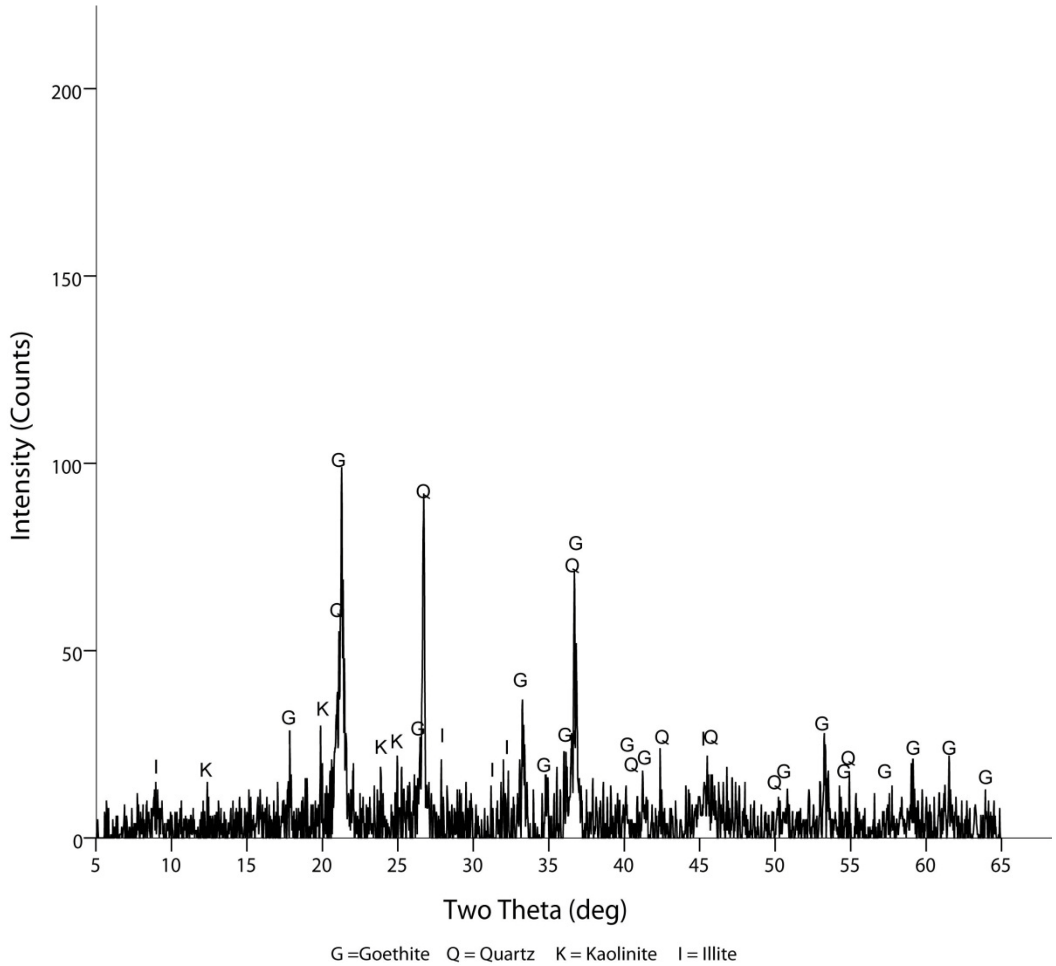


Fig. A.78. G122 Gondwana D yellow

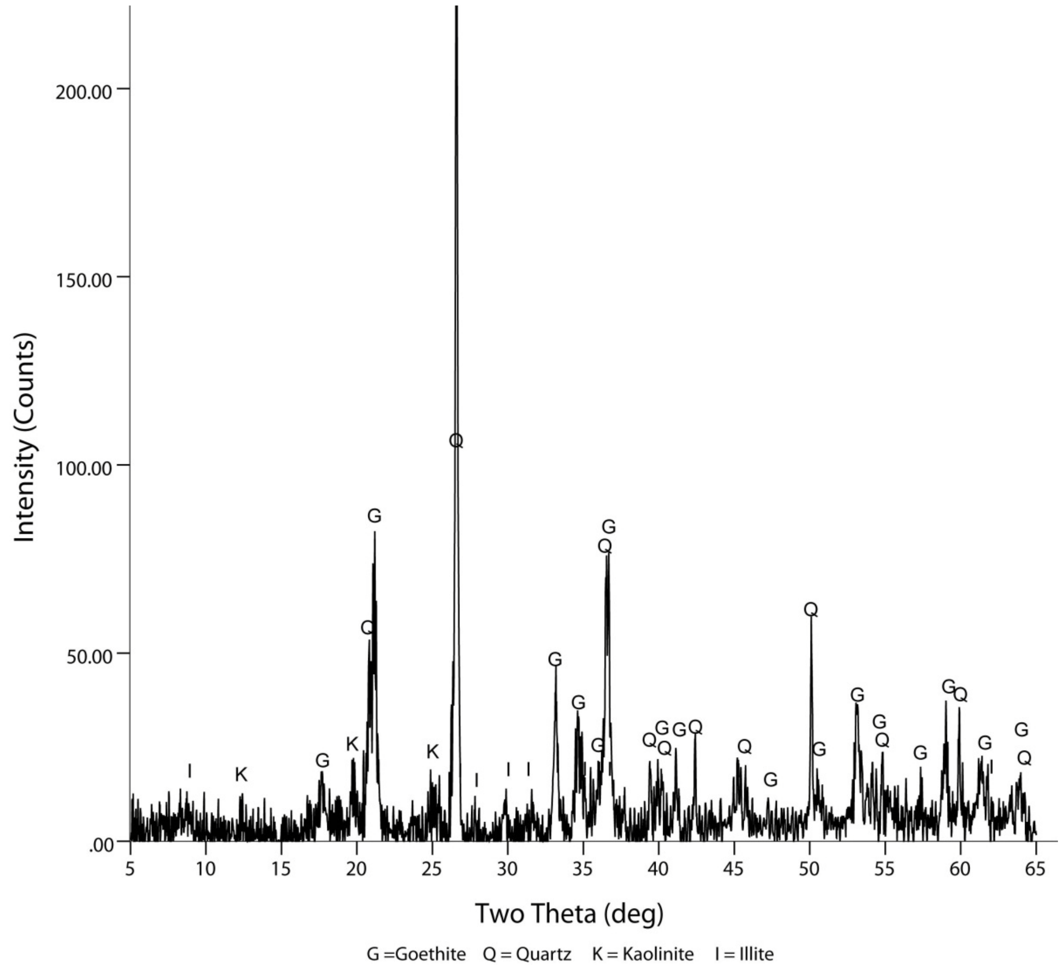


Fig. A.79. G128 Gondwana D yellow

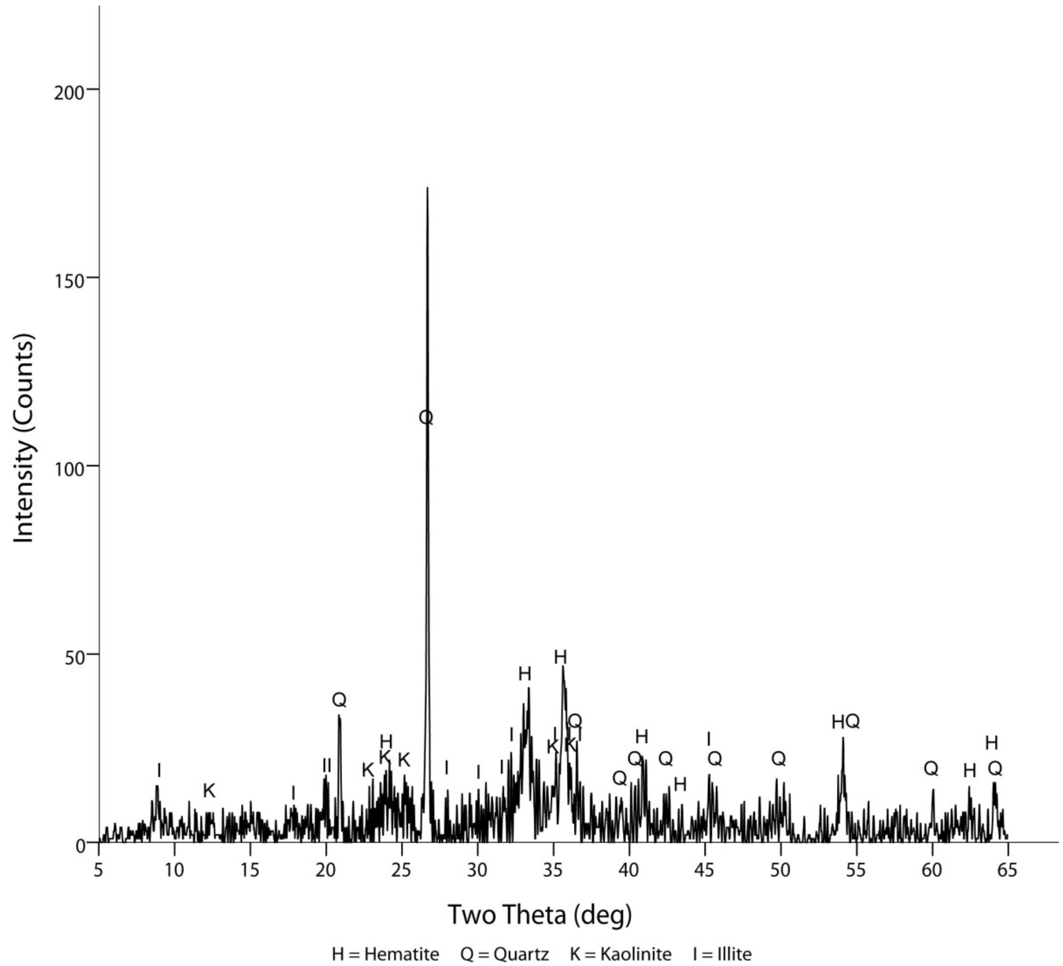


Fig. A.80. G123 Gondwana D yellow heated

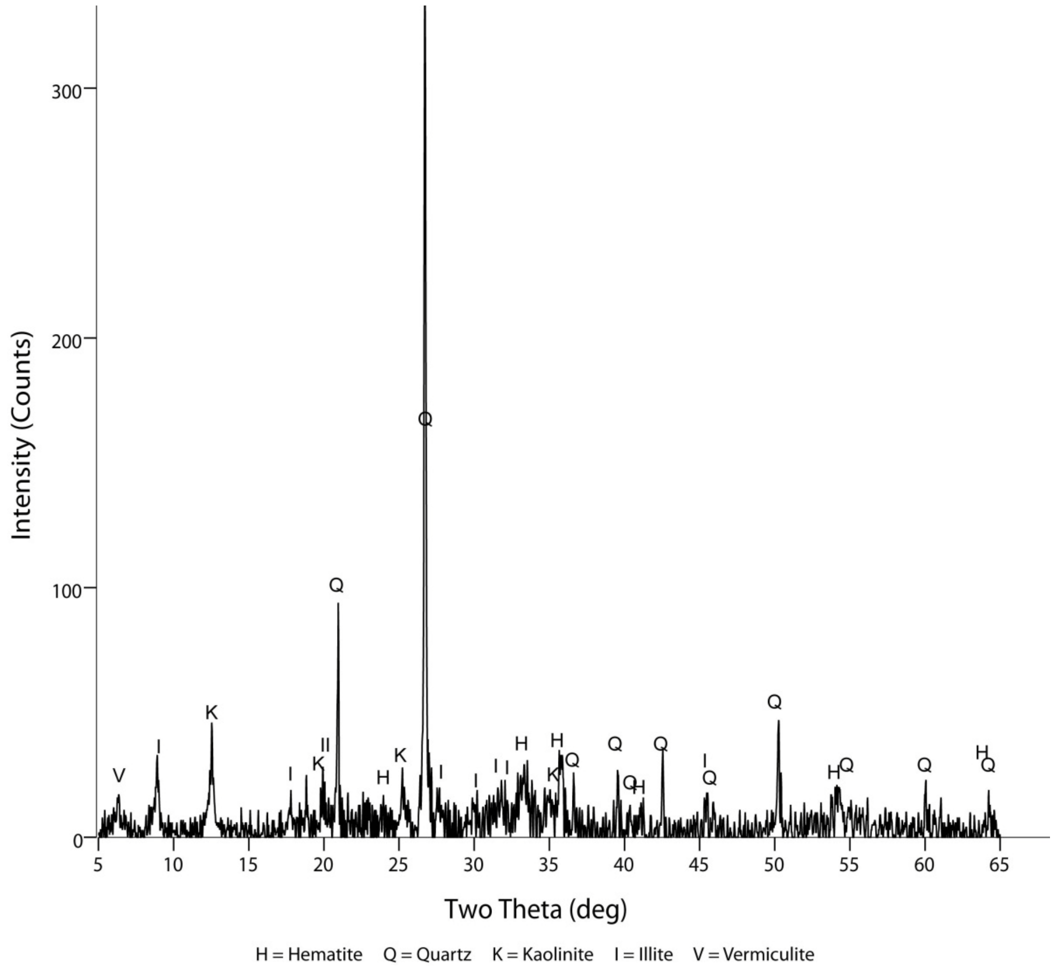


Fig. A.81. G129 Gondwana D yellow heated

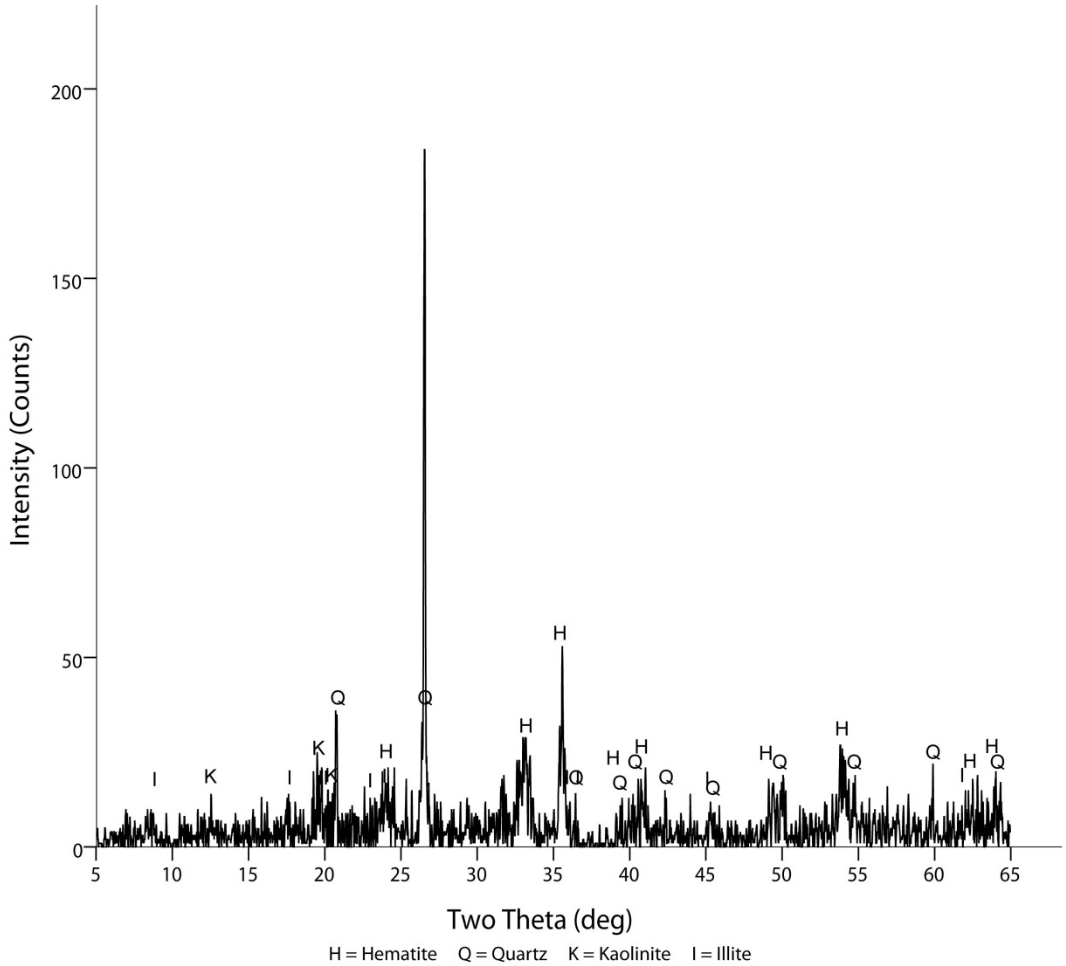


Fig. A.82. G234 Gondwana D yellow heated

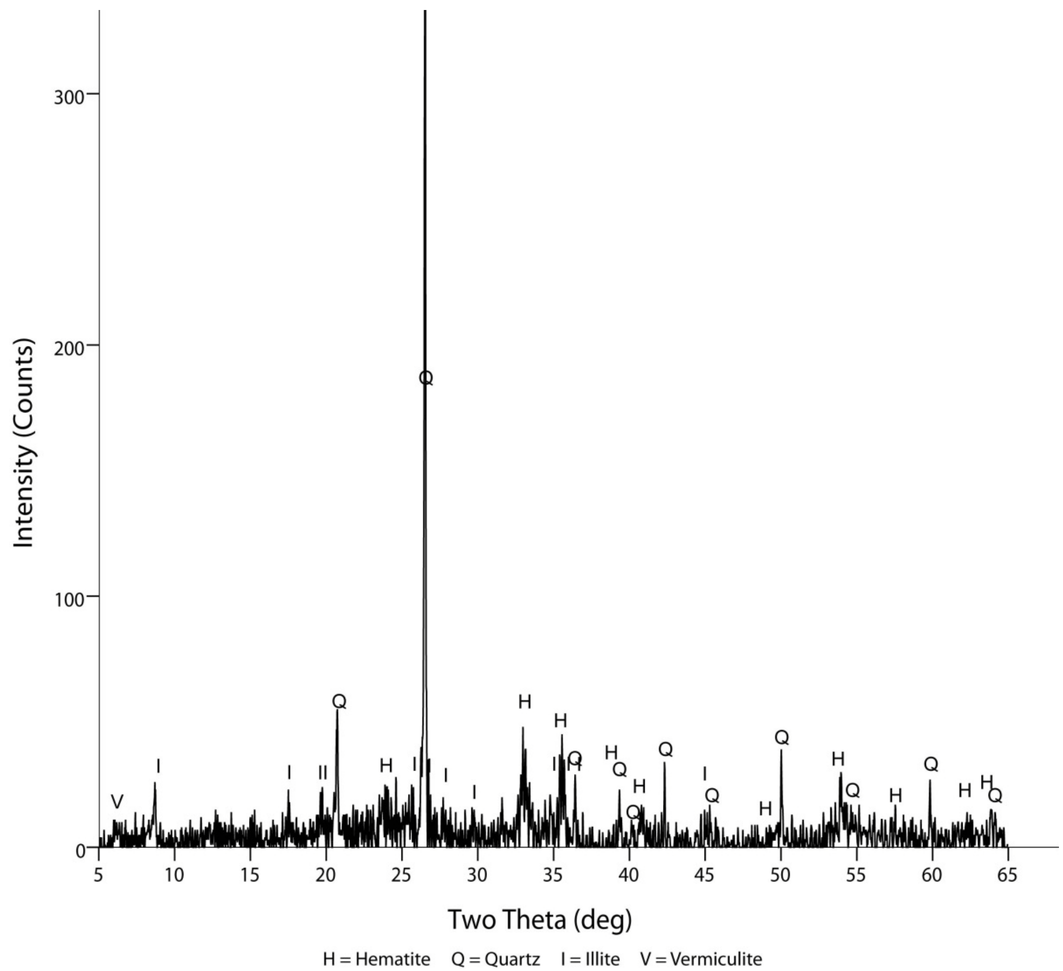


Fig. A.83. G235 Gondwana D yellow heated

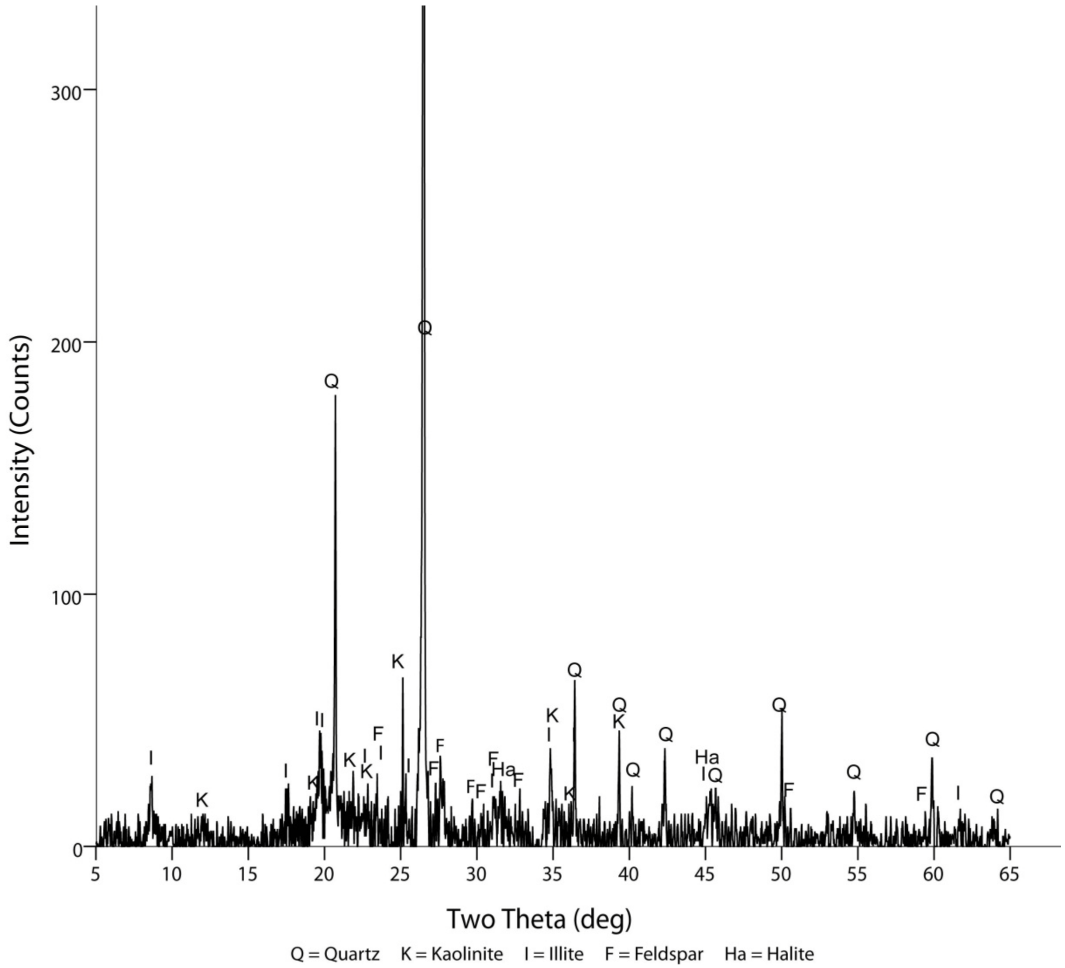


Fig. A.84. G163 Herbertsdale orange

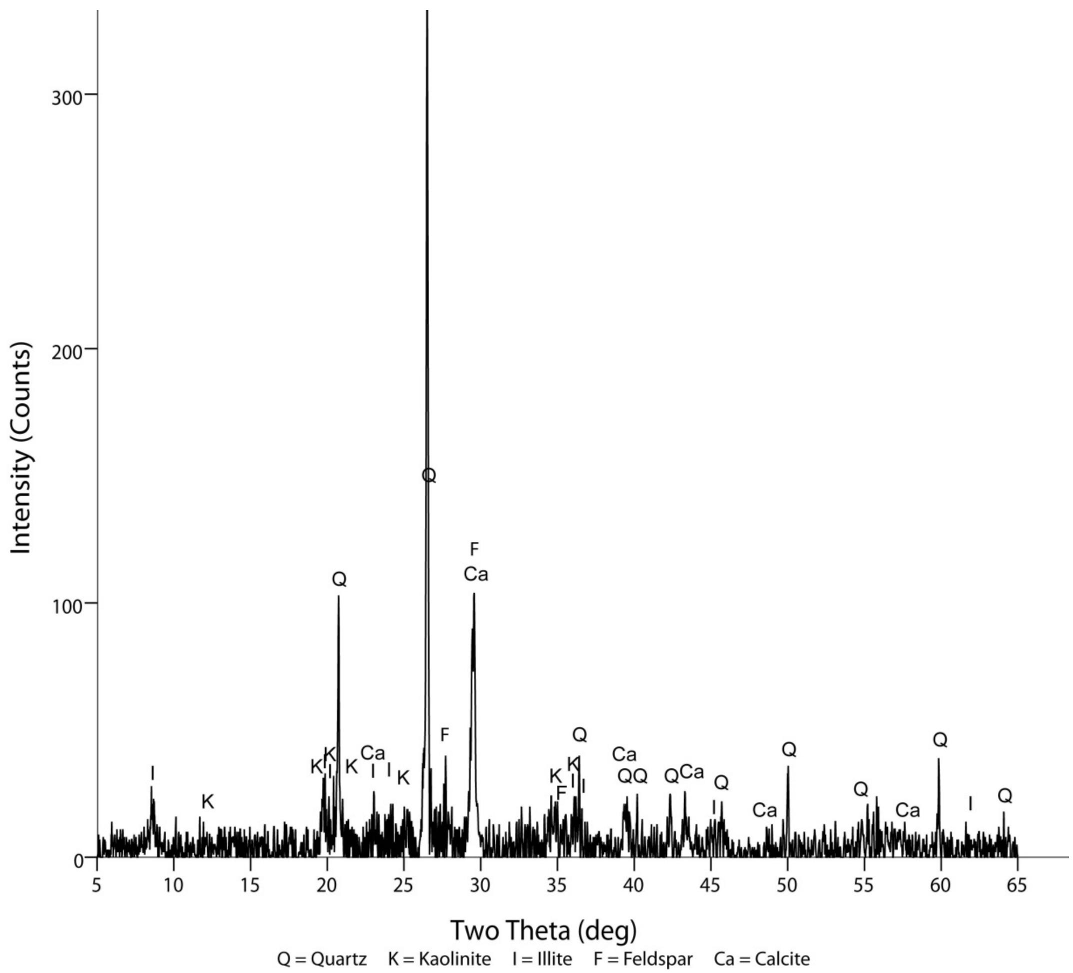


Fig. A.85. G164 Herbertsdale orange

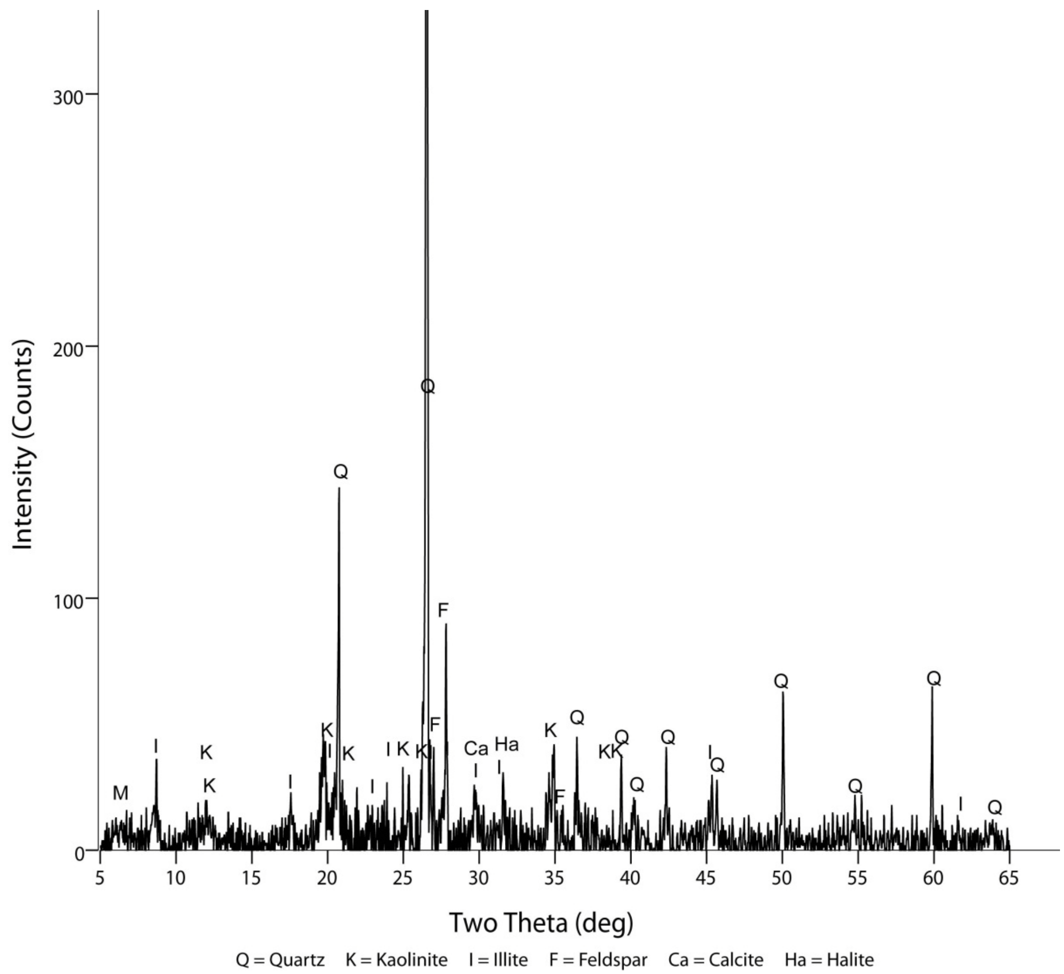


Fig. A.86. G166 Herbertsdale orange

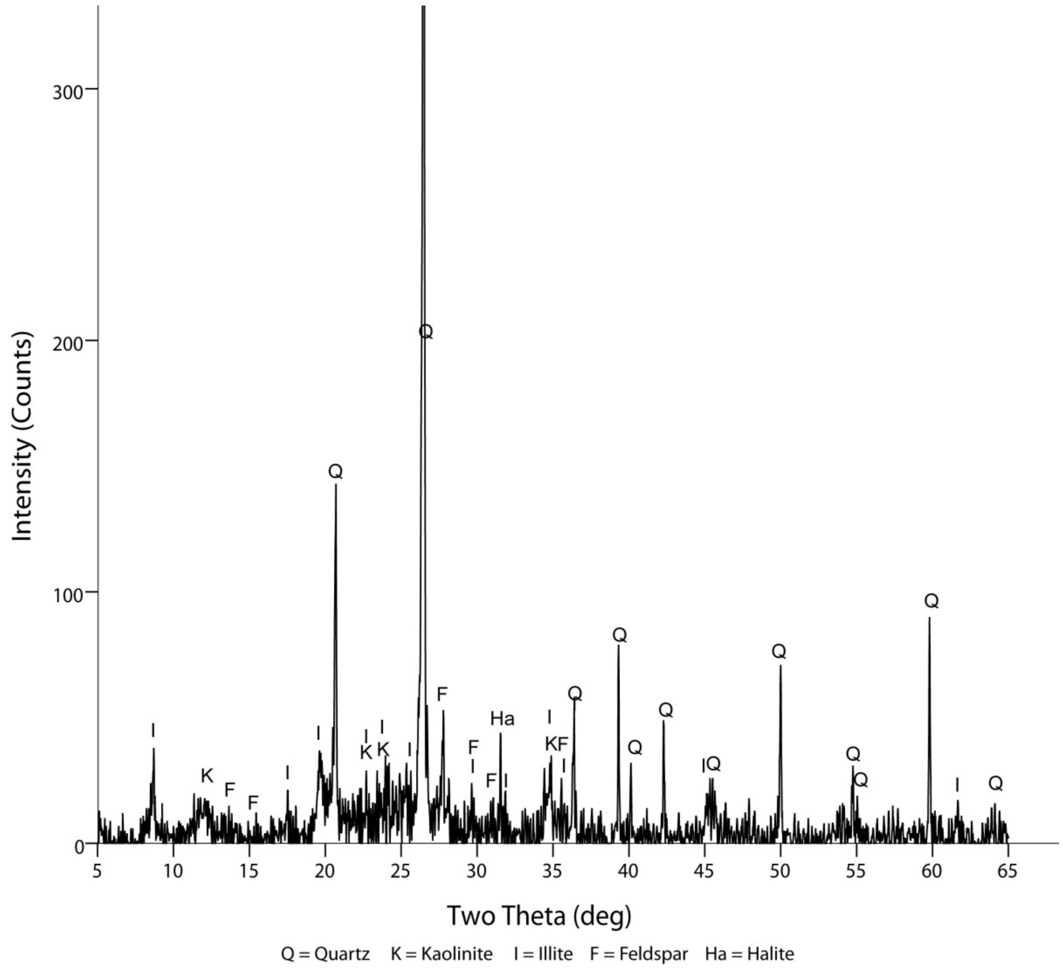


Fig. A.87. G165 Herbertsdale orange heated

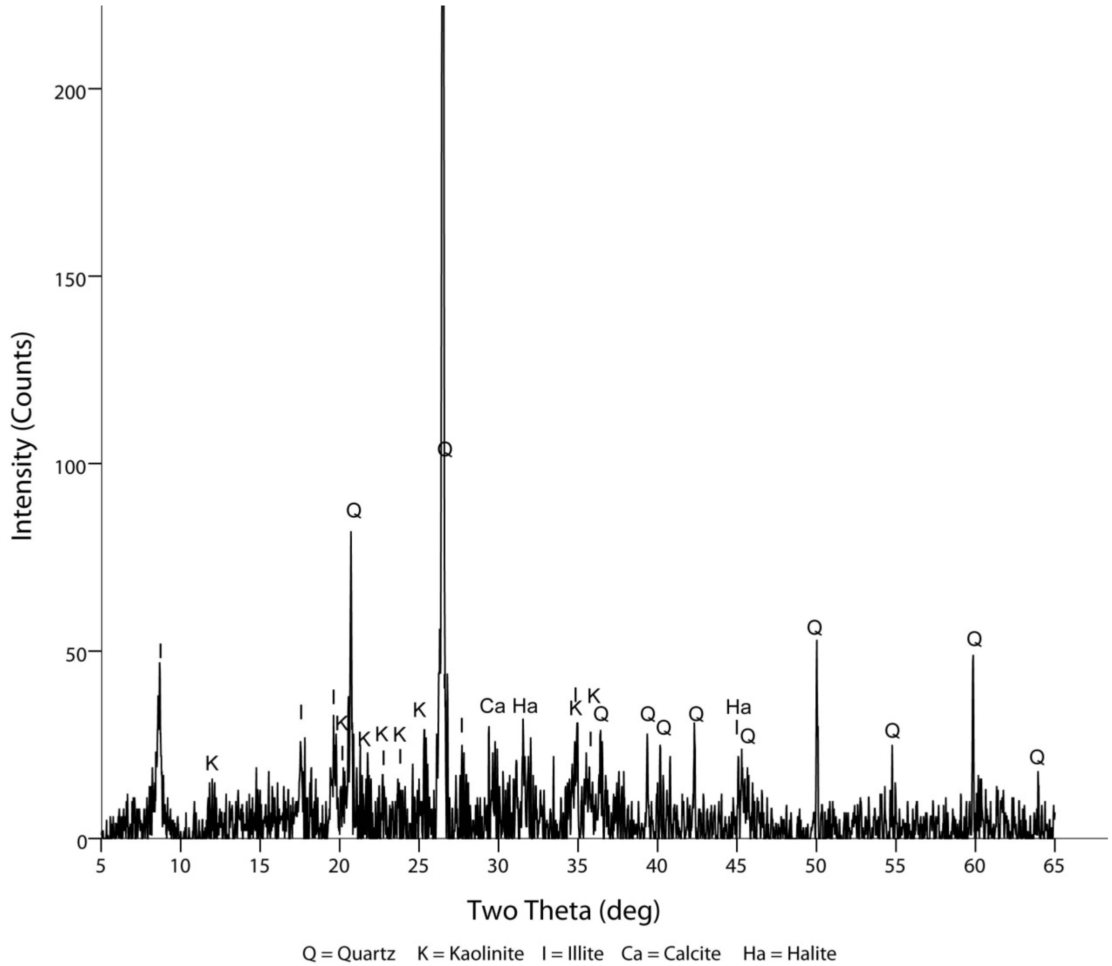


Fig. A.88. G167 Herbertsdale orange heated

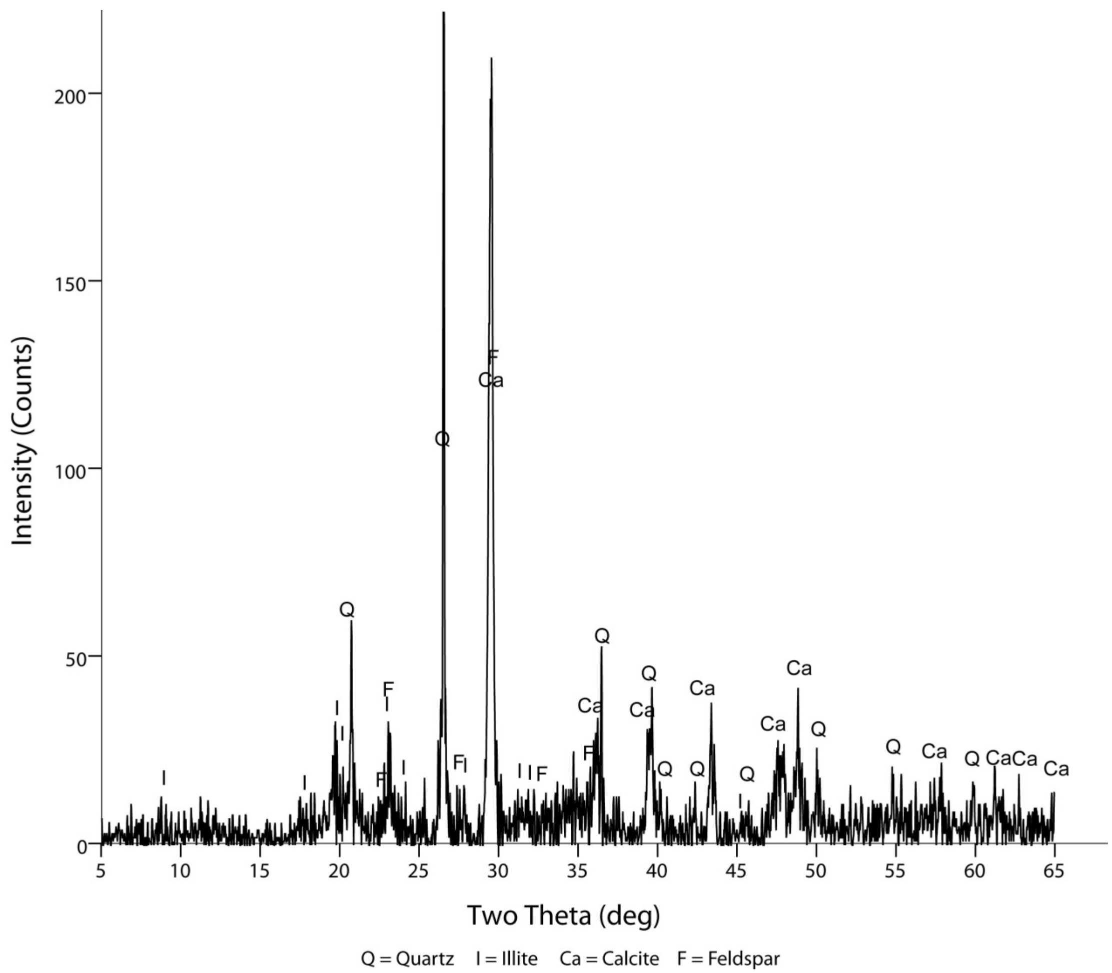


Fig. A.89. G251 Herbertsdale orange heated

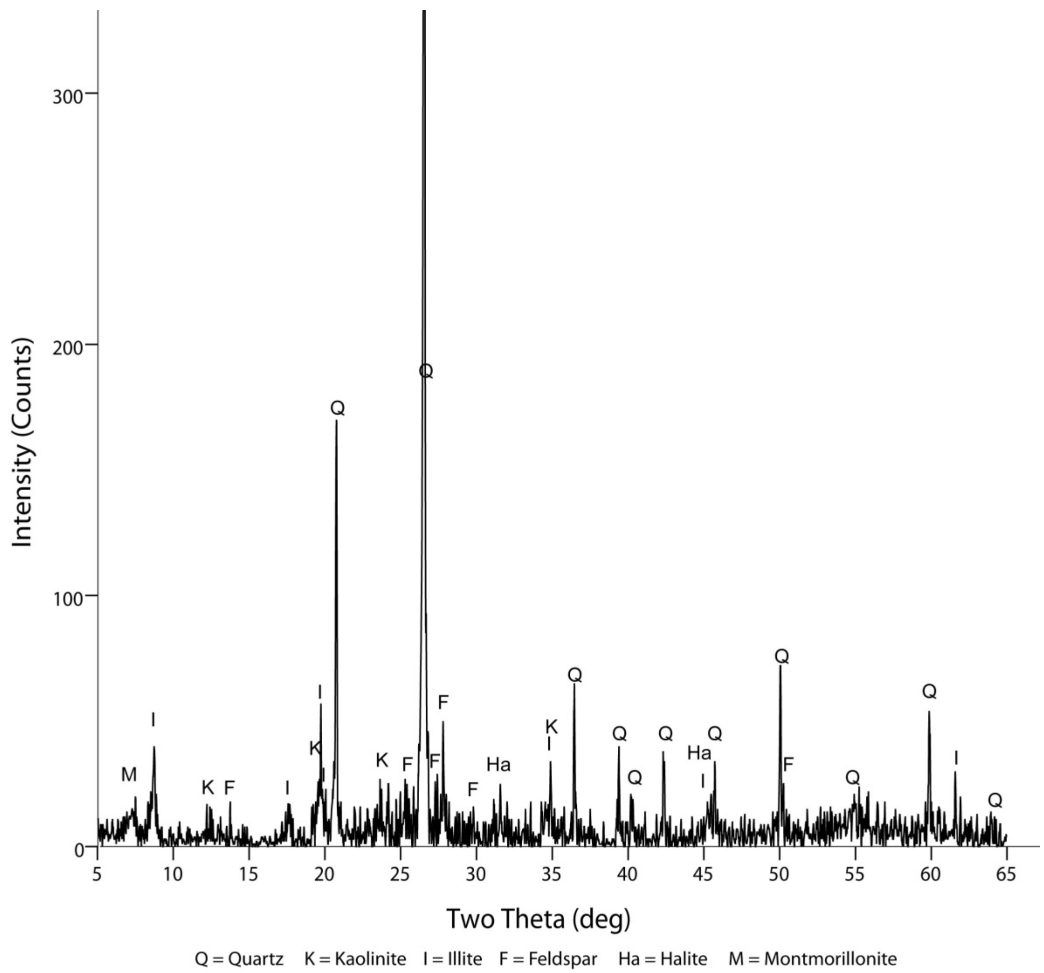


Fig. A.90. G252 Herbertsdale orange heated

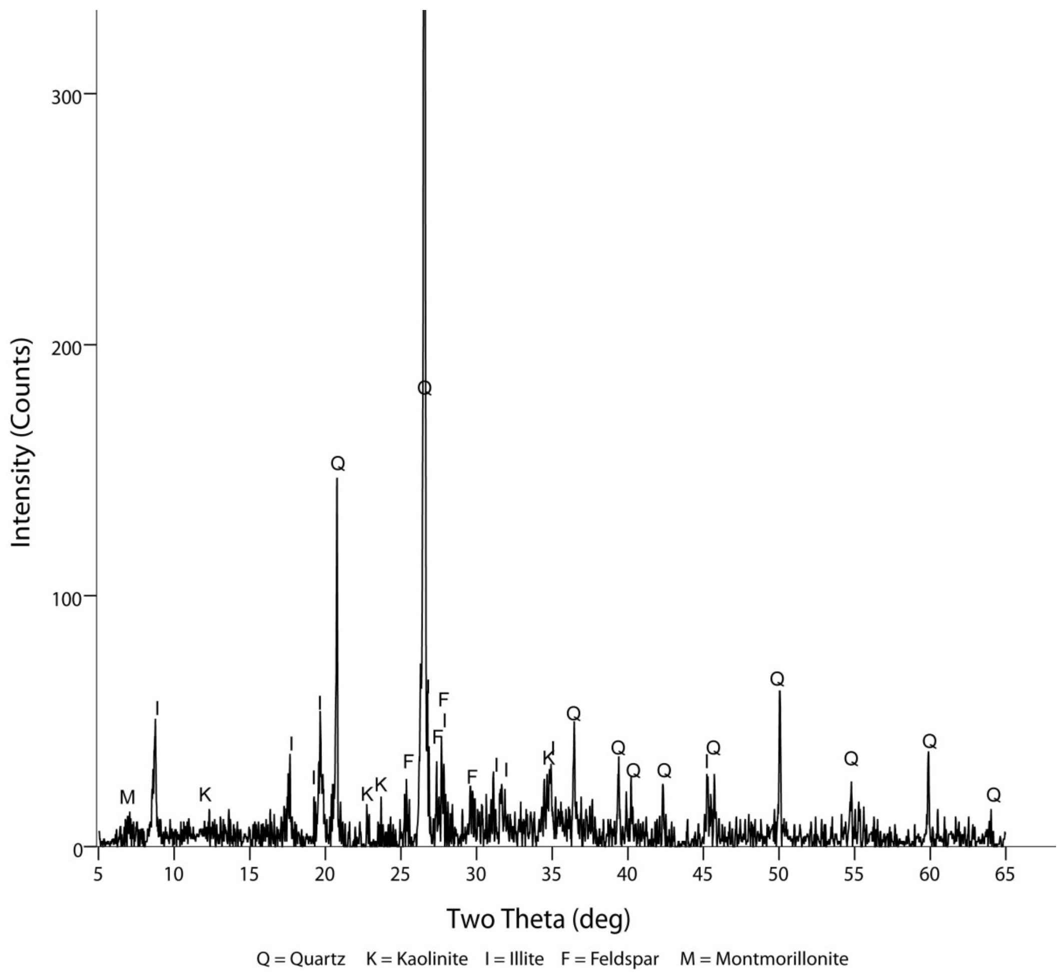


Fig. A.91. G253 Herbertsdale orange heated

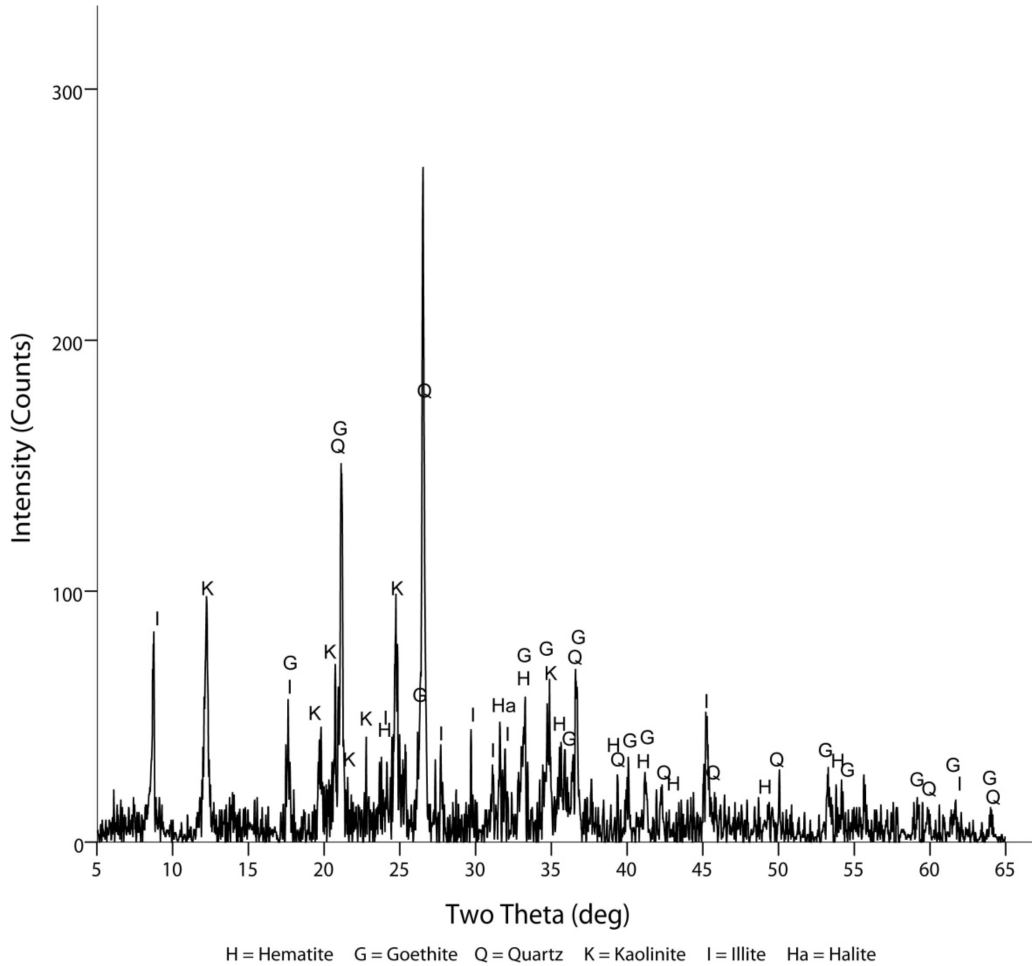


Fig. A.92. G284 Kwa-Nonqaba red

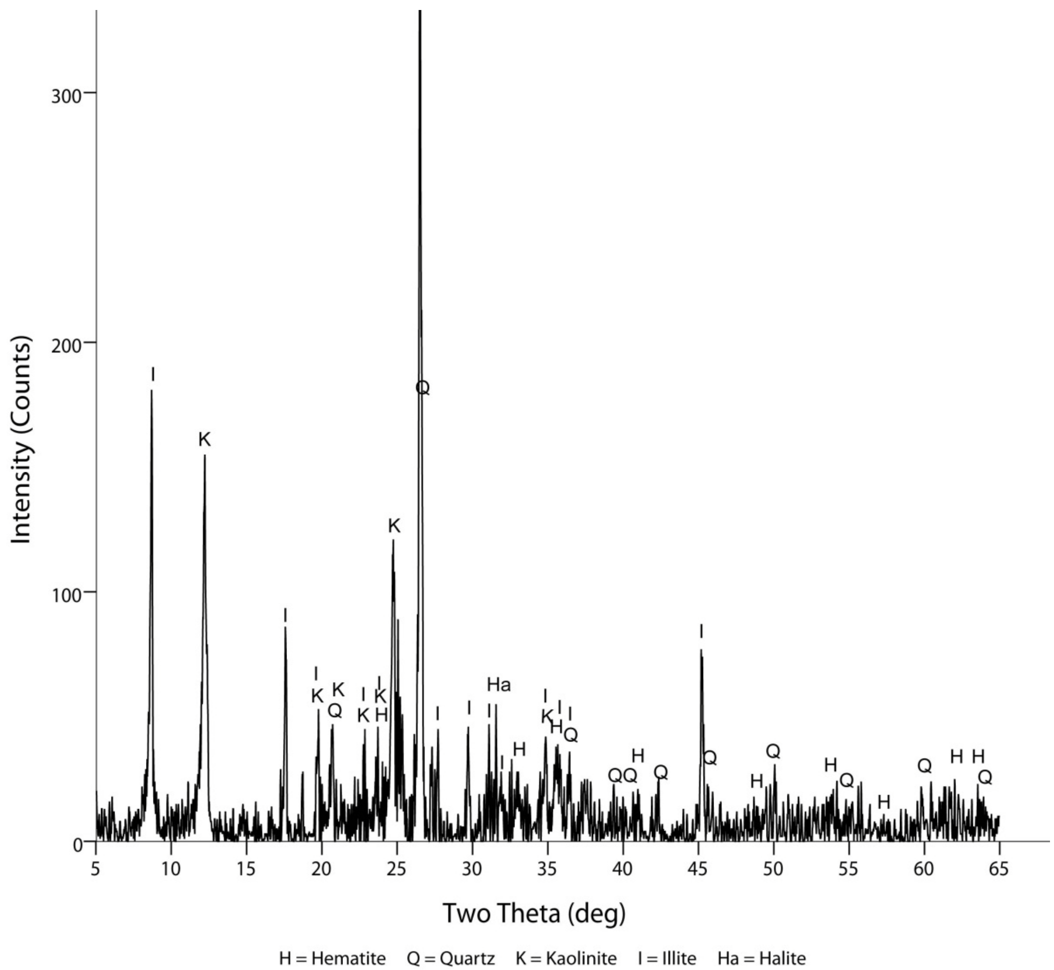


Fig. A.93. G285 Kwa-Nonqaba red

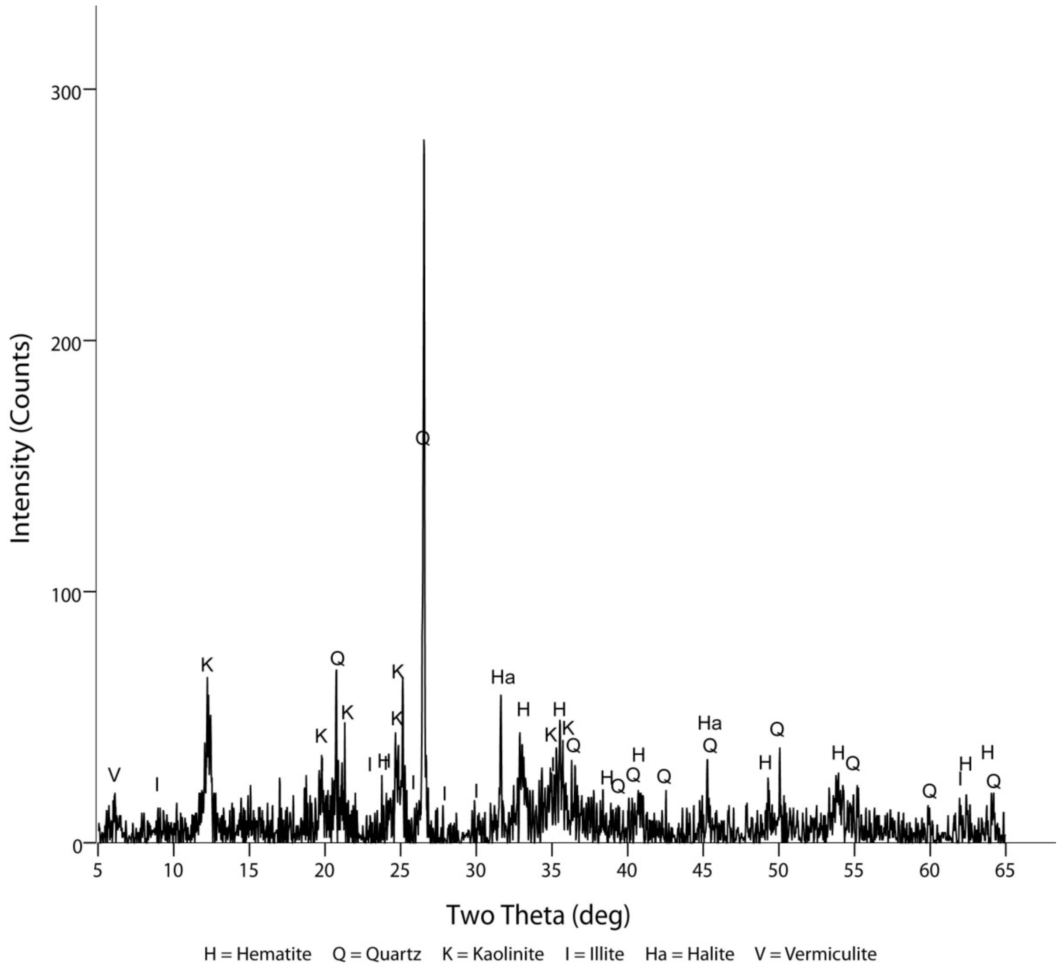


Fig. A.94. G286 Kwa-Nonqaba red

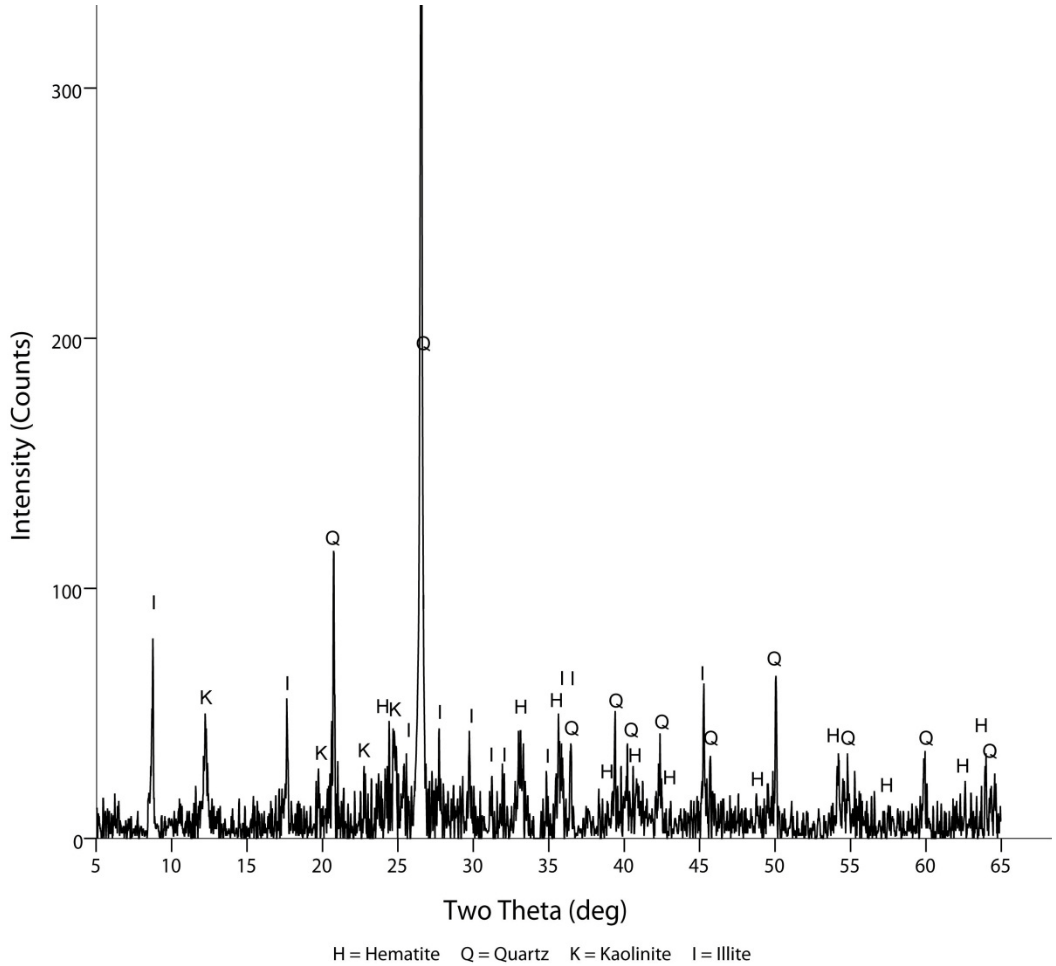


Fig. A.95. G288 Kwa-Nonqaba red

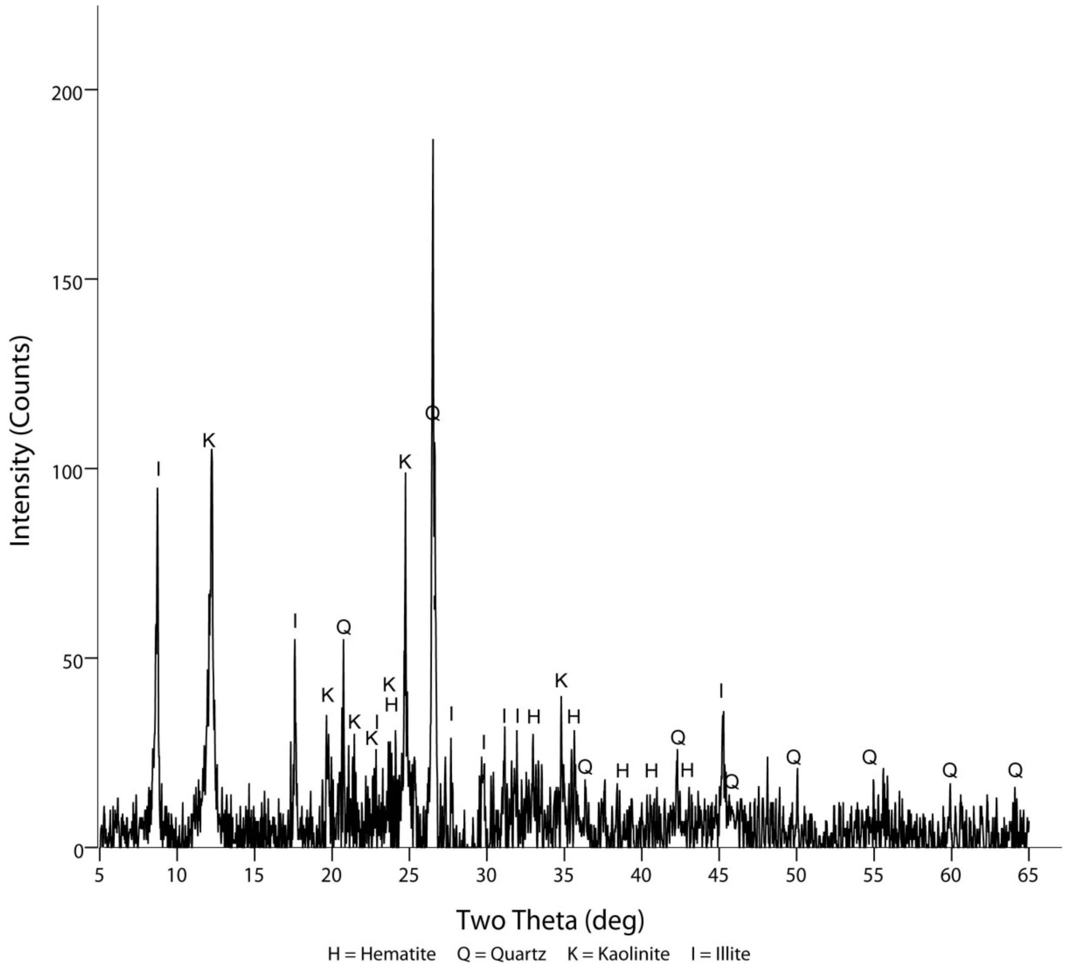


Fig. A.96. G59 Kwa-Nonqaba purple

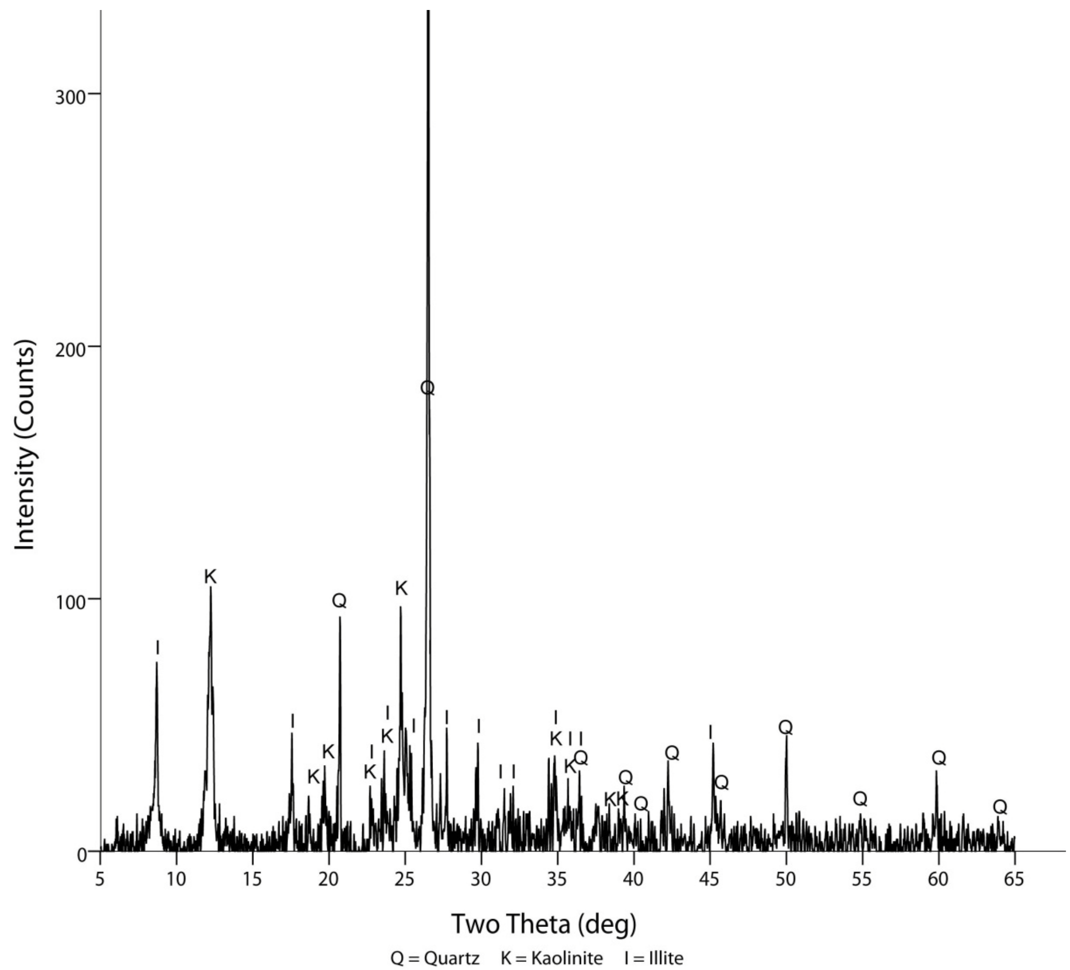


Fig. A.97. G60 Kwa-Nonqaba purple

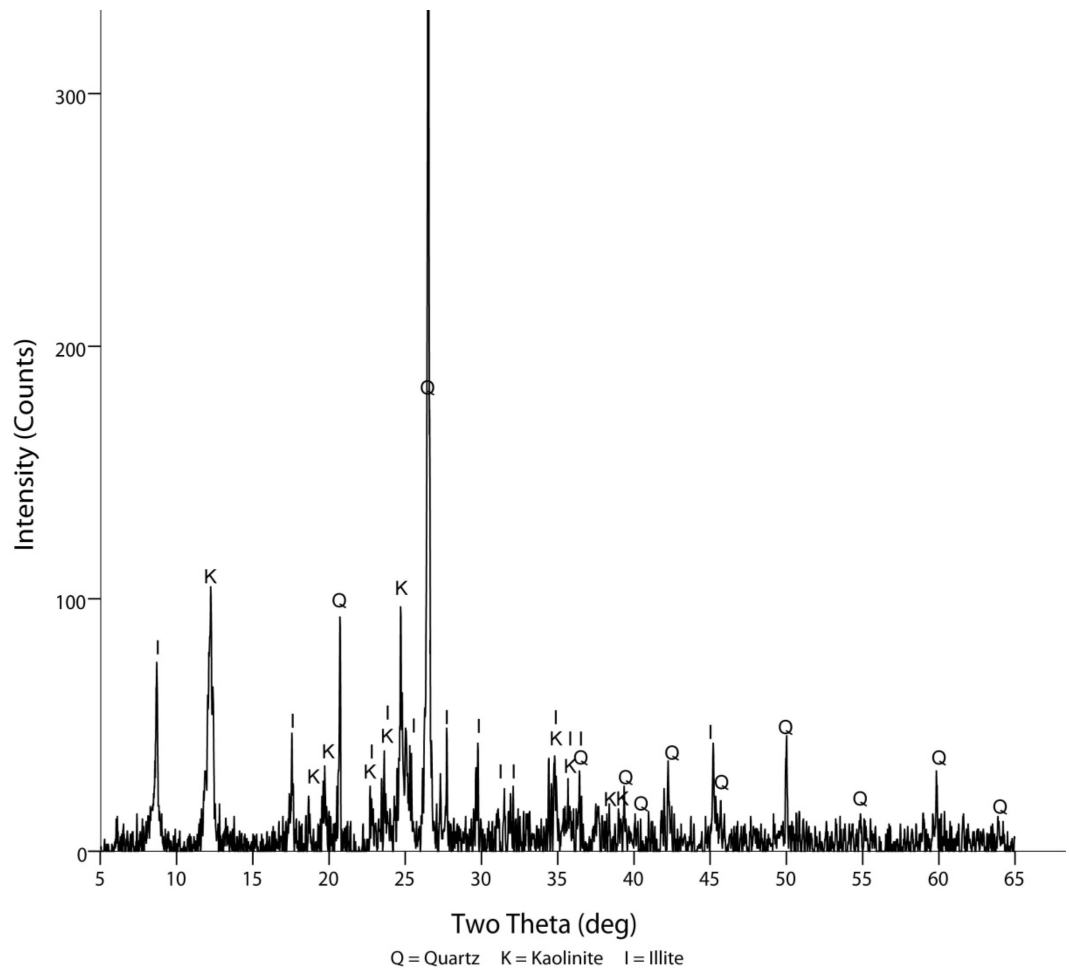


Fig. A.98. G36 Kwa-Nonqaba purple heated

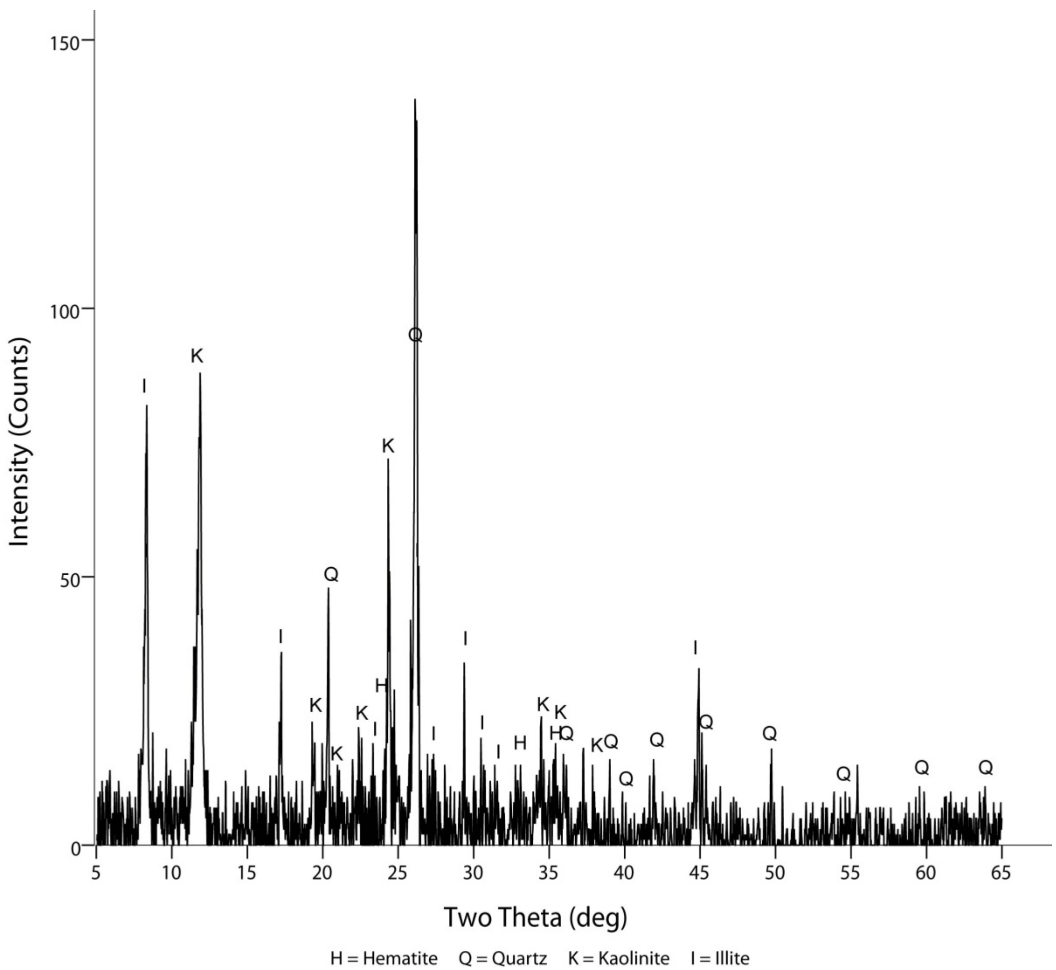


Fig. A.99. G37 Kwa- Nonqaba purple heated

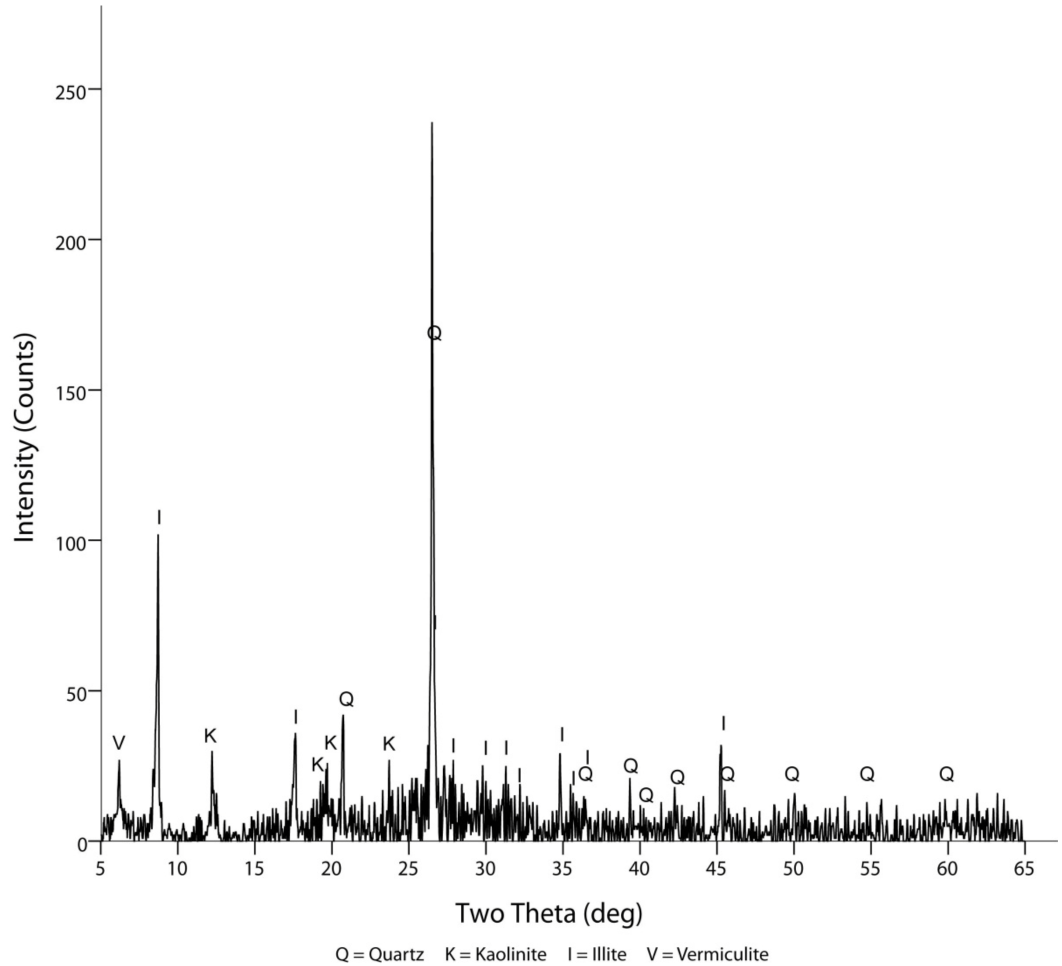


Fig. A.100. G200 Kwa-Nonqaba purple heated

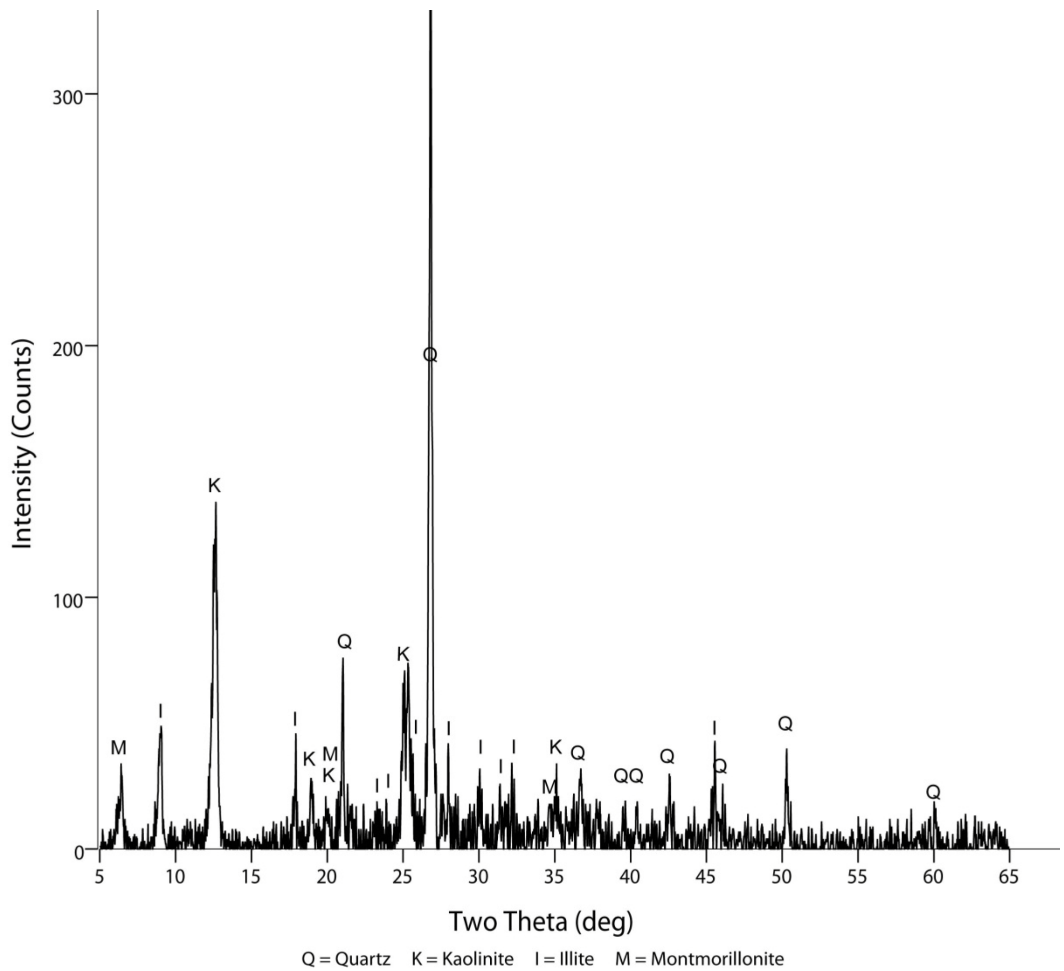


Fig. A.101. G61 Kwa-Nonqaba yellow

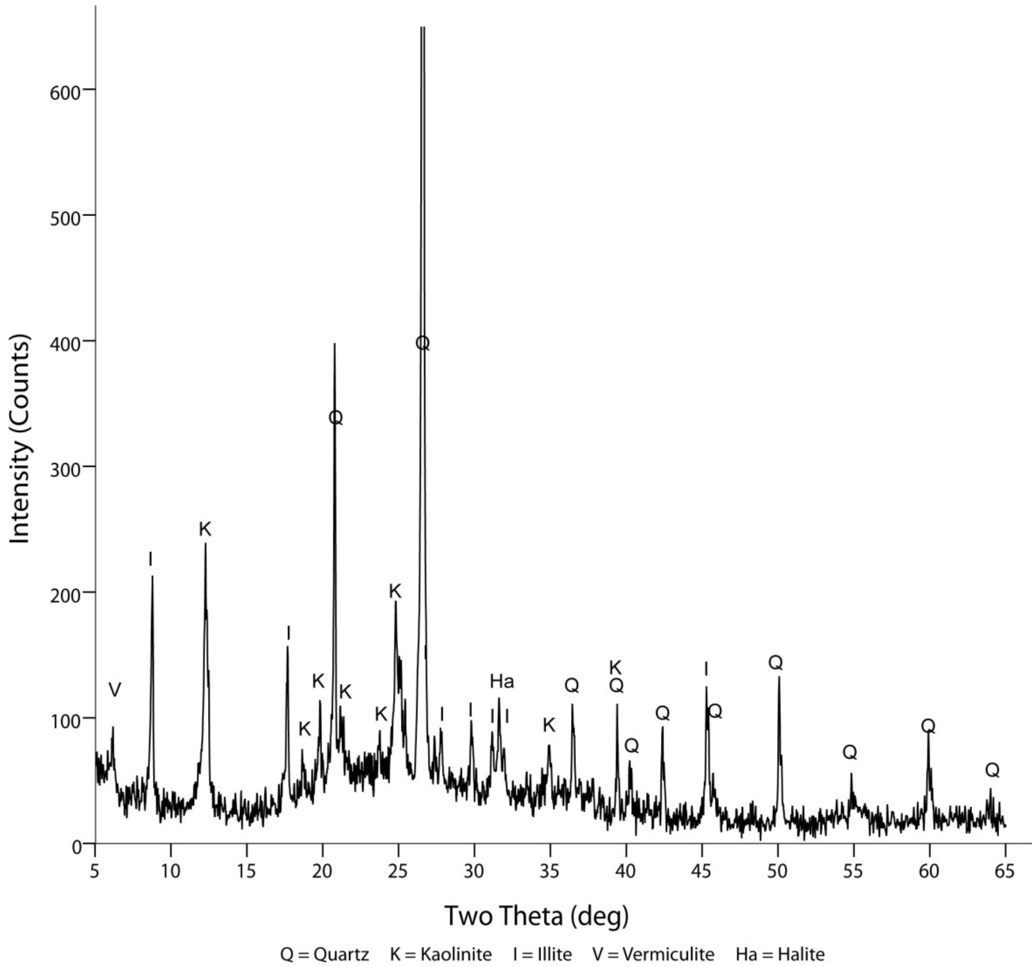


Fig. A.102. G281 Kwa-Nonqaba yellow

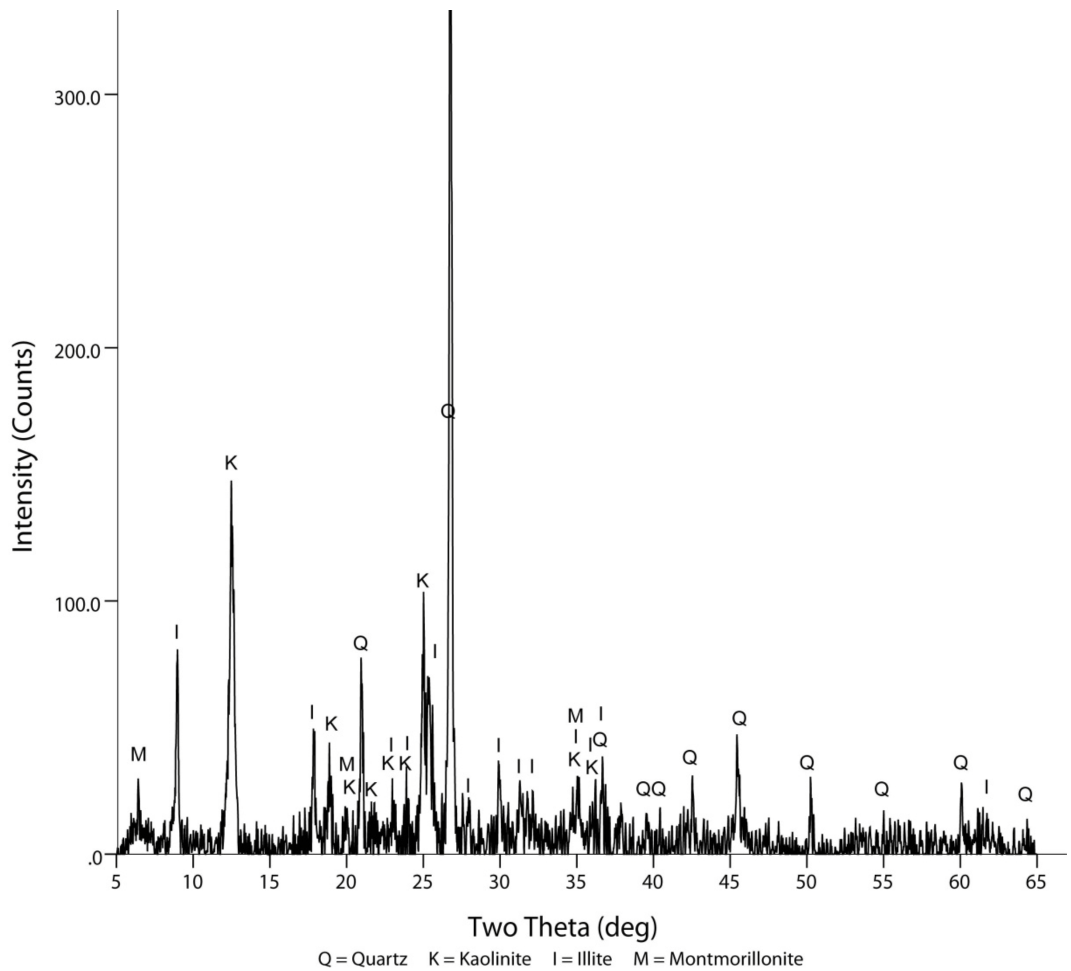


Fig. A.103. G35 Kwa-Nonqaba yellow heated

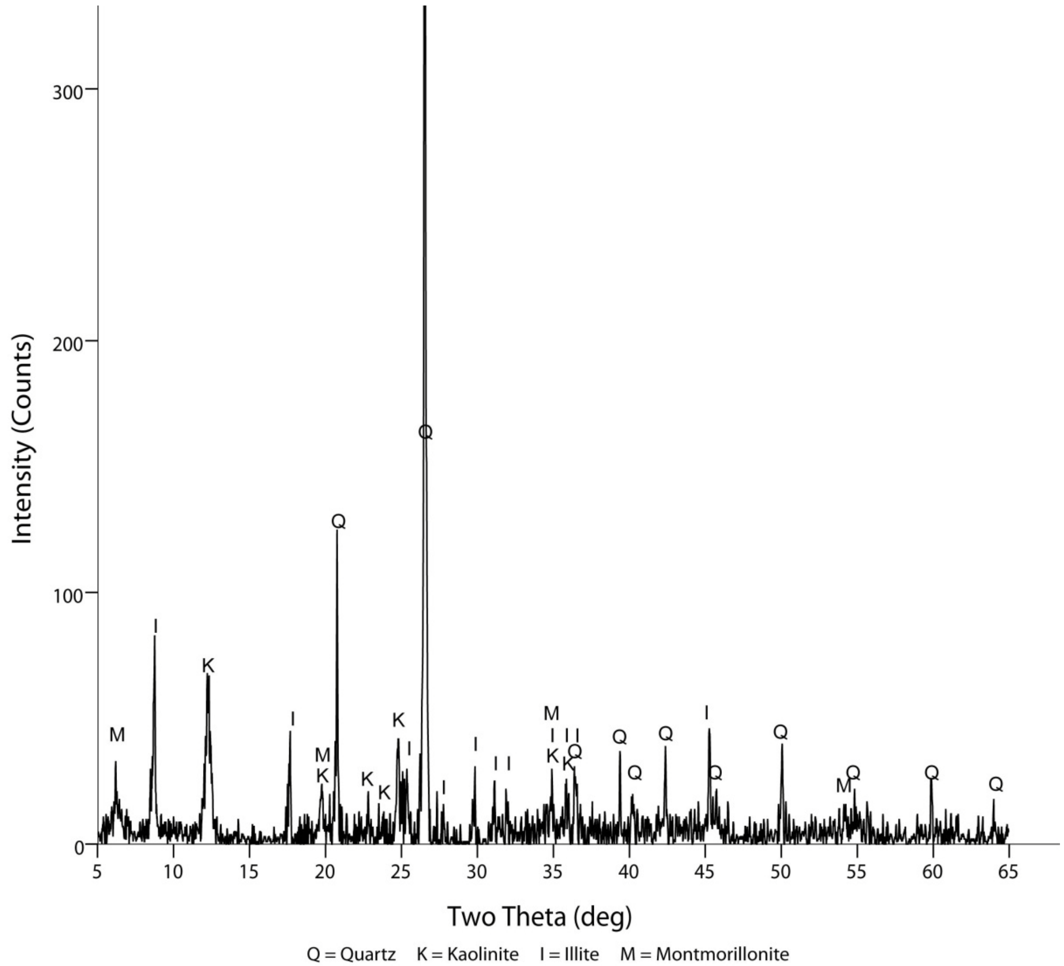


Fig. A.104. G182 Kwa-Nonqaba yellow heated

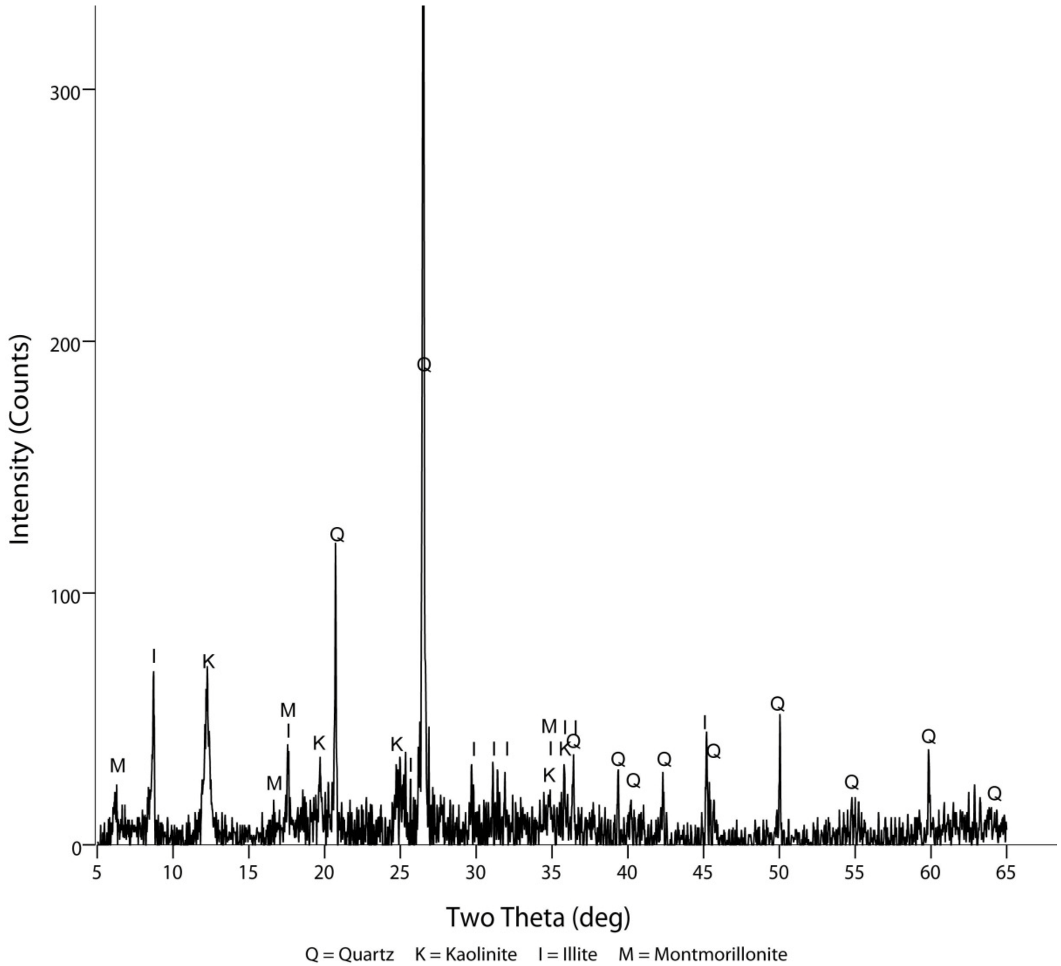


Fig. A.105. G199 Kwa-Nonqaba yellow heated

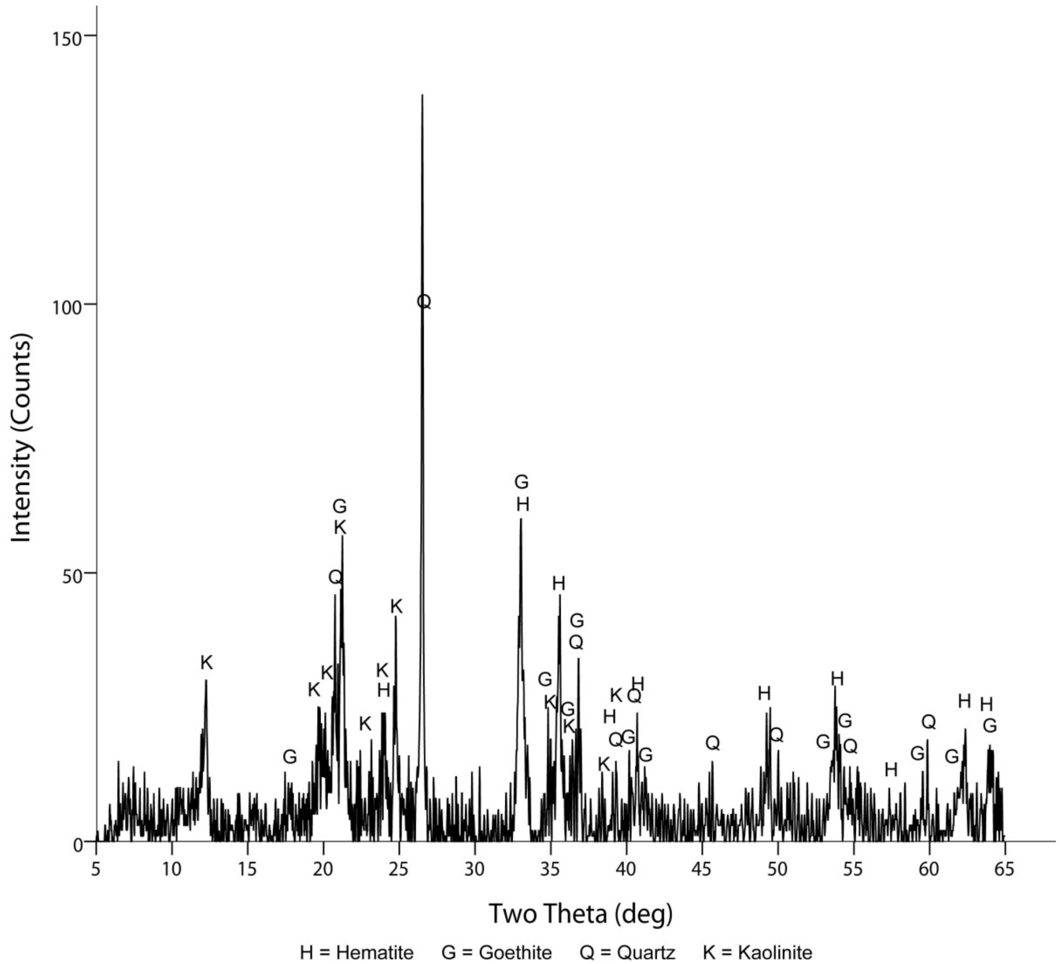


Fig. A.106. G95 Matjesfontein orange

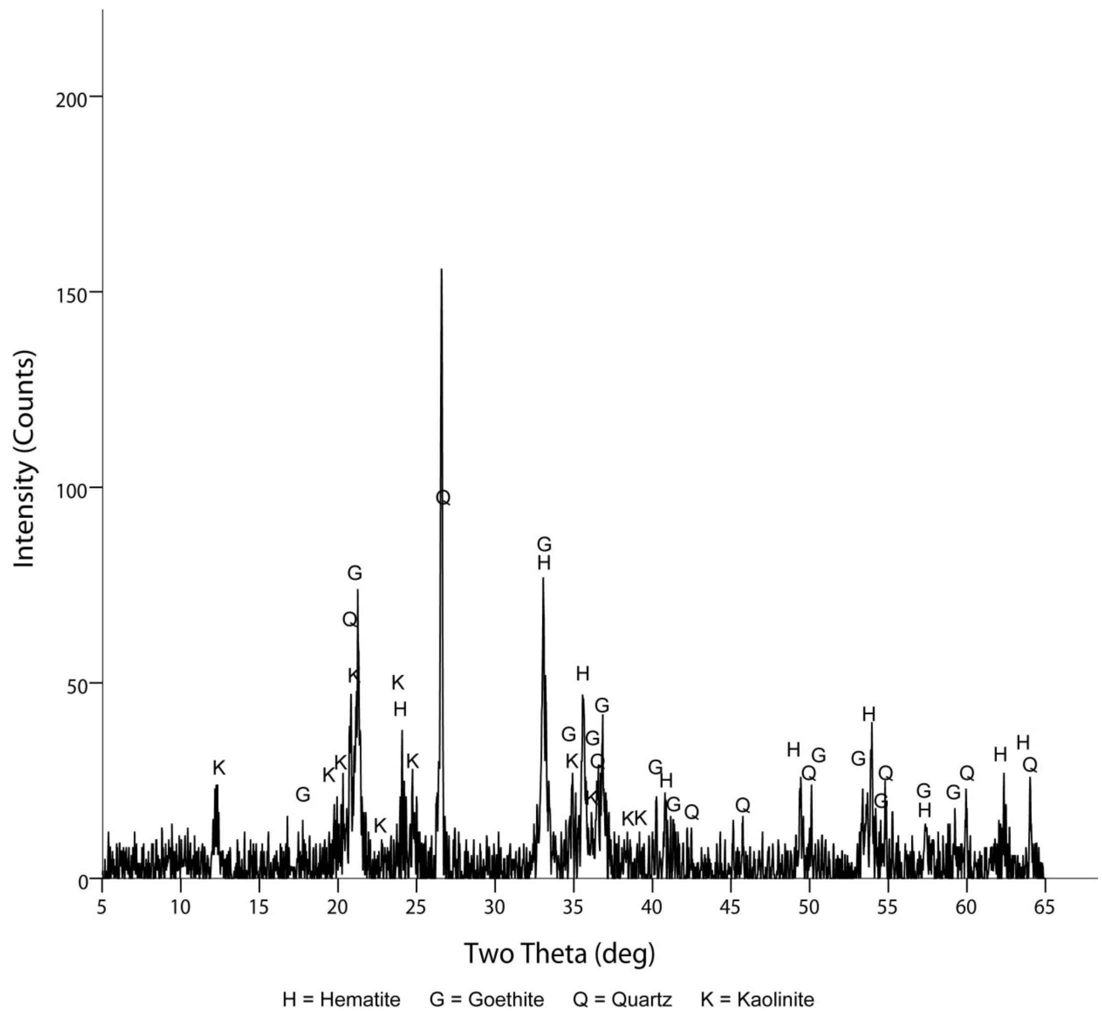


Fig. A.107. G97 Matjesfontein orange

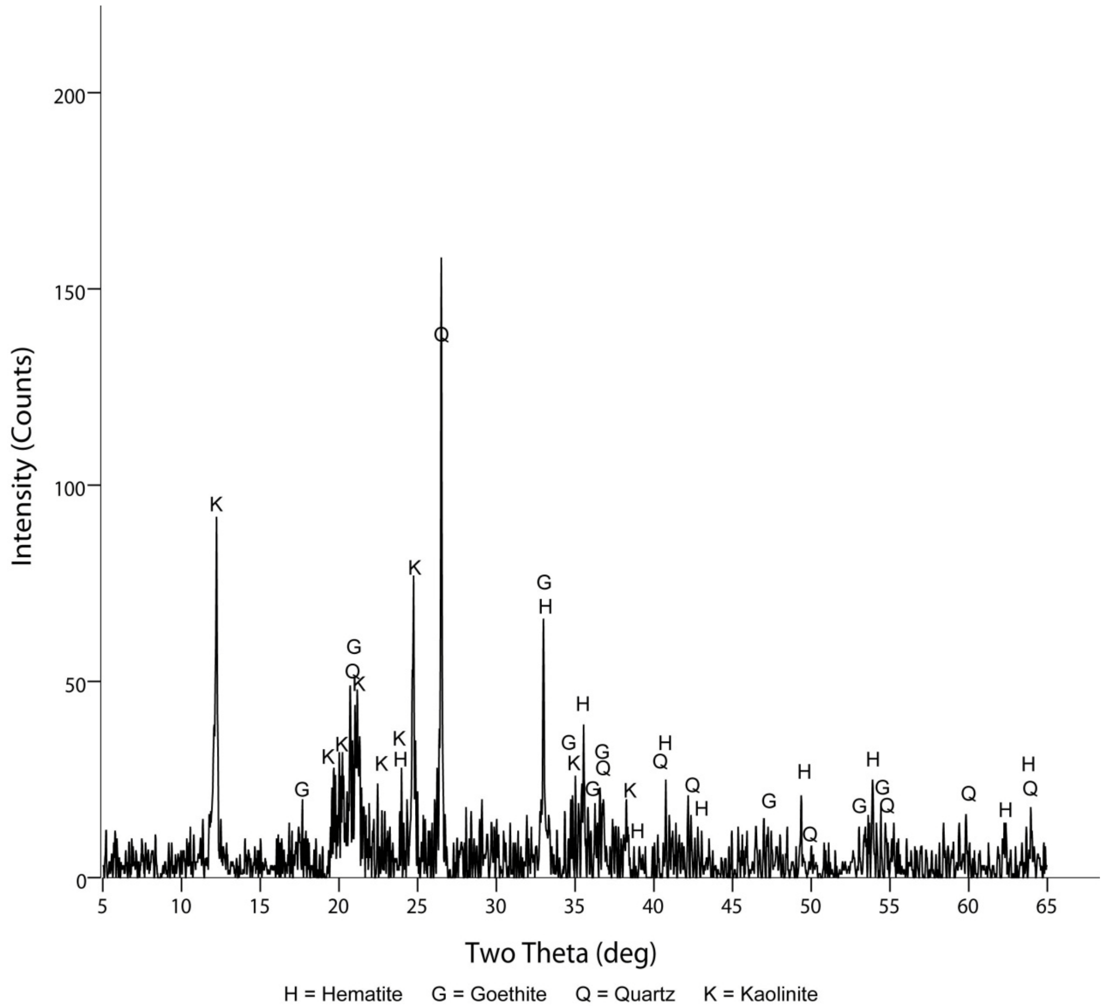


Fig. A.108. G99 Matjsfontein orange

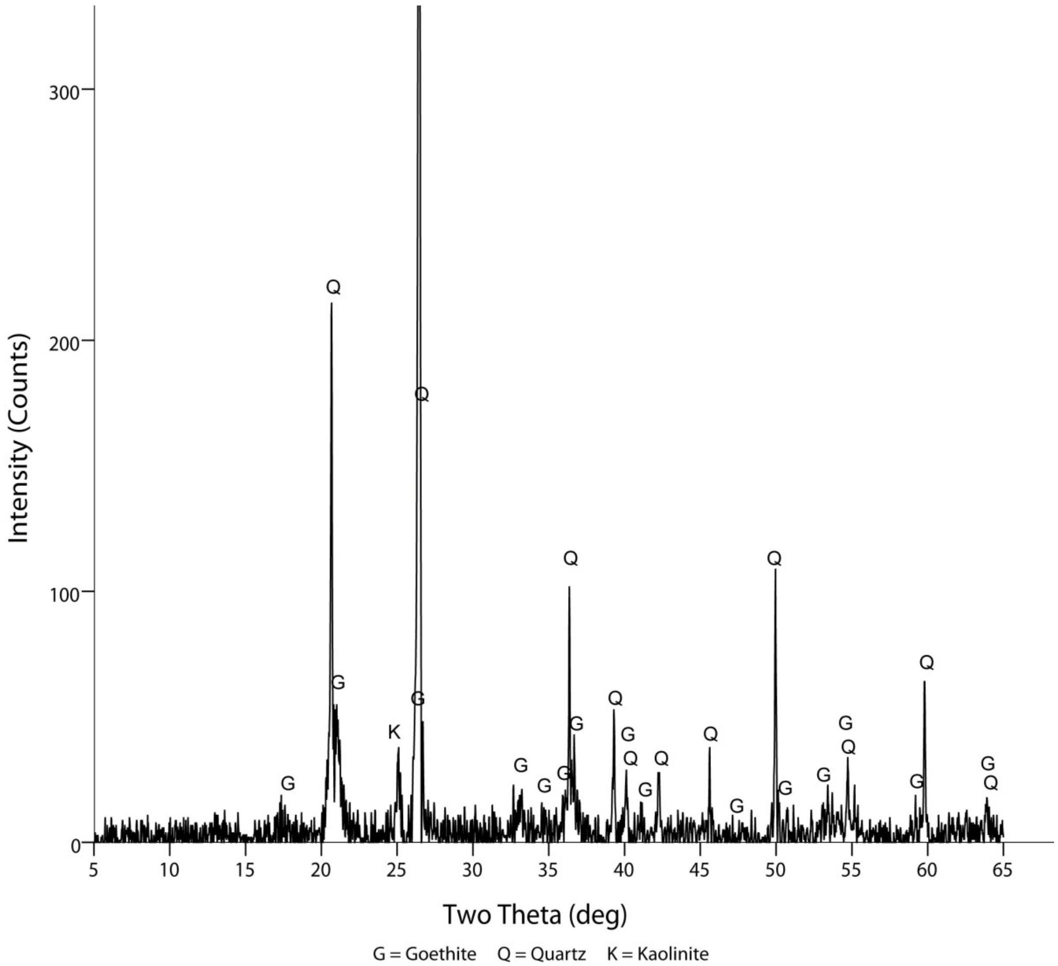


Fig. A.109. G101 Matjesfontein yellow

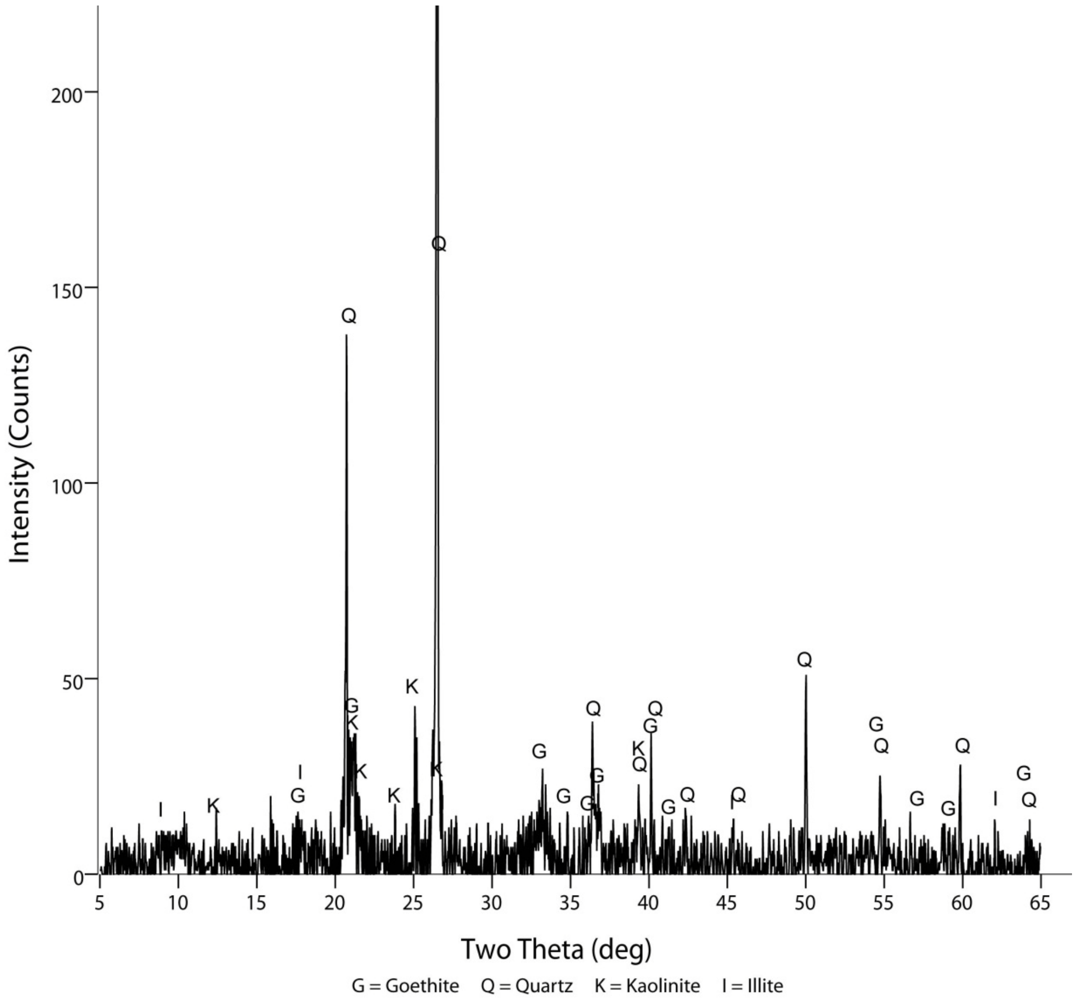


Fig. A.111. G103 Matjesfontein yellow

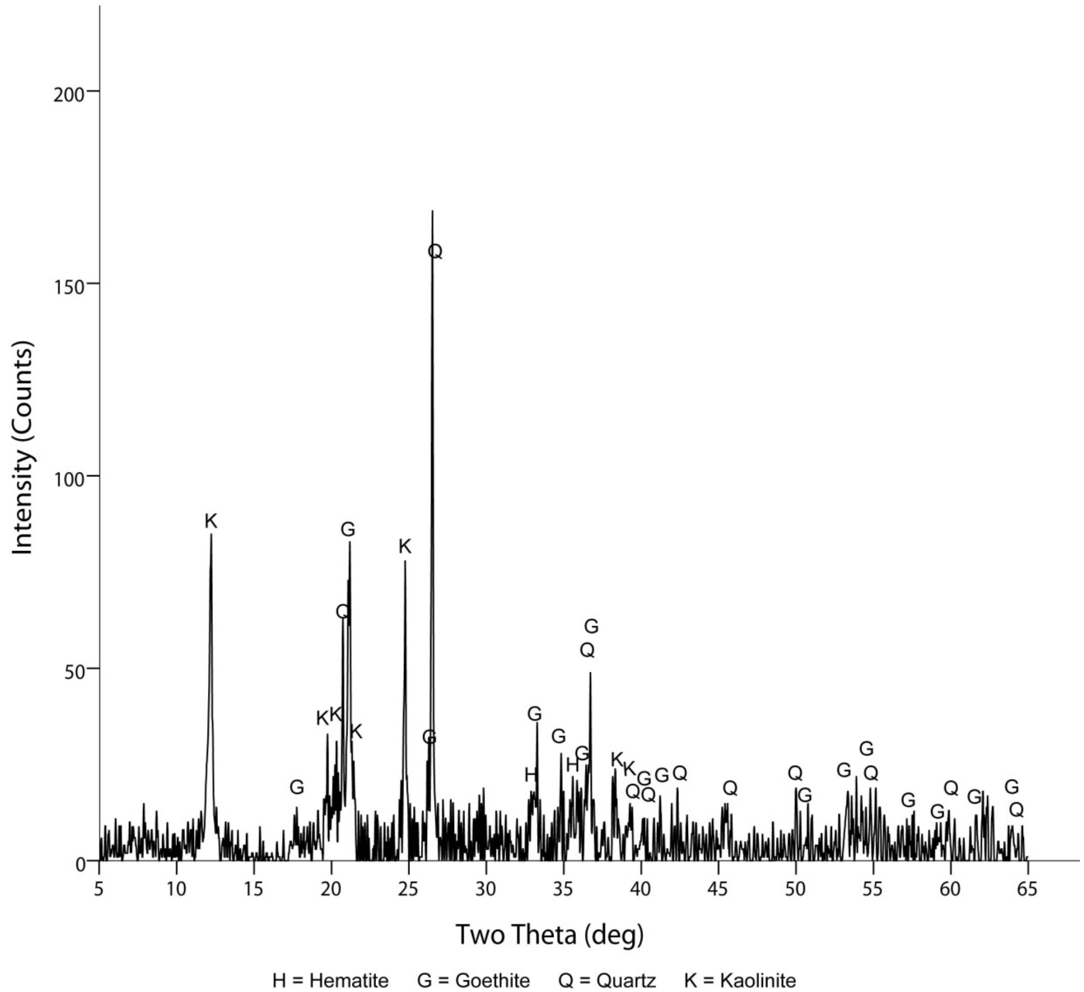


Fig. A.112. G105 Matjesfontein orange

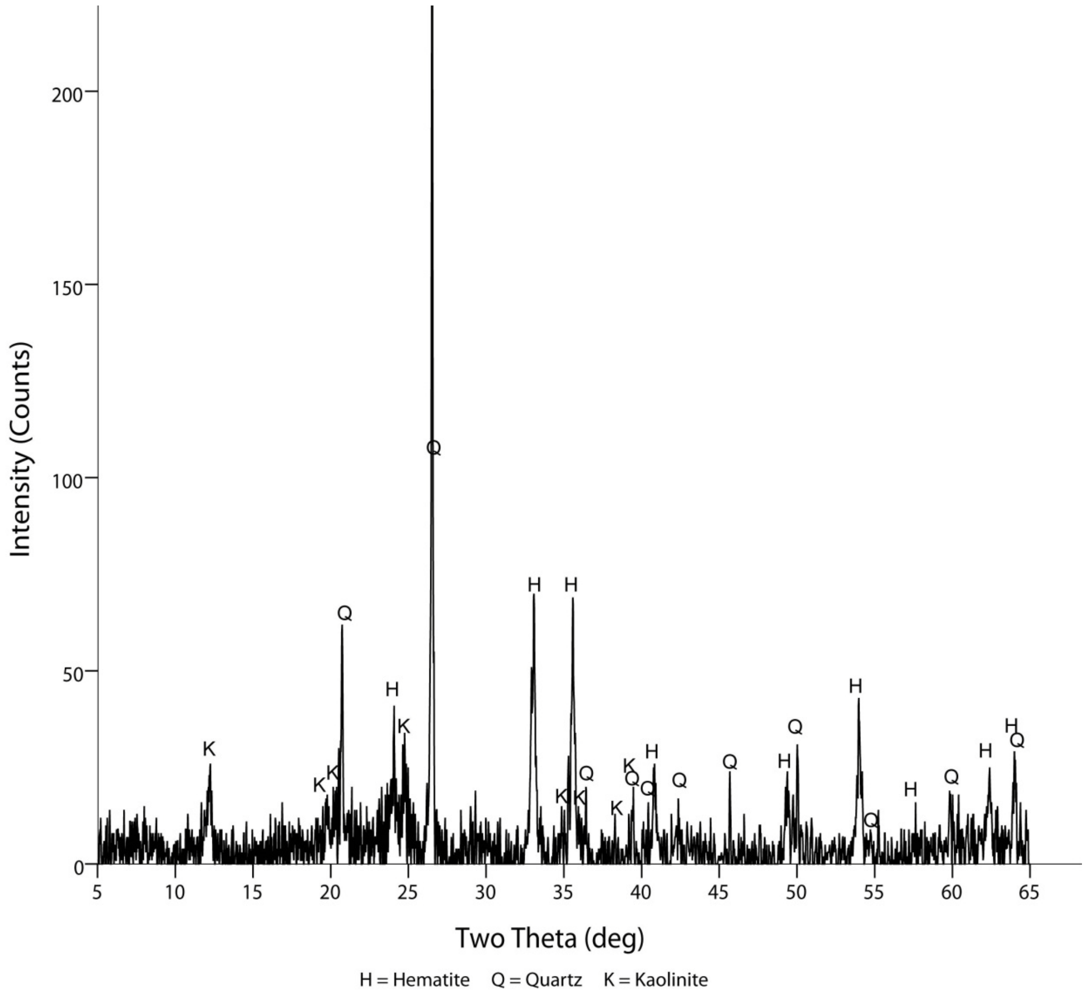


Fig. A.113. G96 Matjesfontein orange heated

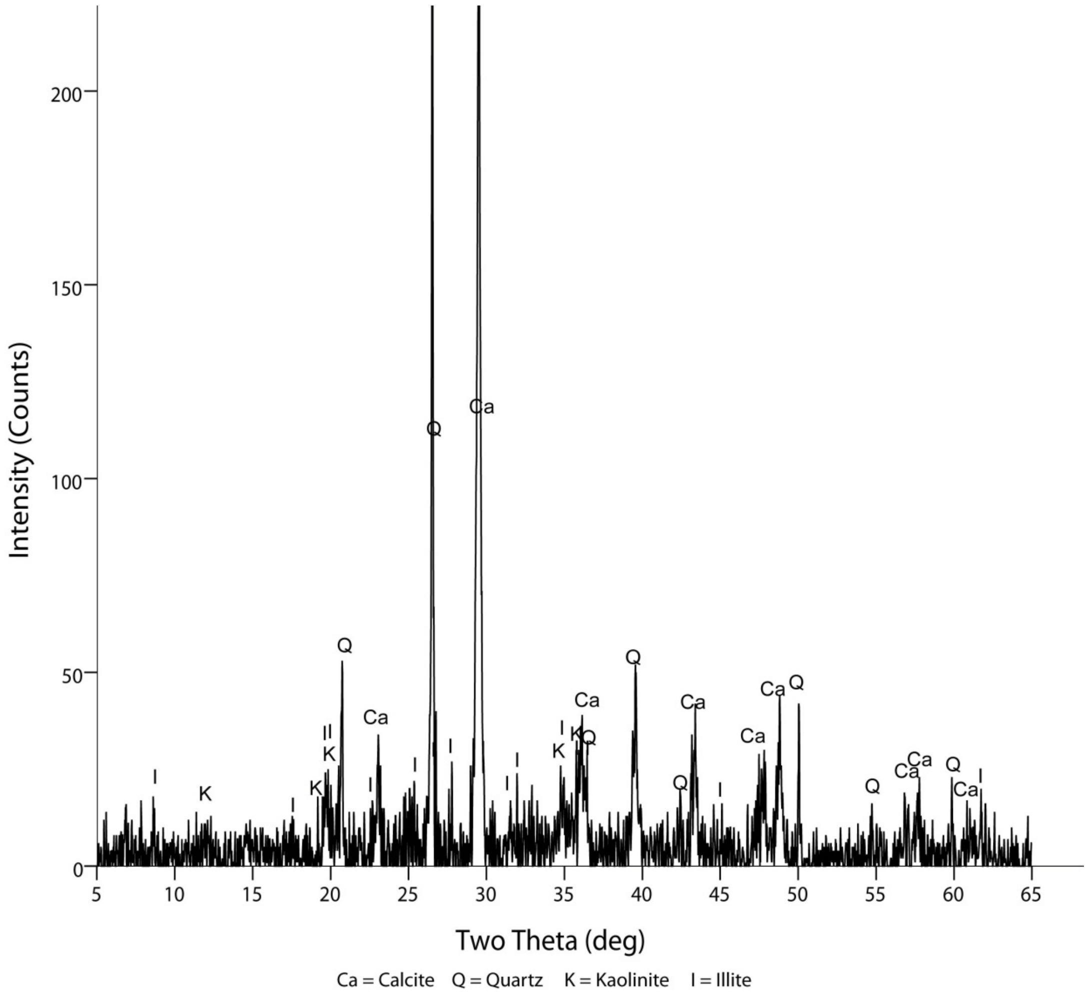


Fig. A.114. G98 Matjesfontein orange heated

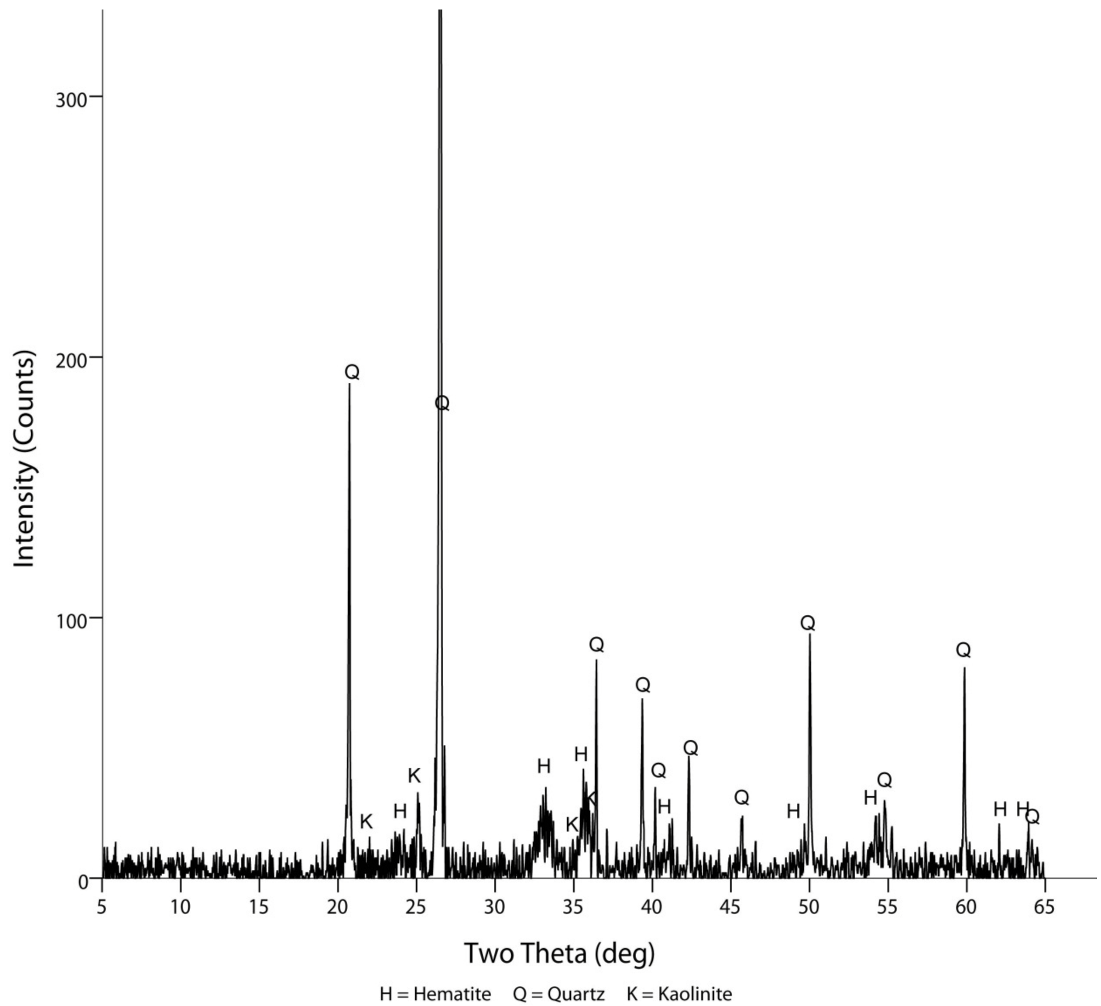


Fig. A.115. G102 Matjesfontein yellow heated

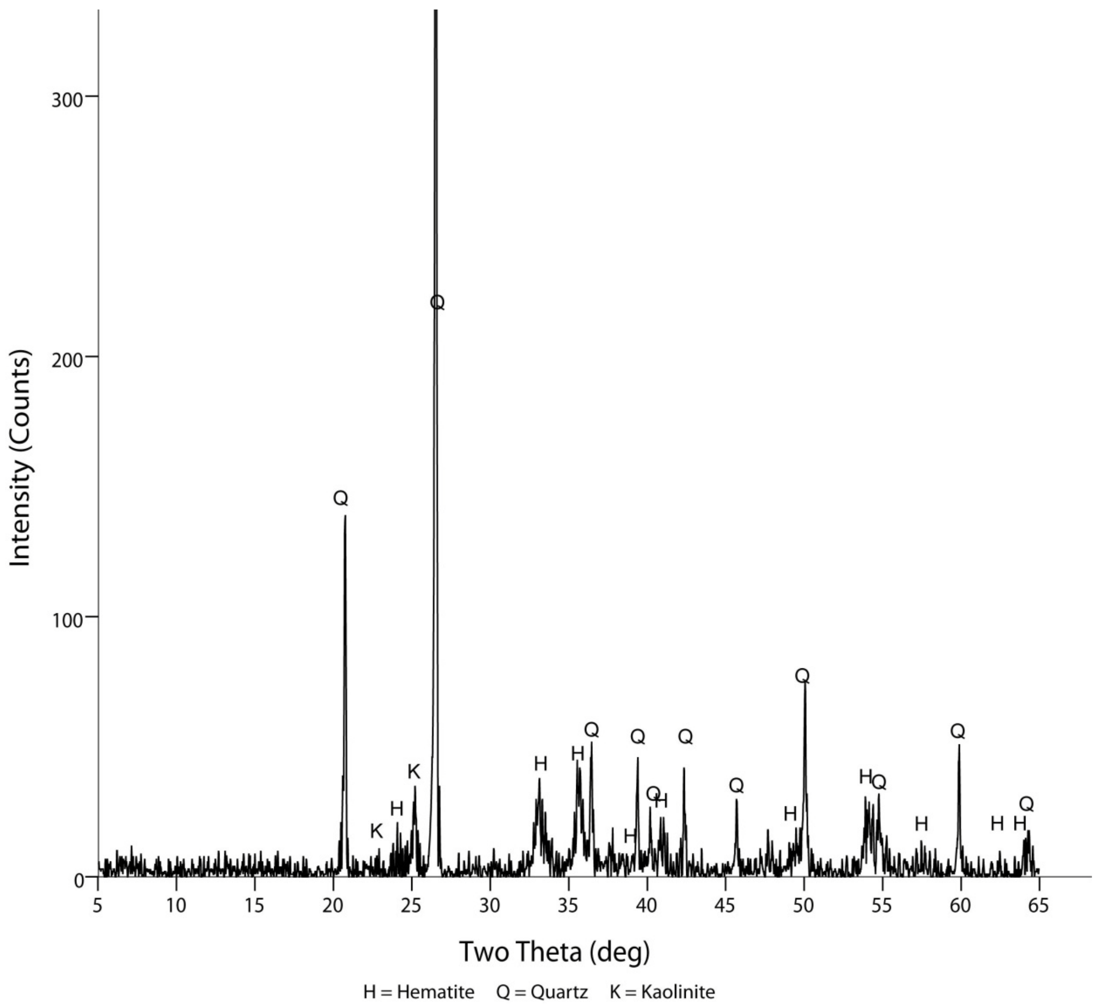


Fig. A.116. G104 Matjesfontein yellow heated

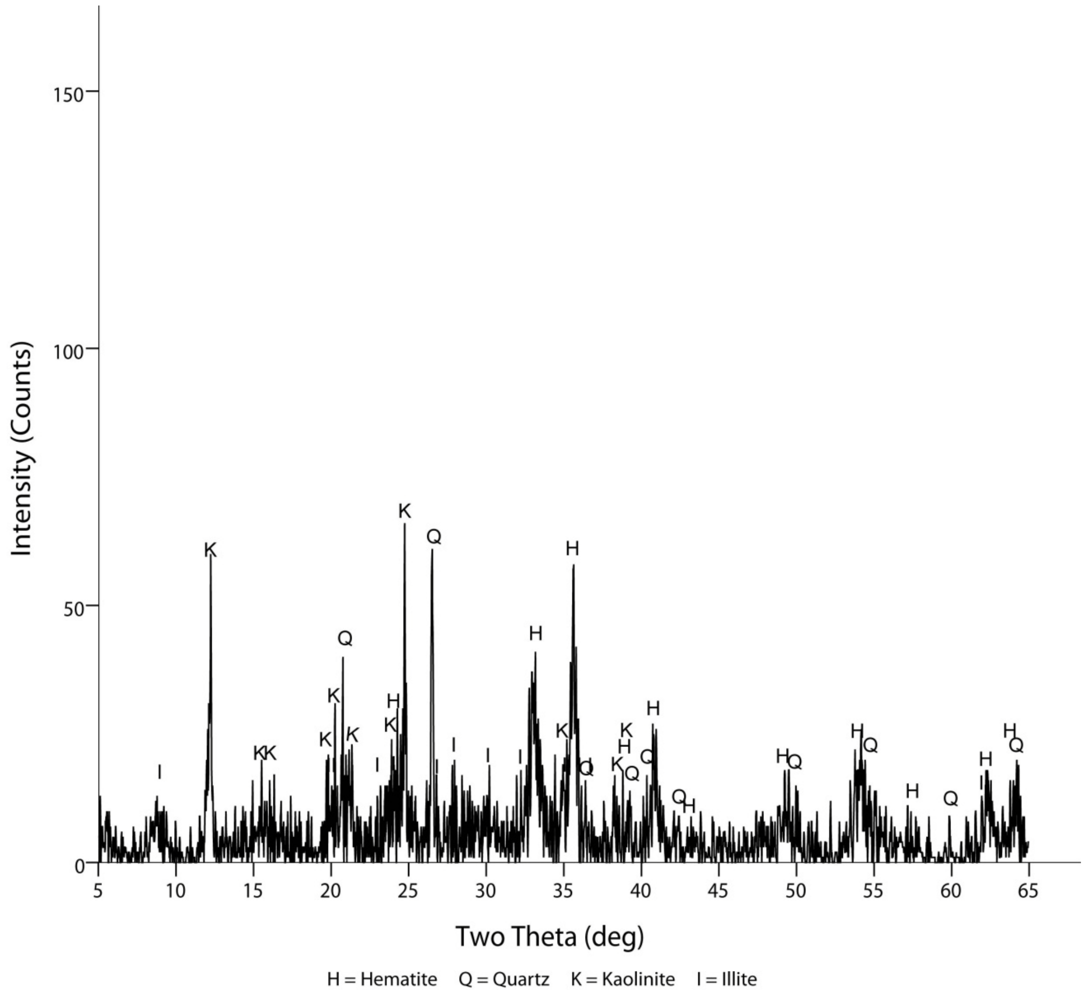


Fig. A.117. G106 Matjesfontein orange heated

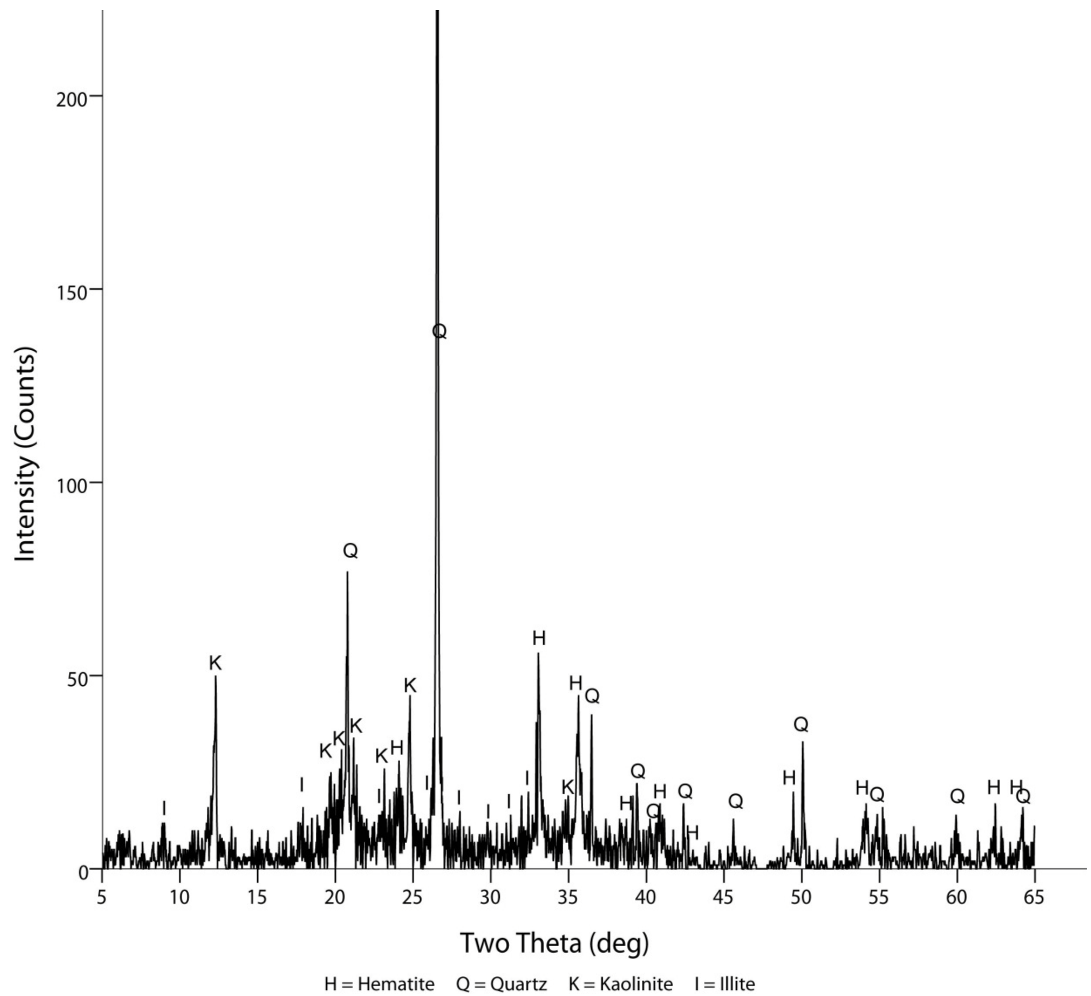


Fig. A.118. G238 Matjesfontein orange heated

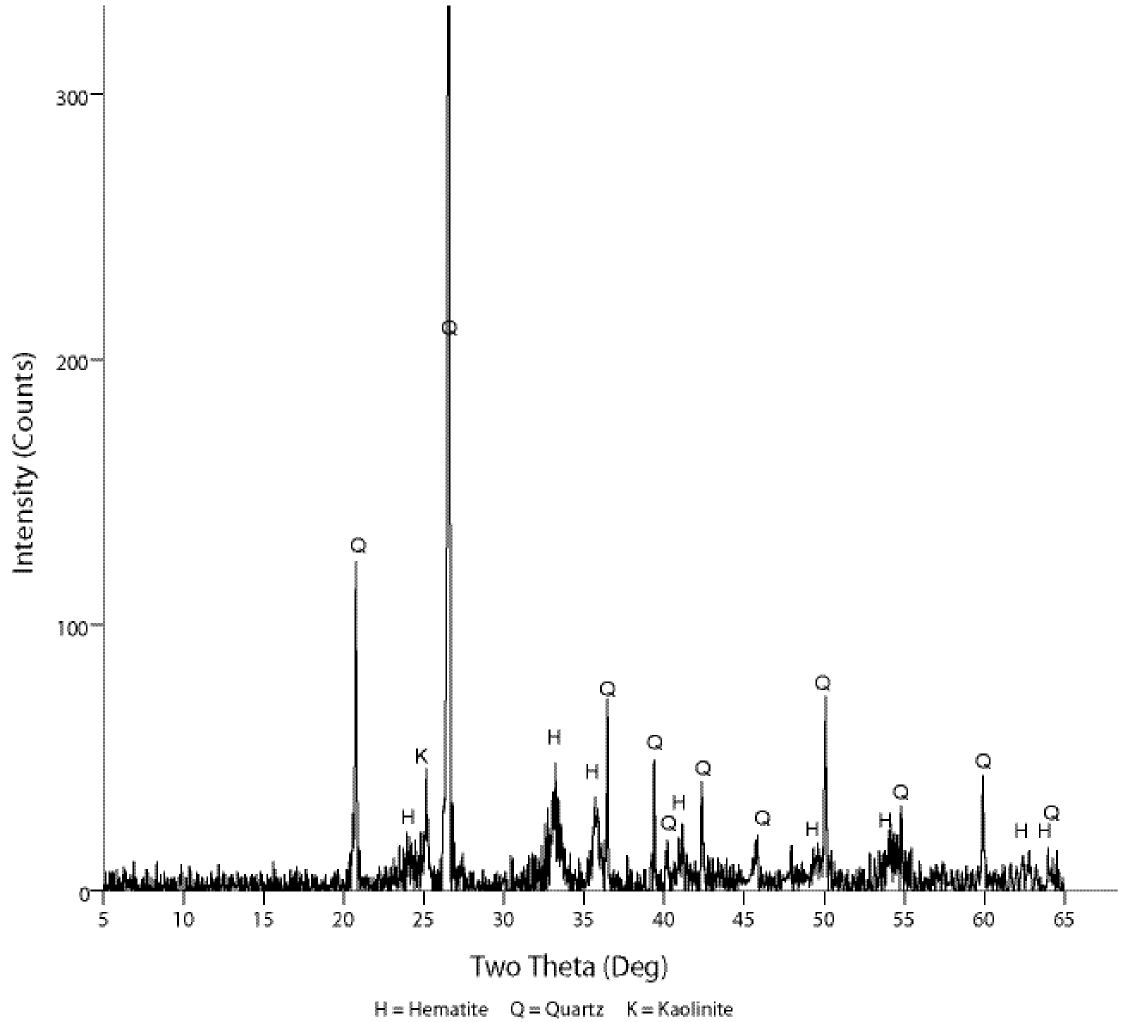


Fig. A.119. G239 Matjesfontein yellow heated

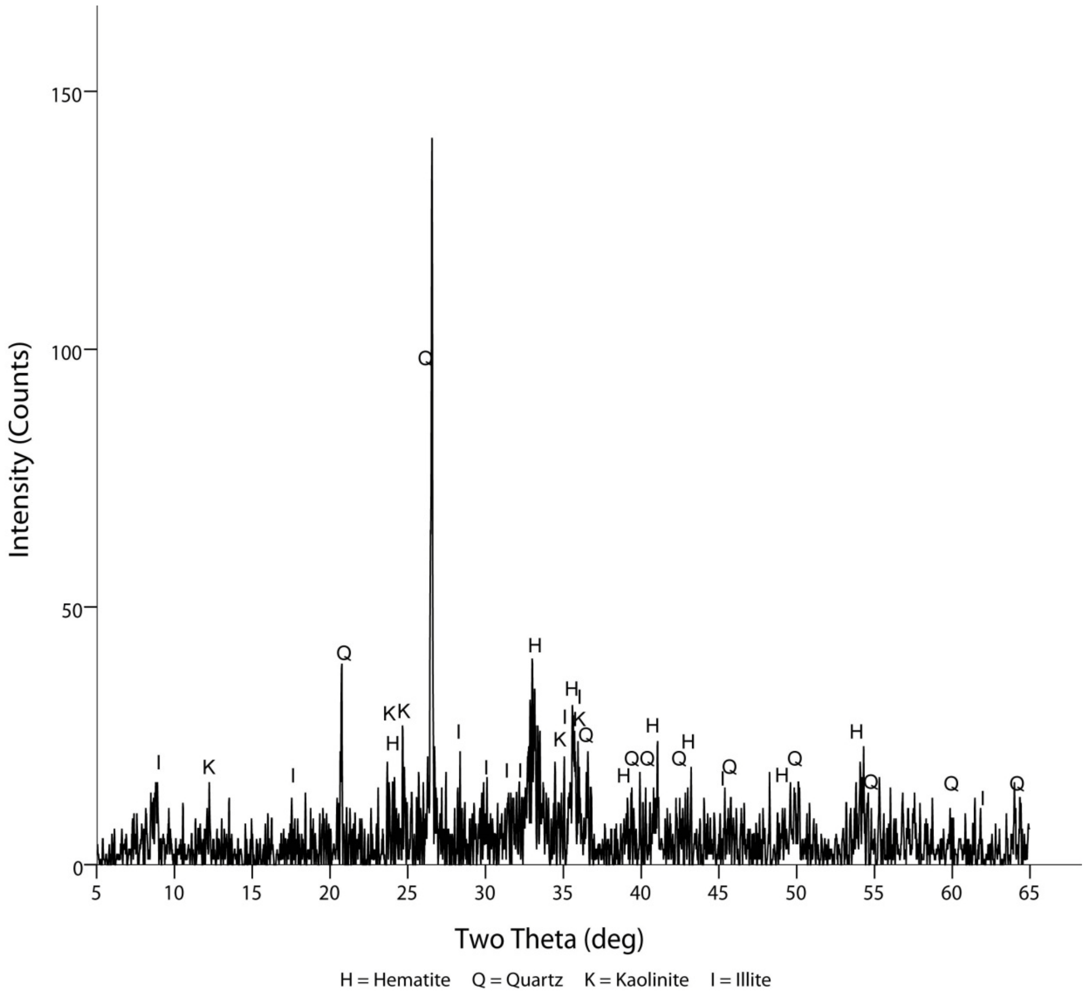


Fig. A.120. G240 Matjesfontein yellow heated

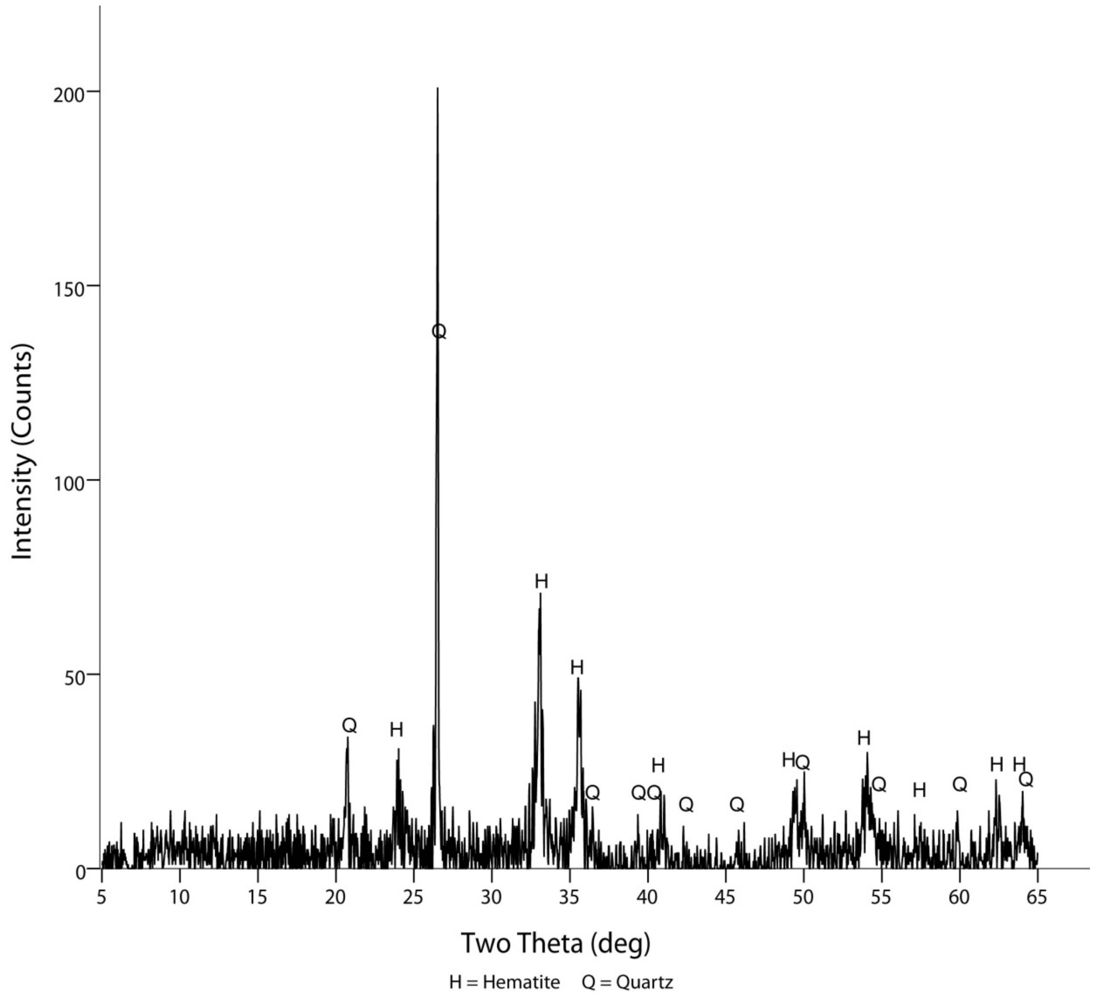


Fig. A.121. G241 Matjesfontein orange heated

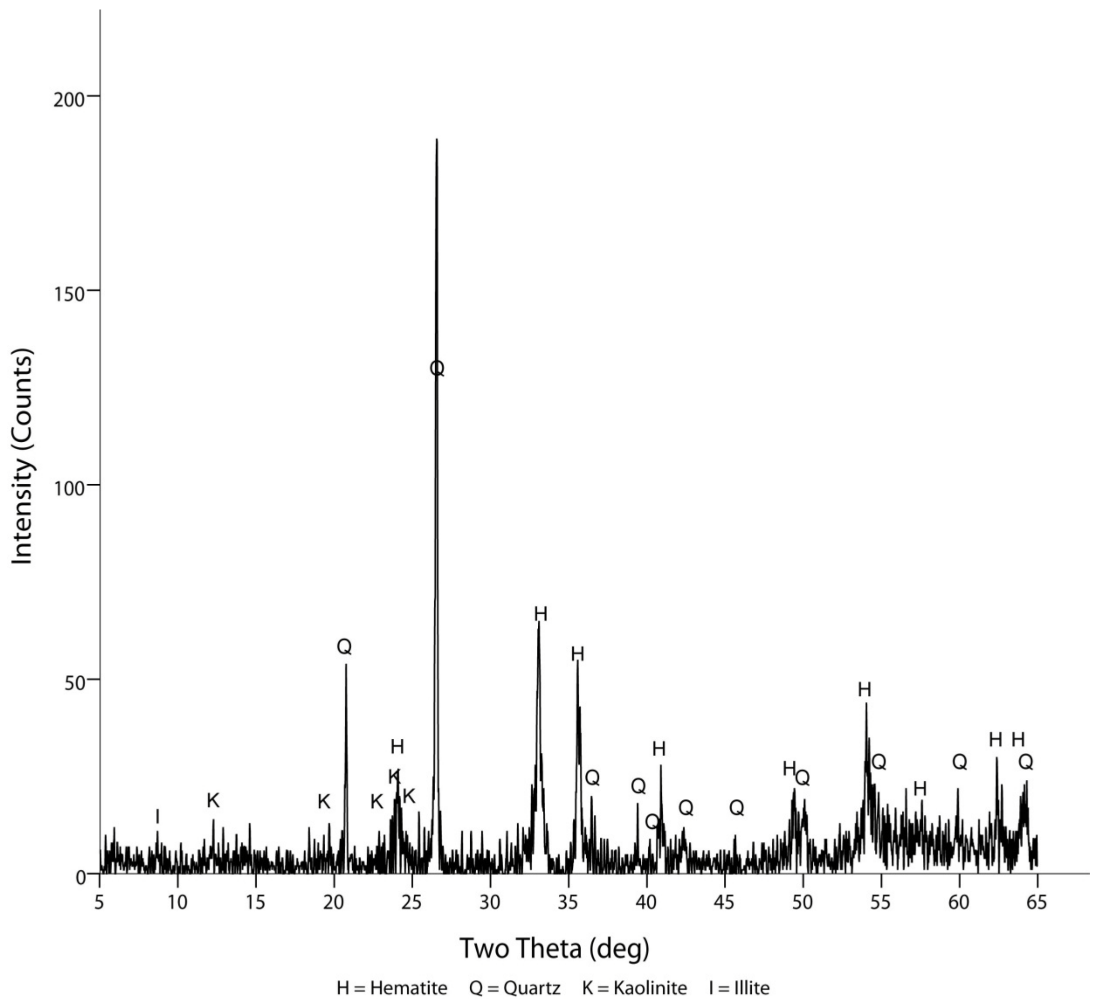


Fig. A.122. G242 Matjesfontein orange heated

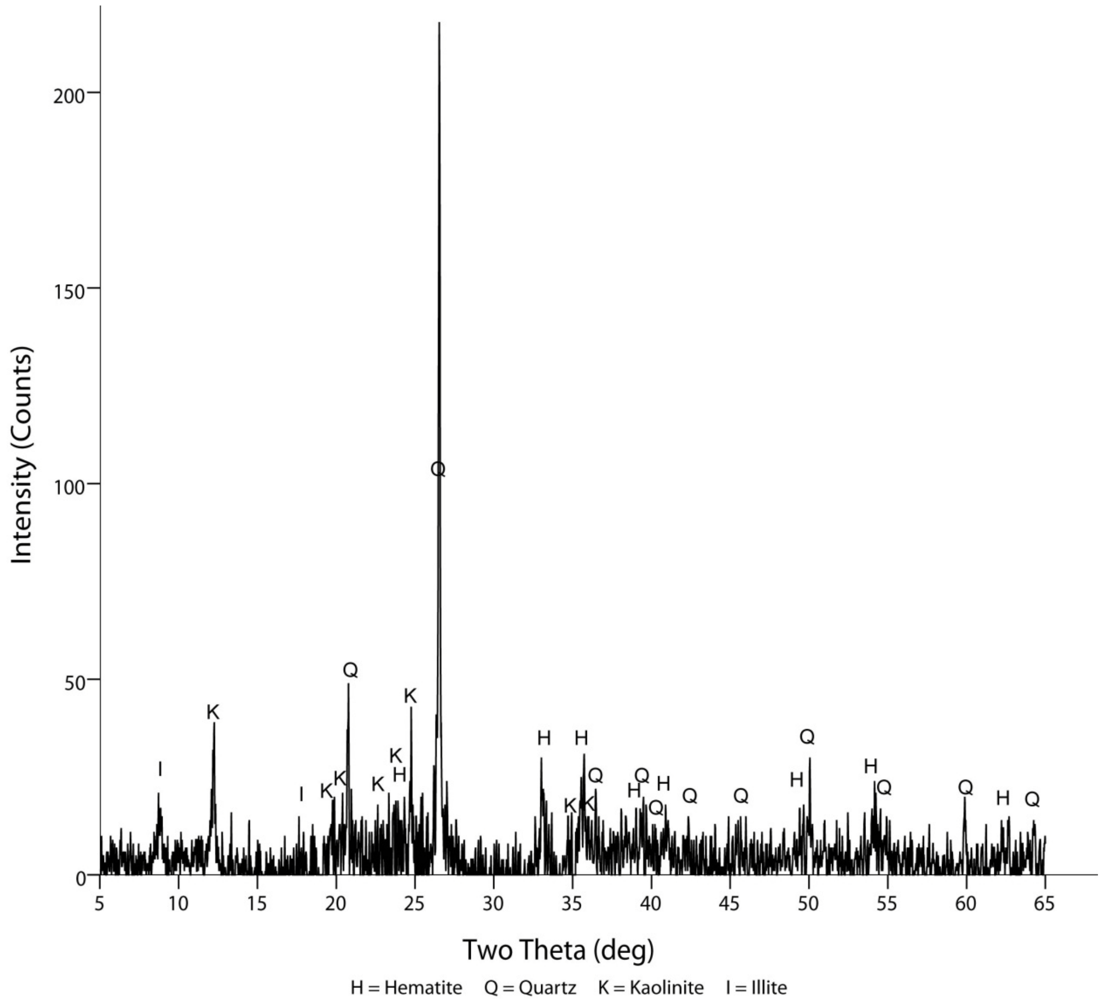


Fig. A.123. G243 Matjesfontein orange heated

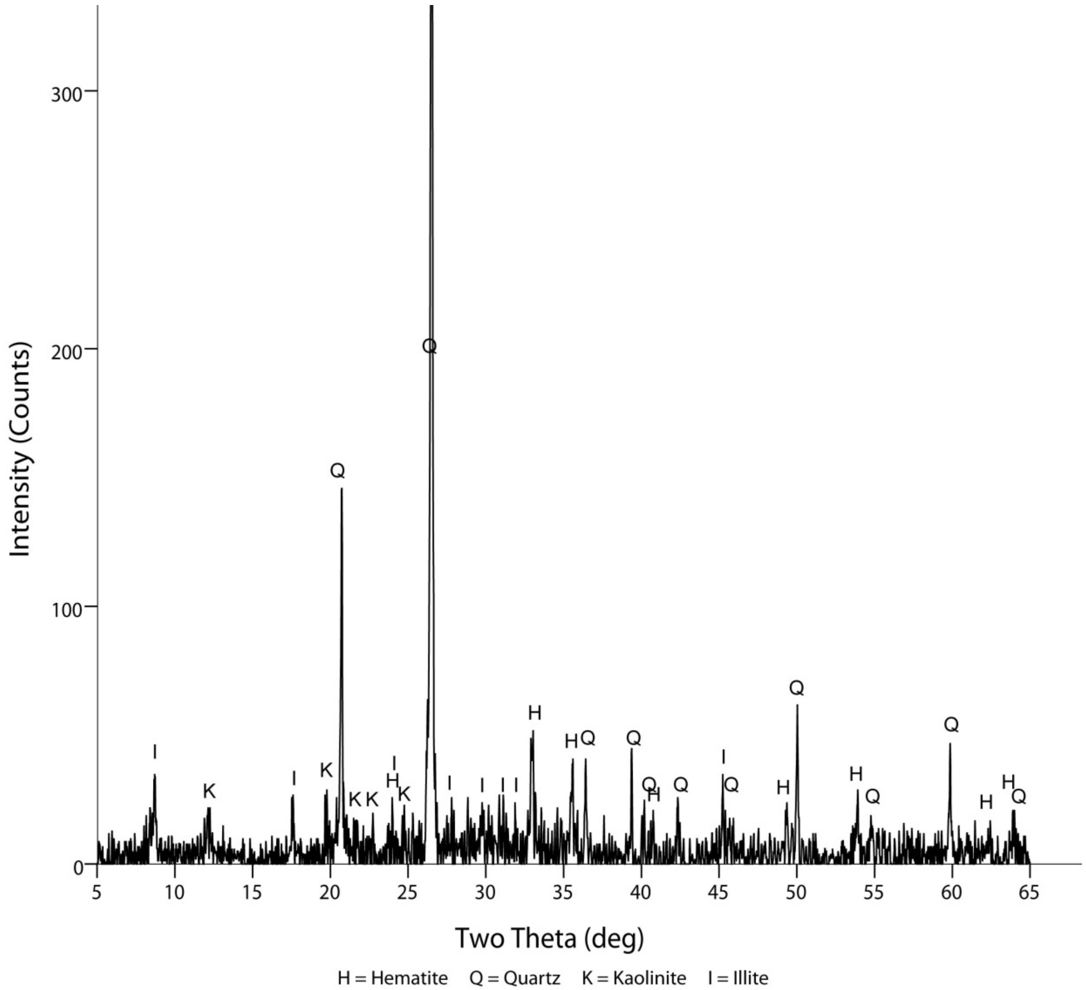


Fig. A.124. G179 Oude Duinigt red

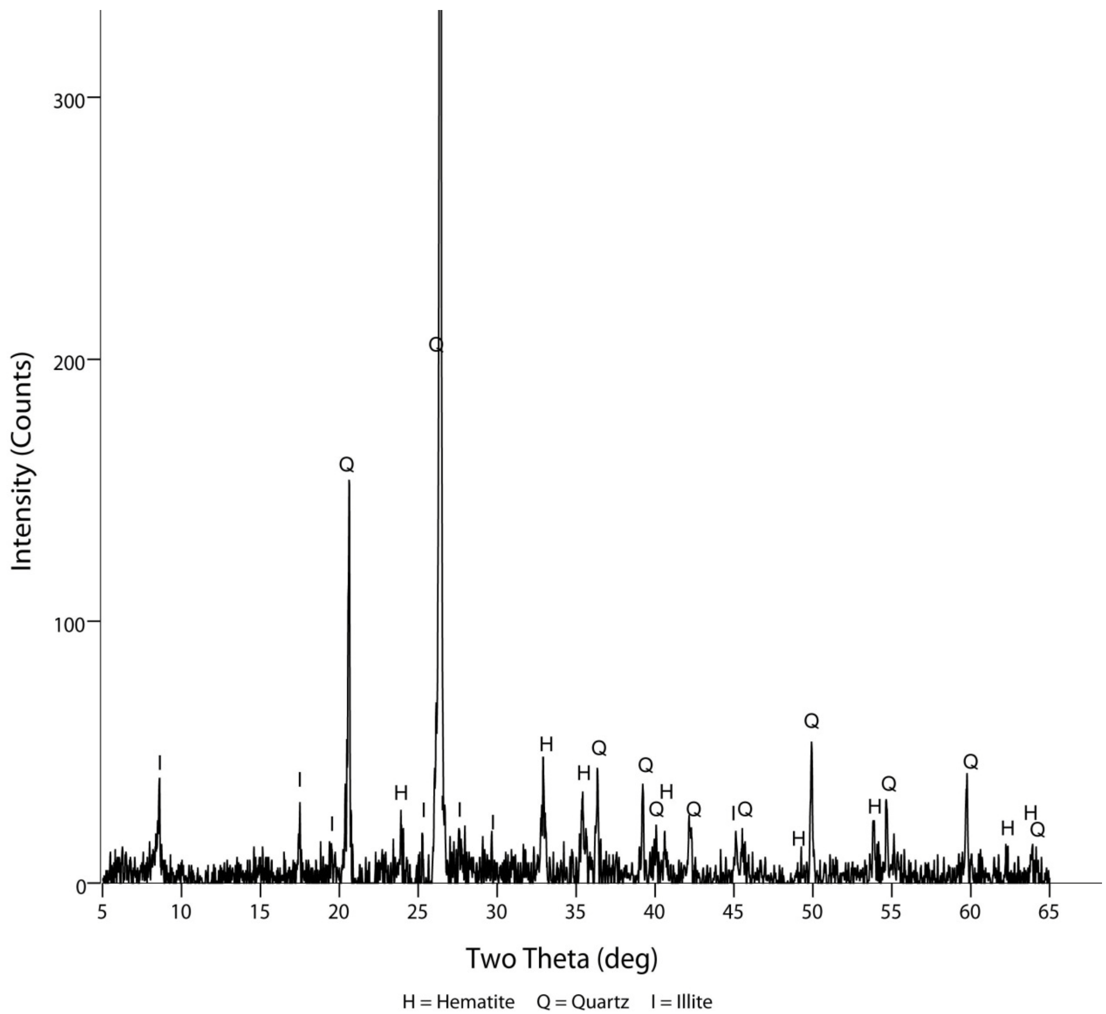


Fig. A.125. G181 Oude Duinigt red heated

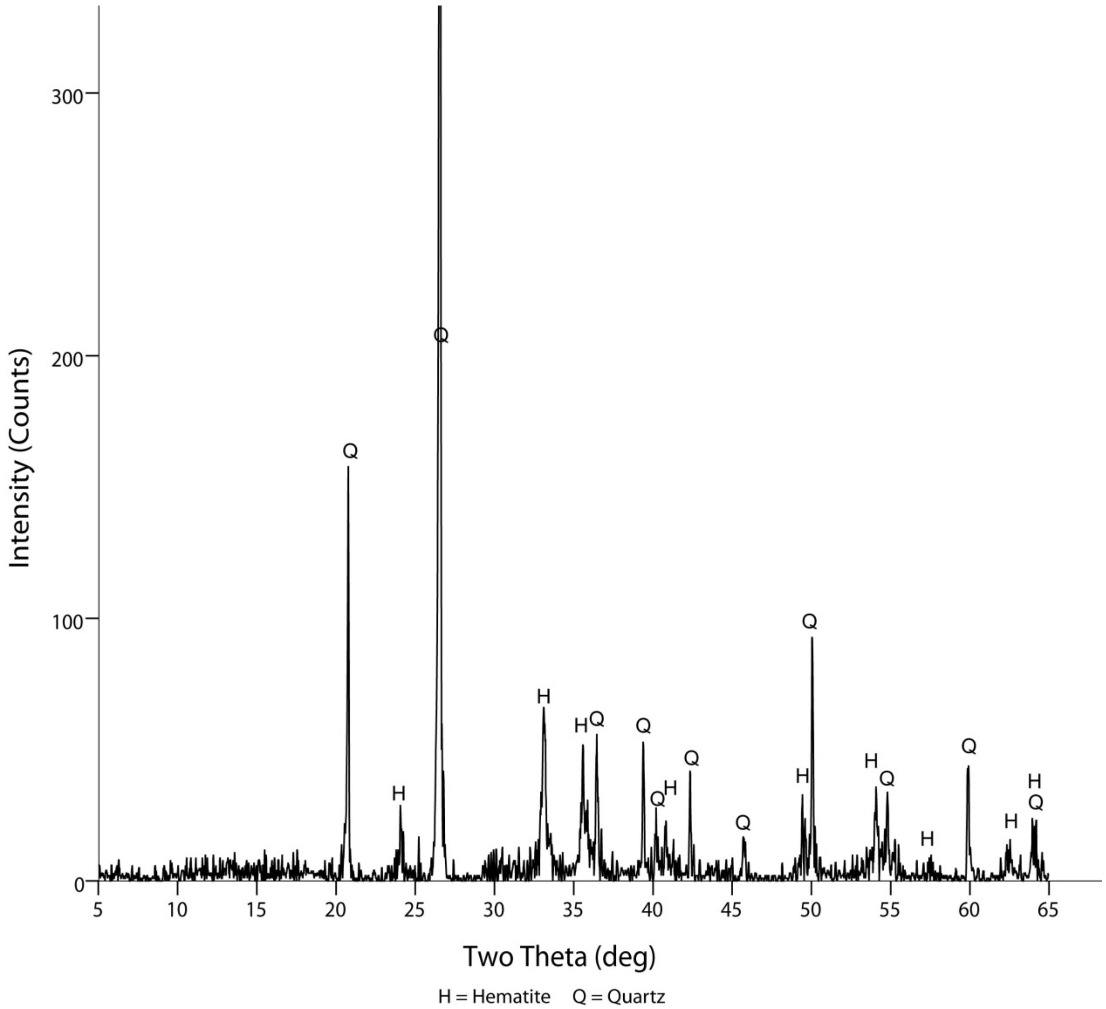


Fig. A.126. G217 Oude Duinigt red heated

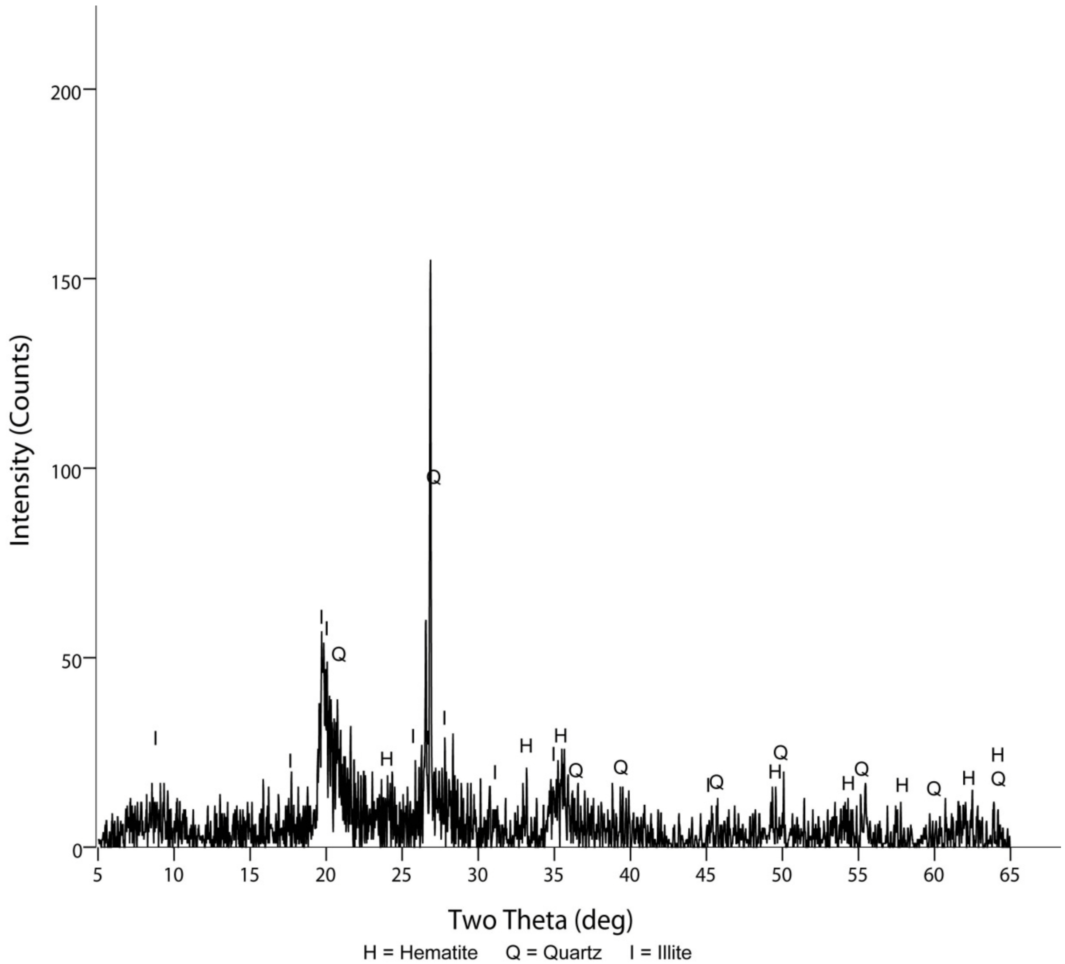


Fig. A.127. G218 Oude Duinigt red heated

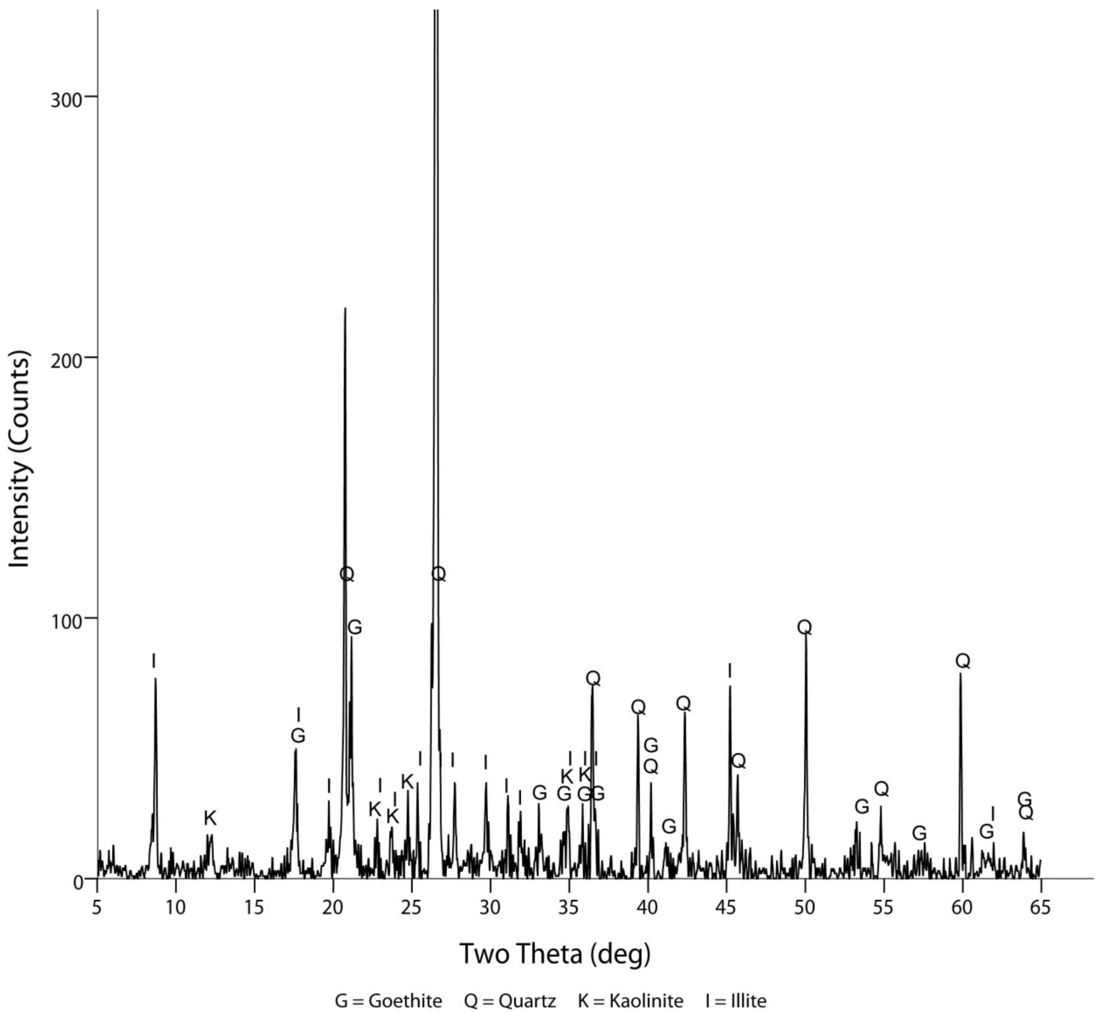


Fig. A.128. G62 Pinnacle Po int A yellow

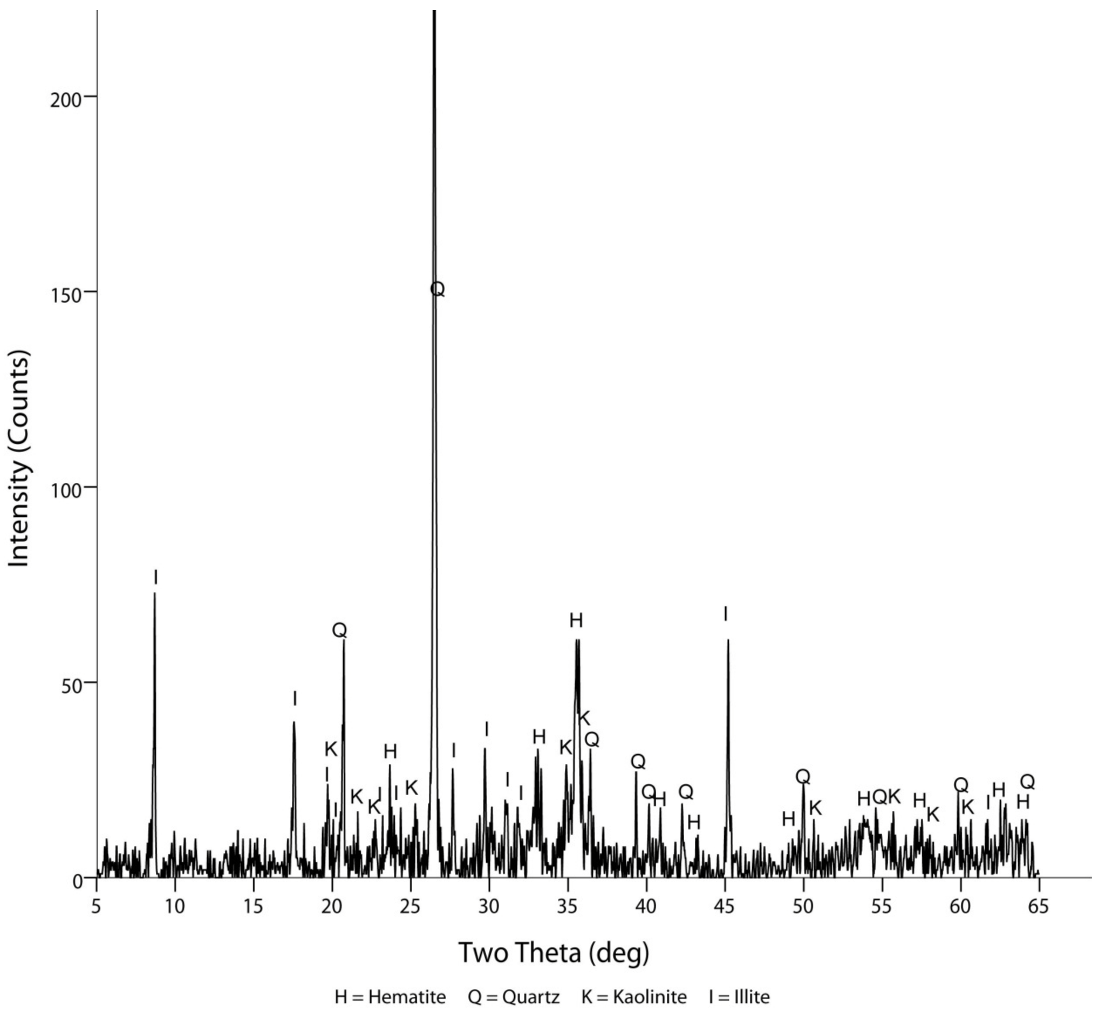


Fig. A.129. G30 Pinnacle Point A yellow heated

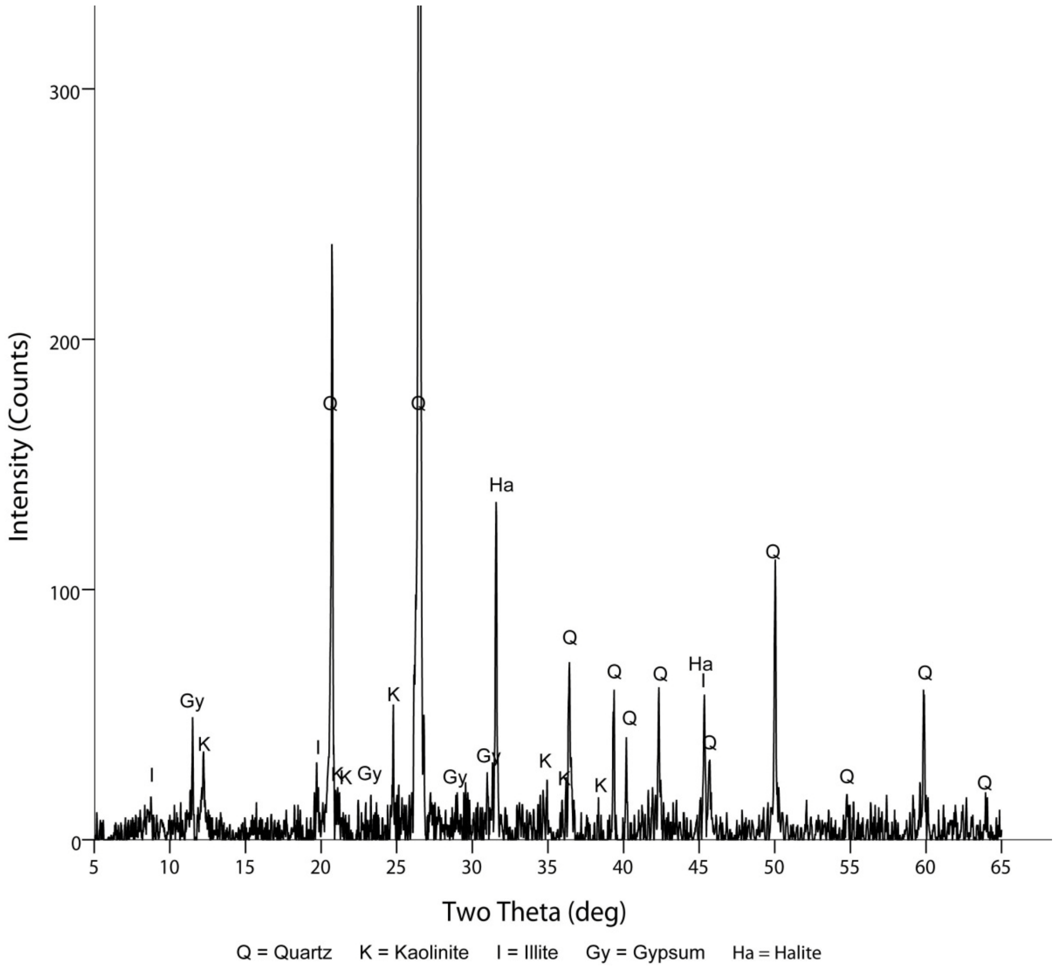


Fig. A.130. G63 Pinnacle Point B yellow

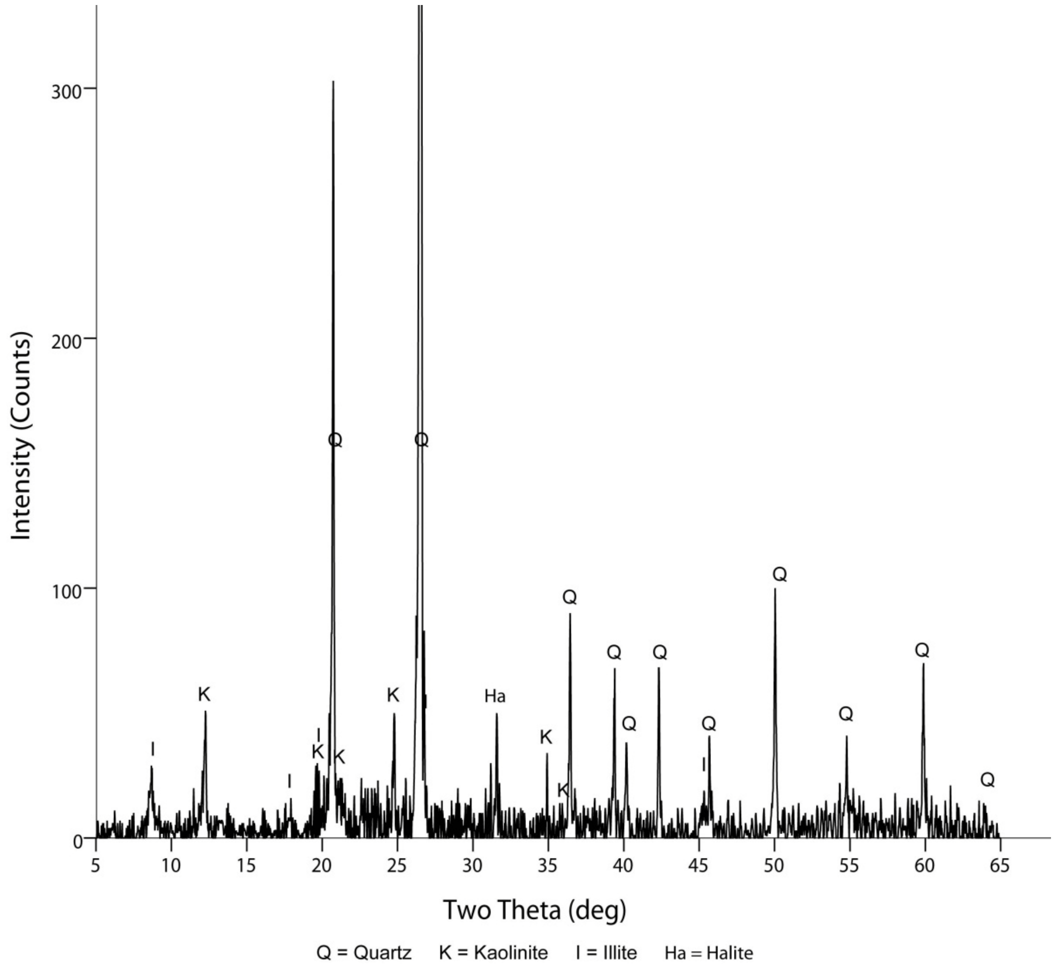


Fig. A.131. G64 Pinnacle Point B yellow

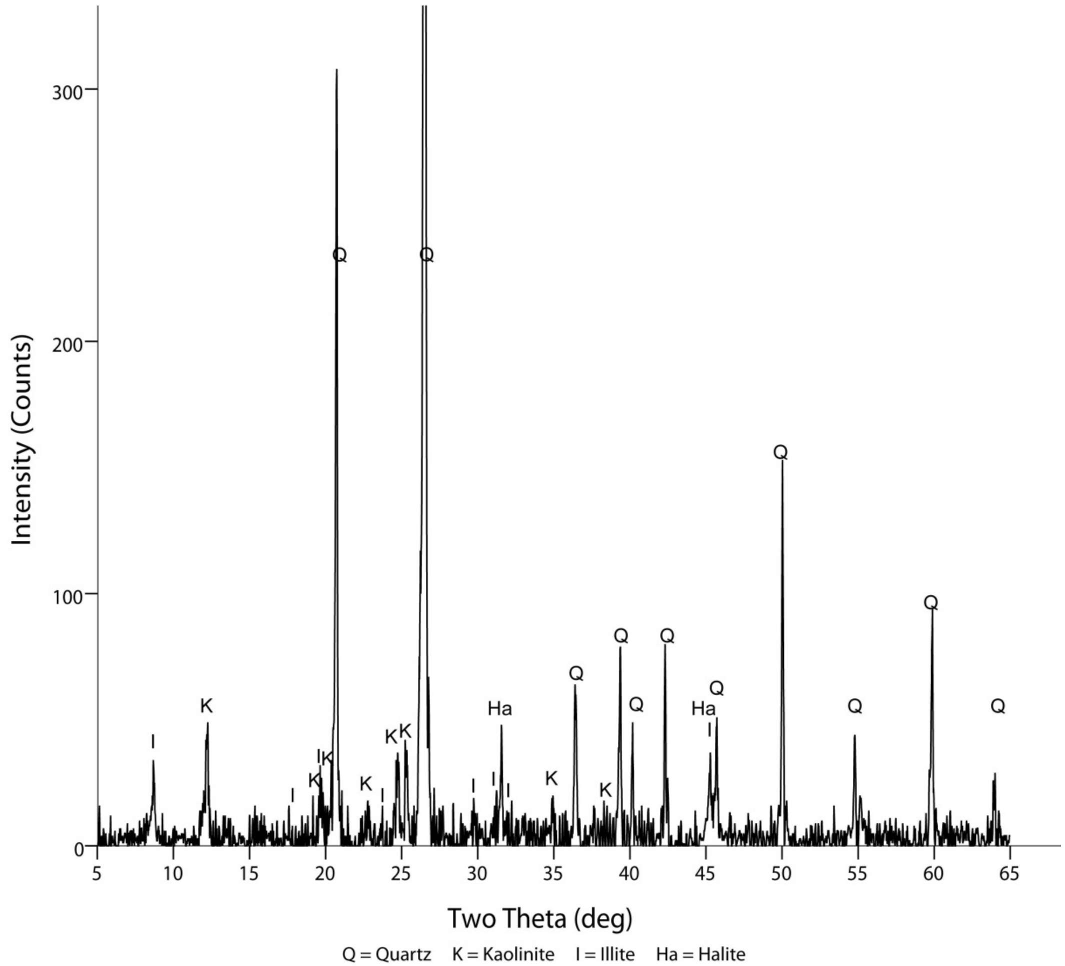


Fig. A.132. G31 Pinnacle Point B yellow heated

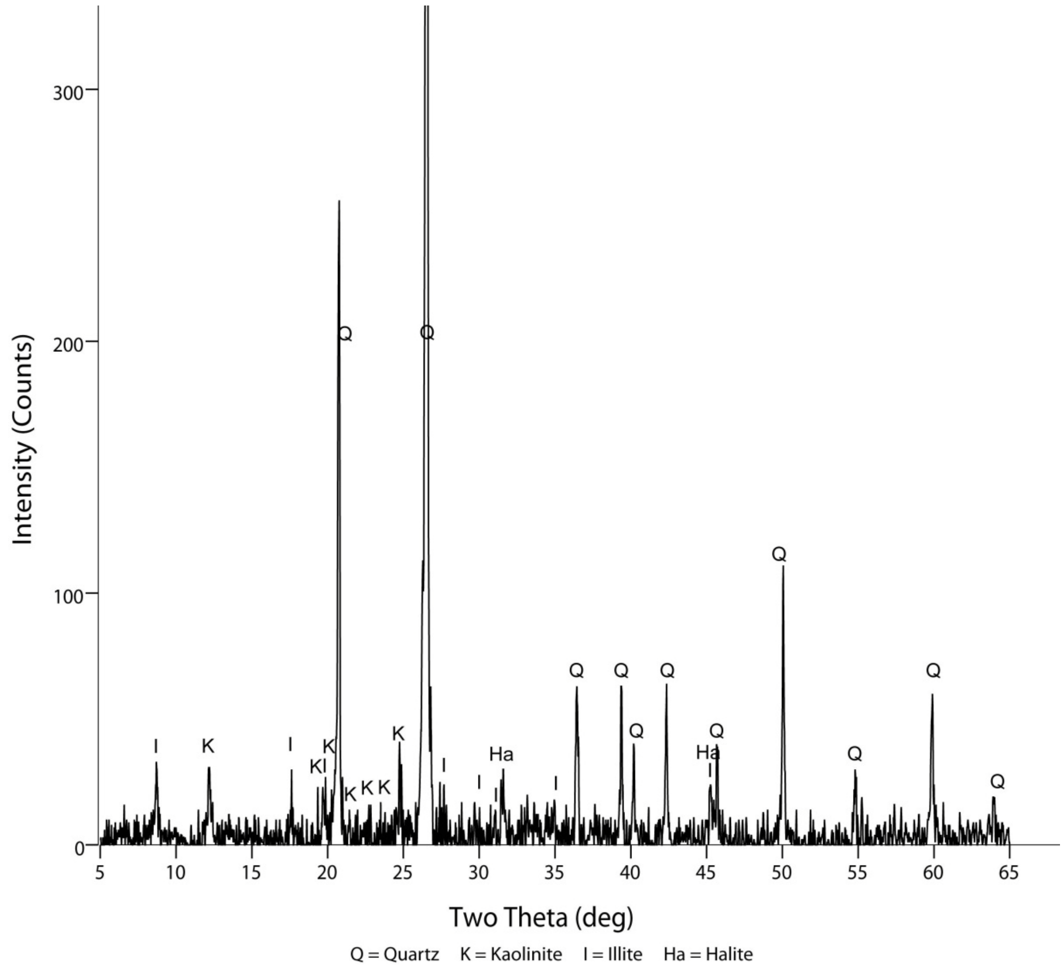


Fig. A.133. G32 Pinnacle Point B yellow heated

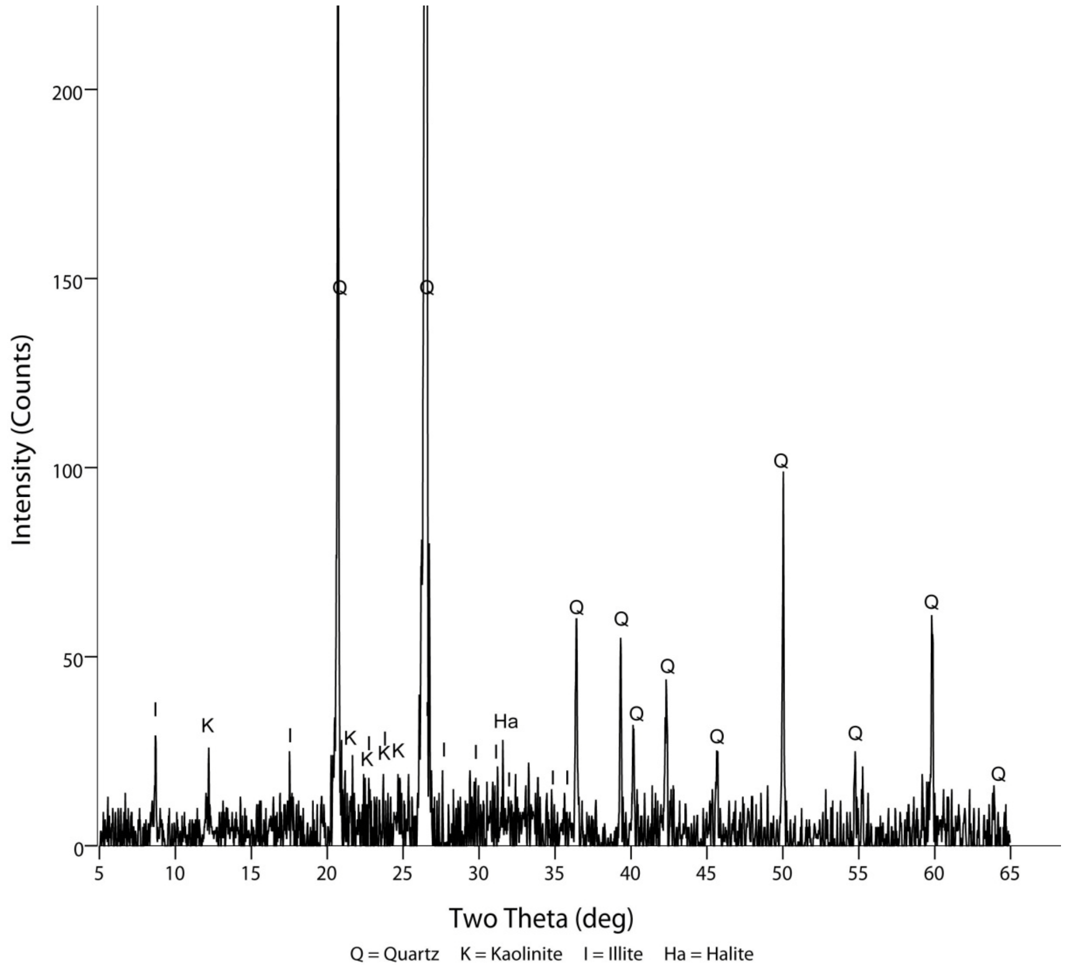


Fig. A.134. G33 Pinnacle Point B yellow heated

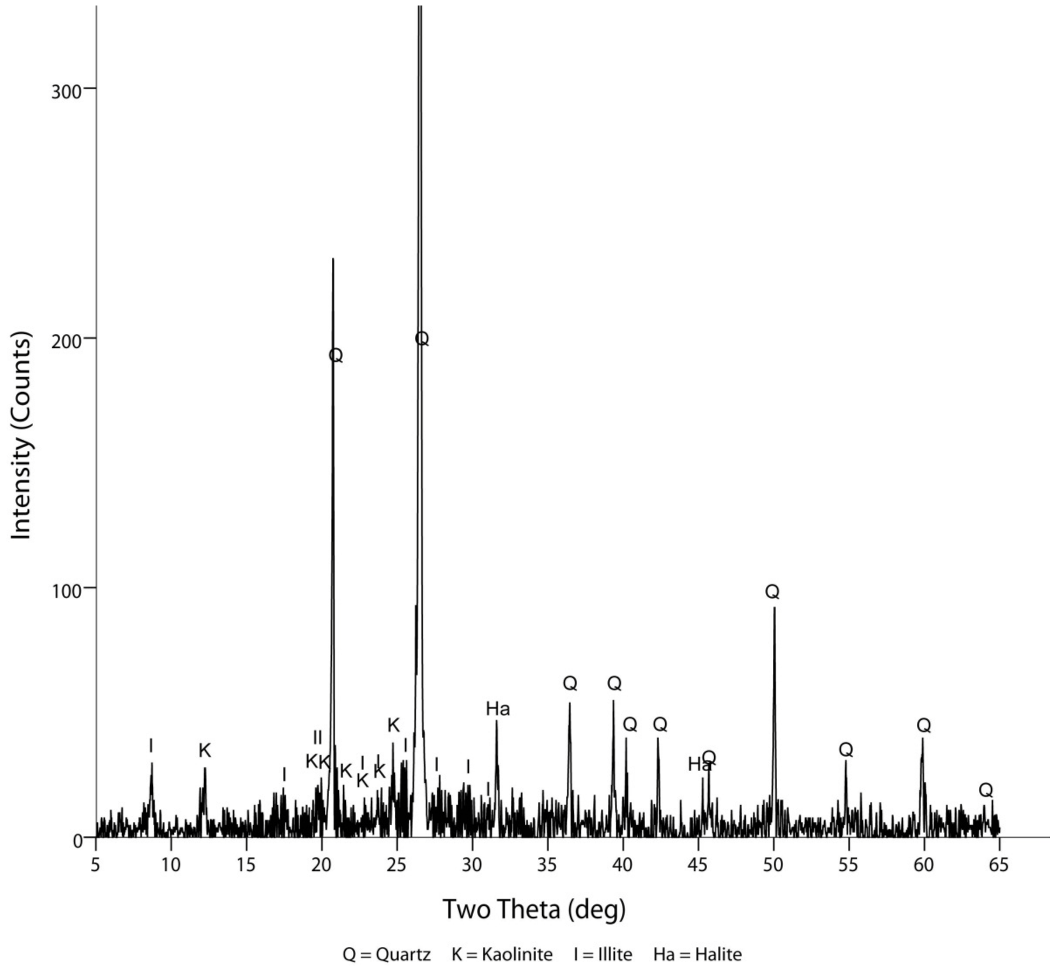


Fig. A.135. G258 Pinnacle Point B yellow heated

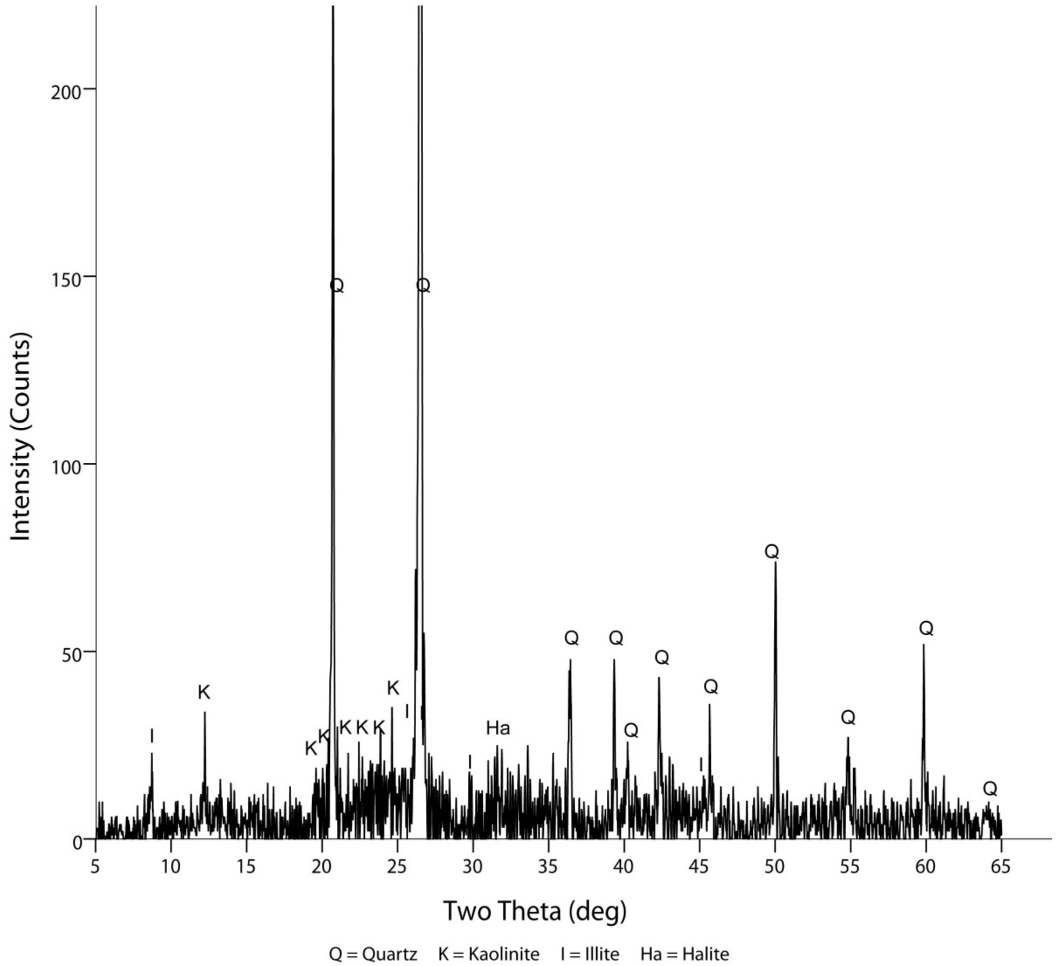


Fig. A.136. G260 Pinnacle Point B yellow heated

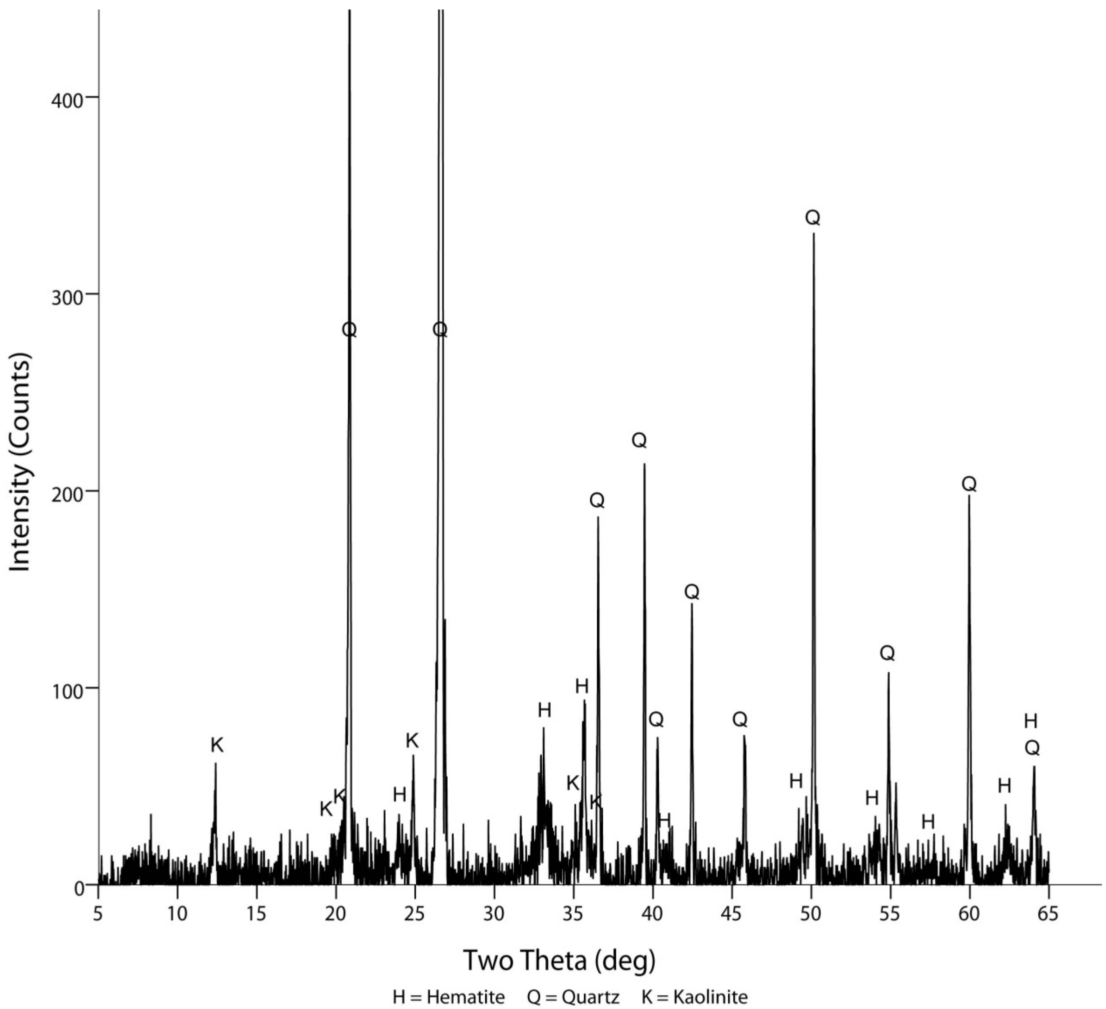


Fig. A.137. G279 Pinnacle Point C red

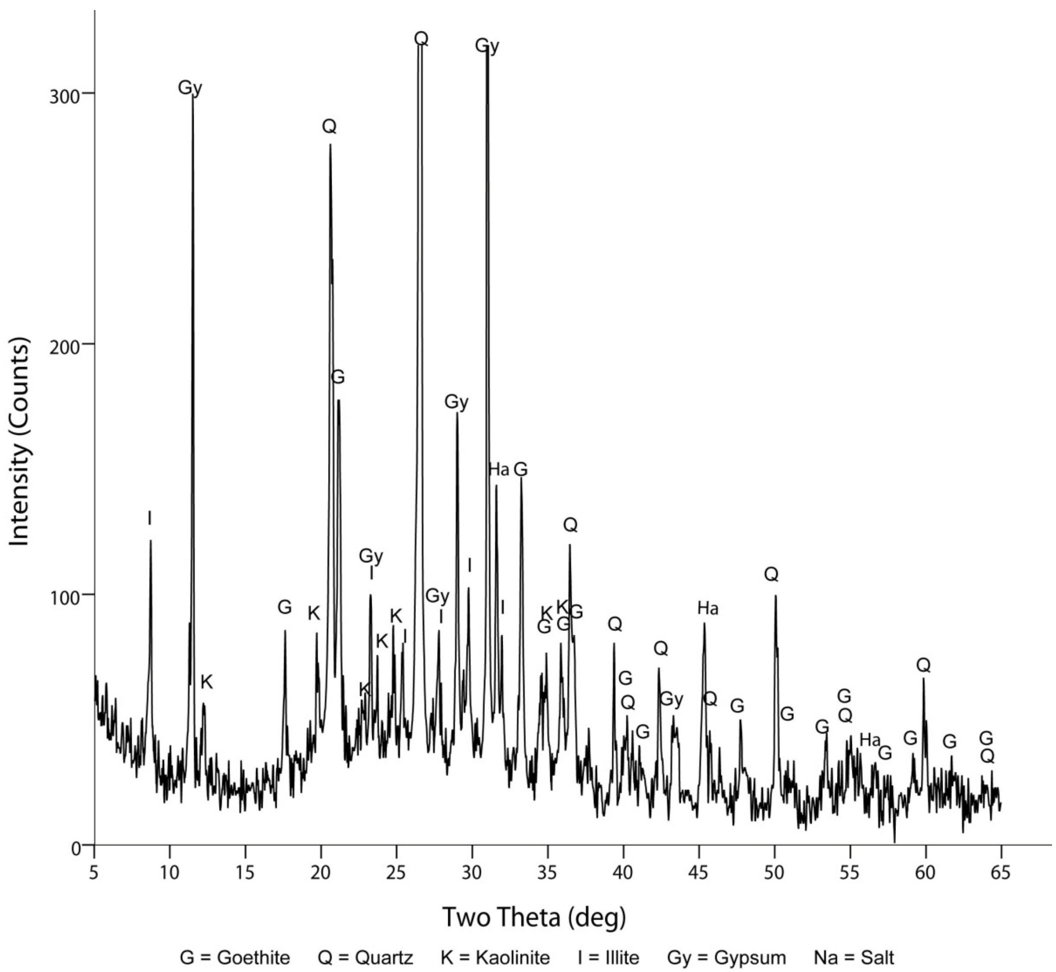


Fig. A.138. G280 Pinnacle Point C yellow

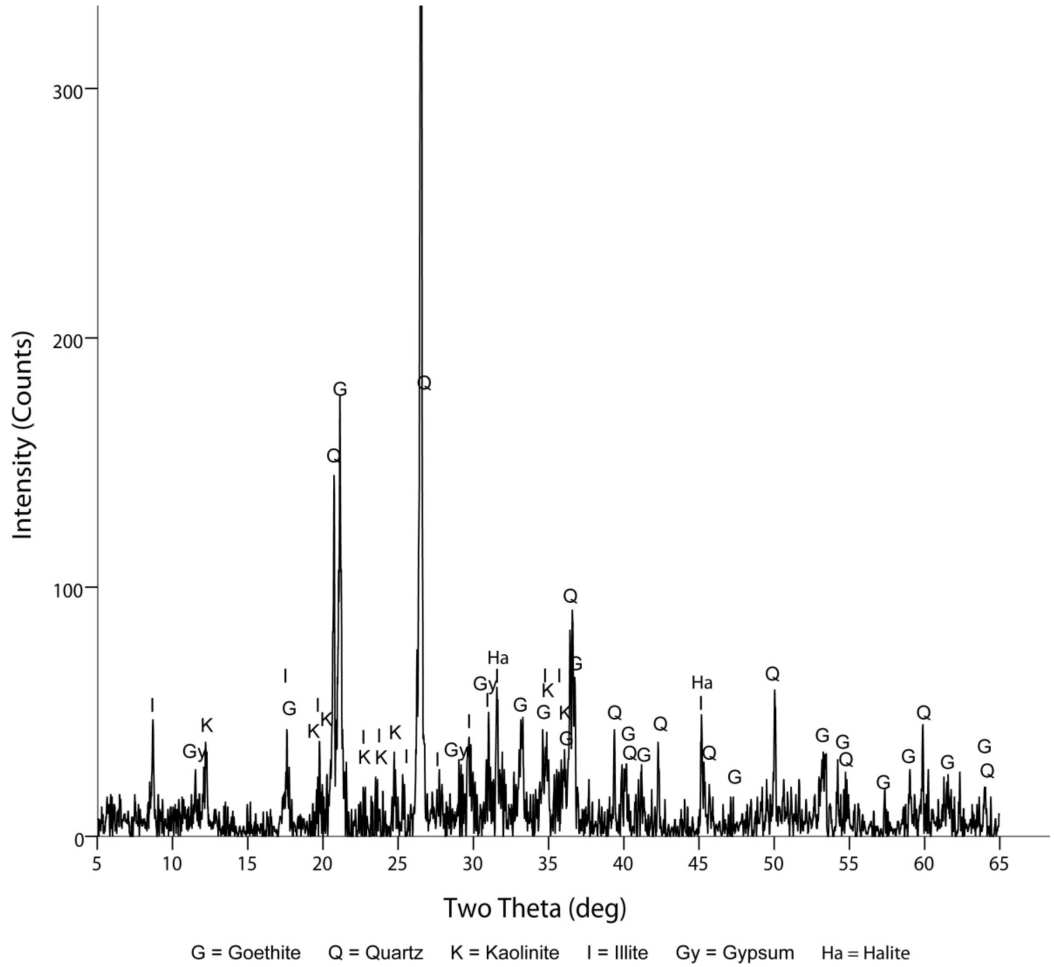


Fig. A.139. G282 Pinnacle Point C yellow

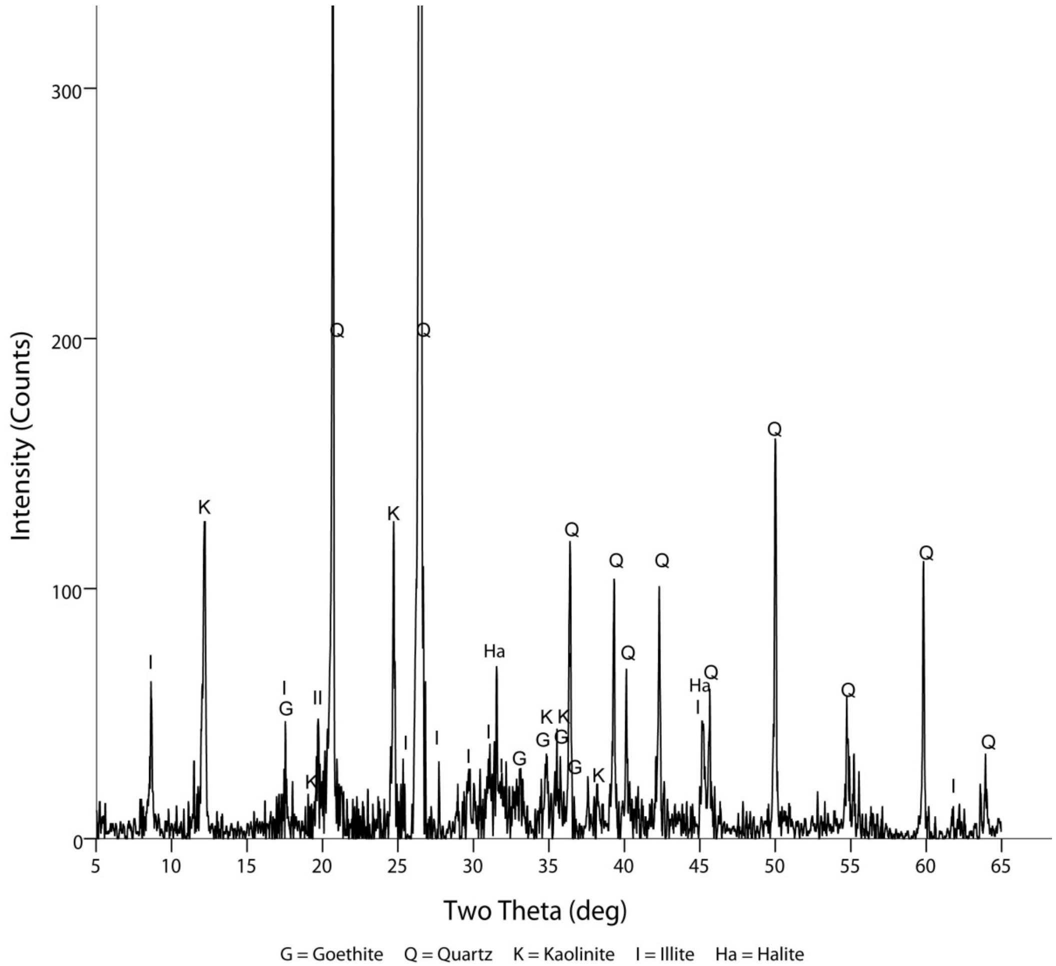


Fig. A.140. G283 Pinnacle Point C yellow

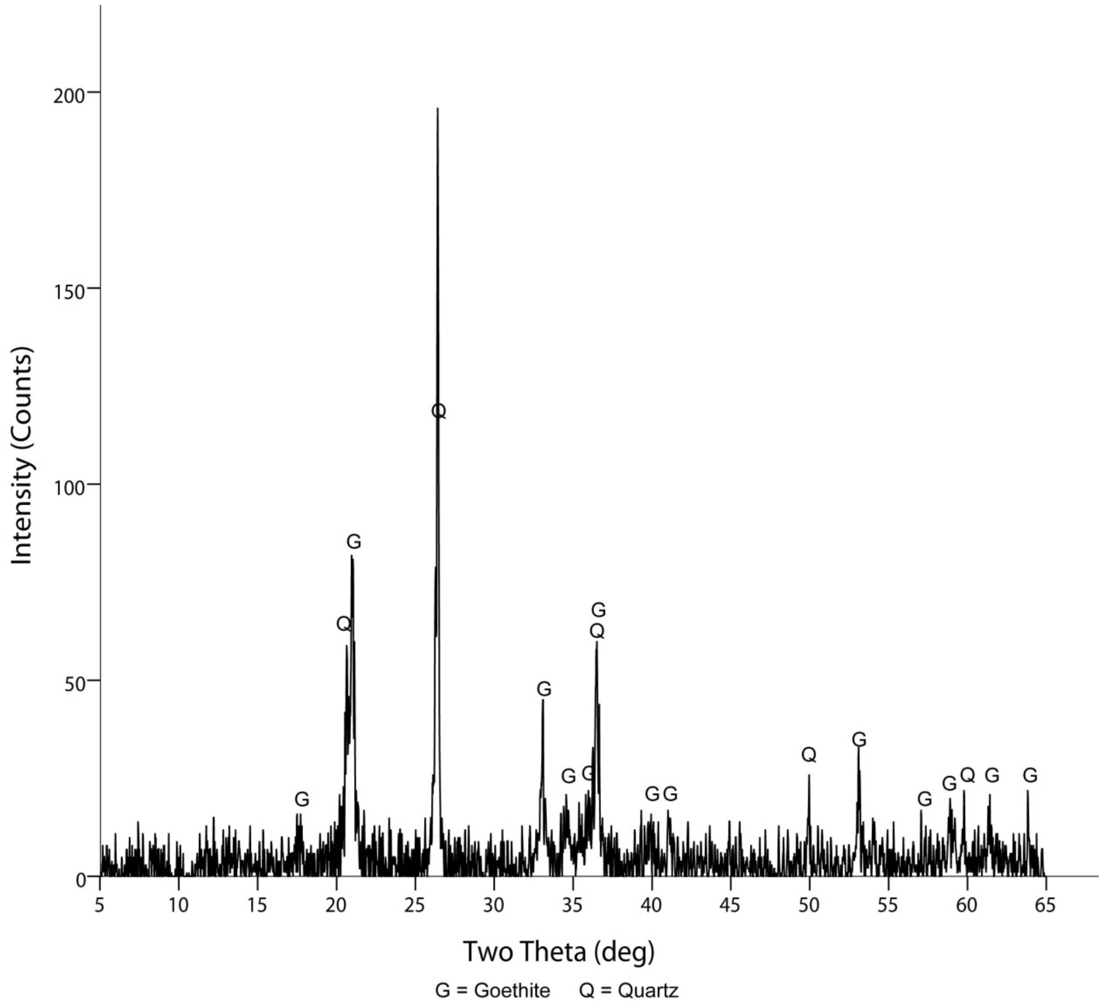


Fig. A.141. G55 Rietvlei A red/orange/yellow

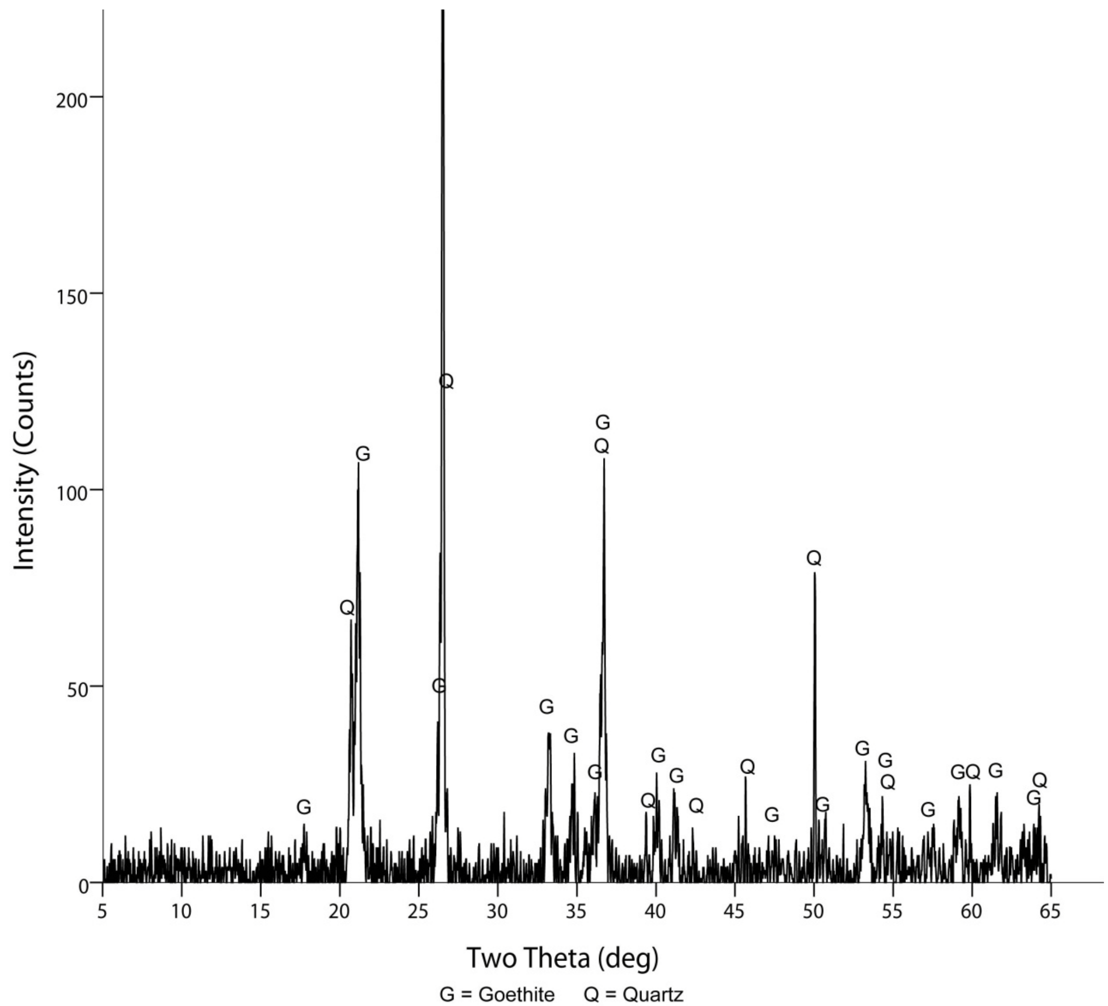


Fig. A.142. G56 Rietvlei A red/orange/yellow

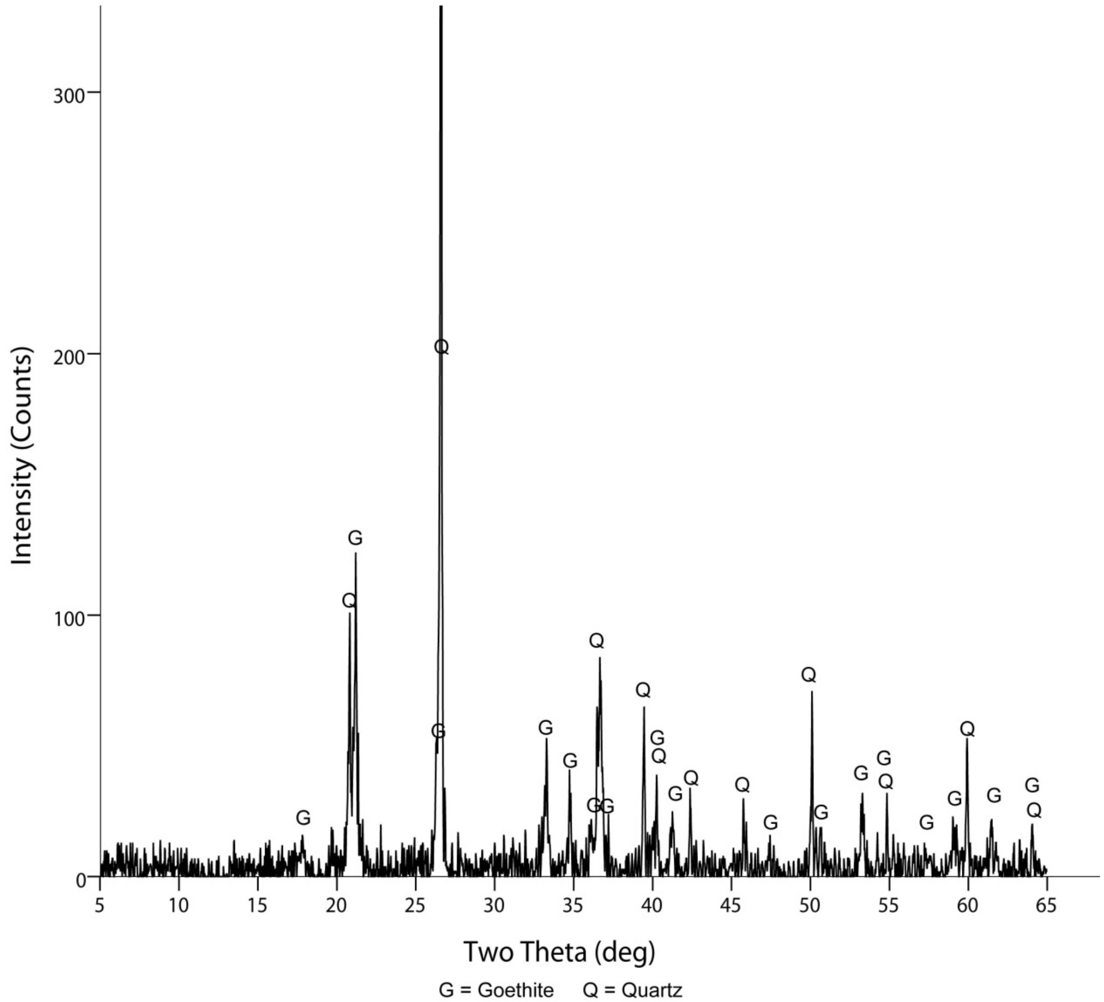


Fig. A.143. G57 Rietvlei A red/orange/yellow

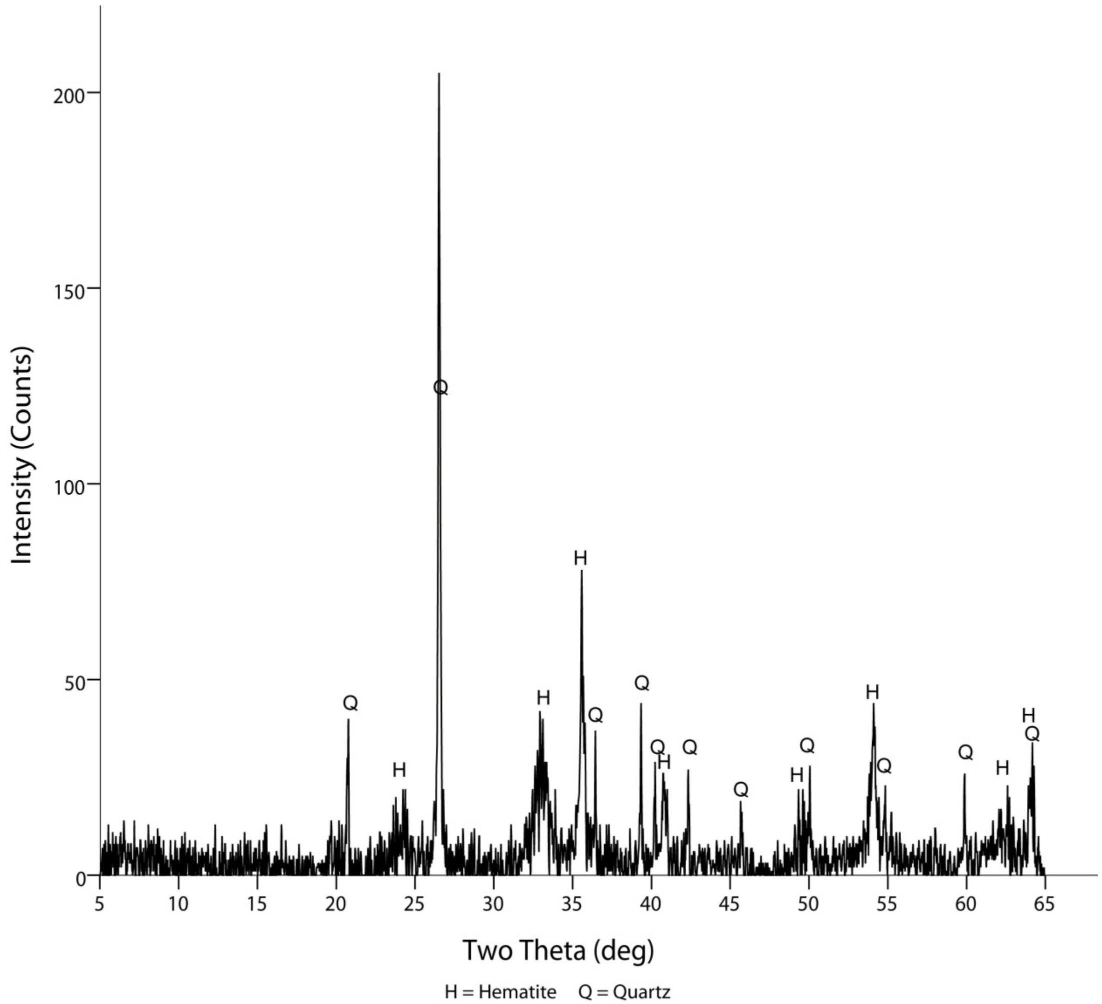


Fig. A.144. G82 Rietvlei A red/orange/yellow heated

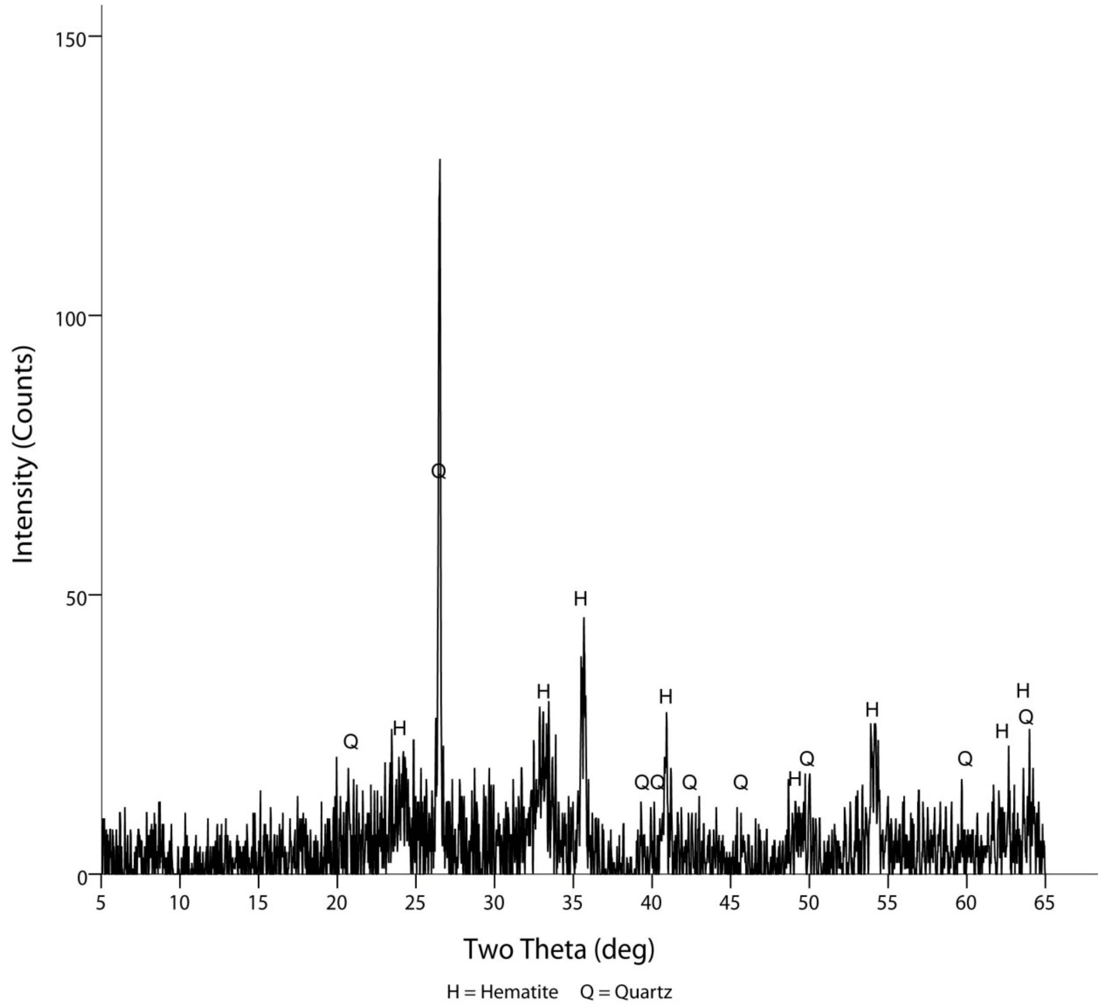


Fig. A.145. G83 Rietvlei A red/orange/yellow heated

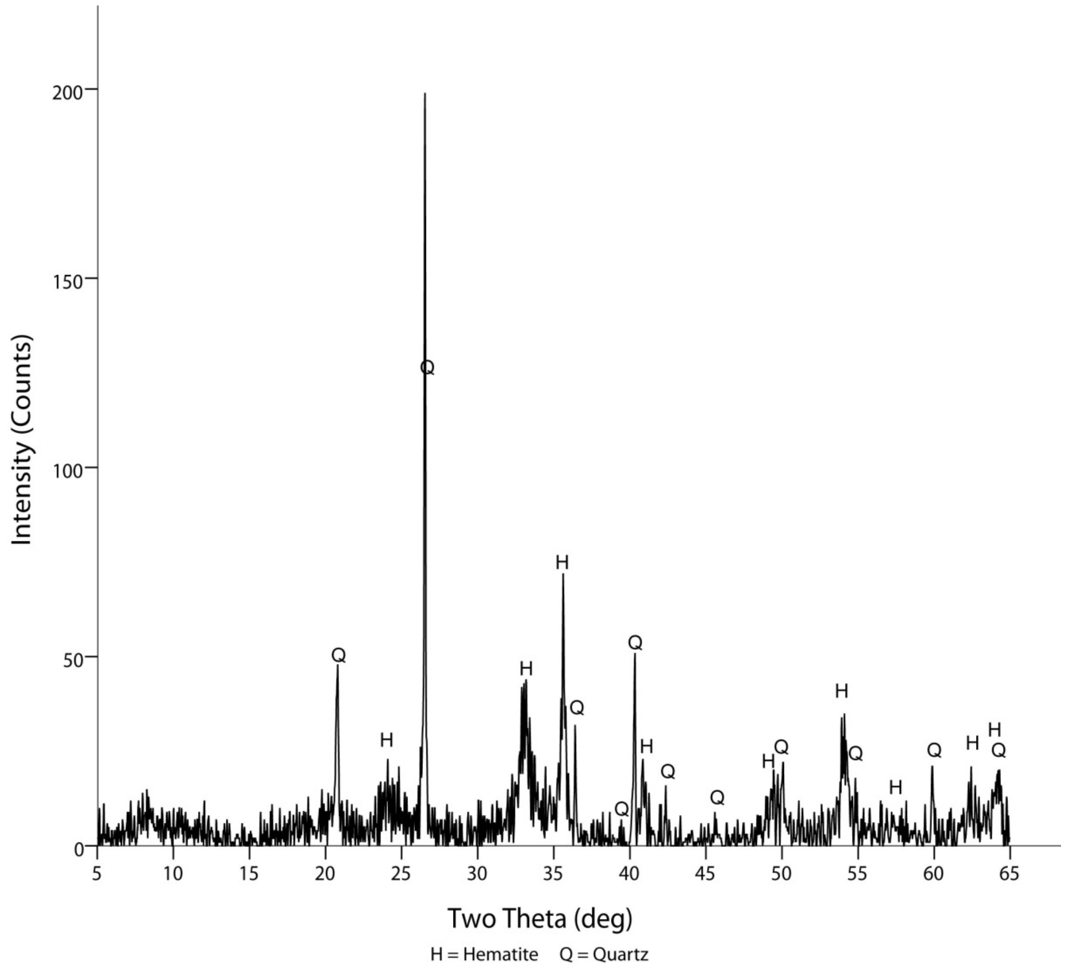


Fig. A.146. G84 Rietvlei A red/orange/yellow heated

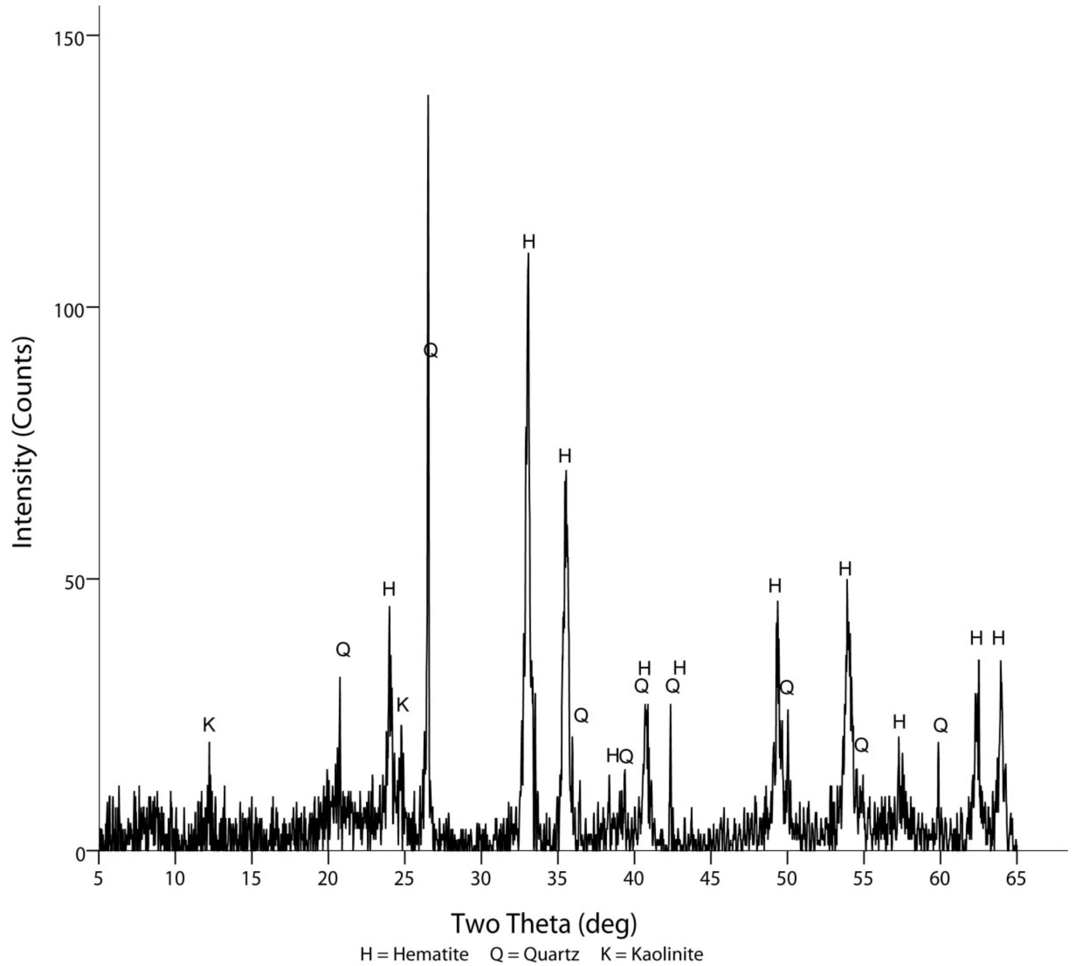


Fig. A.147. G171 Rietvlei A red/orange/yellow heated

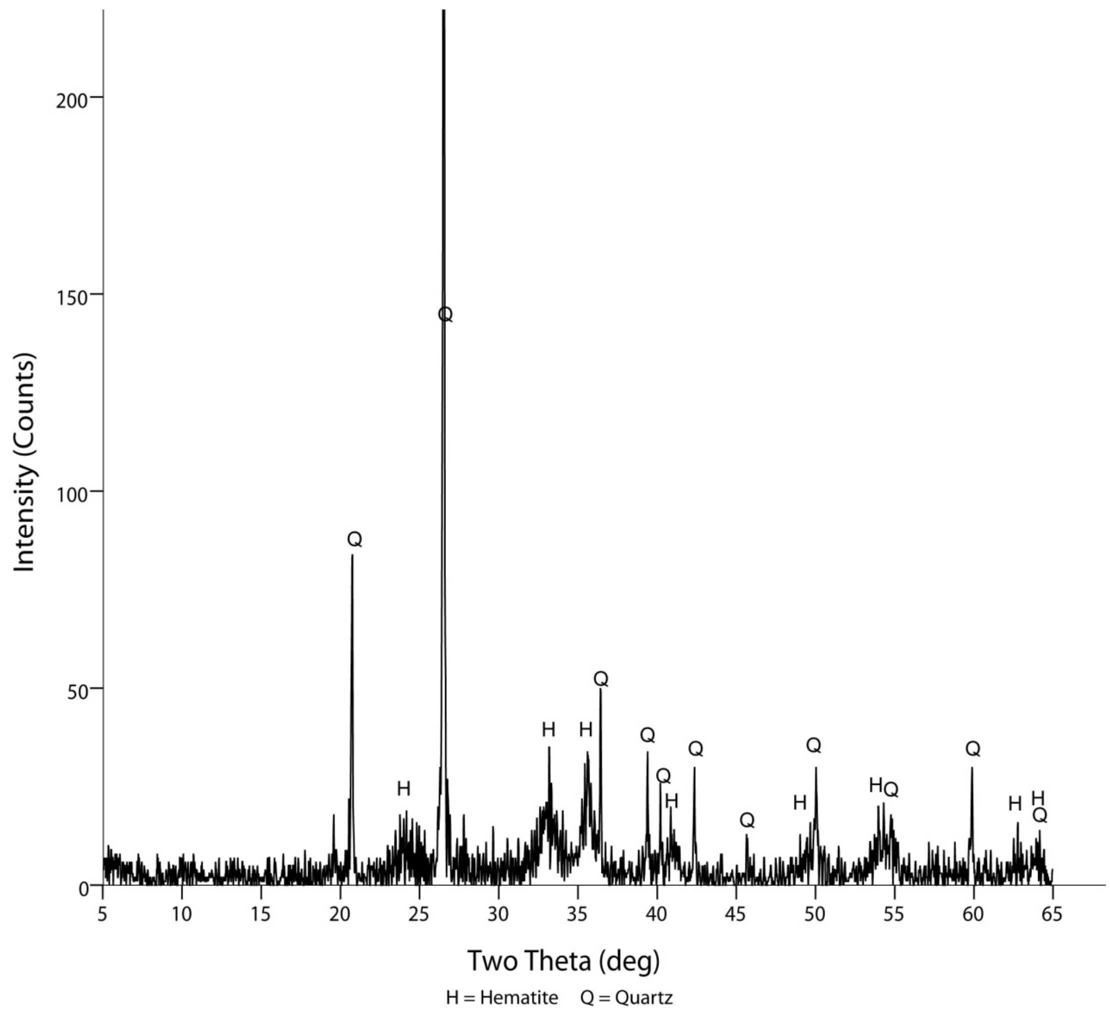


Fig. A.148. G184 Rietvlei A red/orange/yellow heated

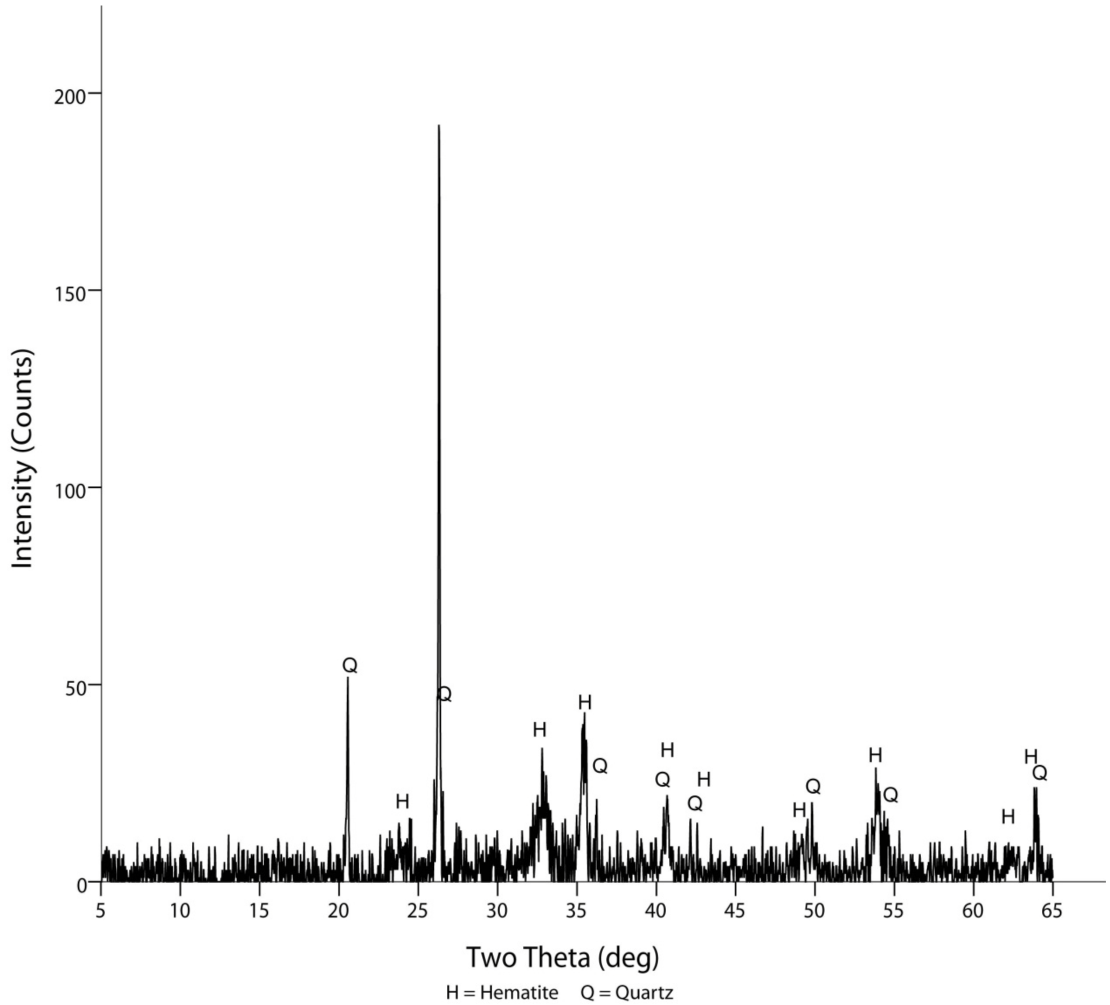


Fig. A.149. G185 Rietvlei A red/orange/yellow heated

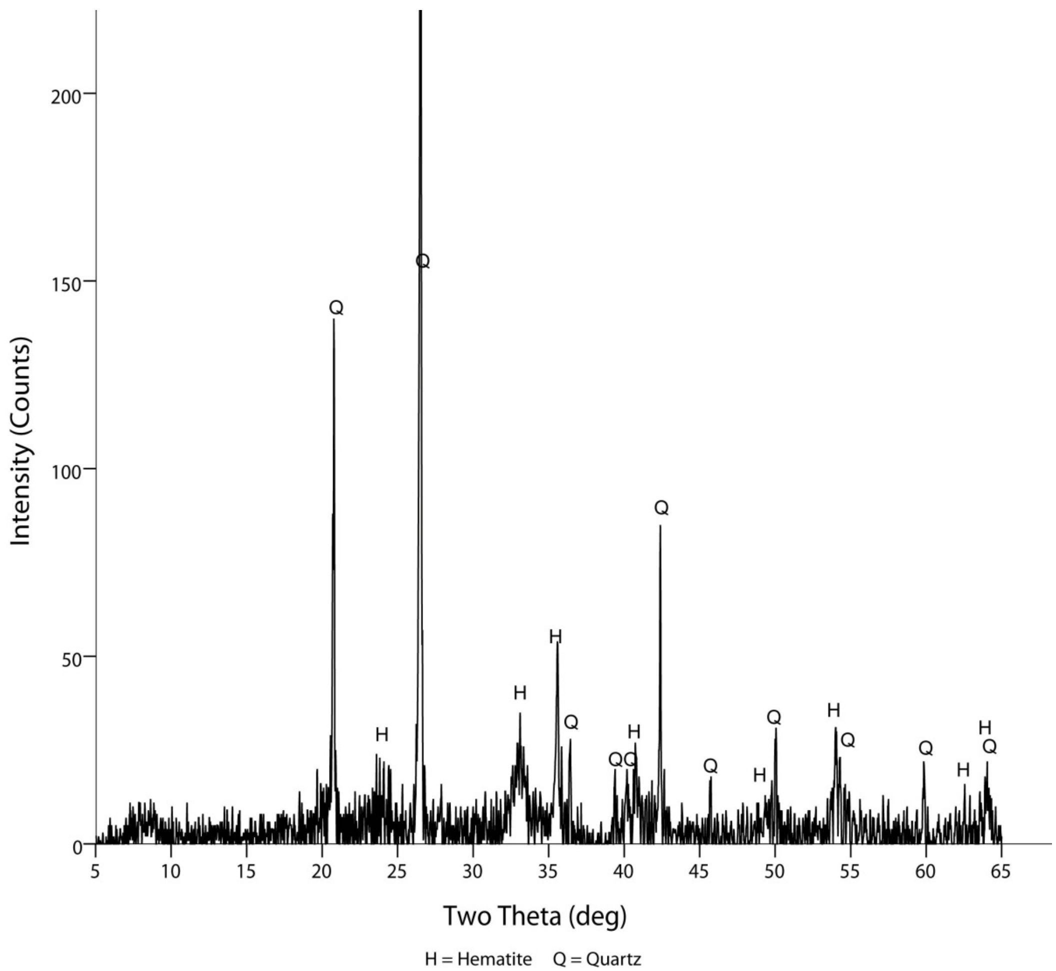


Fig. A.150. G186 Rietvlei A red/orange/yellow heated

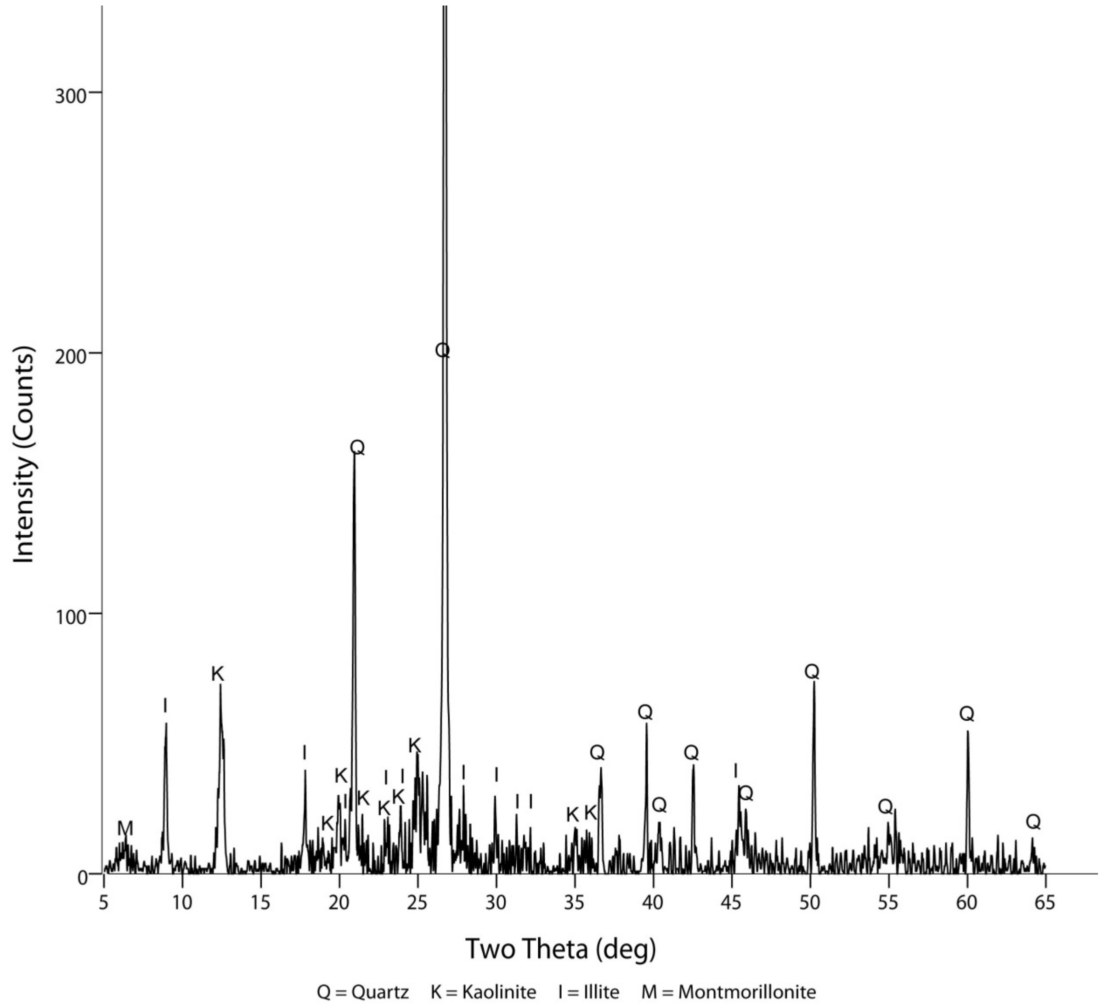


Fig. A.151. G110 Rietvlei B red

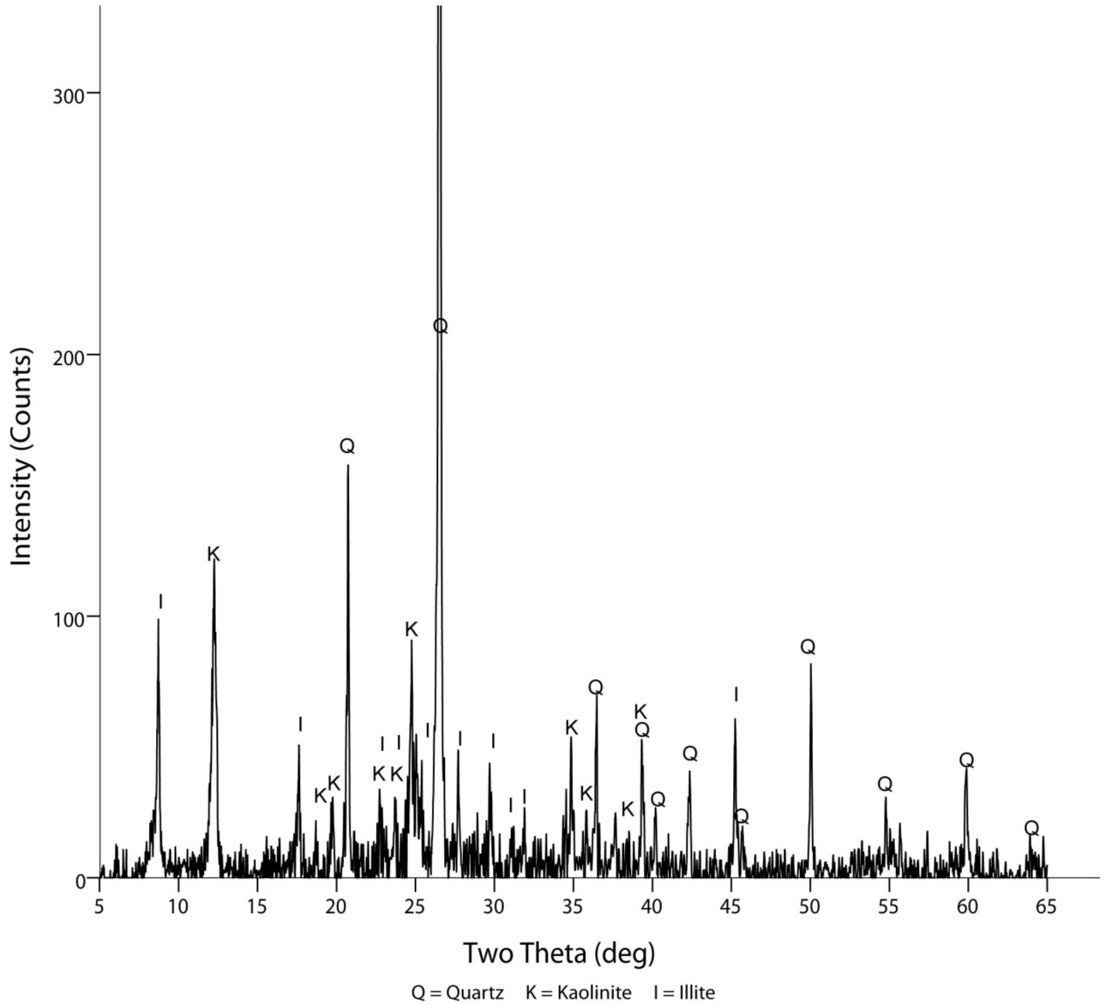


Fig. A.152. G113 Rietvlei B red

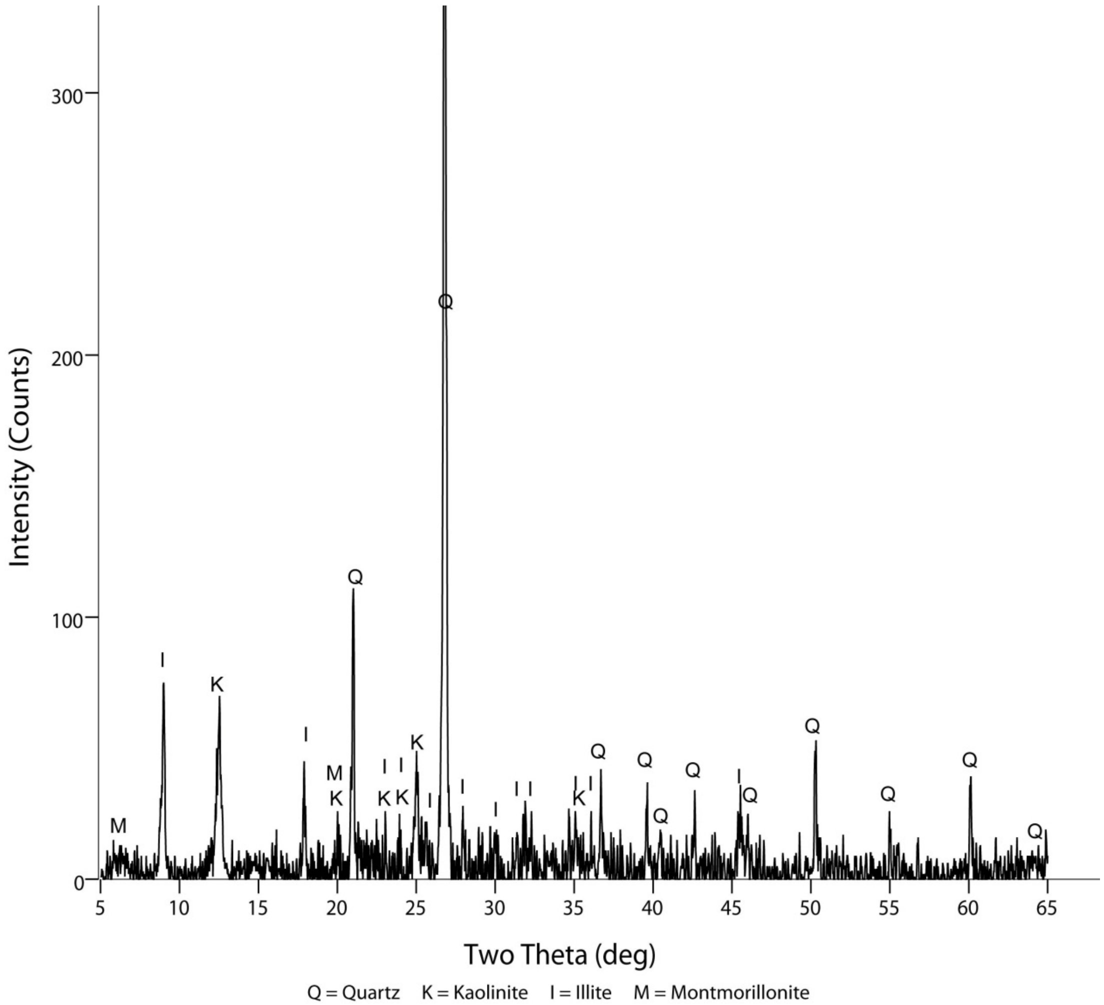


Fig. A.153. G116 Rietvlei B red

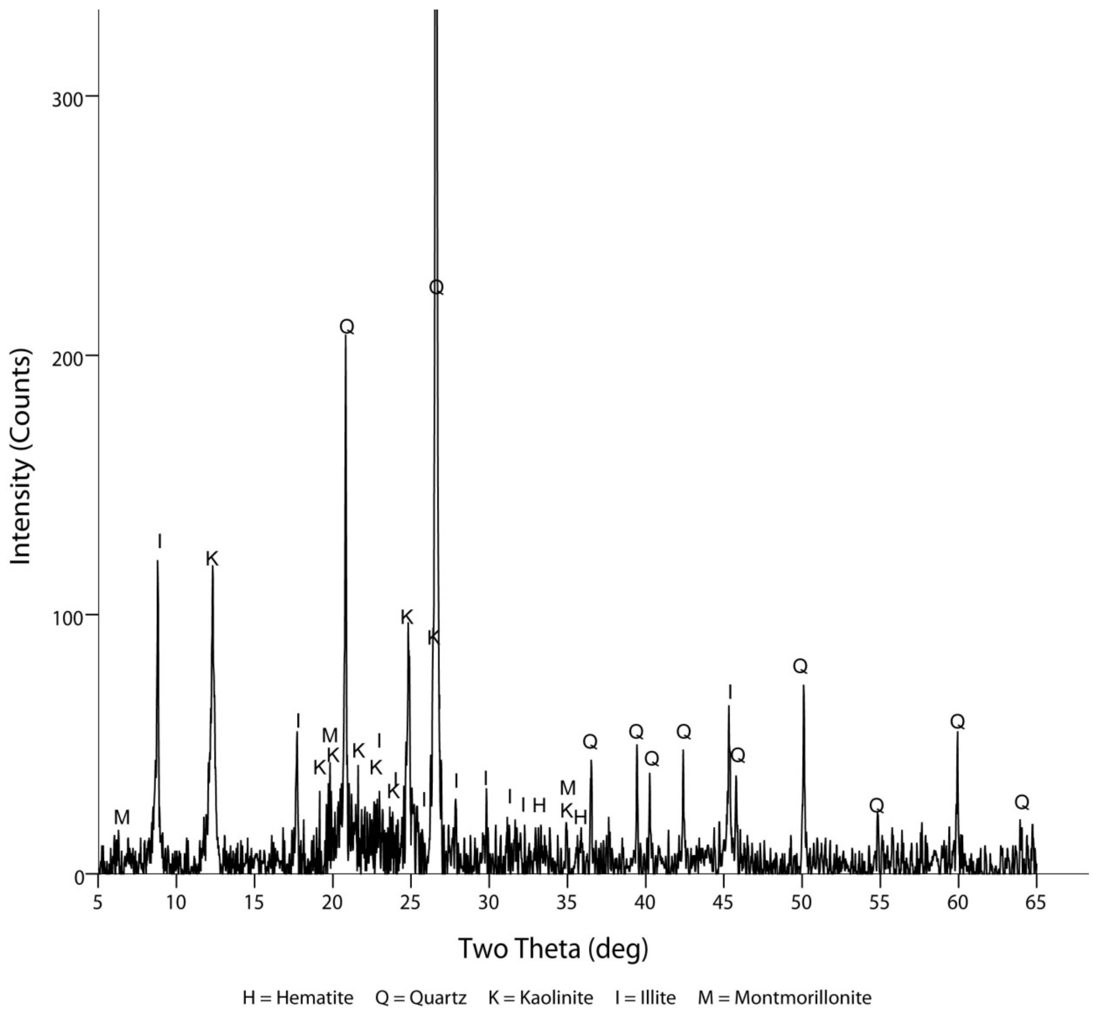


Fig. A.154. G111 Rietvlei B red heated

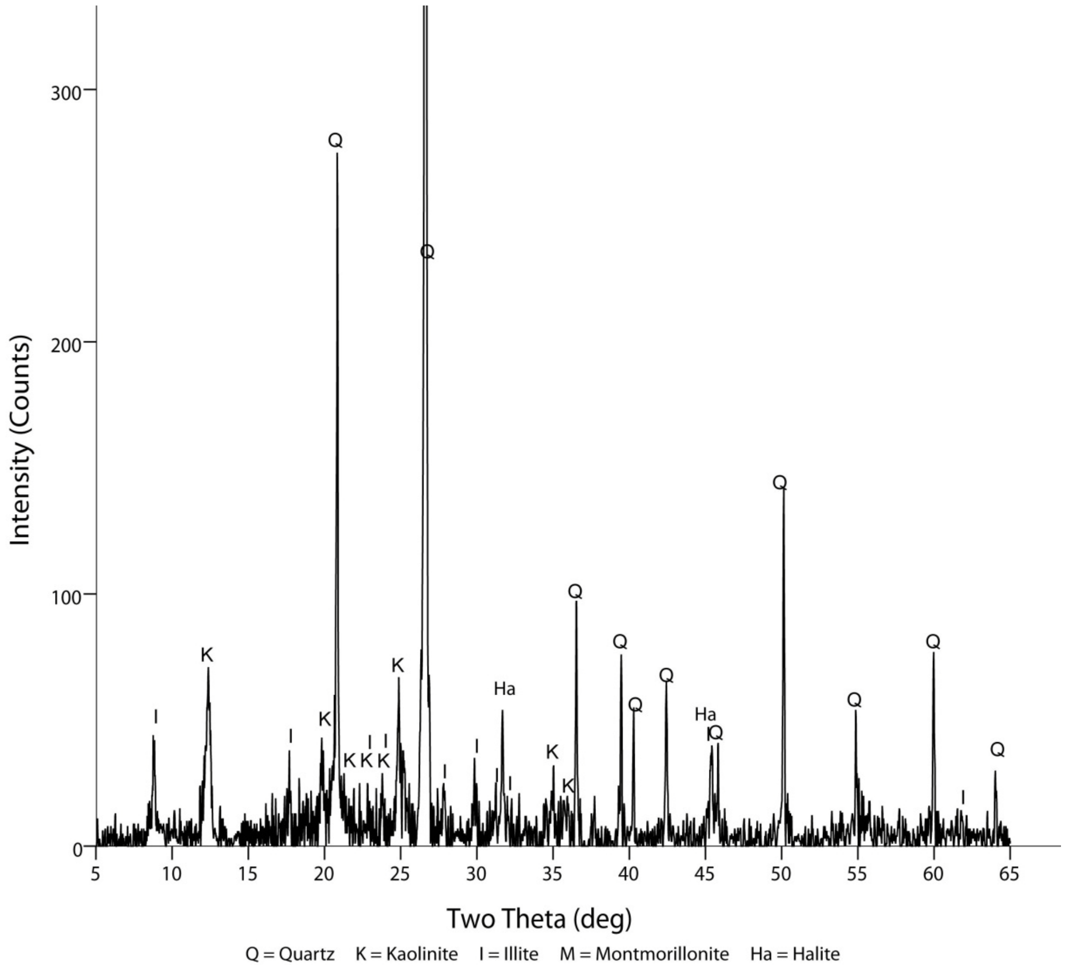


Fig. A.155. G112 Rietvlei B red heated

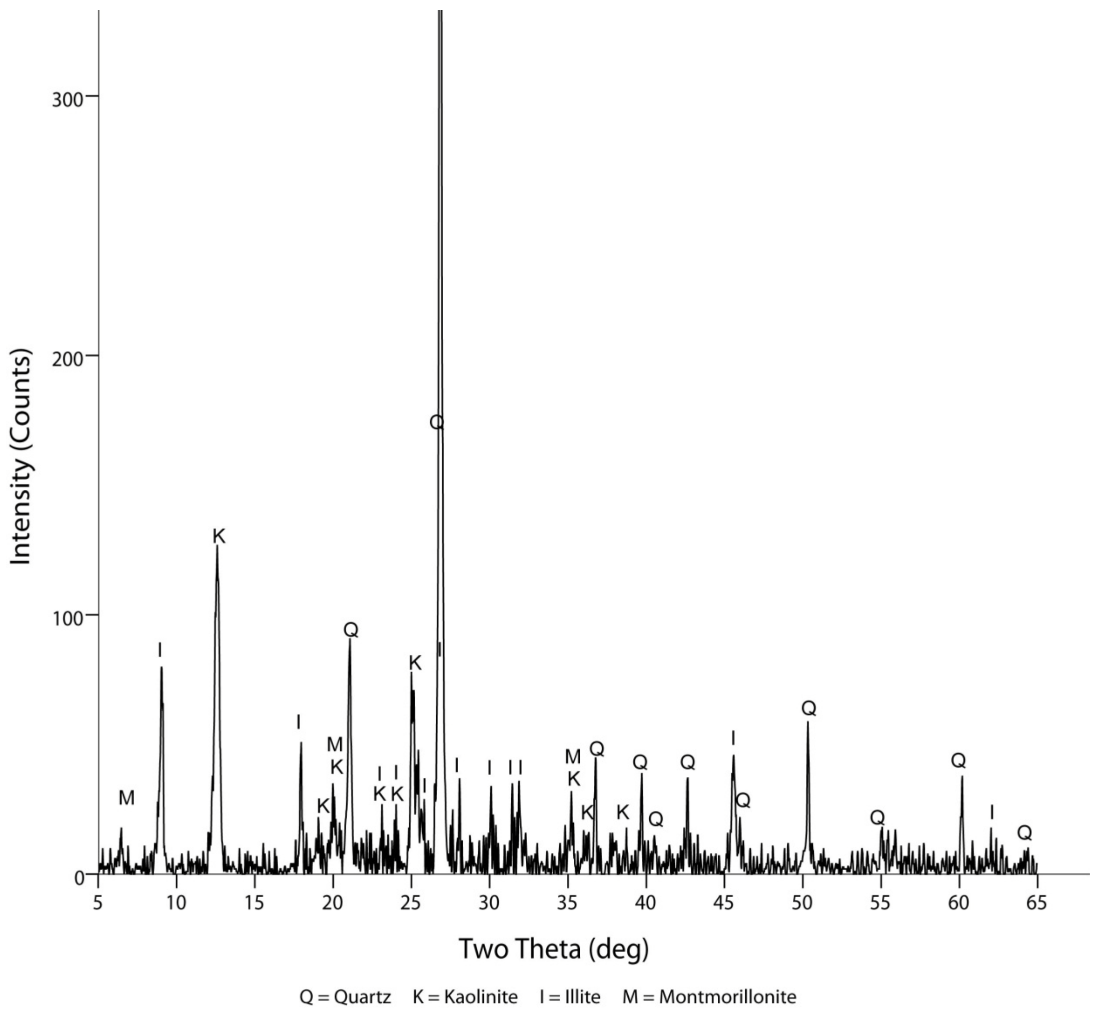


Fig. A.156. G114 Rietvlei B red heated

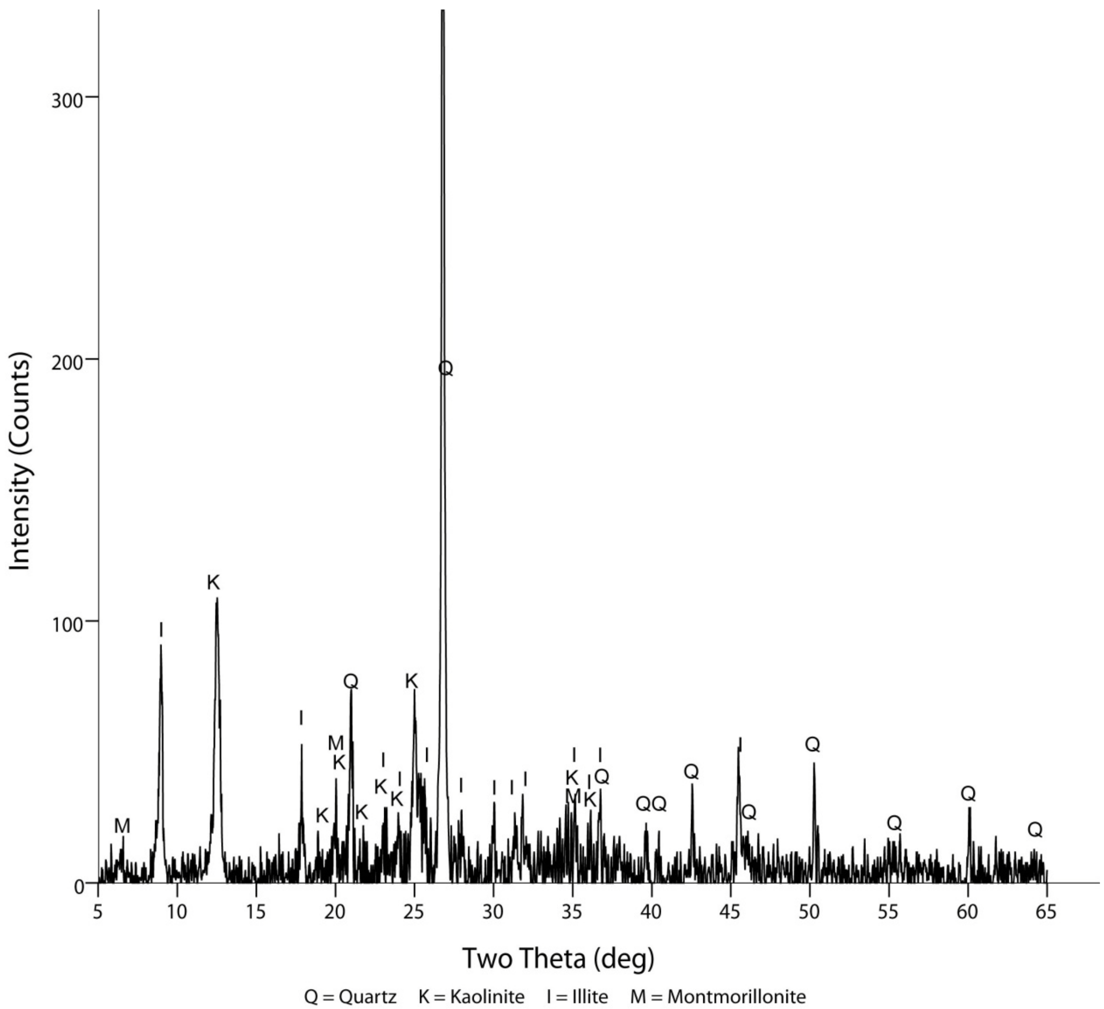


Fig. A.157. G115 Rietvlei B red heated

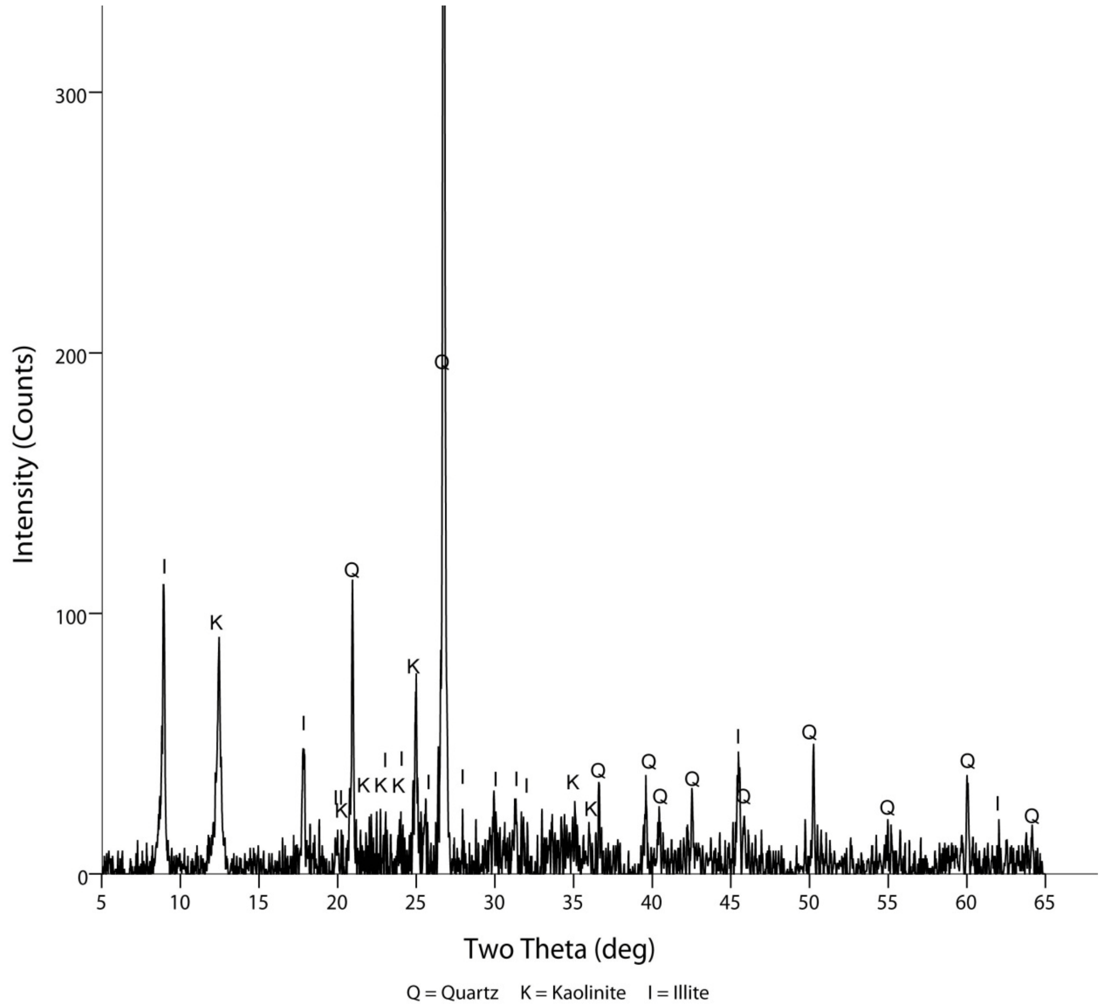


Fig. A.158. G117 Rietvlei B red heated

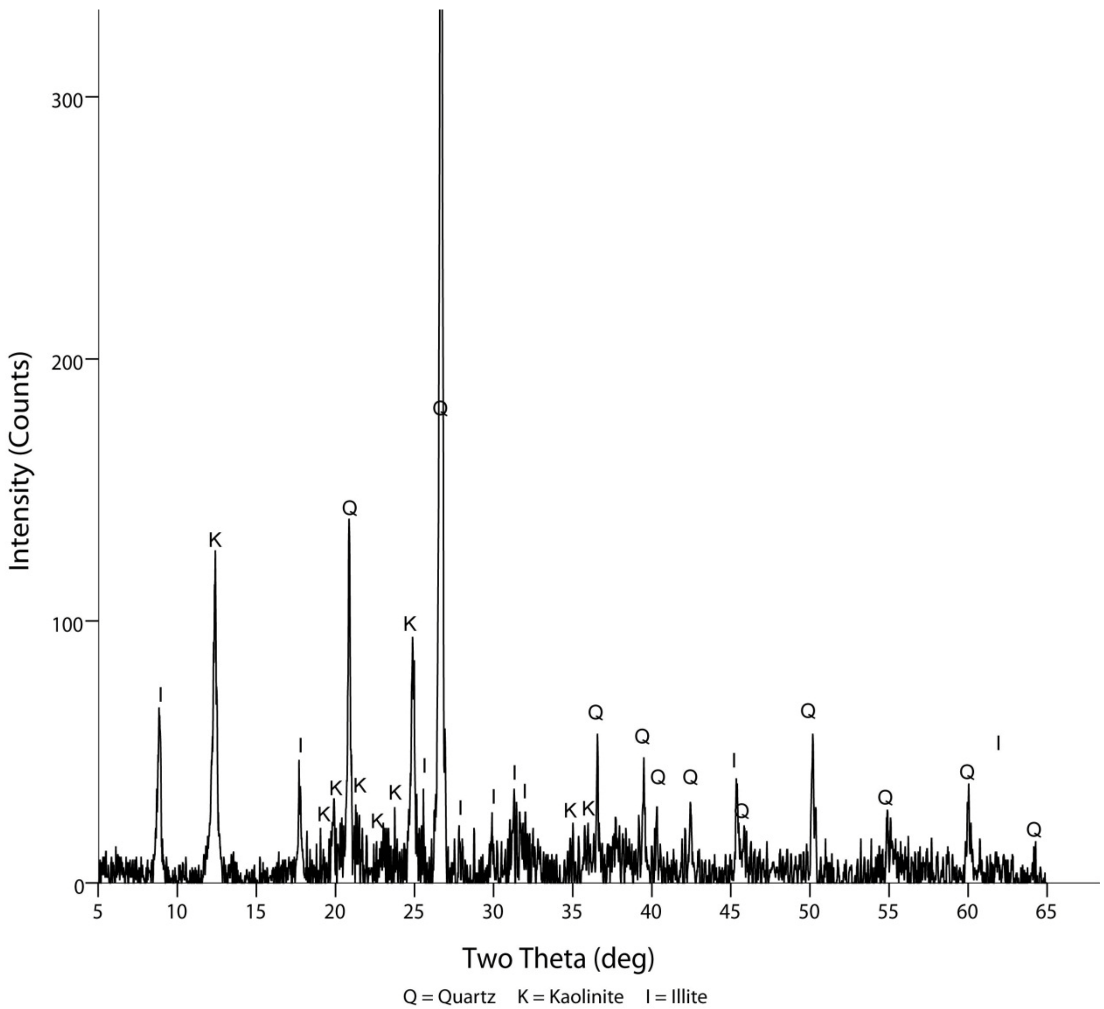


Fig. A.159. G118 Rietvlei B red heated

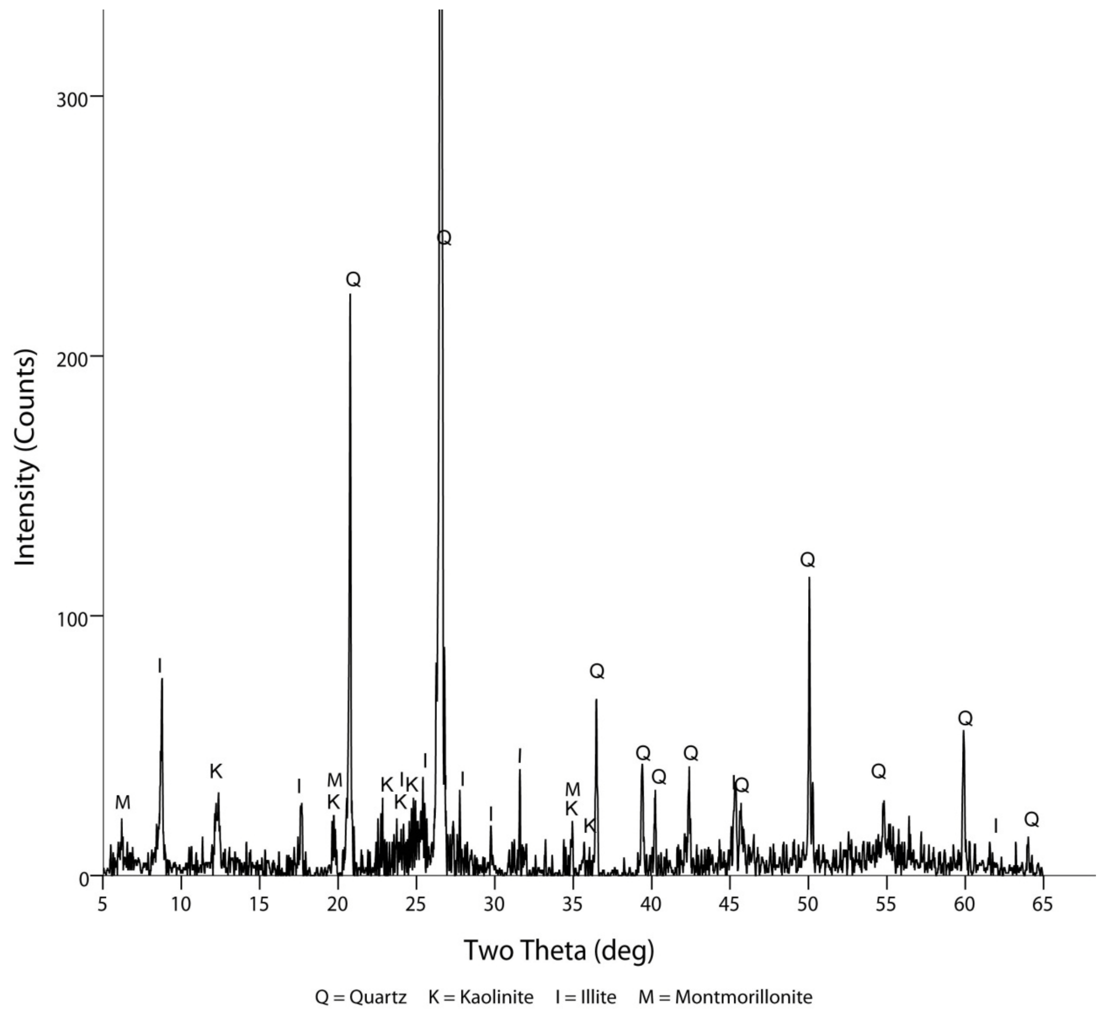


Fig. A.160. G187 Rietvlei B red heated

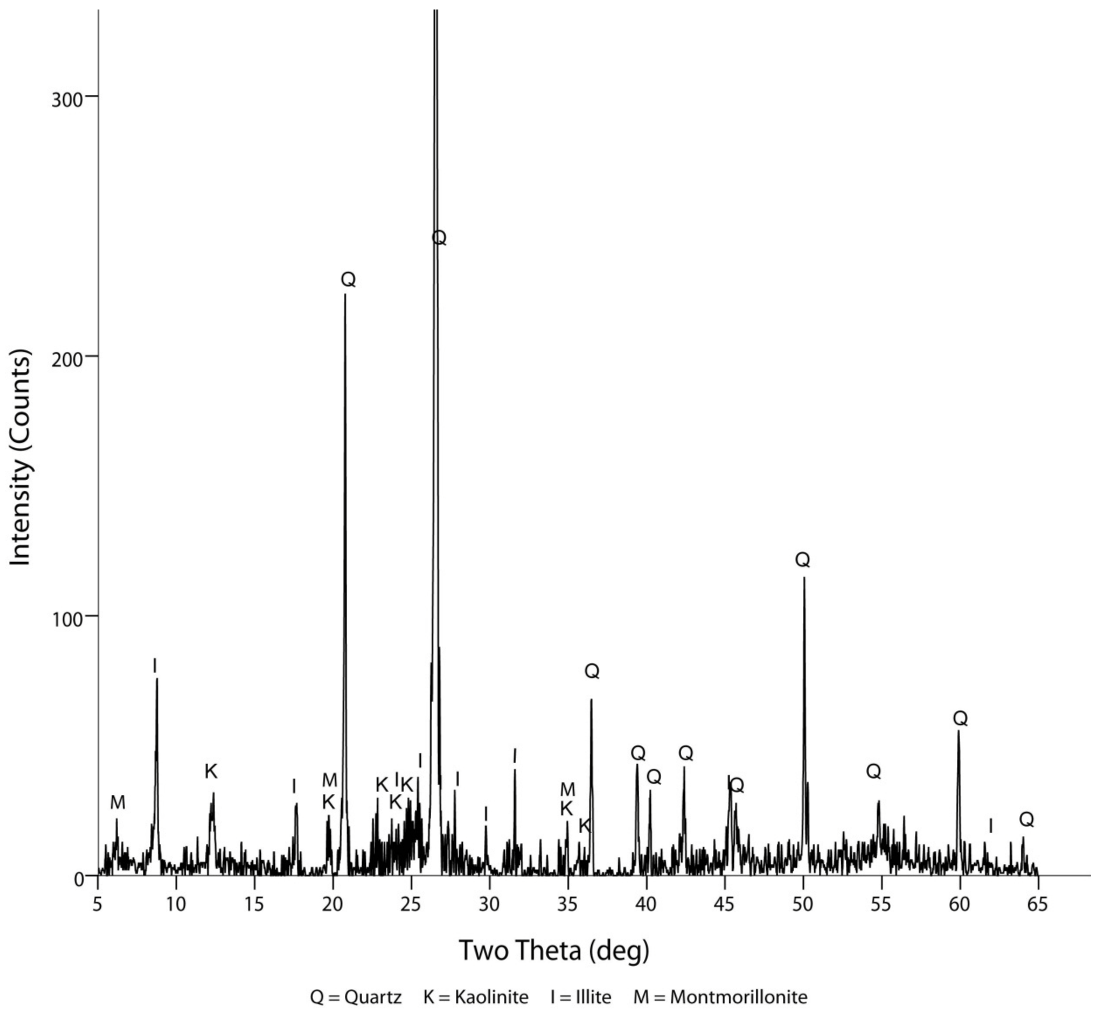


Fig. A.161. G188 Rietvlei B red heated

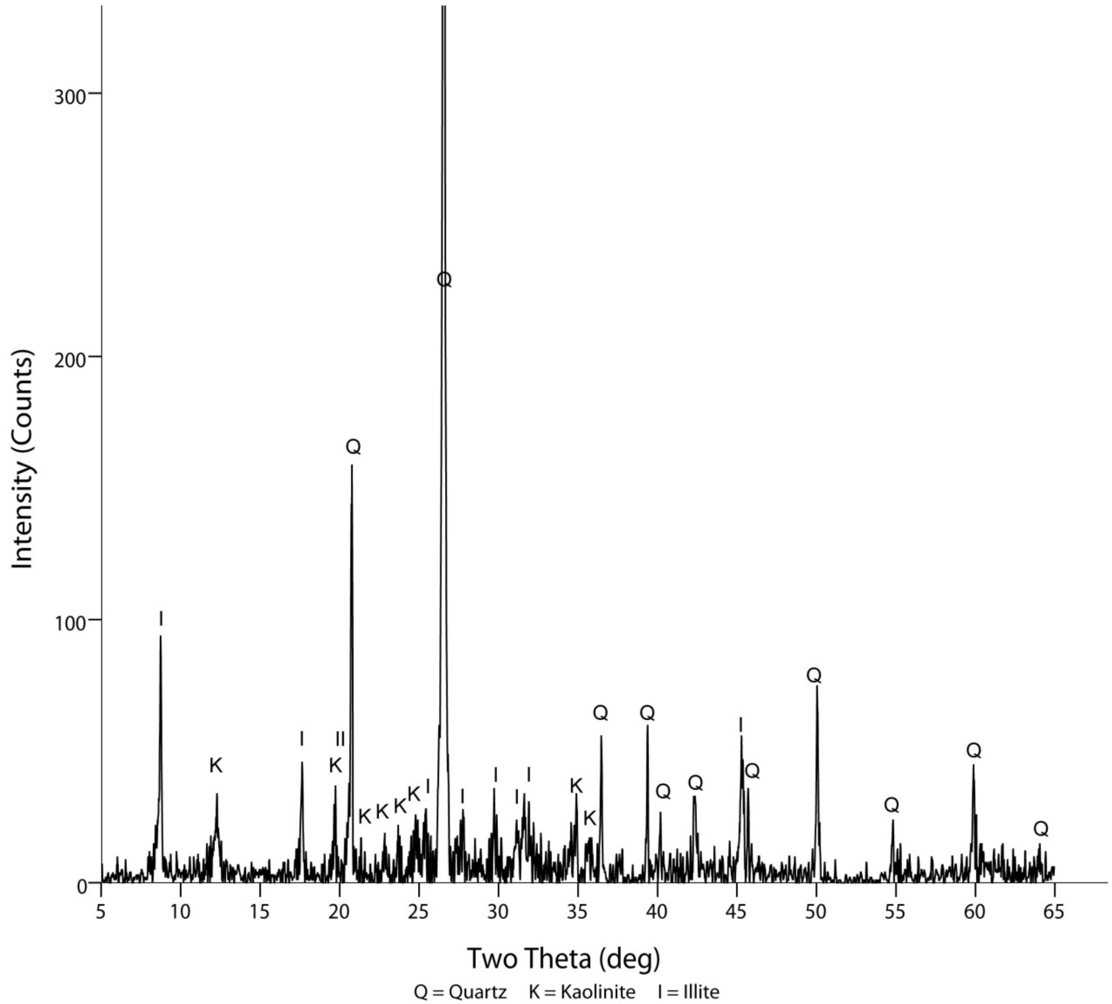


Fig. A.162. G189 Rietvlei B red heated

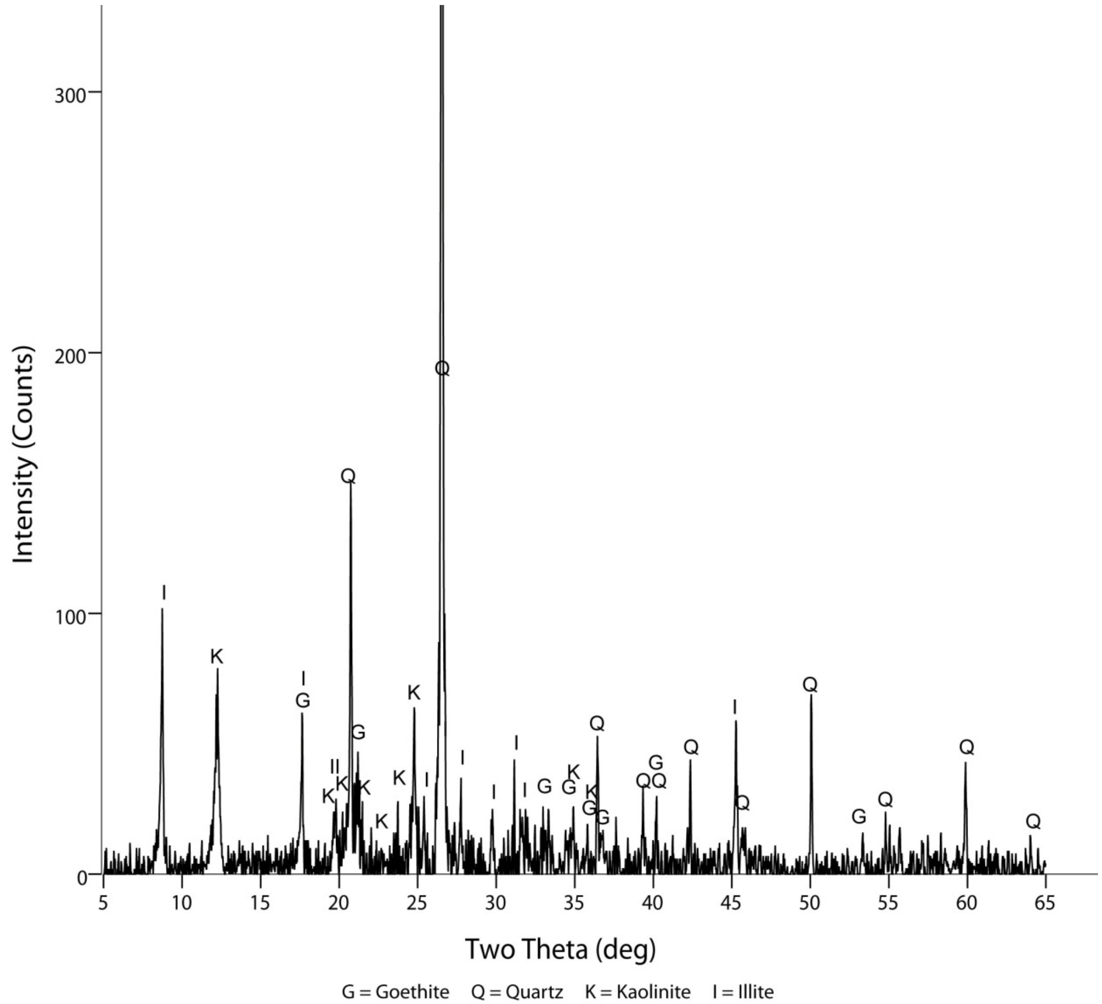


Fig. A.163. G107 Rietvlei B yellow

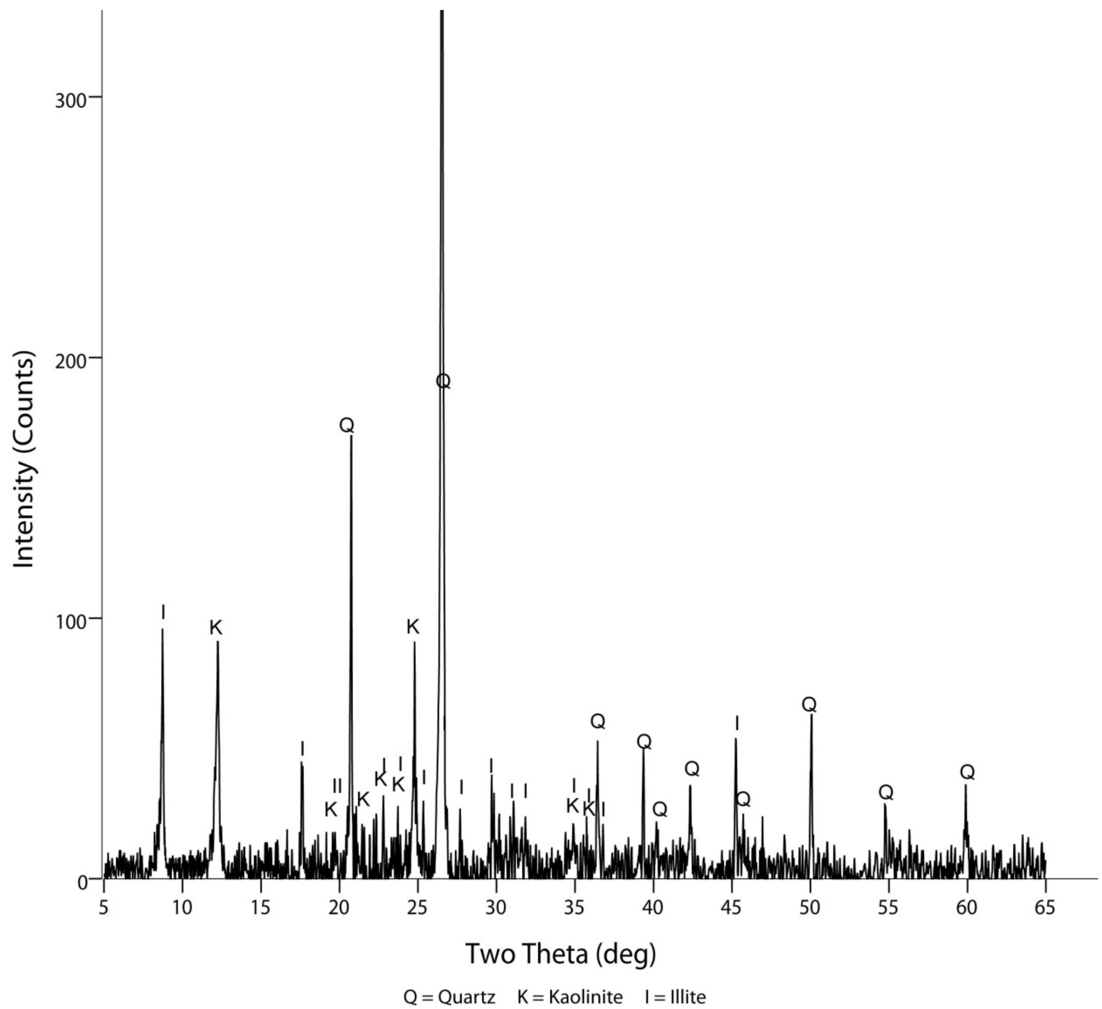


Fig. A.164. G119 Rietvlei B yellow

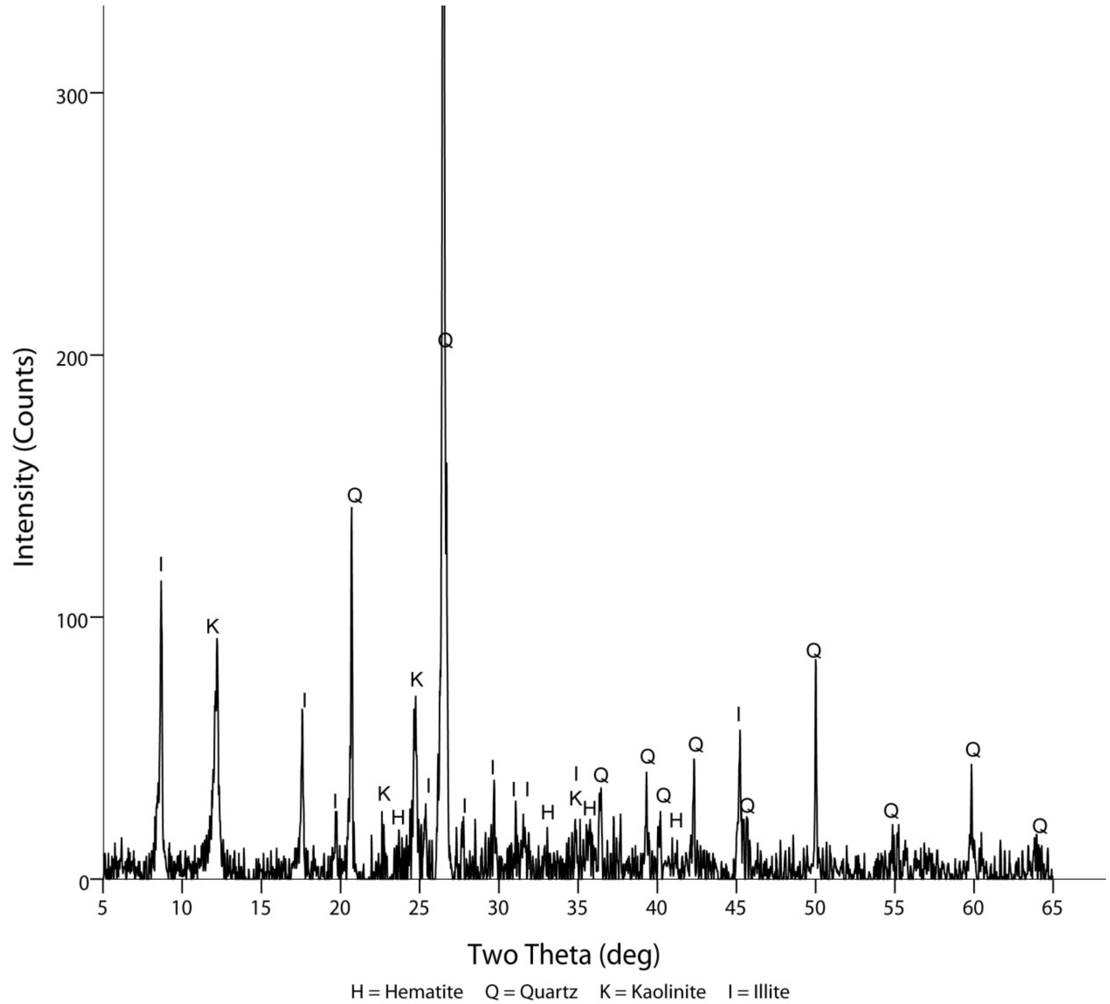


Fig. A.165. G108 Rietvlei B yellow heated

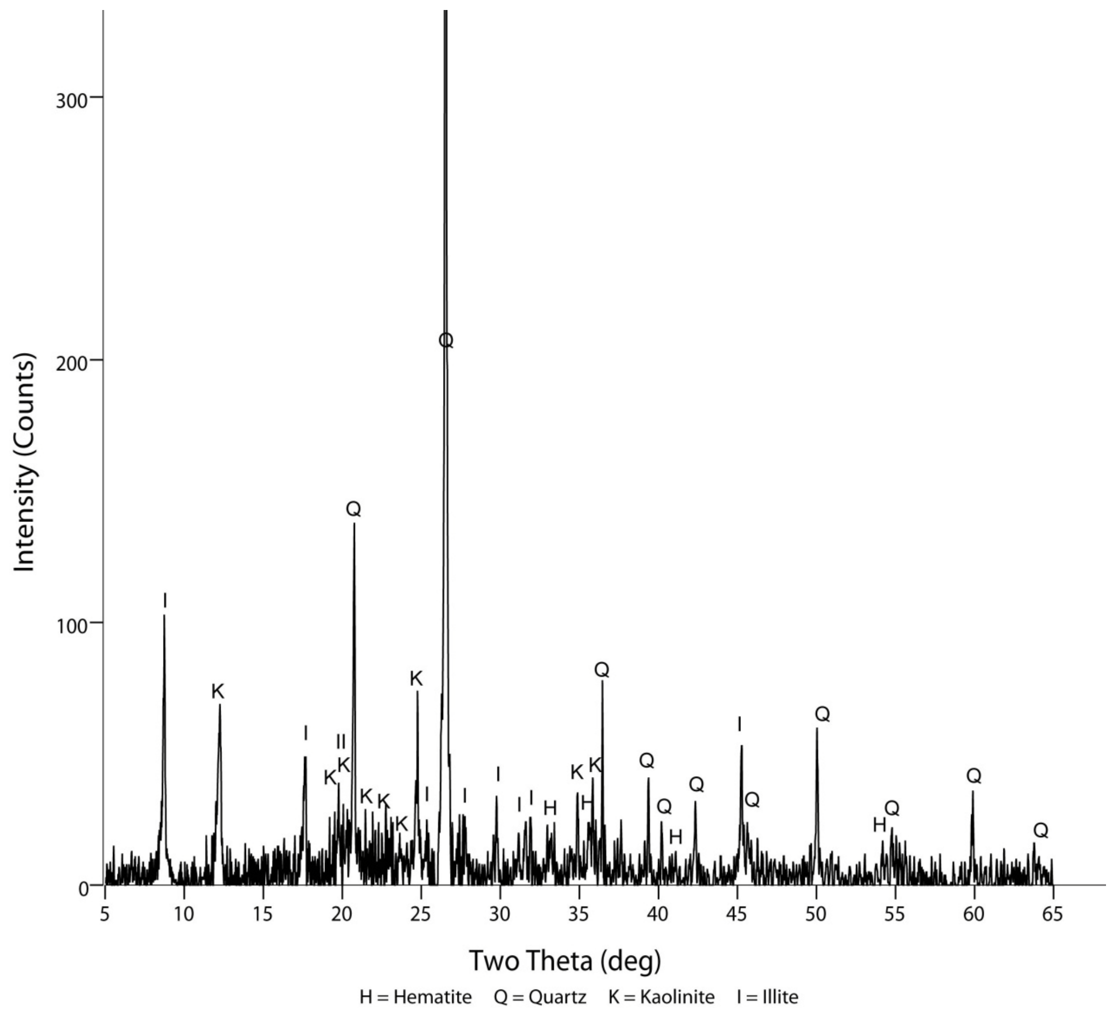


Fig. A.166. G109 Rietvlei B yellow heated

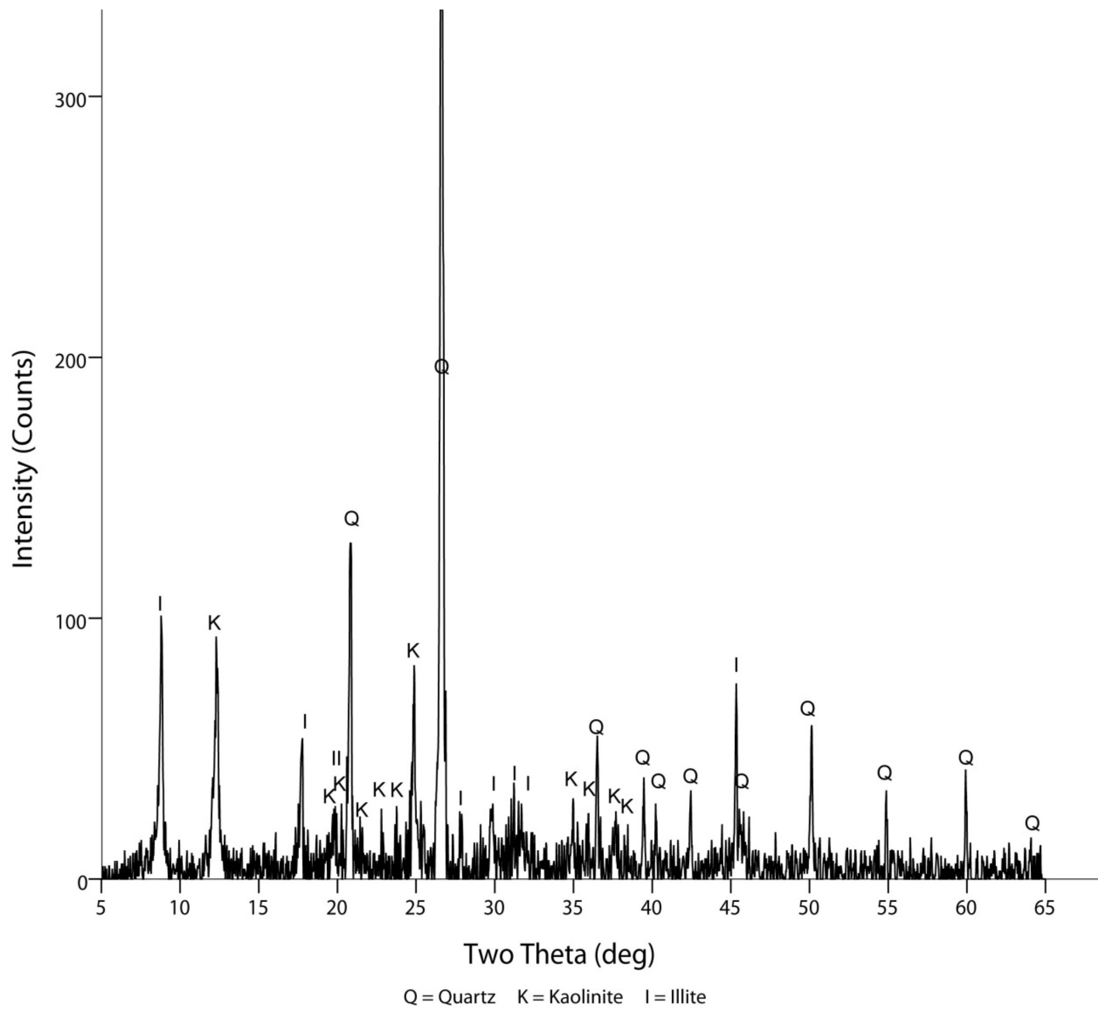


Fig. A.167. G120 Rietvlei B yellow heated

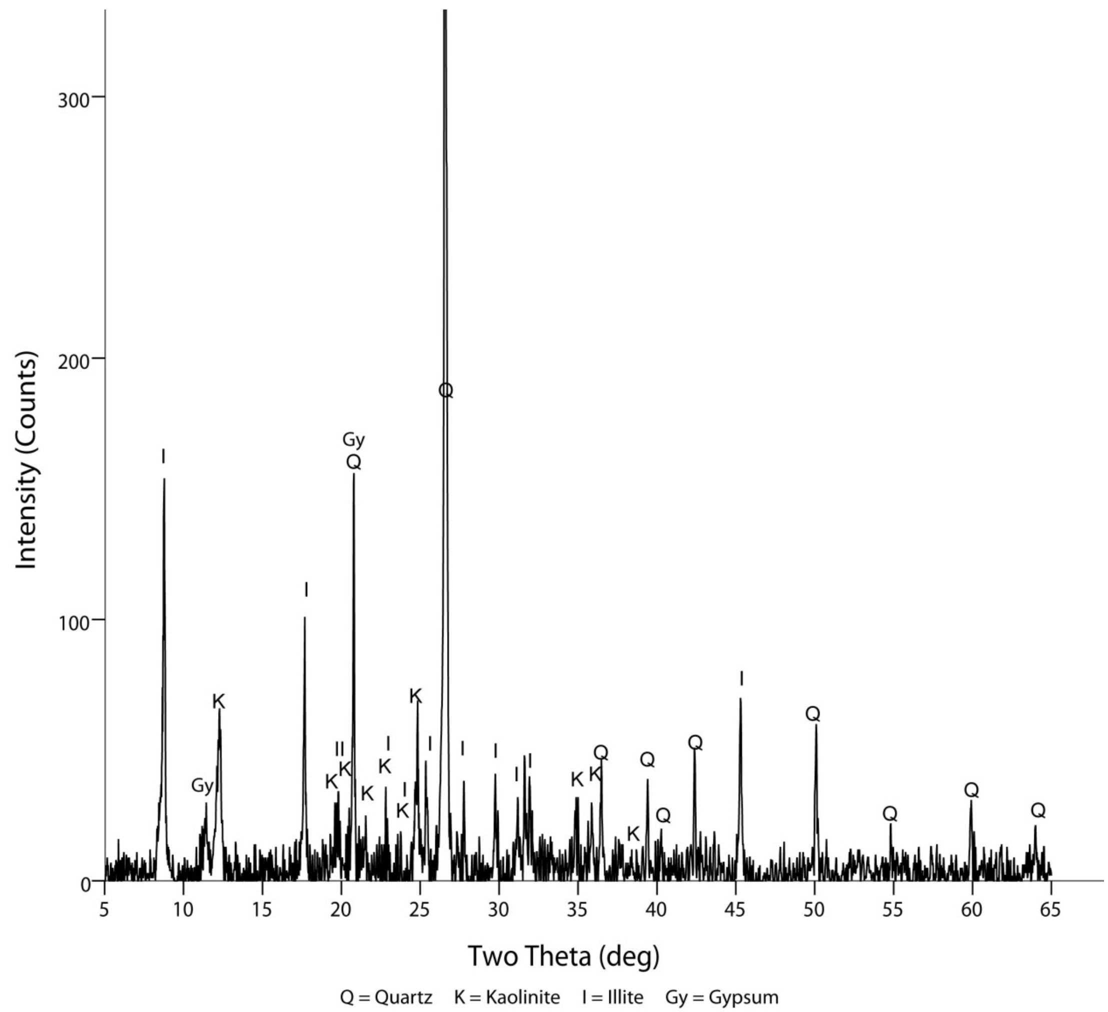


Fig. A.168. G121 Rietvlei B yellow heated

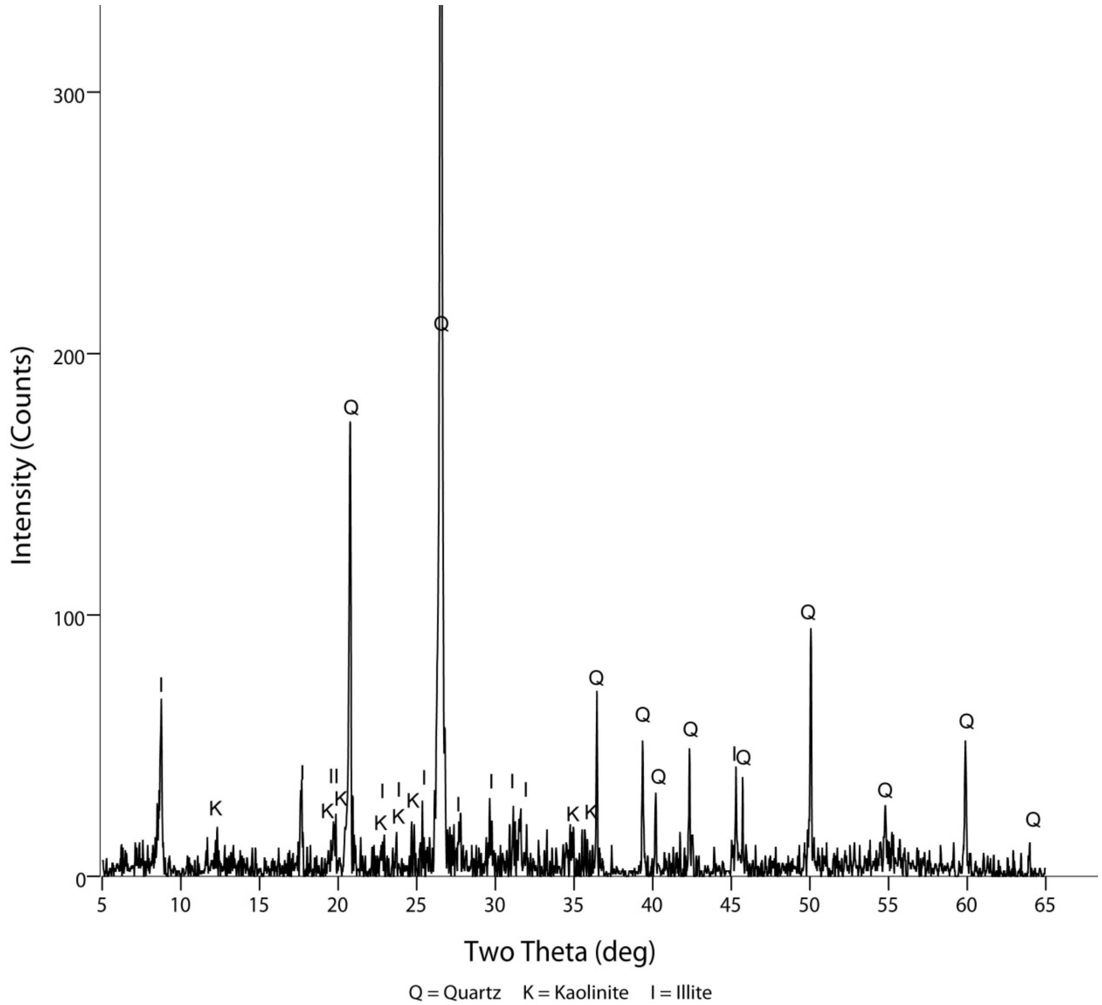


Fig. A.169. G190 Rietvlei B yellow heated

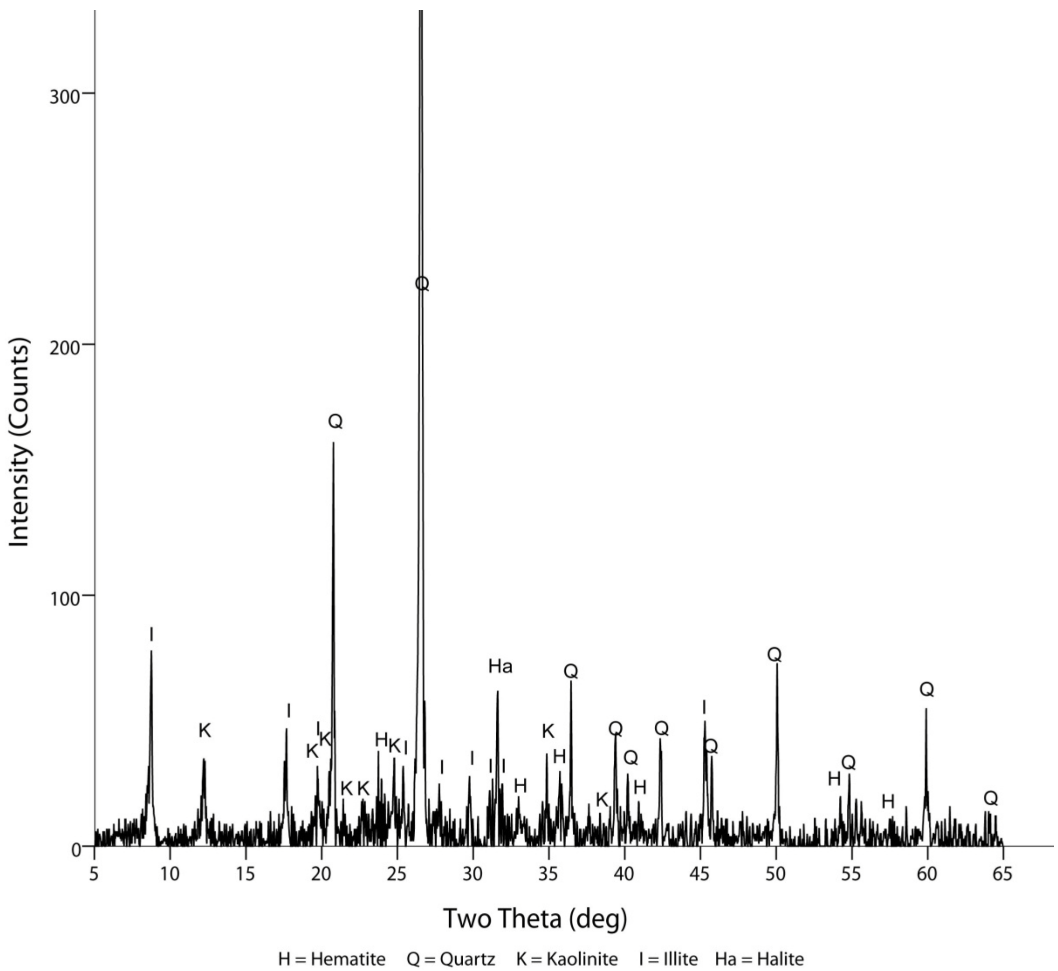


Fig. A.170. G191 Rietvlei B yellow heated

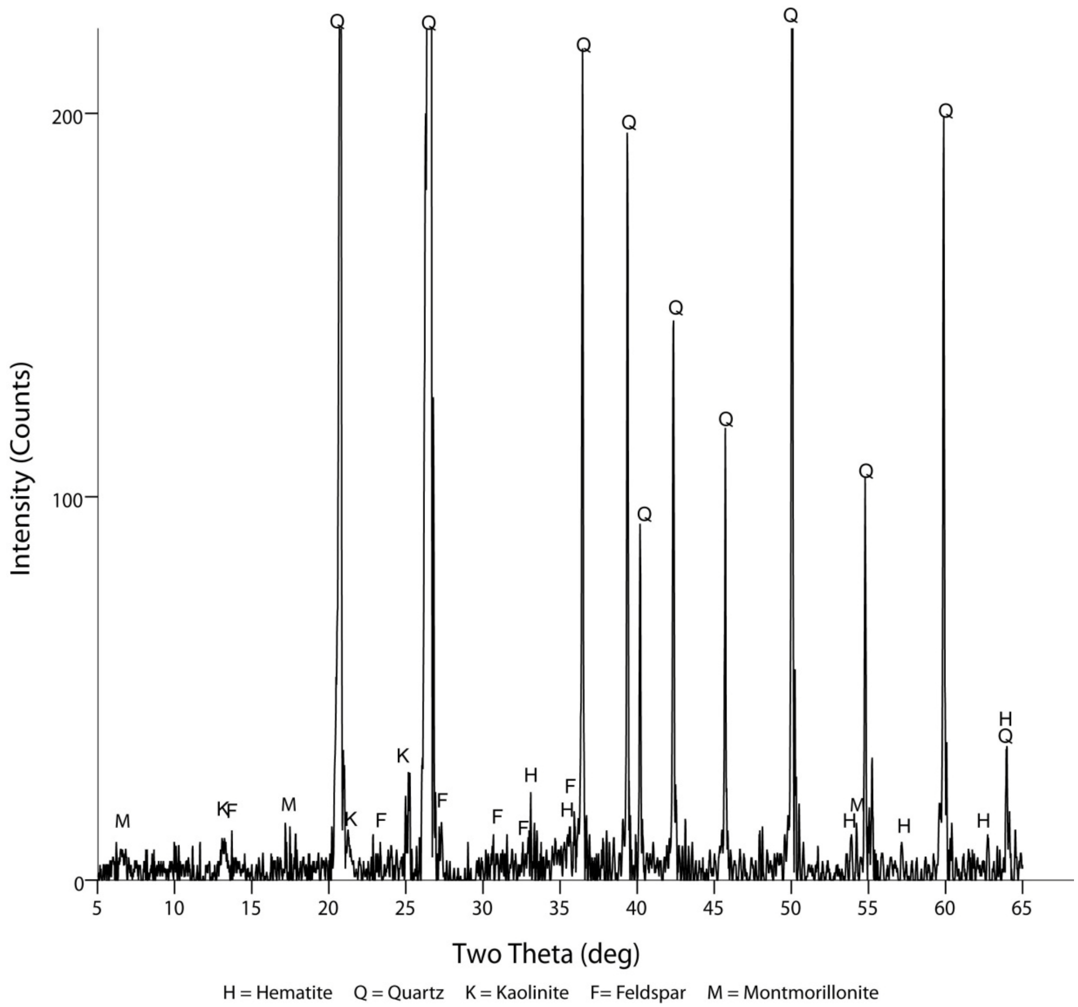


Fig. A.171. G140 Rivercrossing red/orange

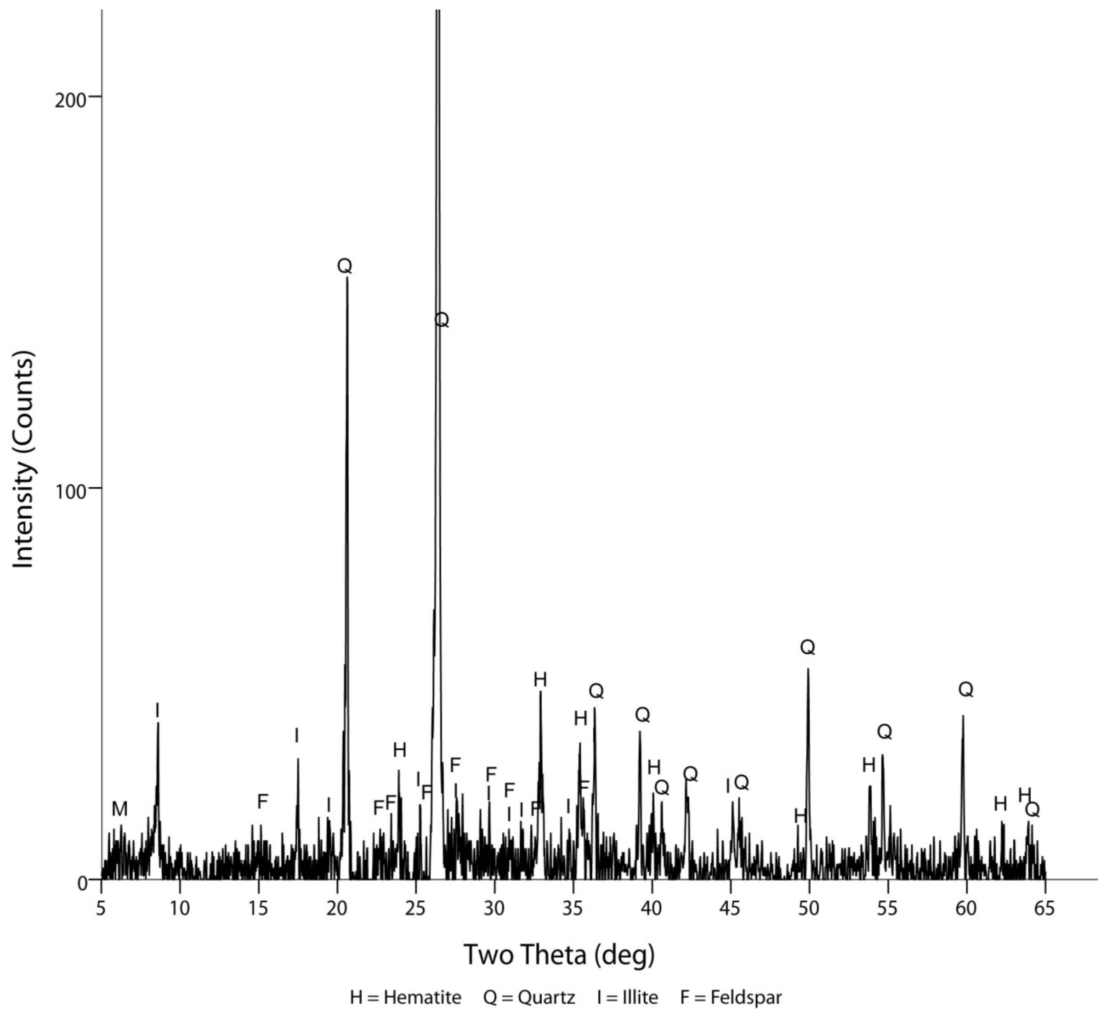


Fig. A.172. G142 Rivercross ing red/orange

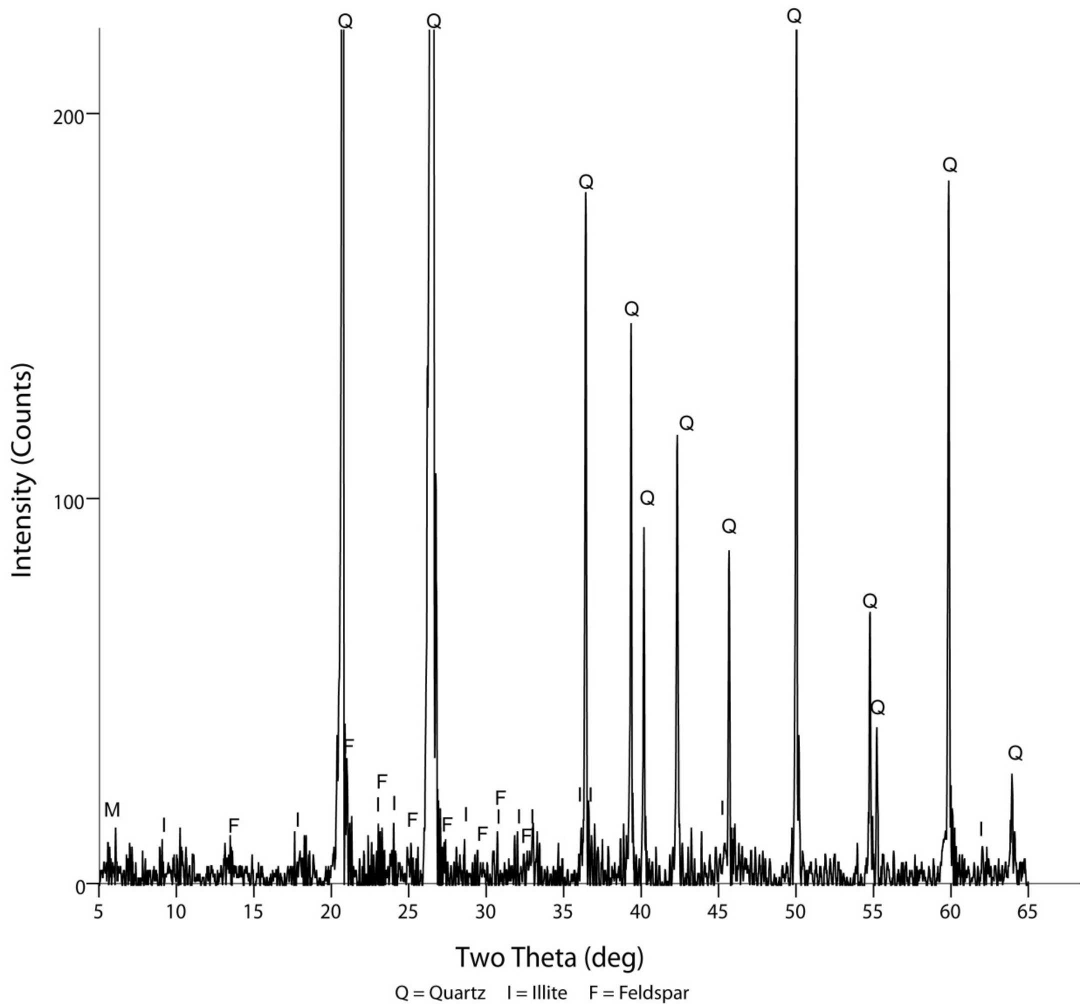


Fig. A.173. G144 Rivercrossing red/orange

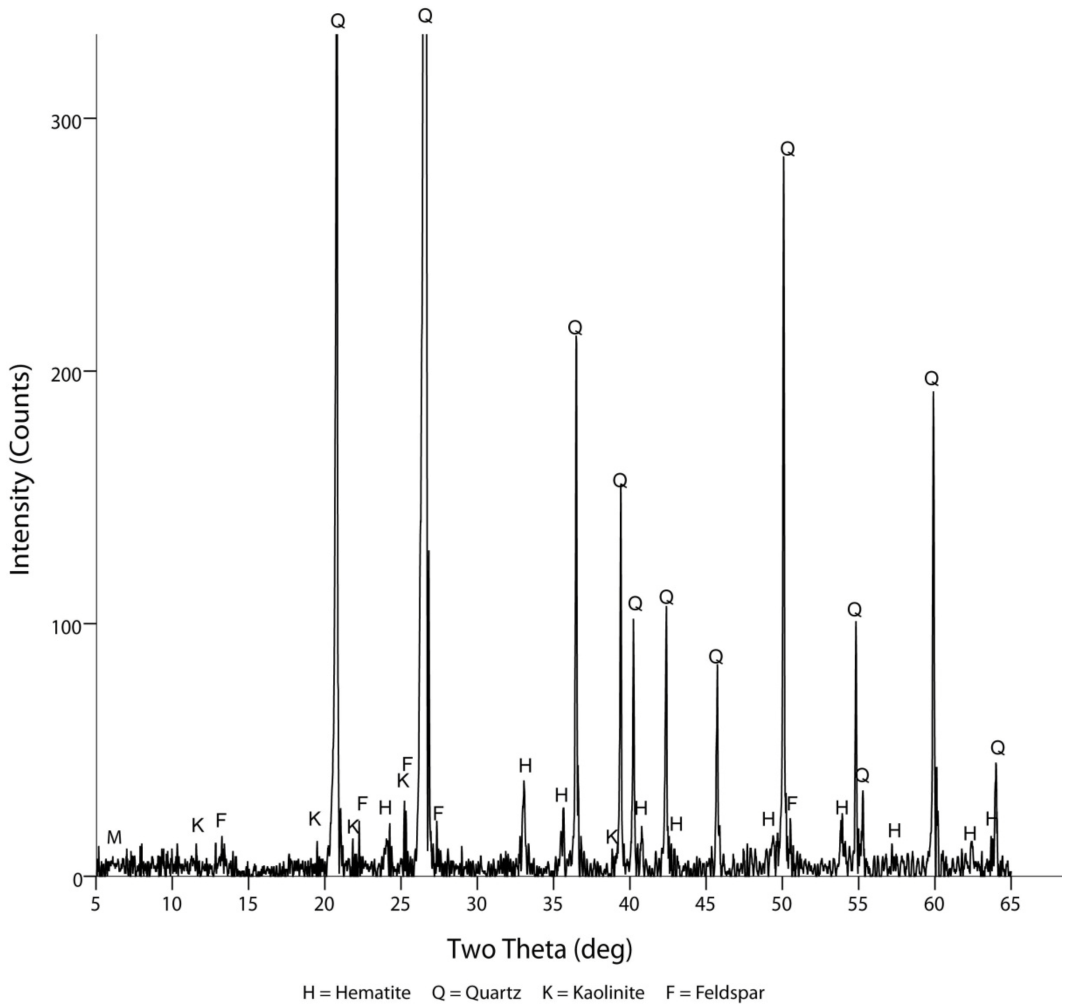


Fig. A.174. G146 Rivercrossing red/orange

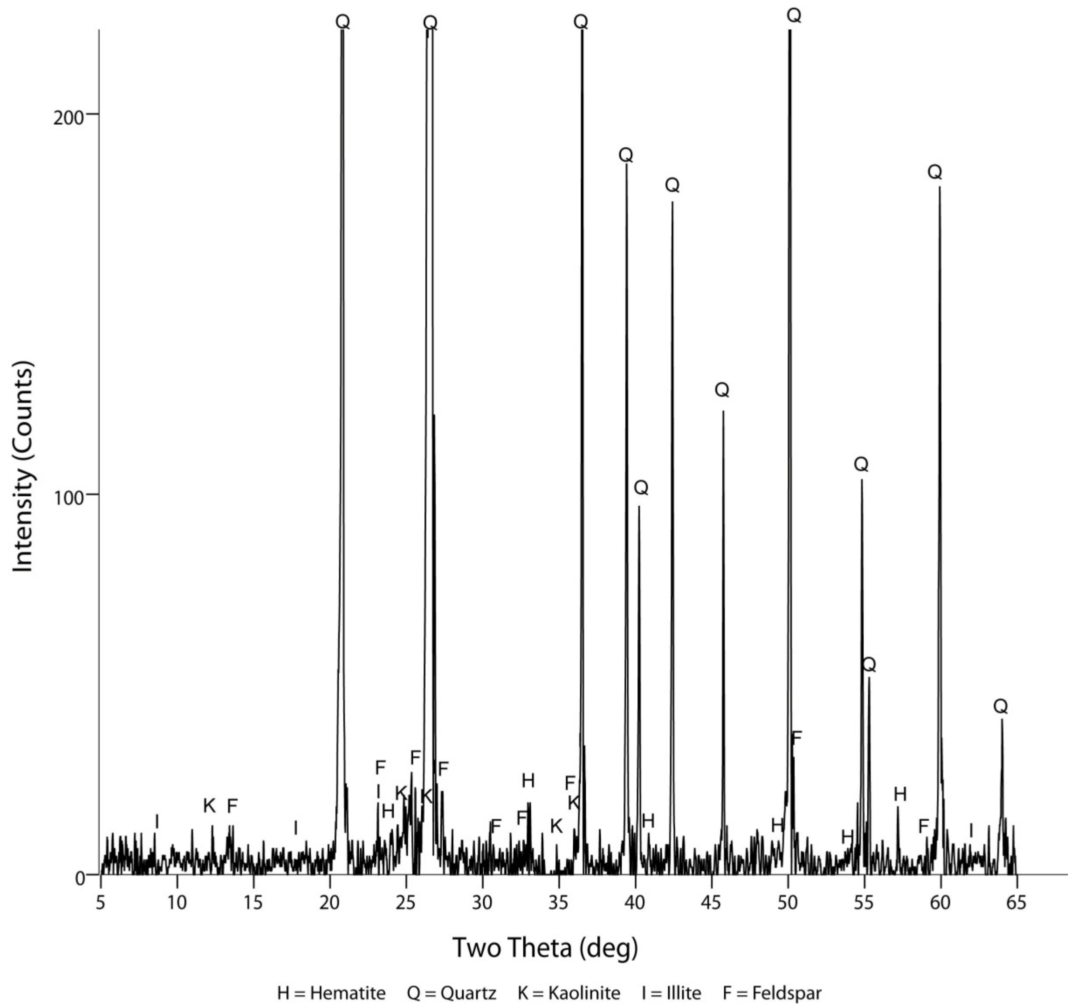


Fig. A.175. G148 Rivercrossing red/orange

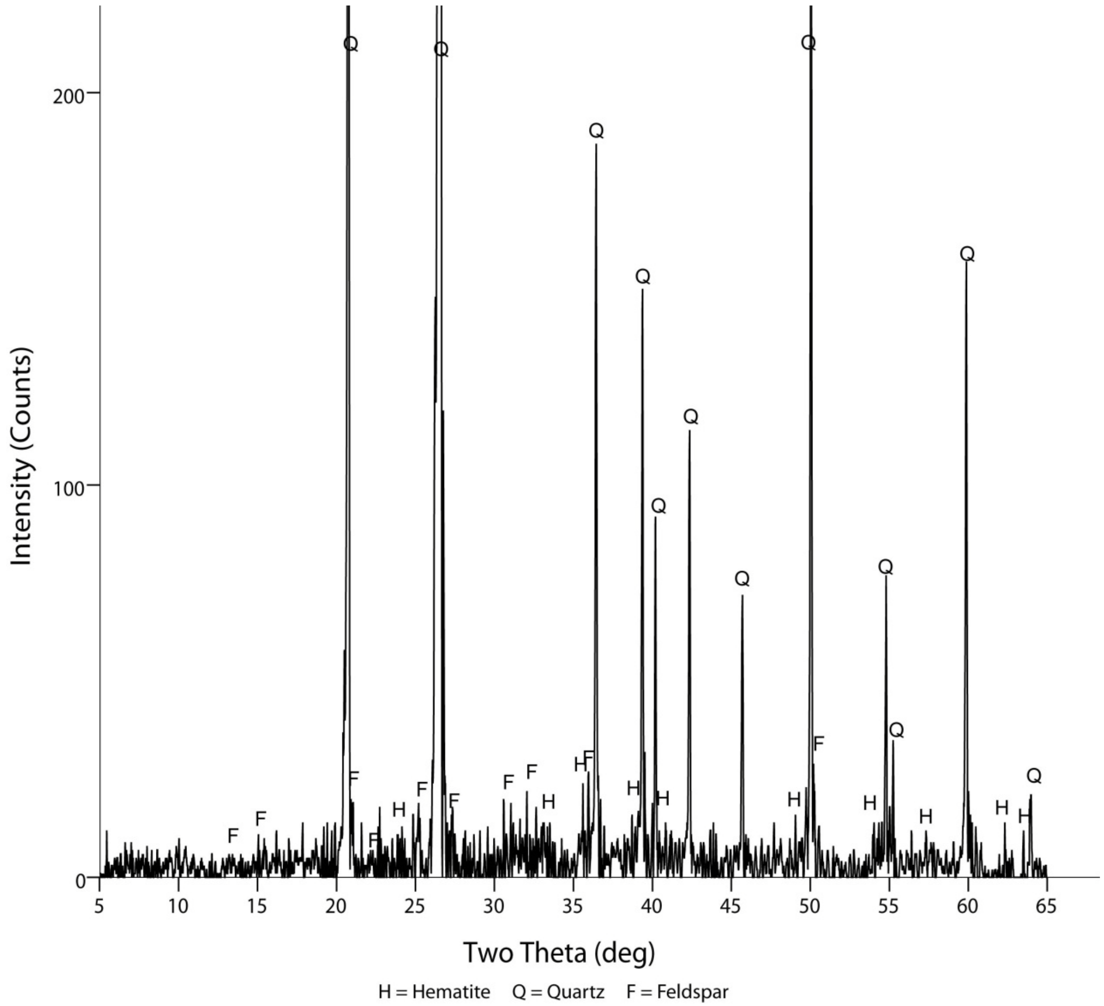


Fig. A.176. G141 Rivercrossing red/orange heated

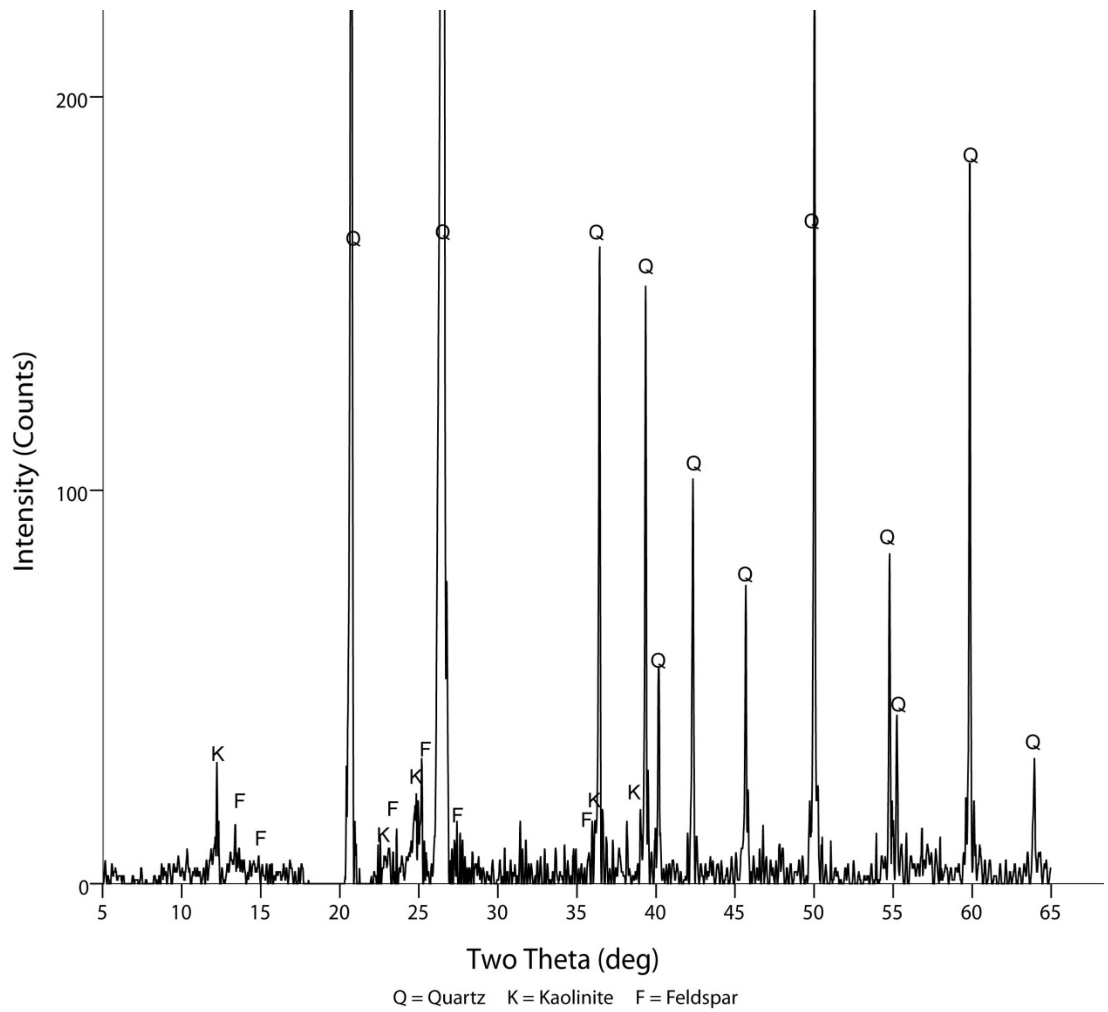


Fig. A.177. G143 Rivercrossing red/orange heated

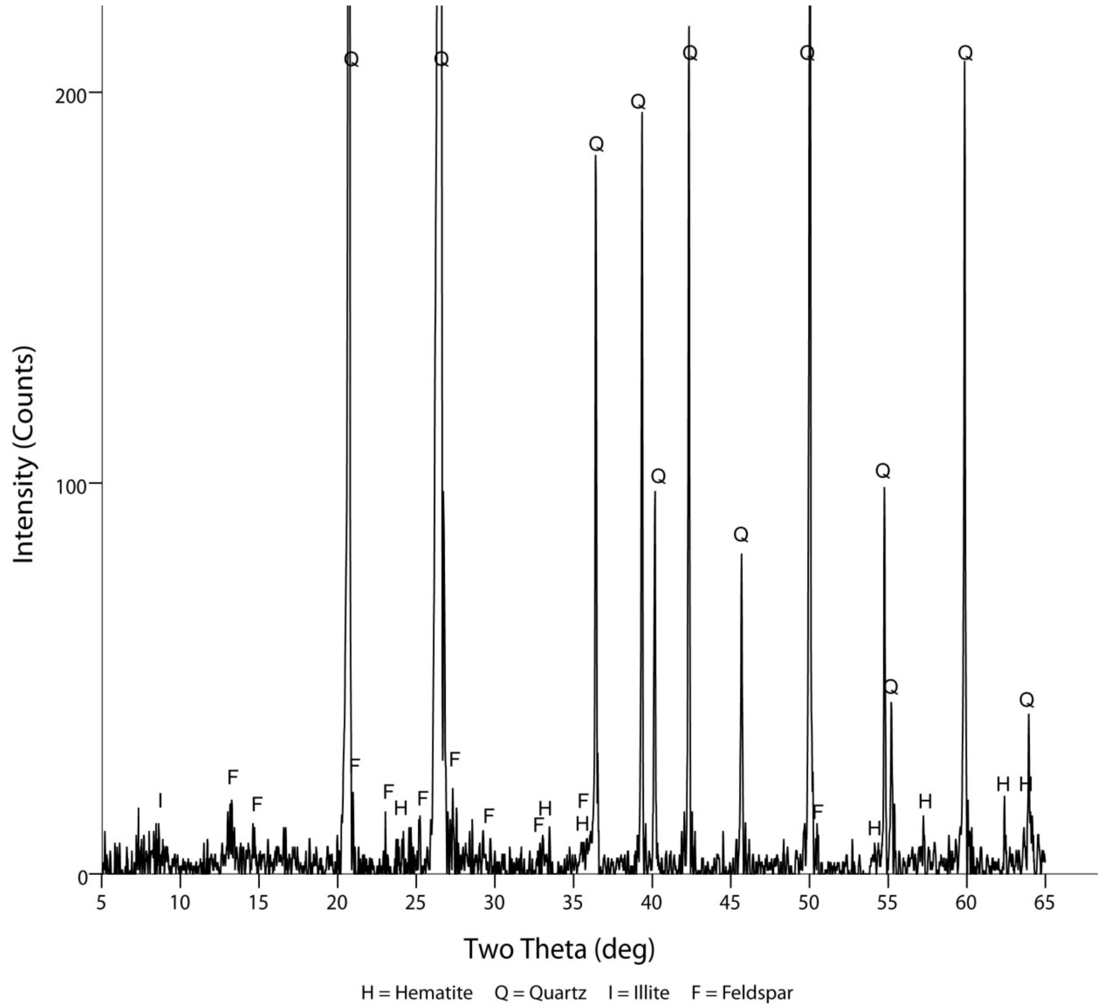


Fig. A.178. G145 Rivercrossing red/orange heated

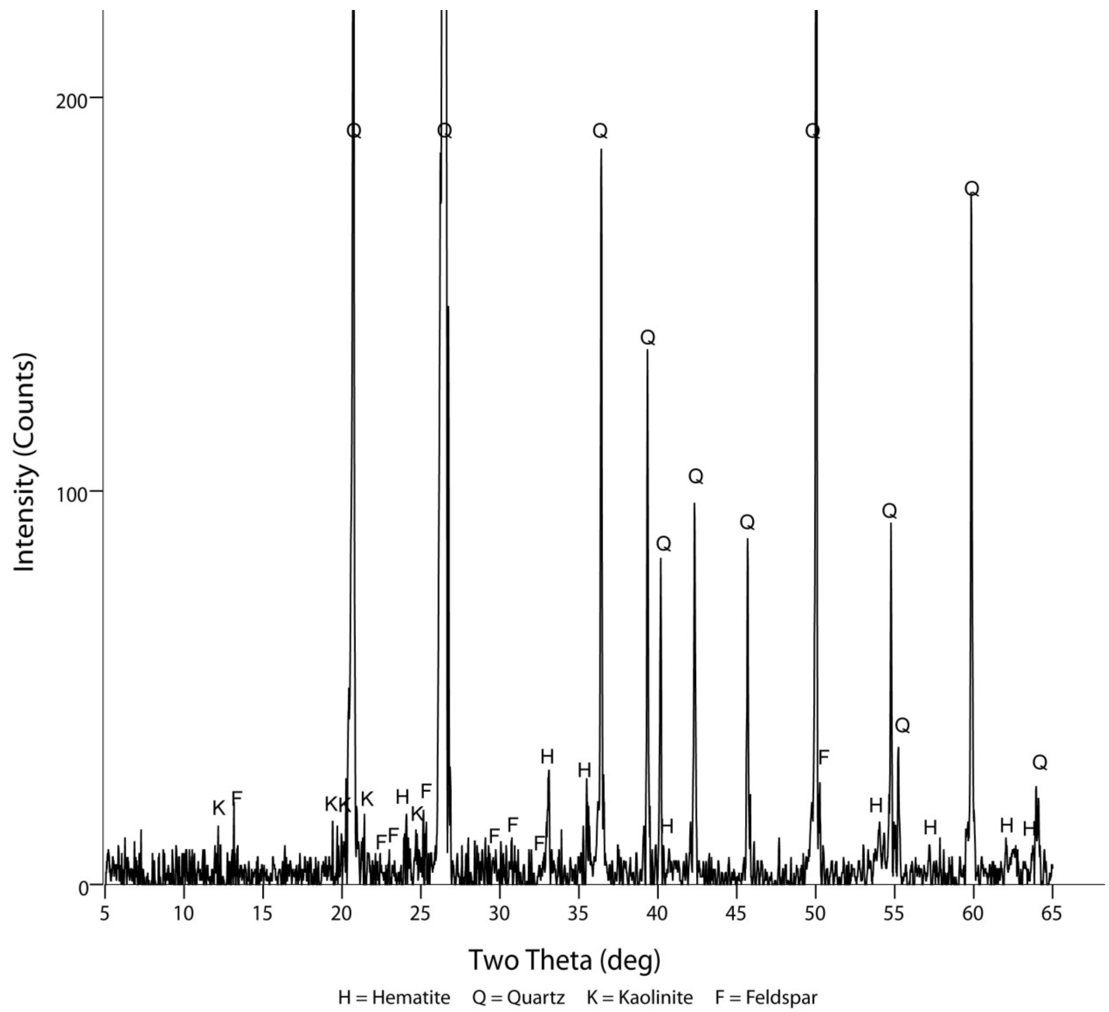


Fig. A.179. G147 Rivercrossing red/orange heated

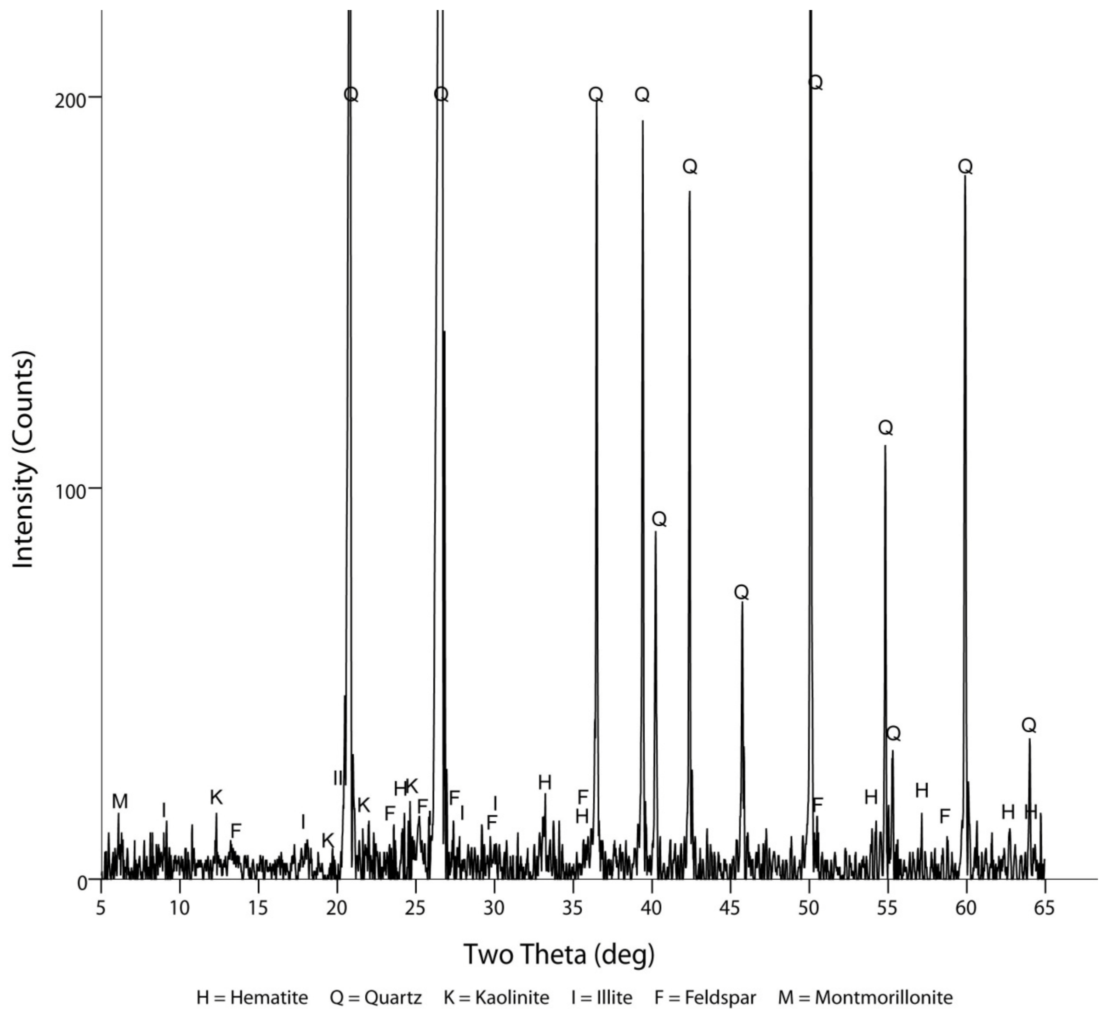


Fig. A.180. G149 Rivercrossing red/orange heated

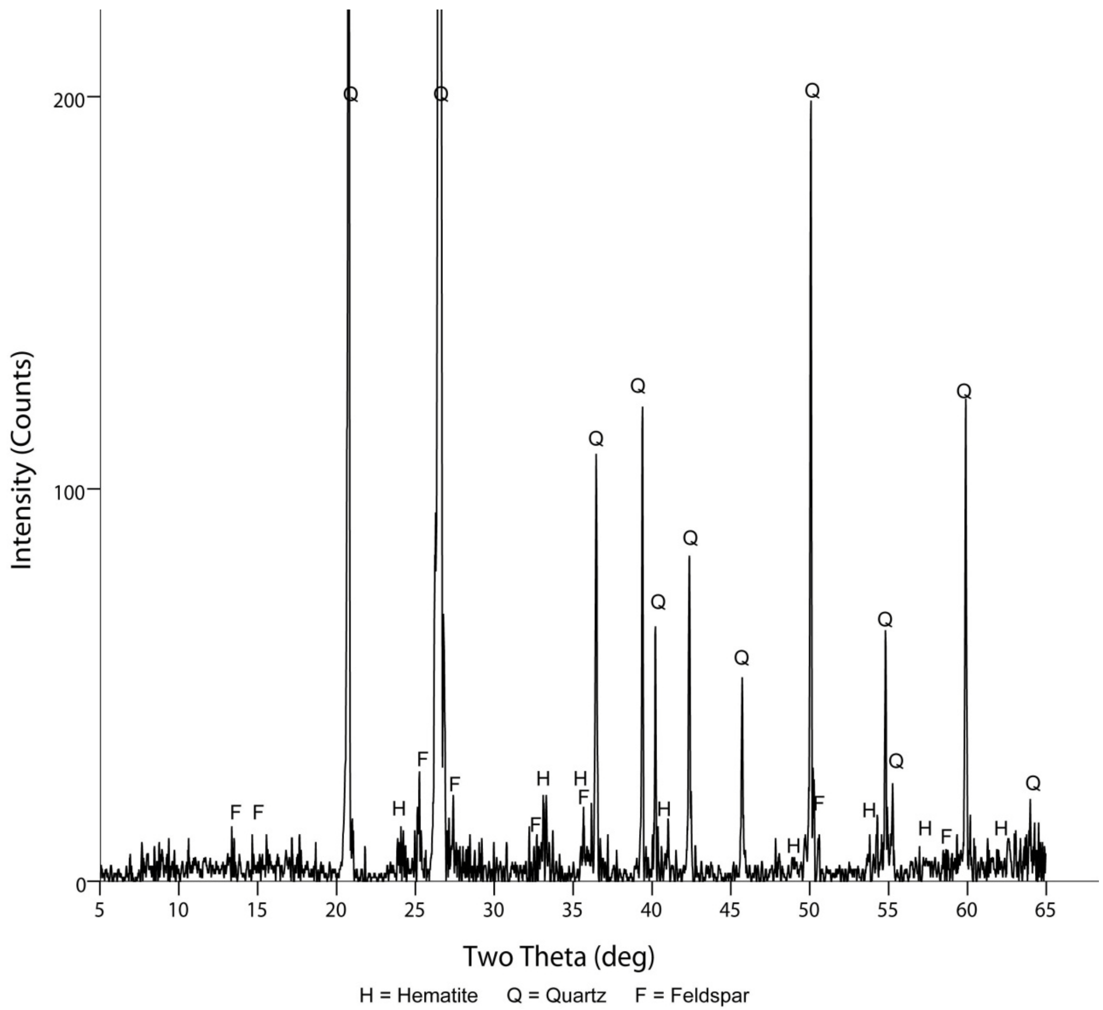


Fig. A.181. G227 Rivercrossing red/orange heated

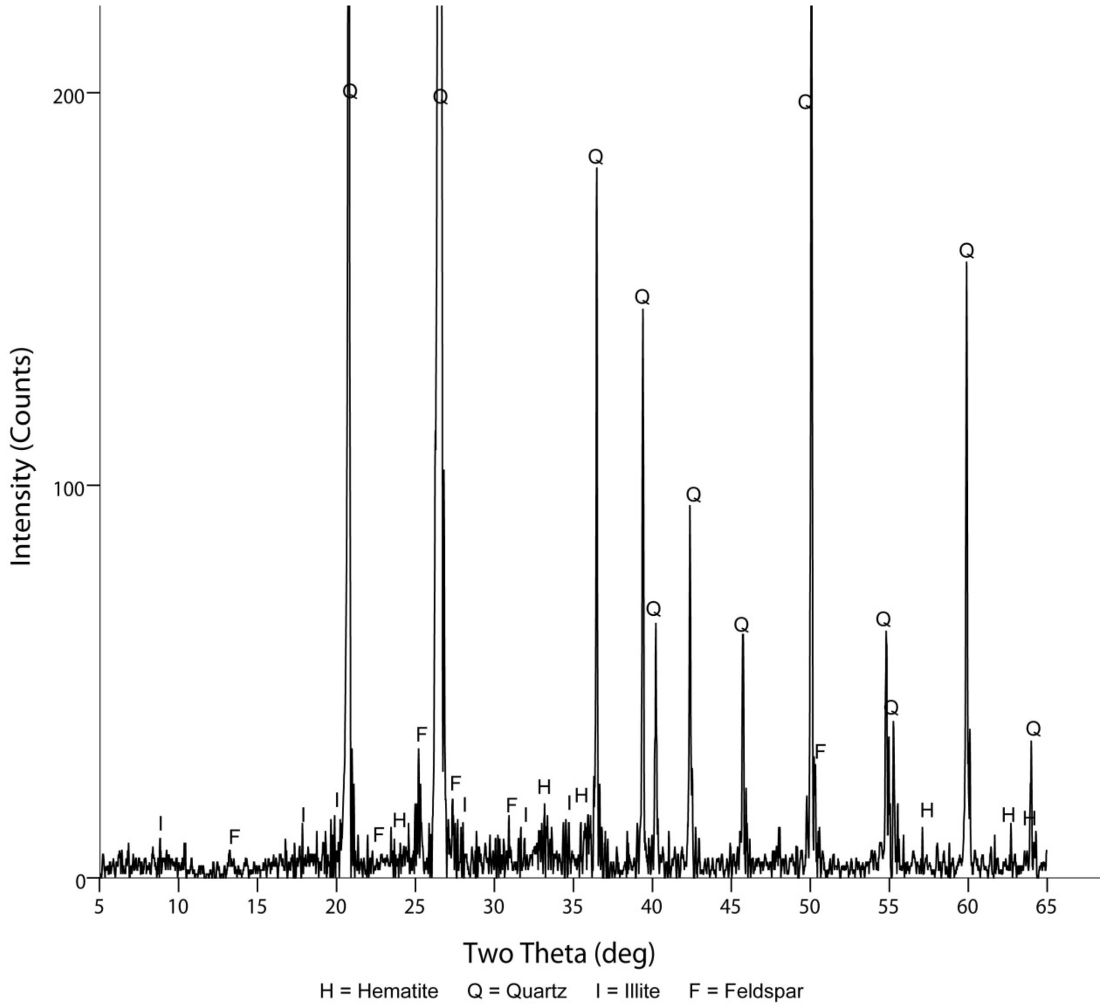


Fig. A.182. G228 Rivercrossing red/orange heated

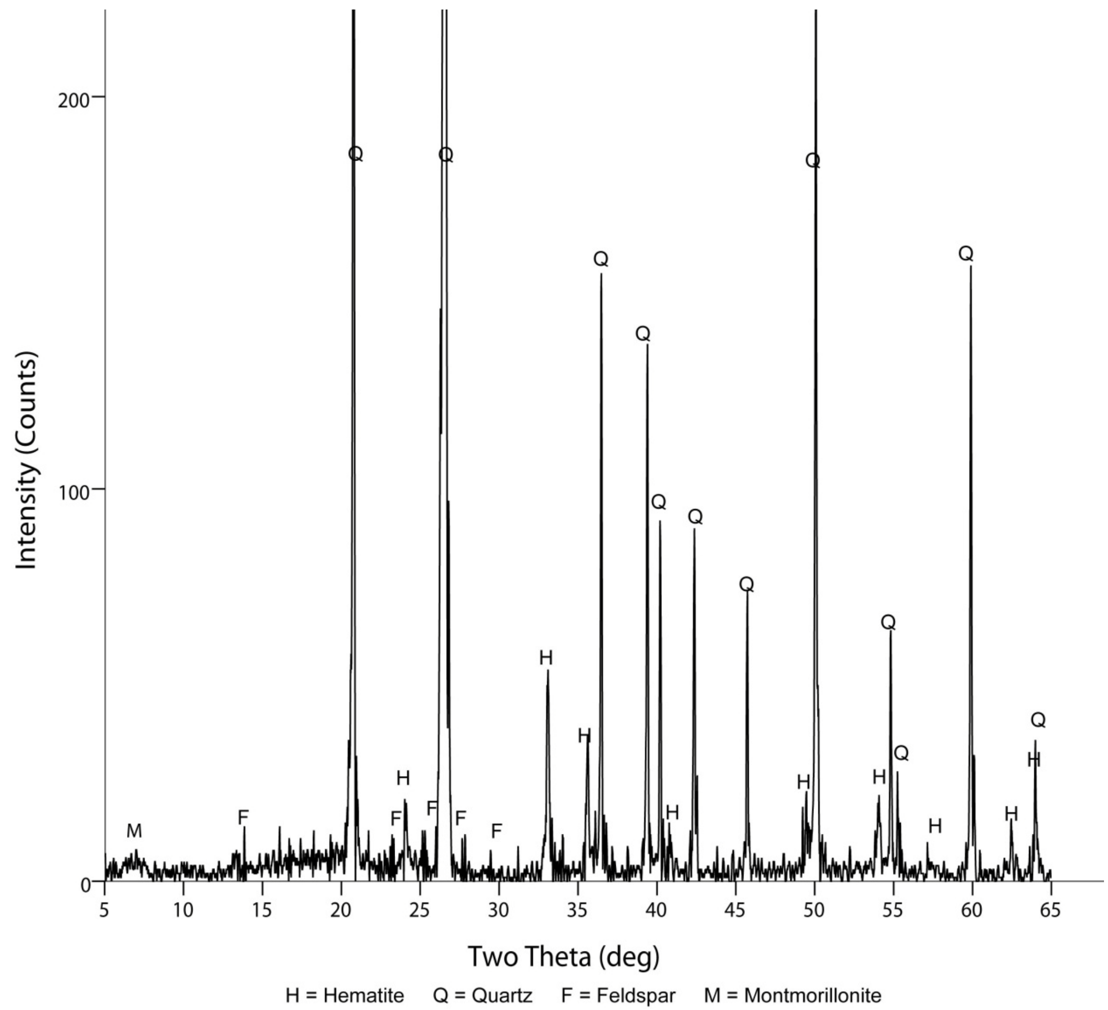


Fig. A.183. G229 Rivercrossing red/orange heated

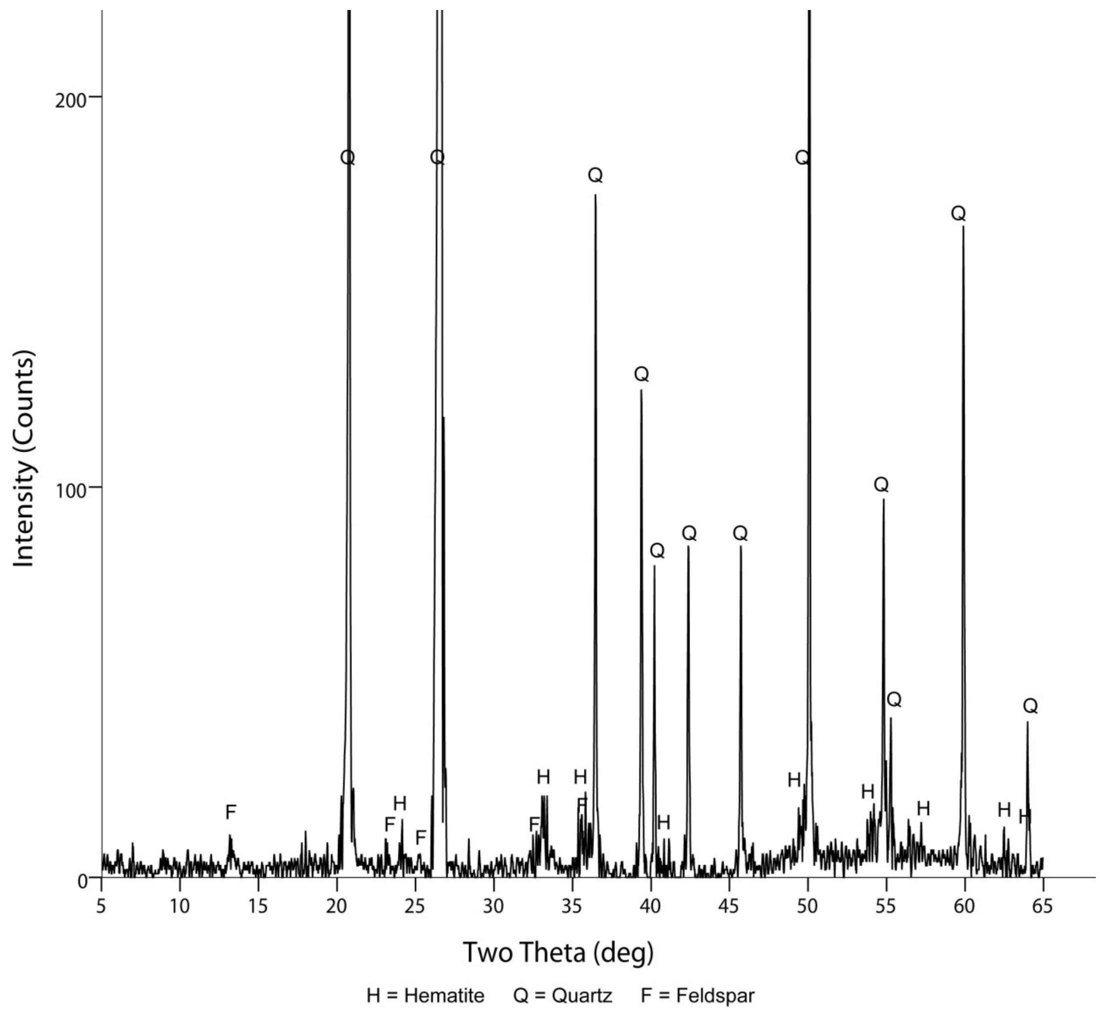


Fig. A.184. G230 Rivercrossing red/orange heated

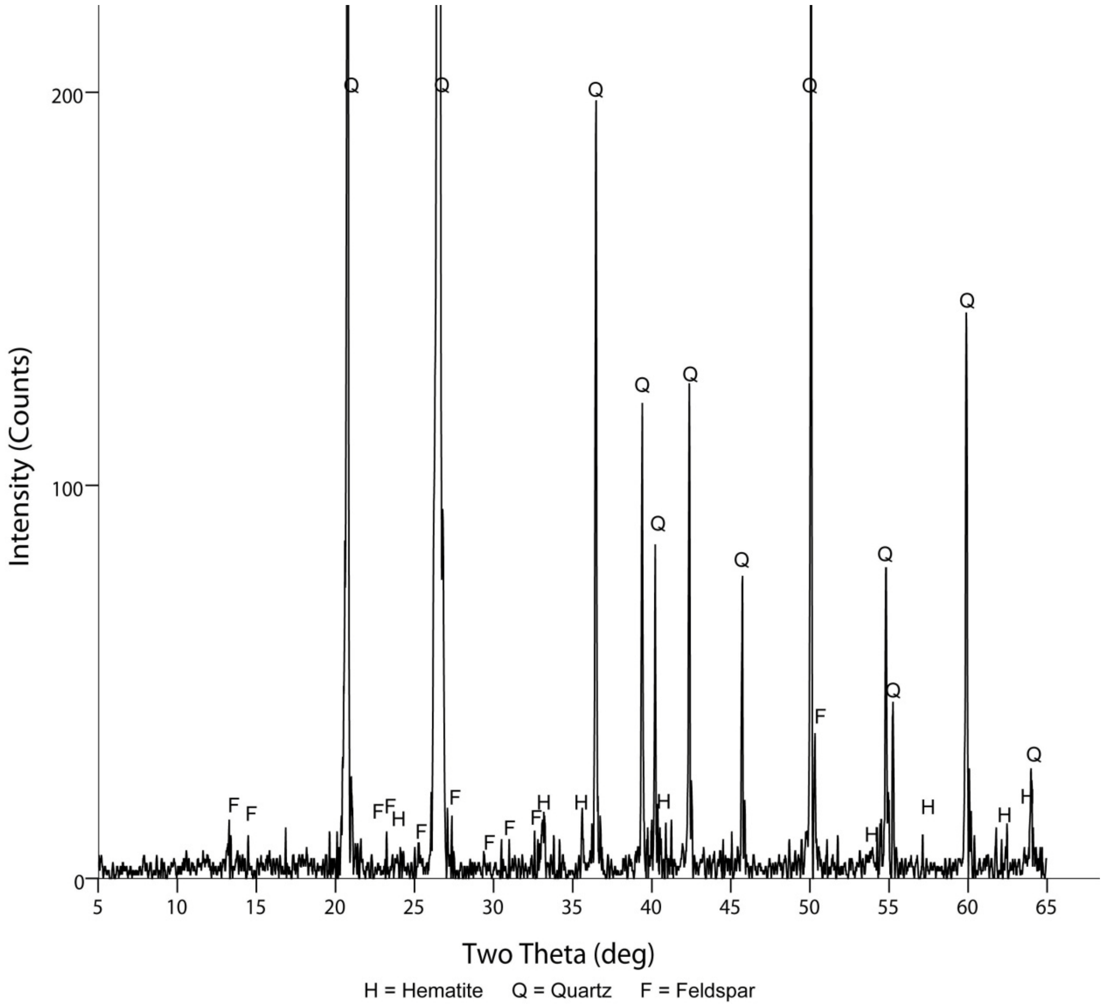


Fig. A.185. G231 Rivercrossing red/orange heated

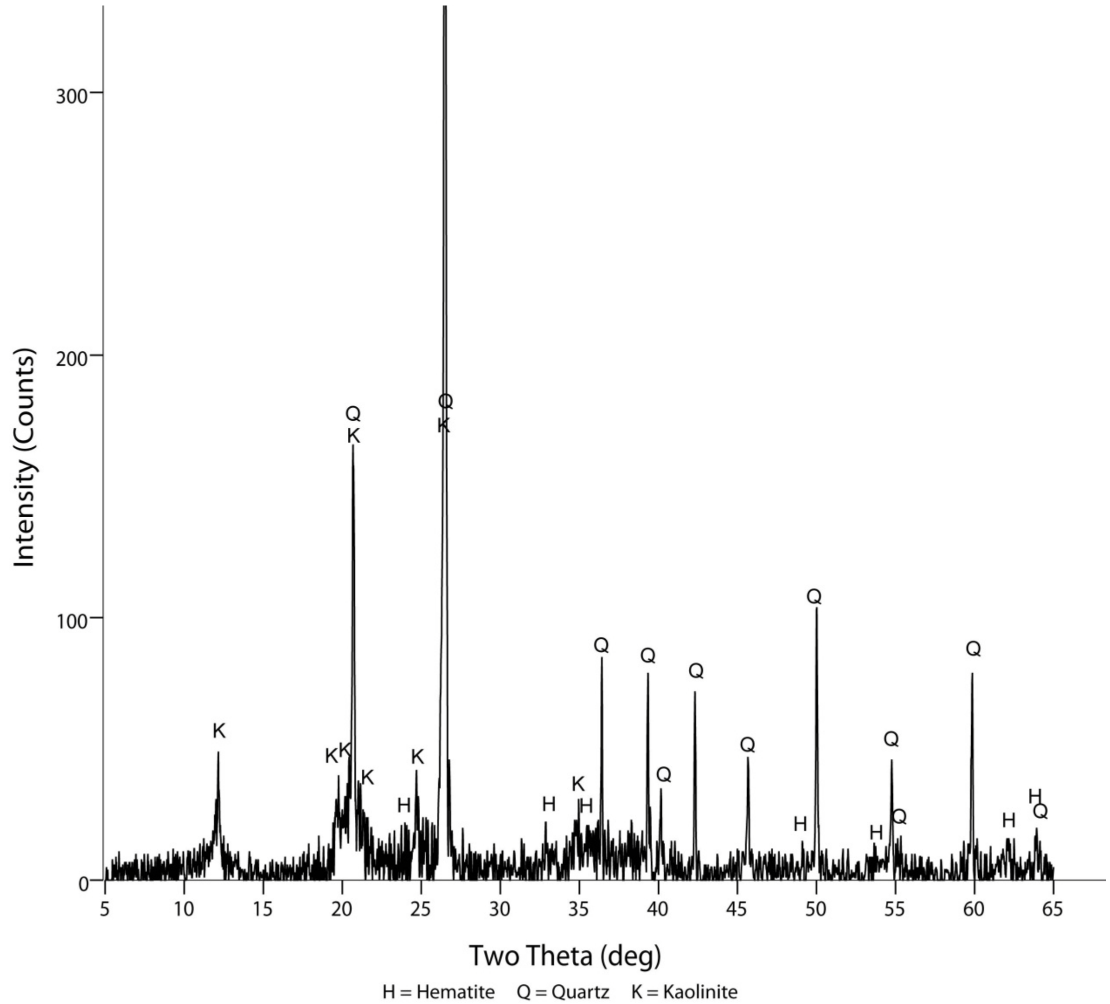


Fig. A.186. G53 Riversdale red/orange

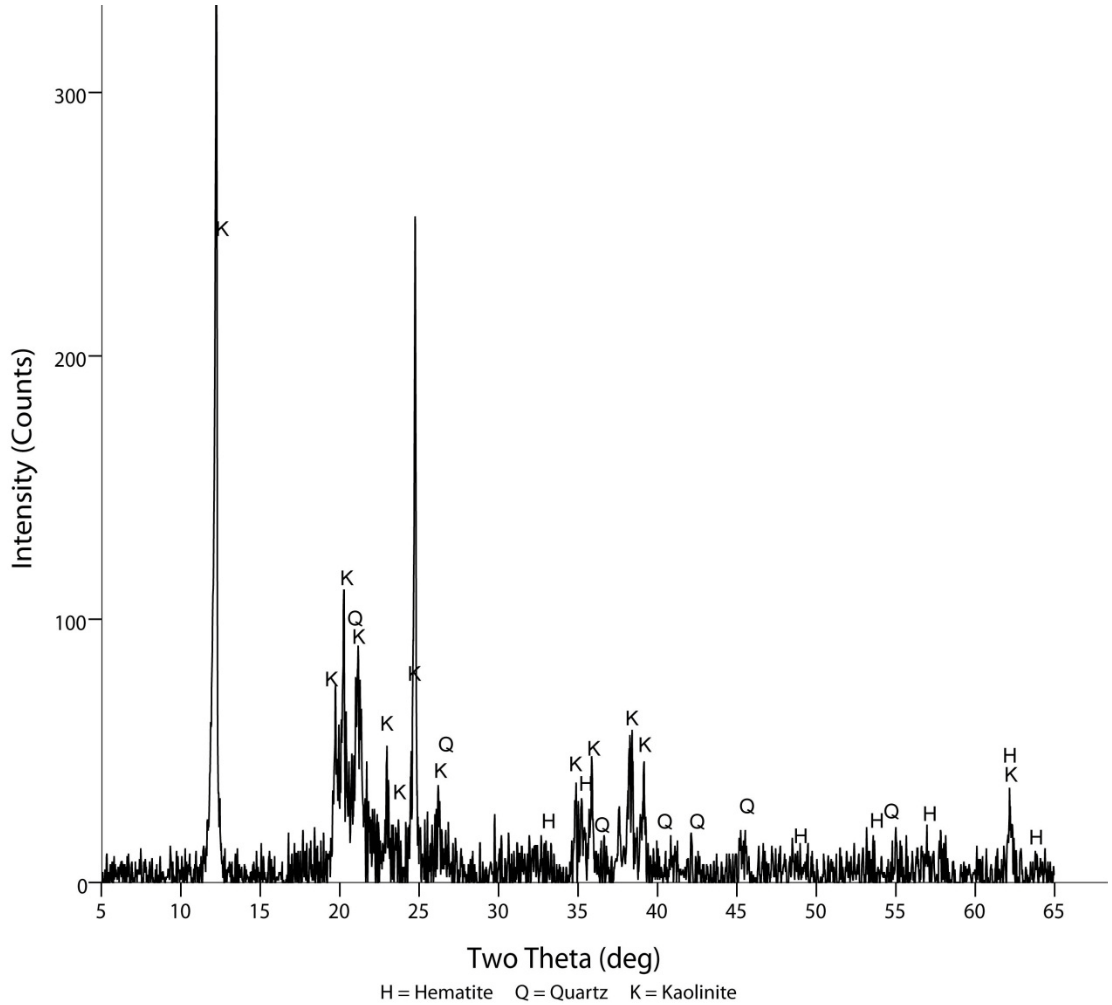


Fig. A.187. G54 Riversdale red/orange

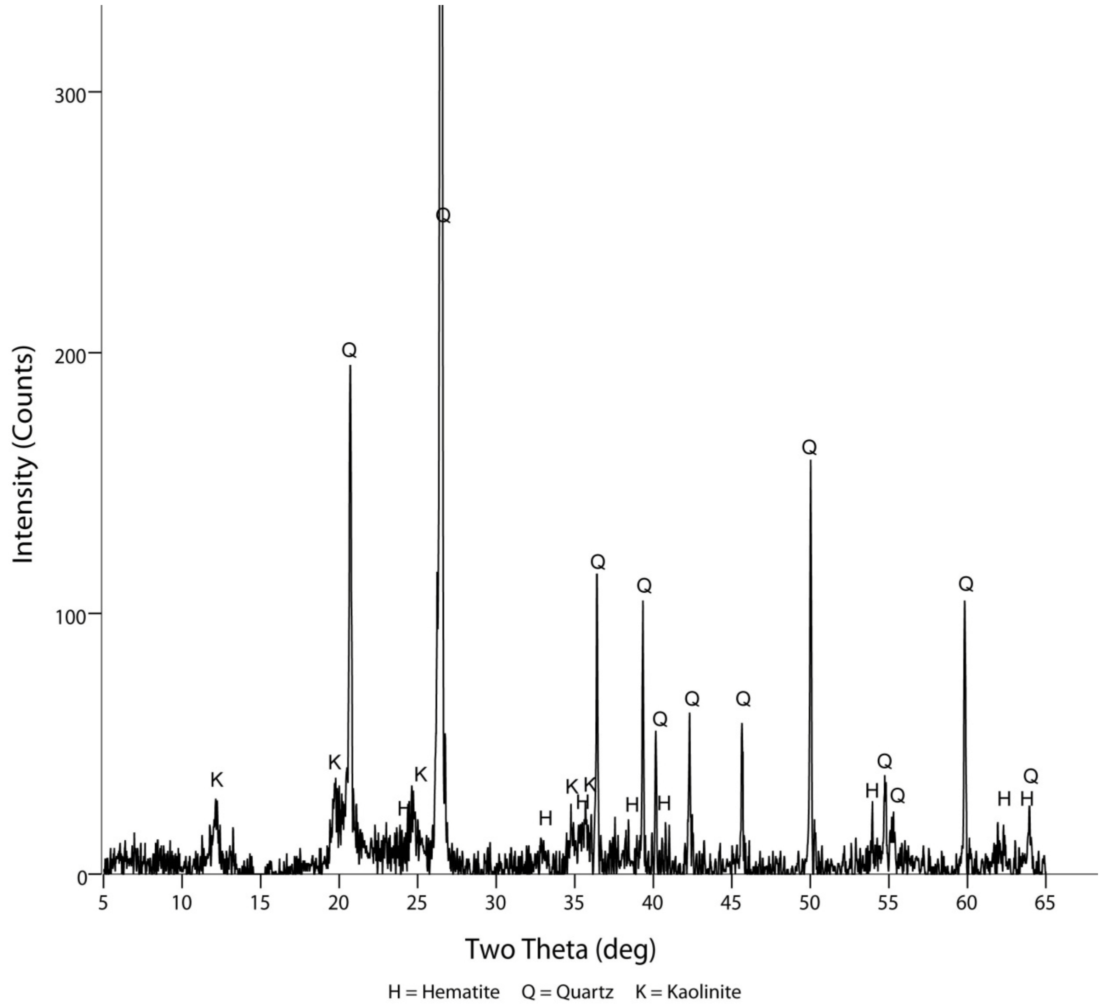


Fig. A.188. G79 Riversdale red/orange heated

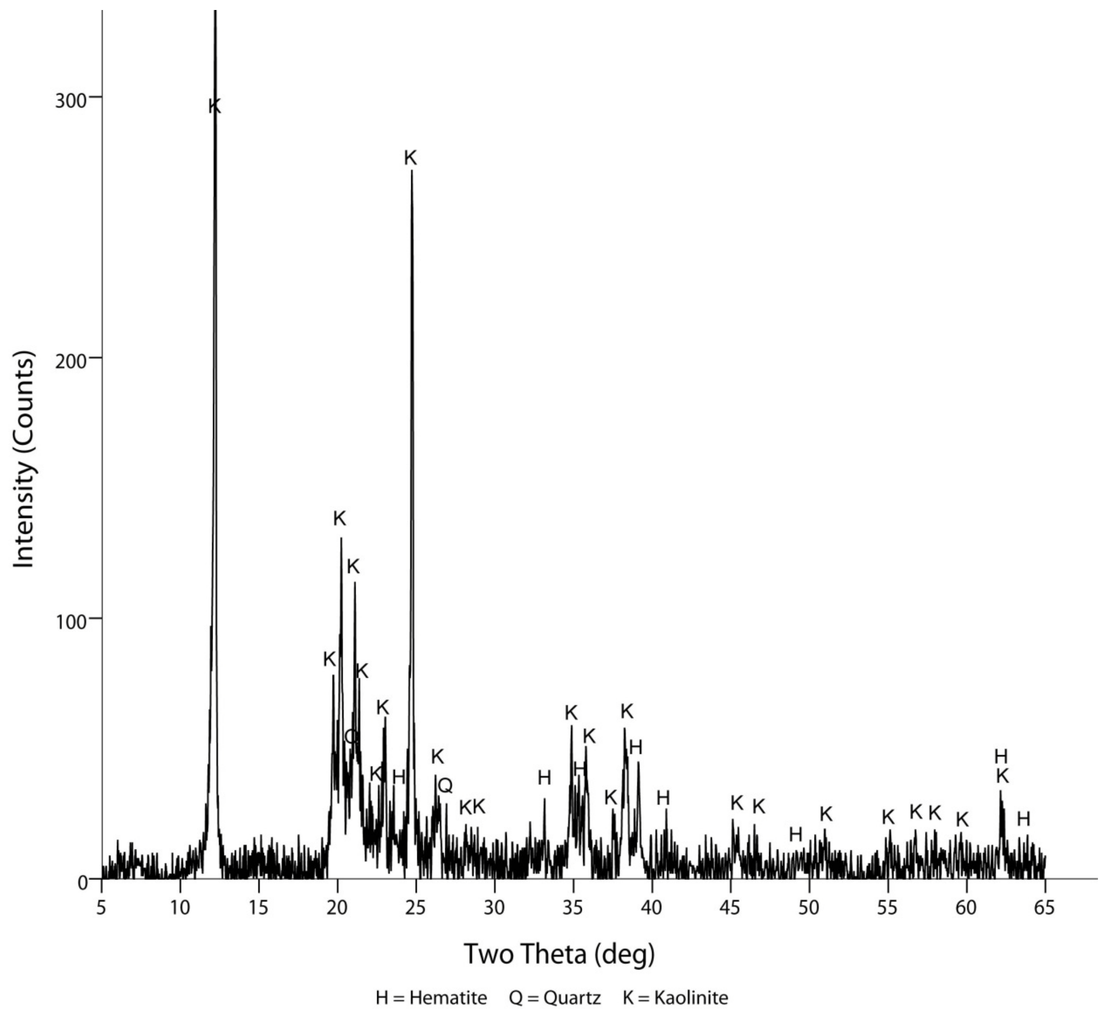


Fig. A.189. G81 Riversdale red/orange heated

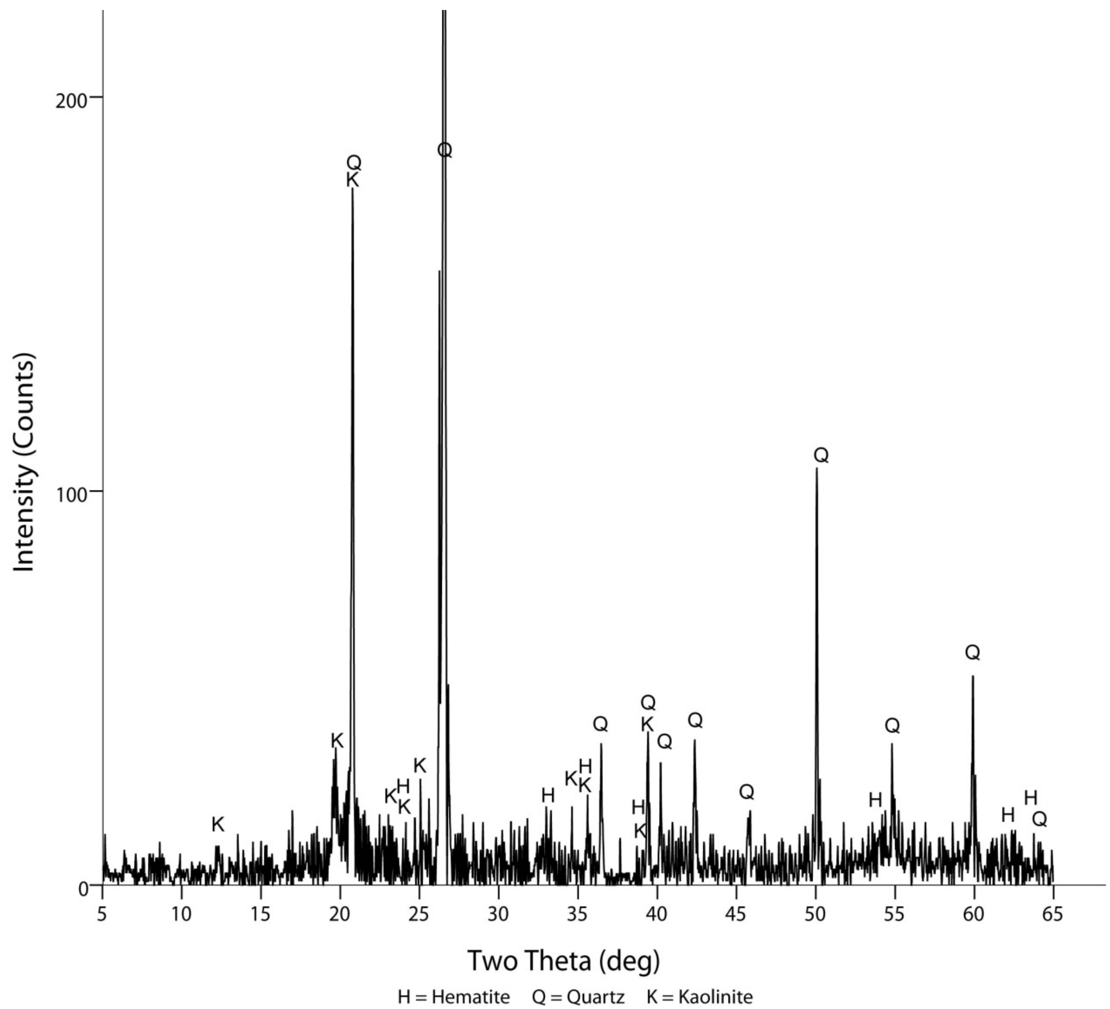


Fig. A.190. G254 Riversdale red/orange heated

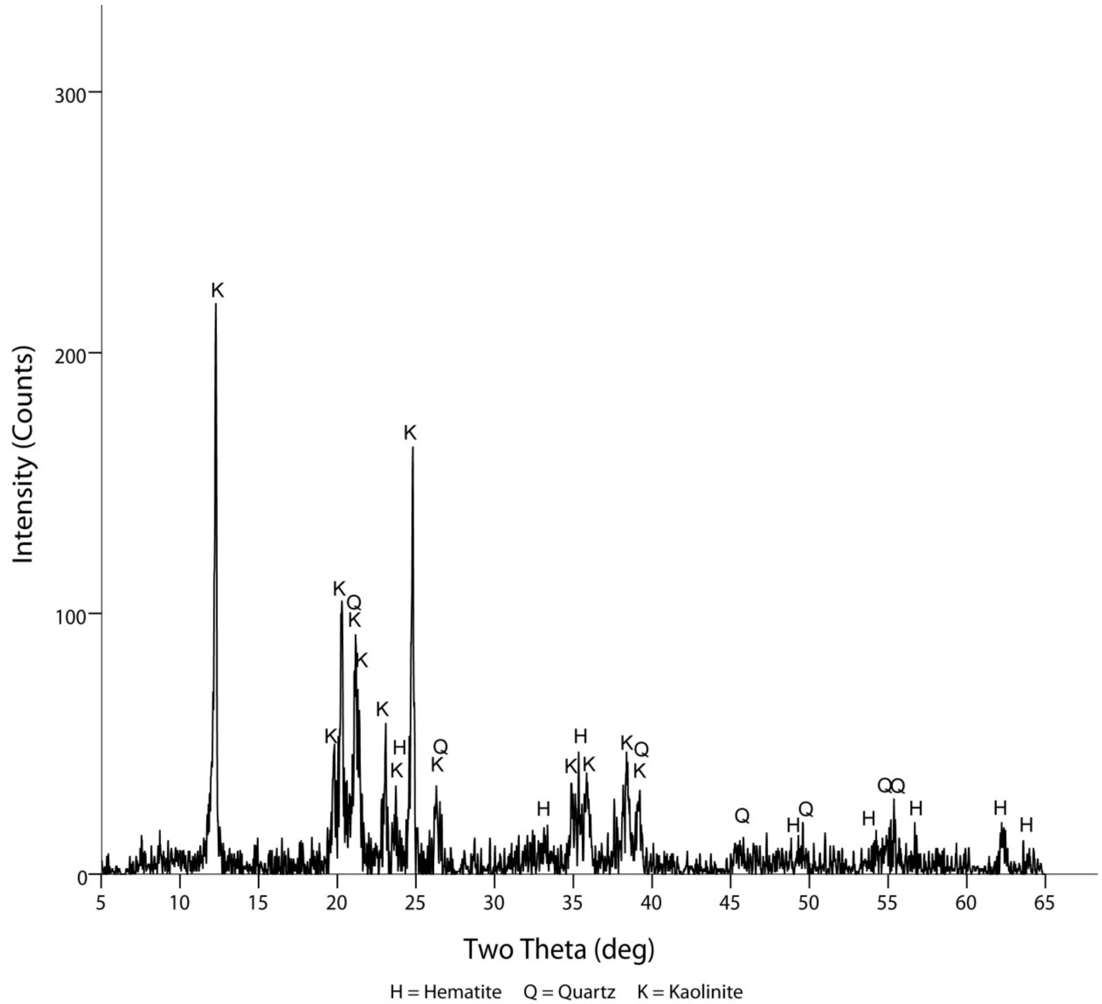


Fig. A.191. G255 Riversdale red/orange heated

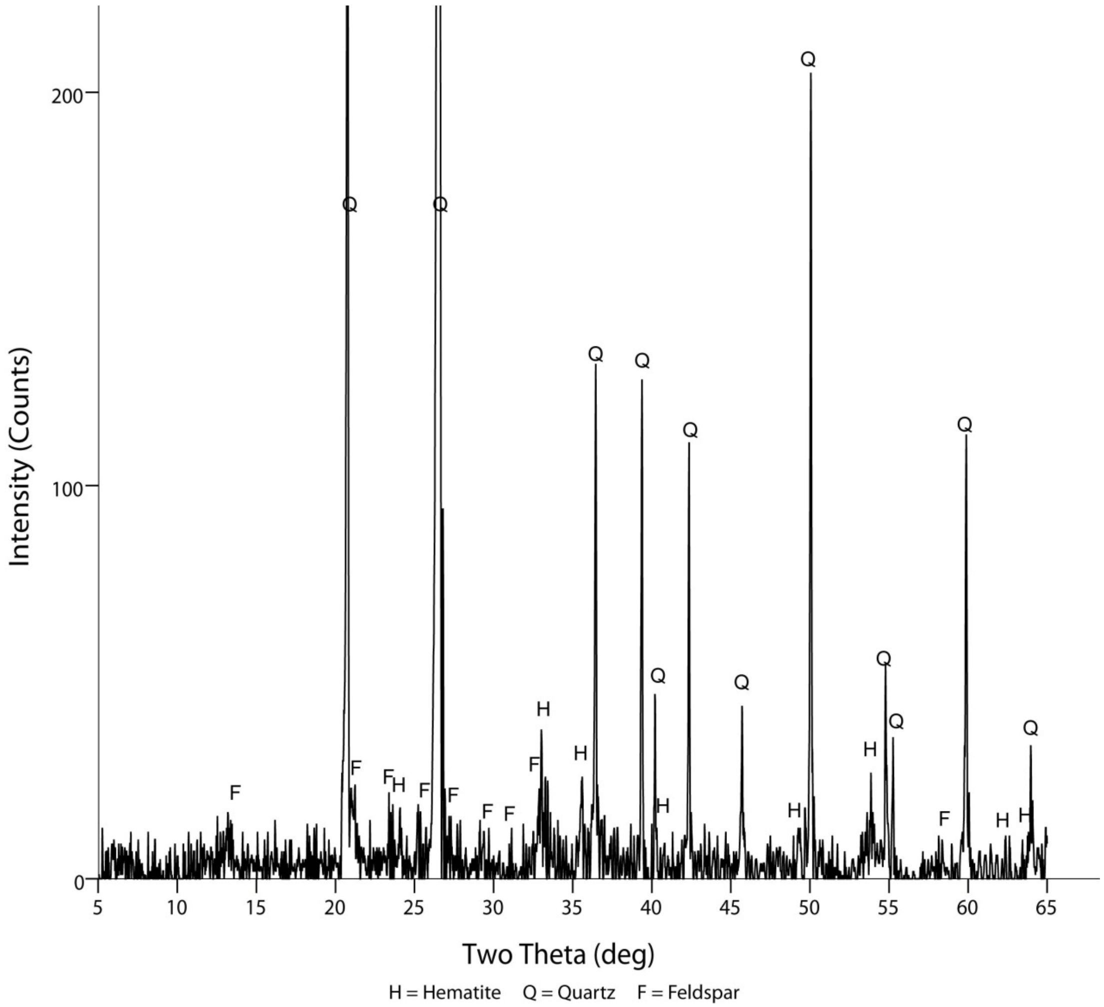


Fig. A.192. G175 Roodekrans red

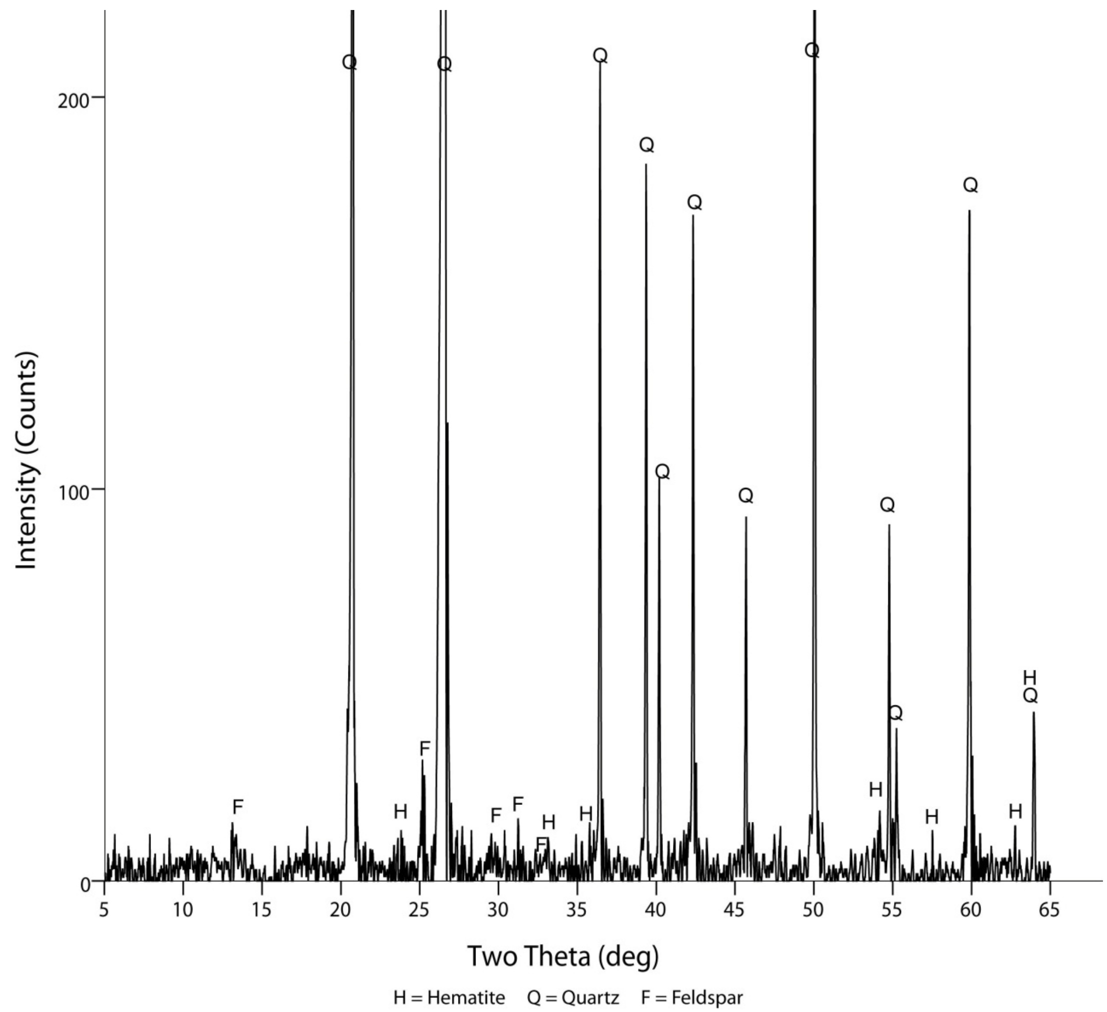


Fig. A.193. G177 Roodekrans red

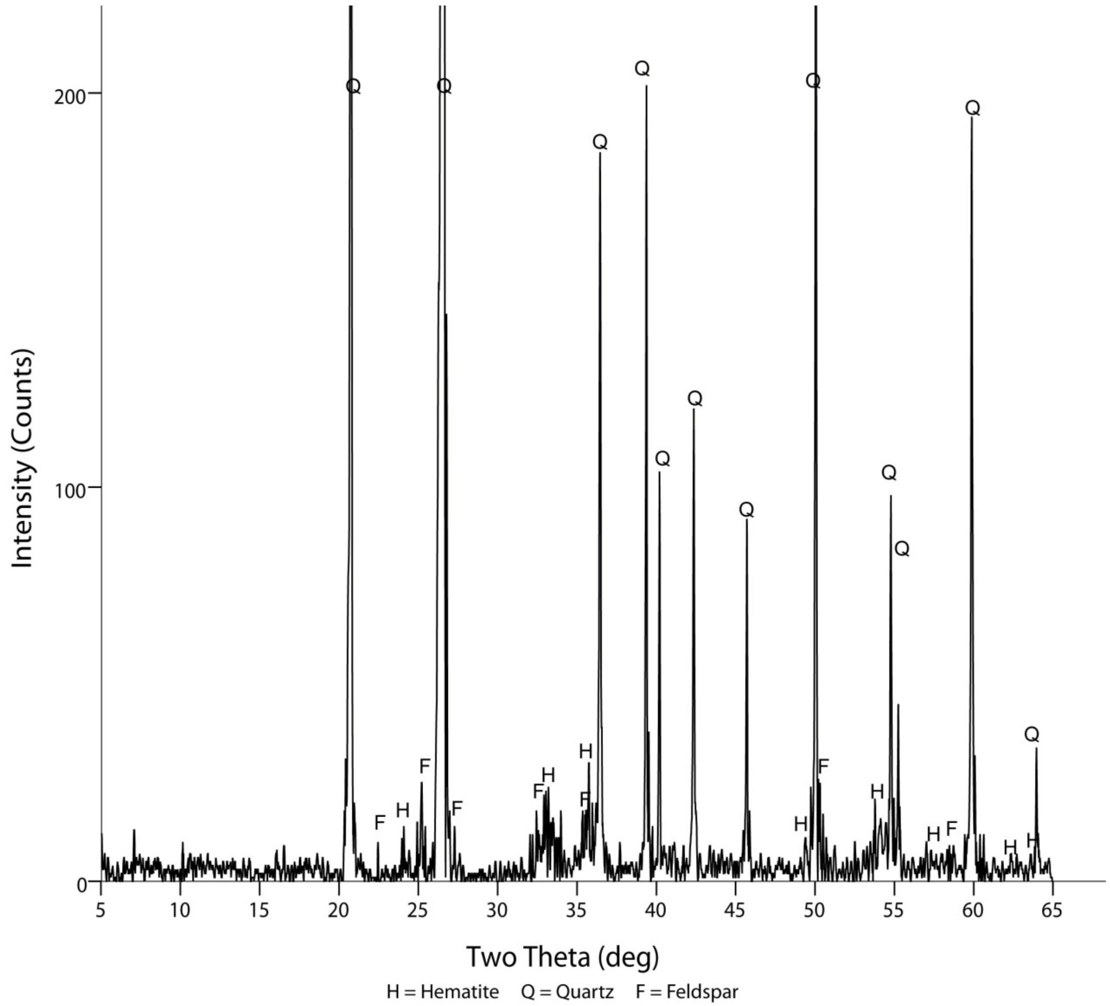


Fig. A.194. G176 Roodekrans red heated

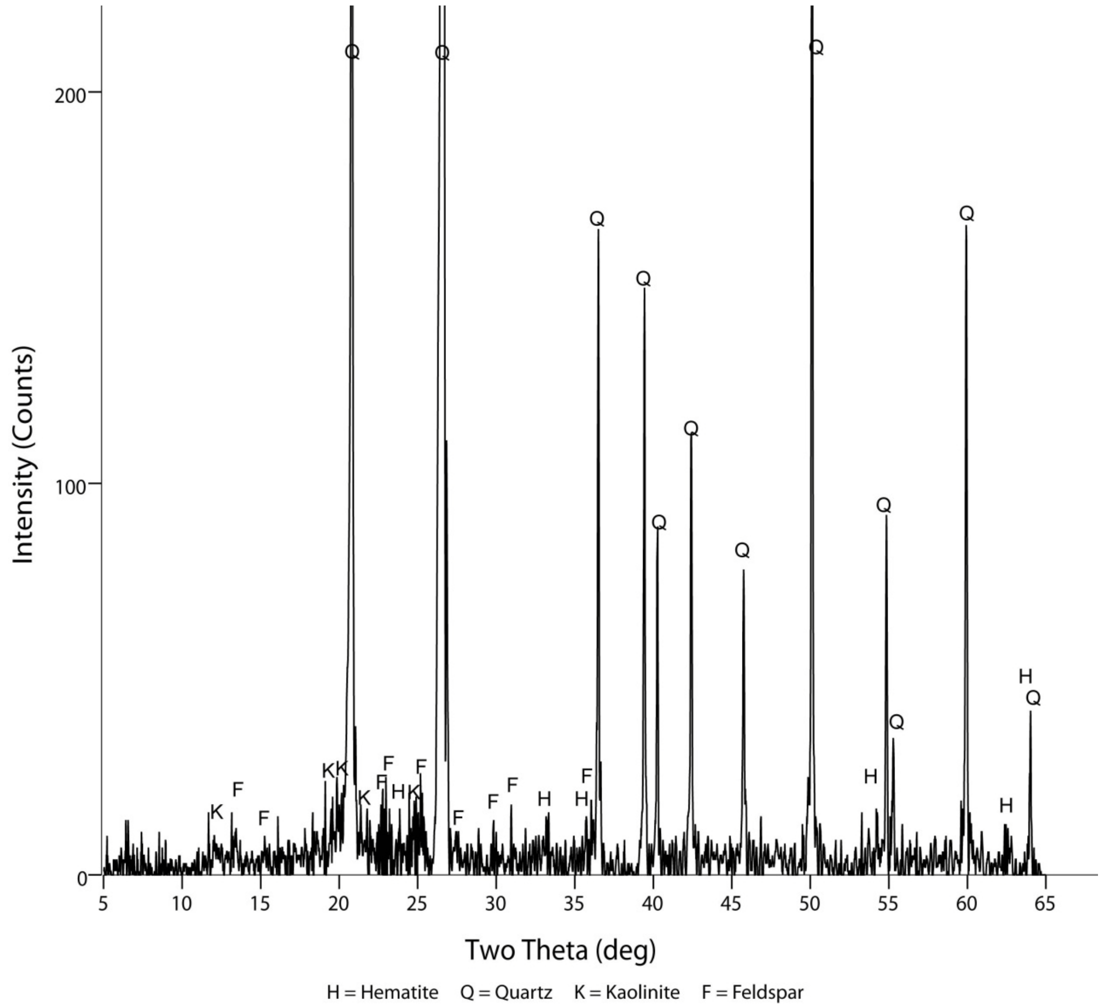


Fig. A.195. G178 Roodekrans red heated

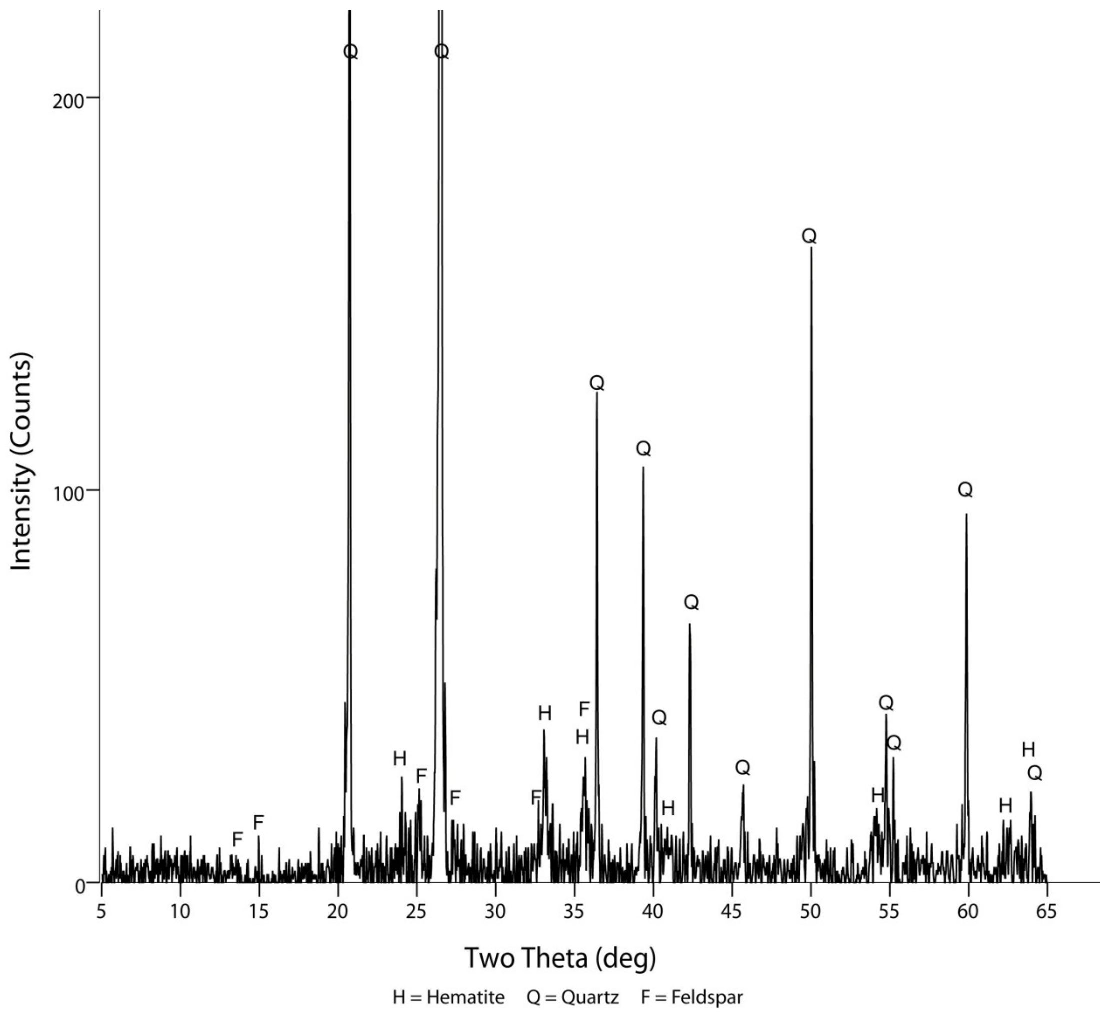


Fig. A.196. G244 Roodekrans red heated

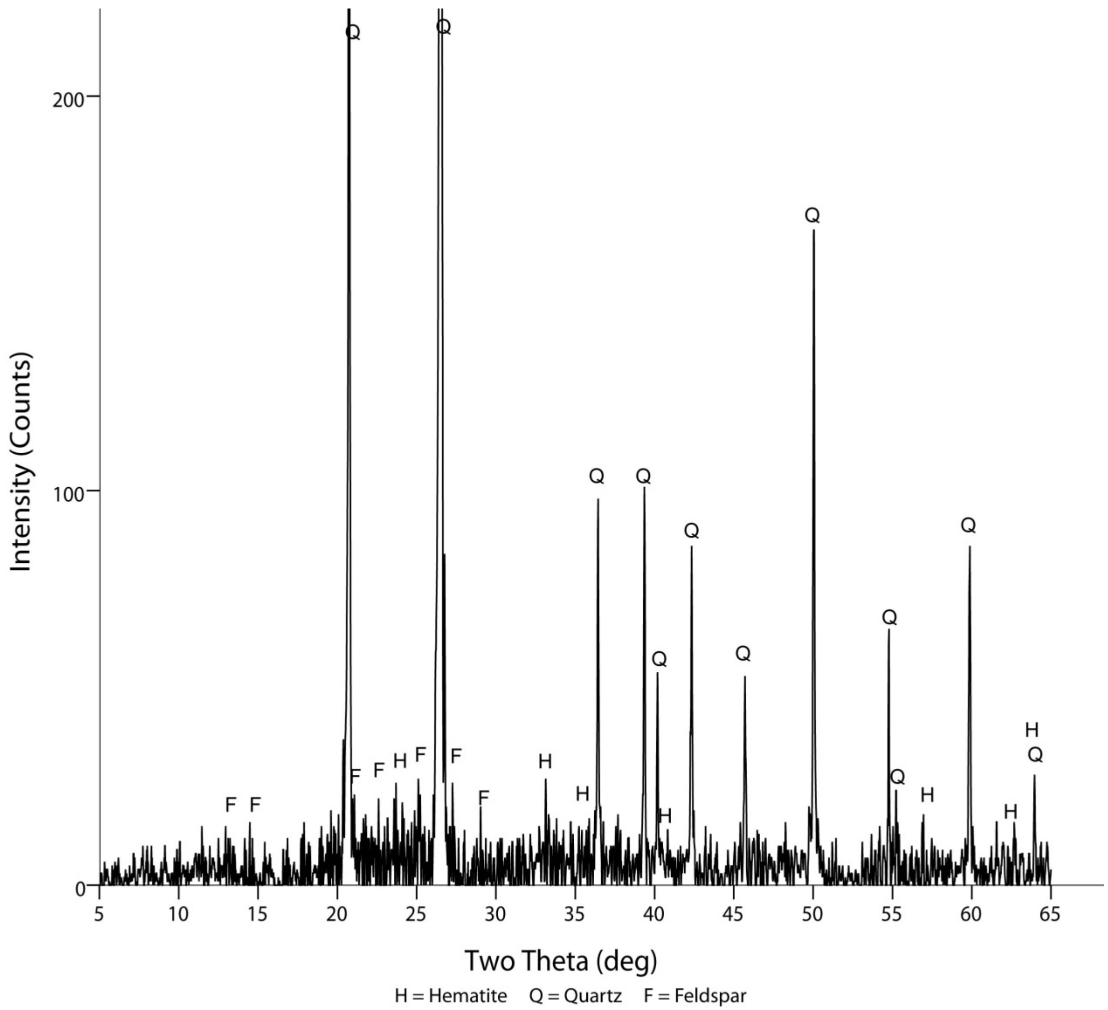


Fig. A.197. G245 Roodekrans red heated

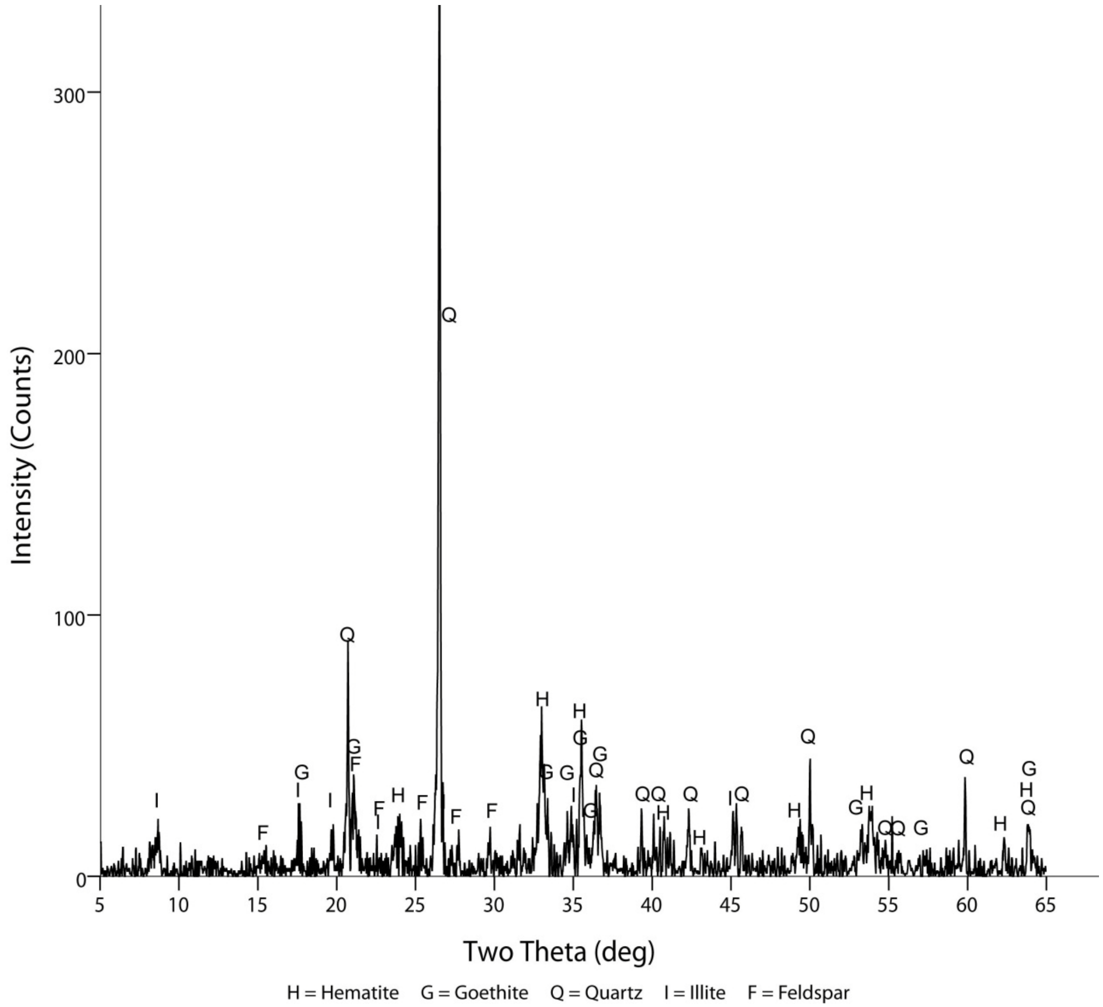


Fig. A.198. G39 Rooikoppie red

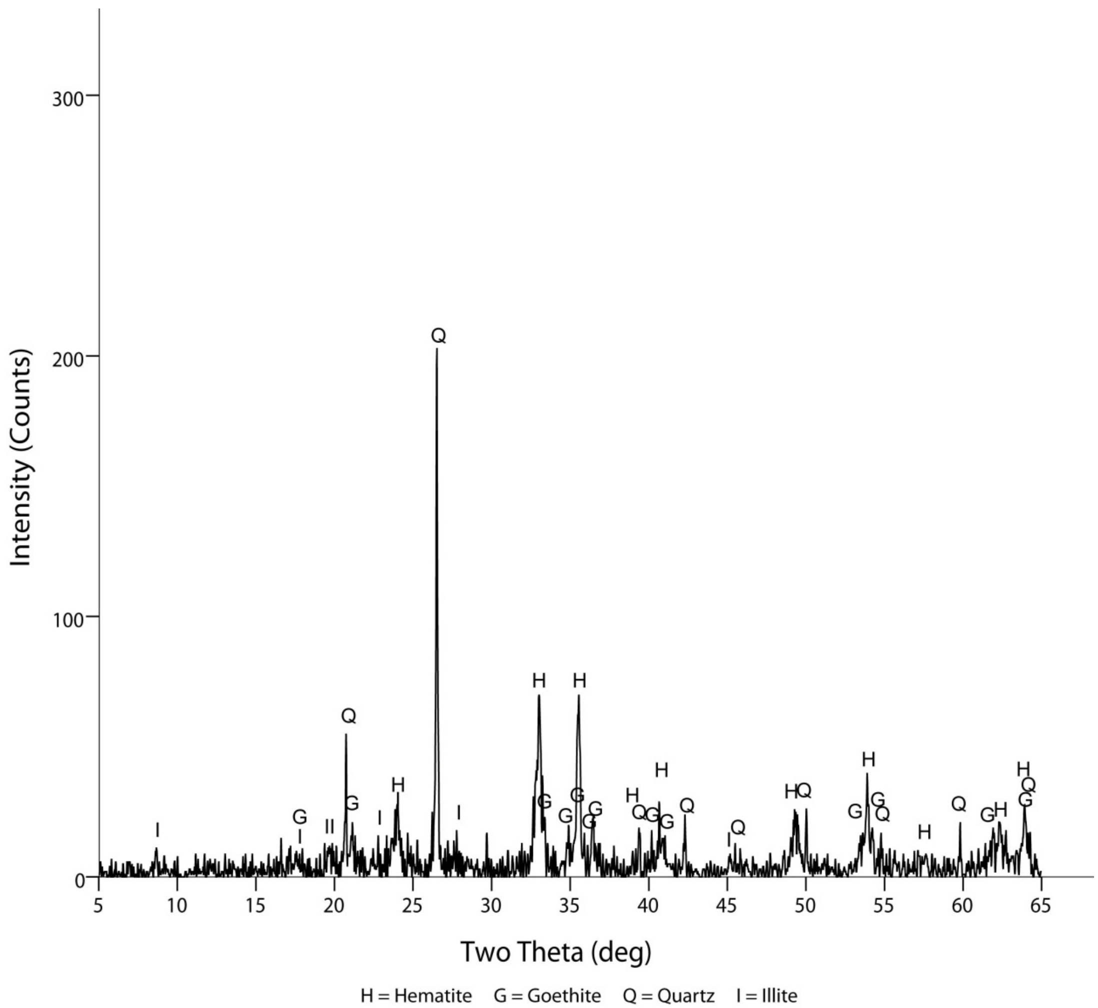


Fig. A.199. G41 Rooikoppie red

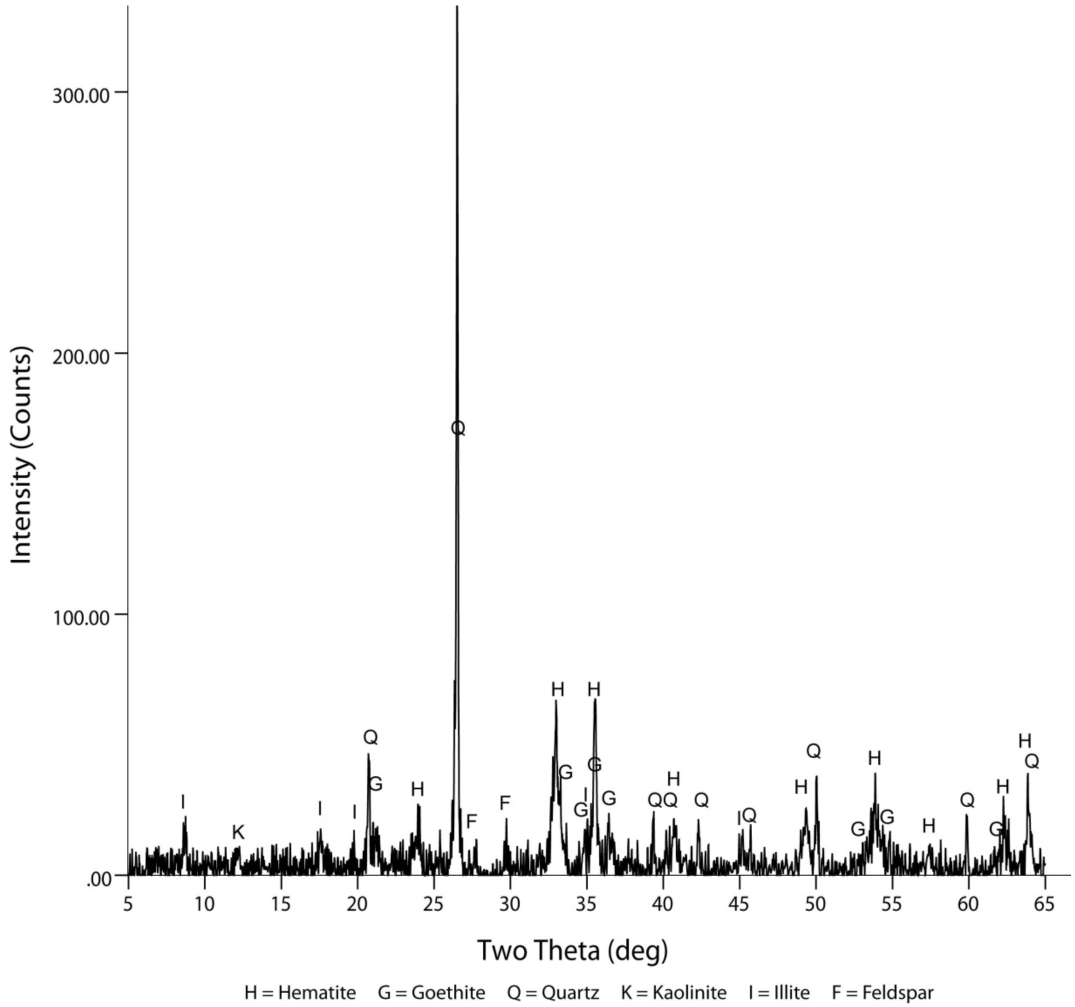


Fig. A.200. G42 Rooikoppie red

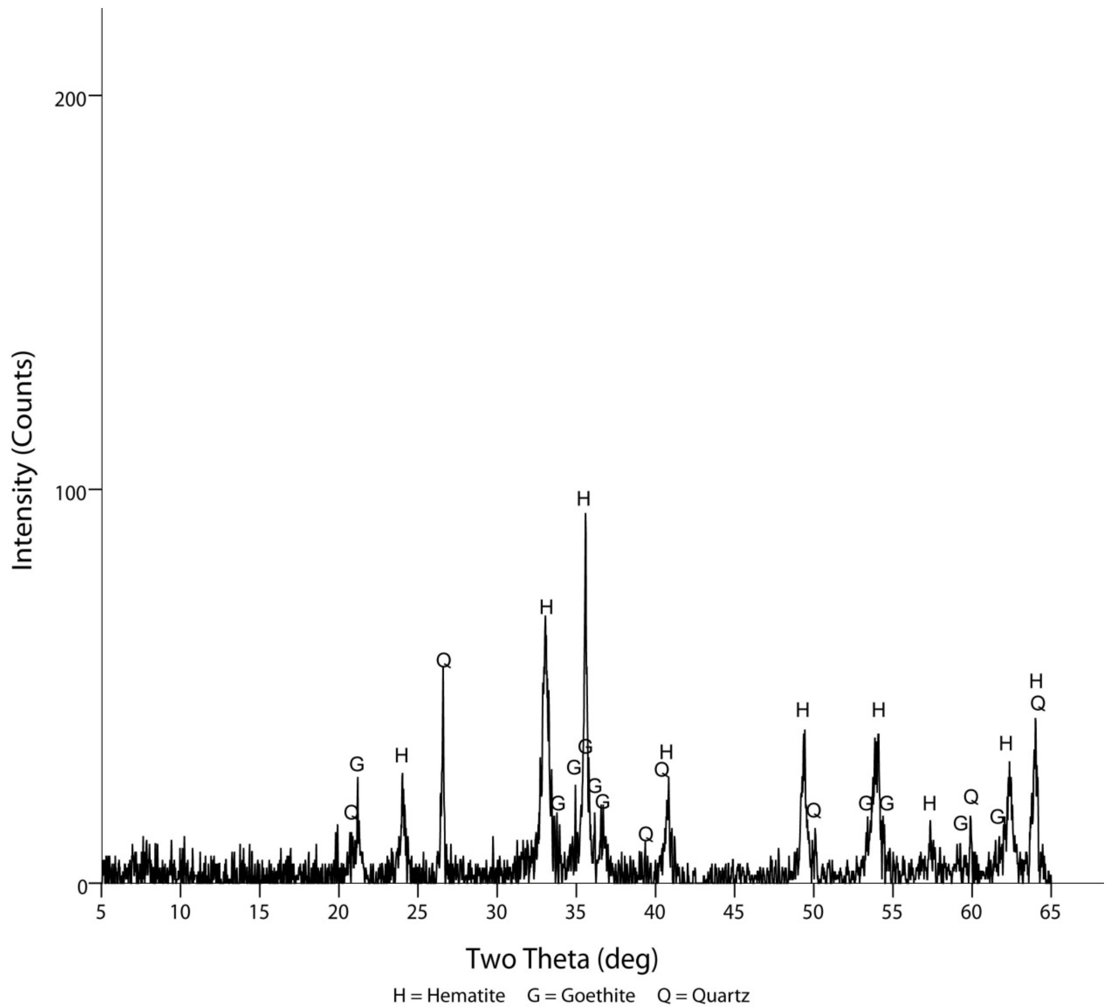


Fig. A.201. G43 Rooikoppie red

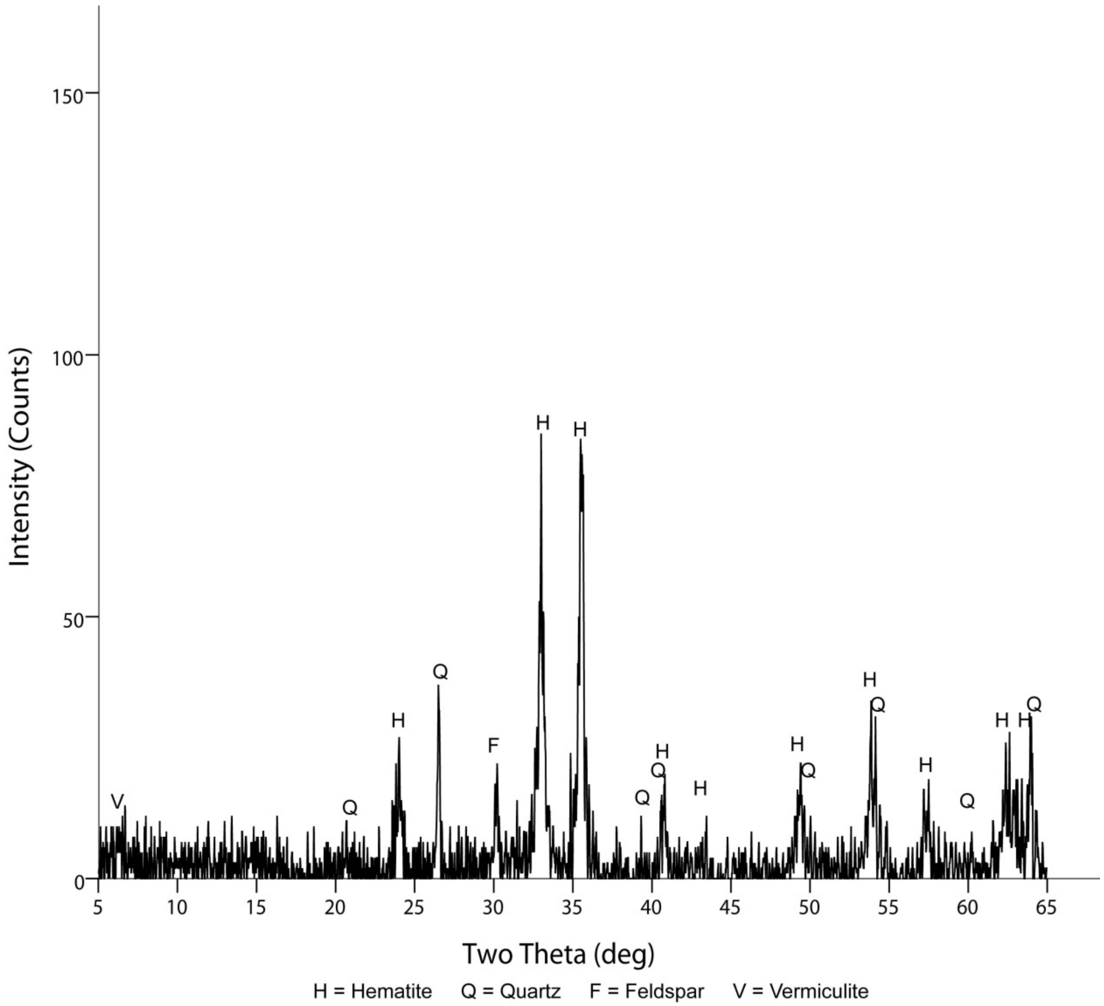


Fig. A.202. G7 Rooikoppie red heated

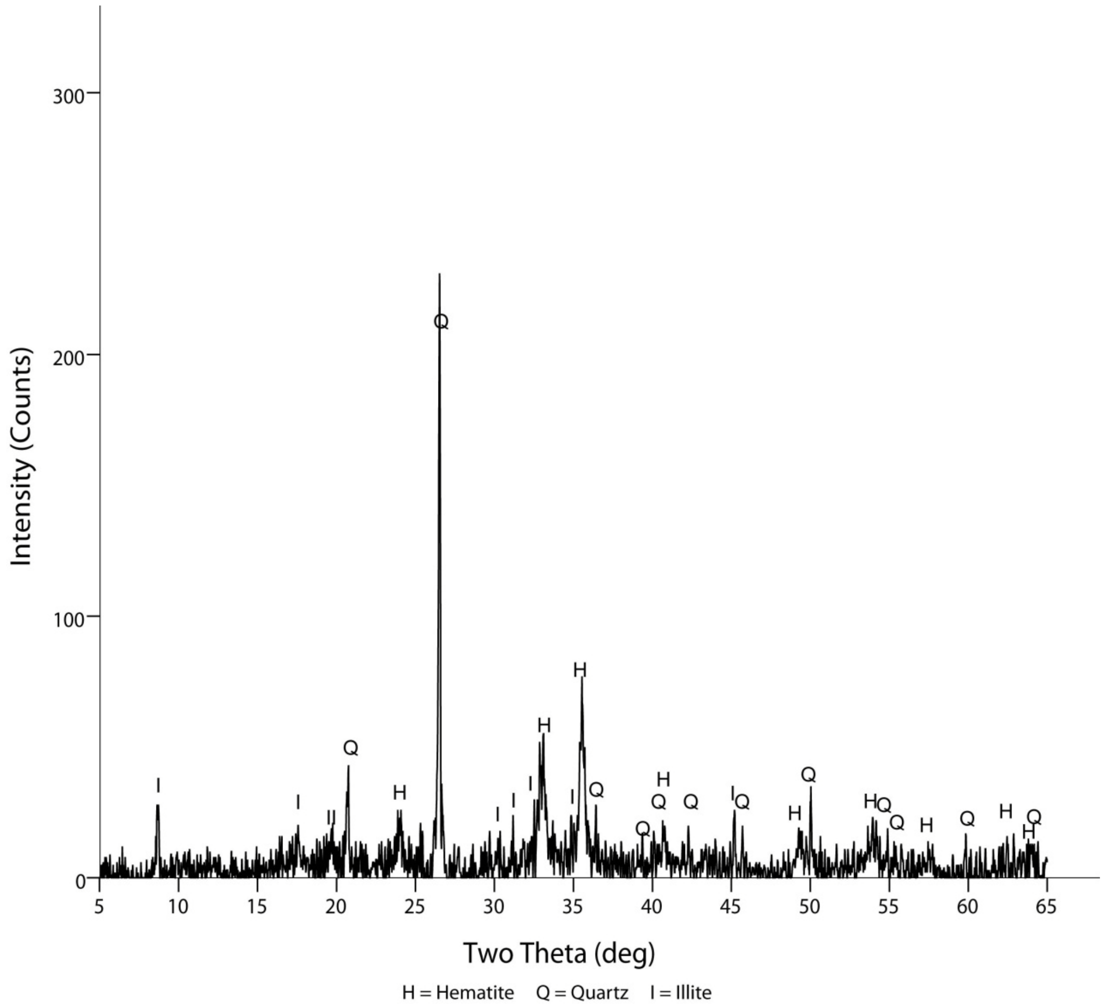


Fig. A.203. G8 Rooikoppie red heated

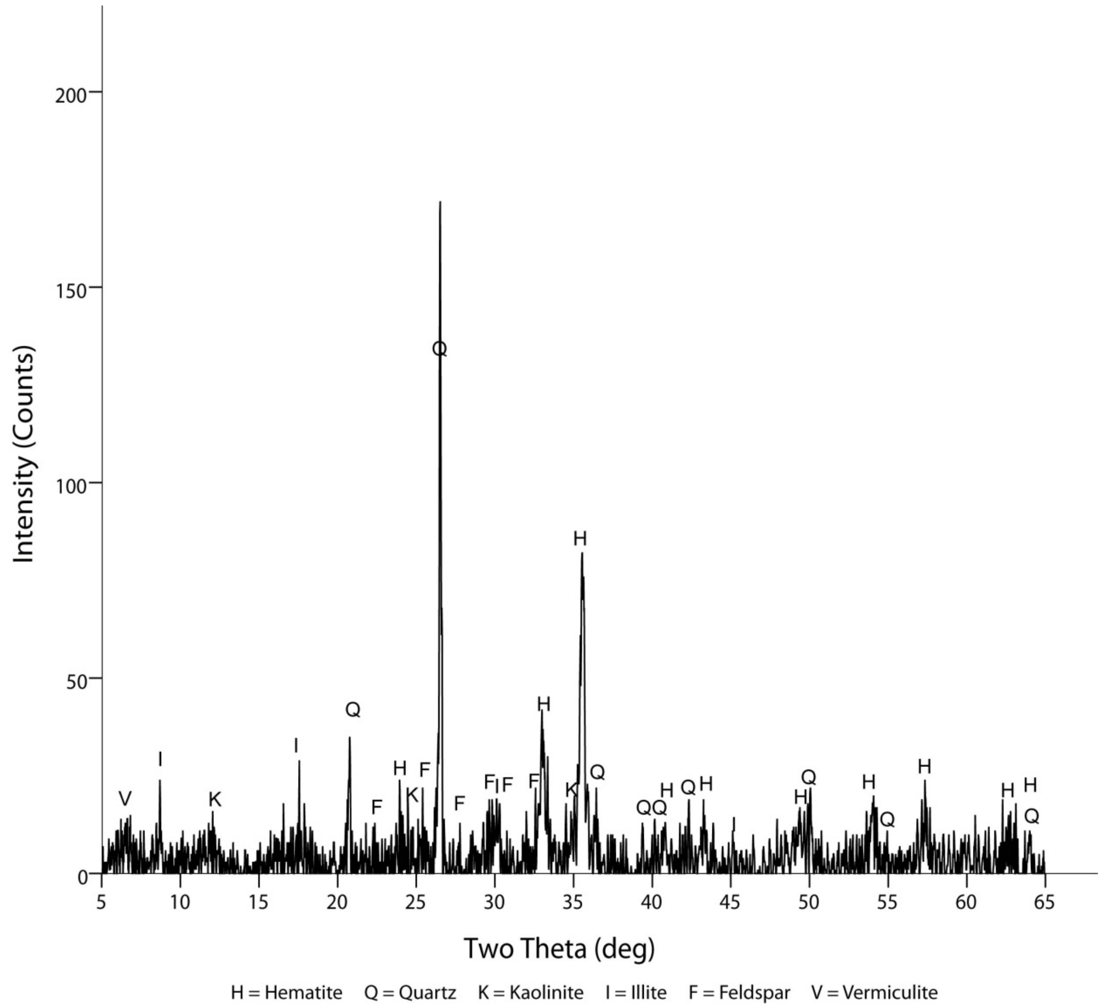


Fig. A.204. G11 Rooikoppie red heated

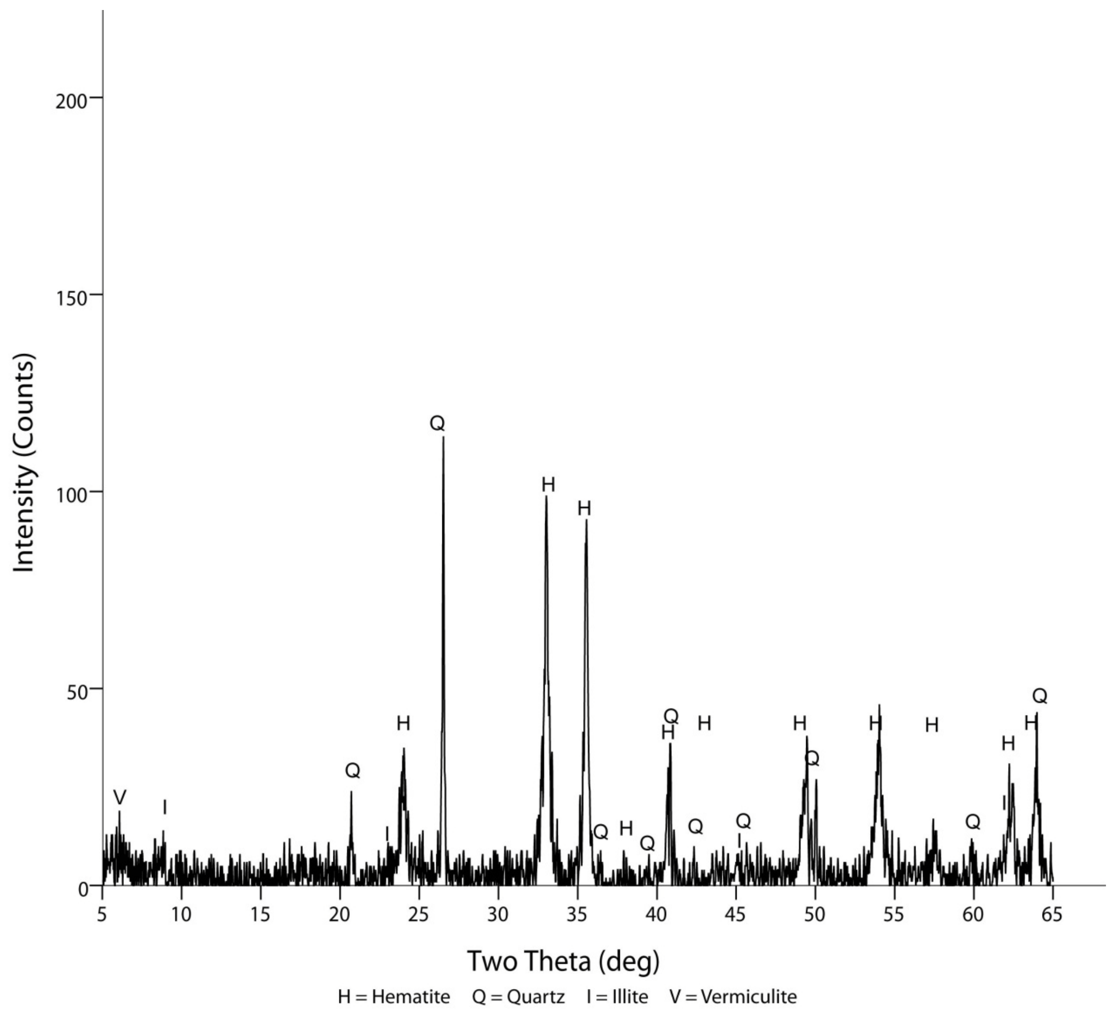


Fig. A.205. G12 Rooikoppie red heated

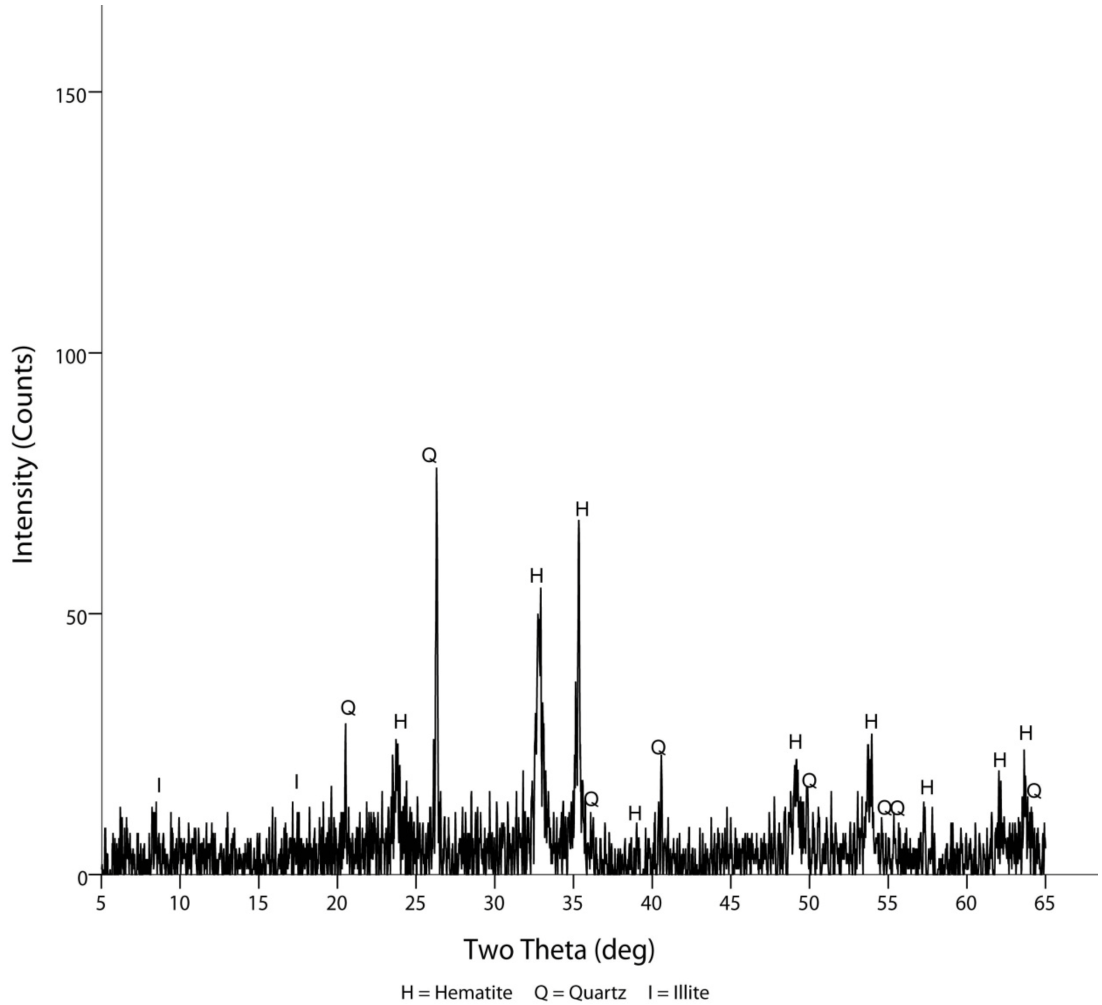


Fig. A.206. G204 Rooikoppie red heated

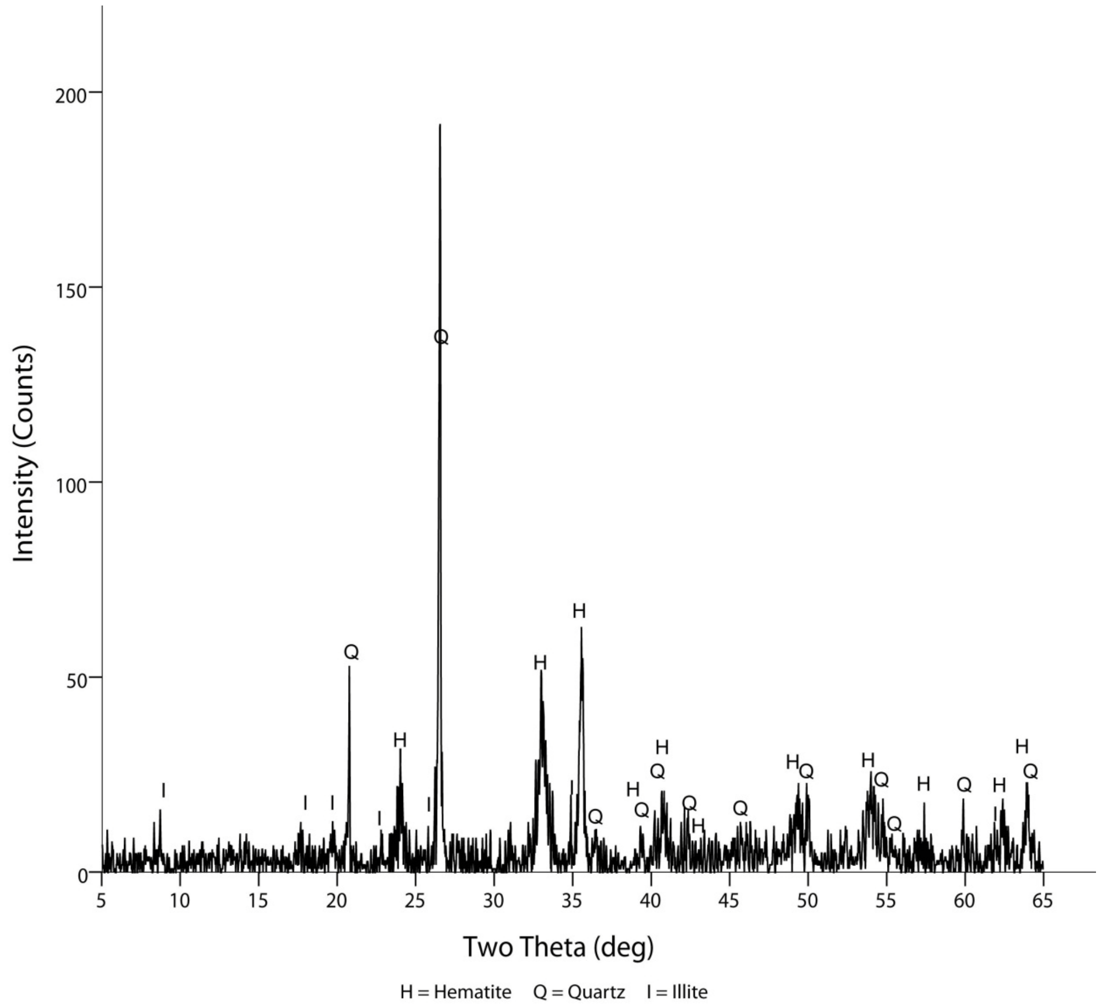


Fig. A.207. G205 Rooikoppie red heated

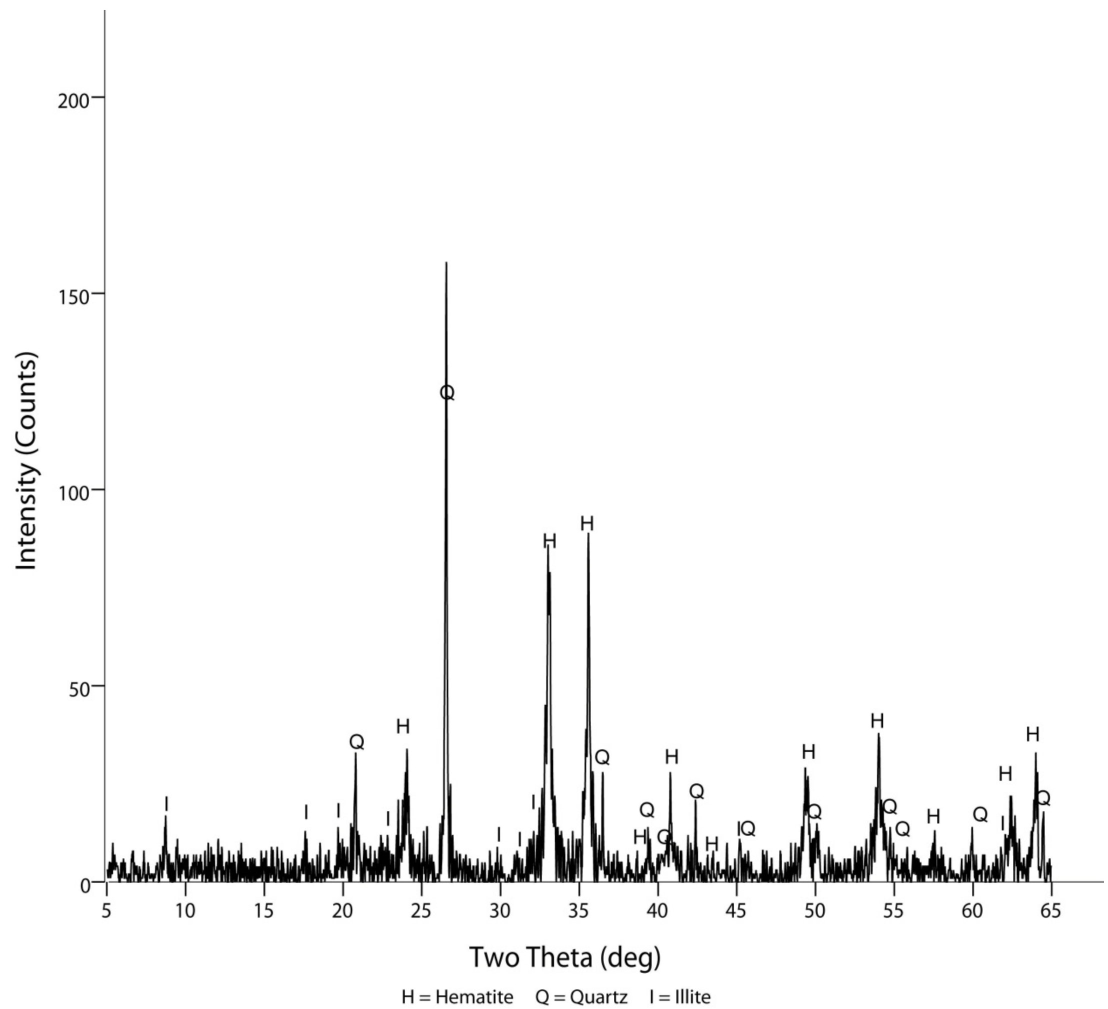


Fig. A.208. G206 Rooikoppie red heated

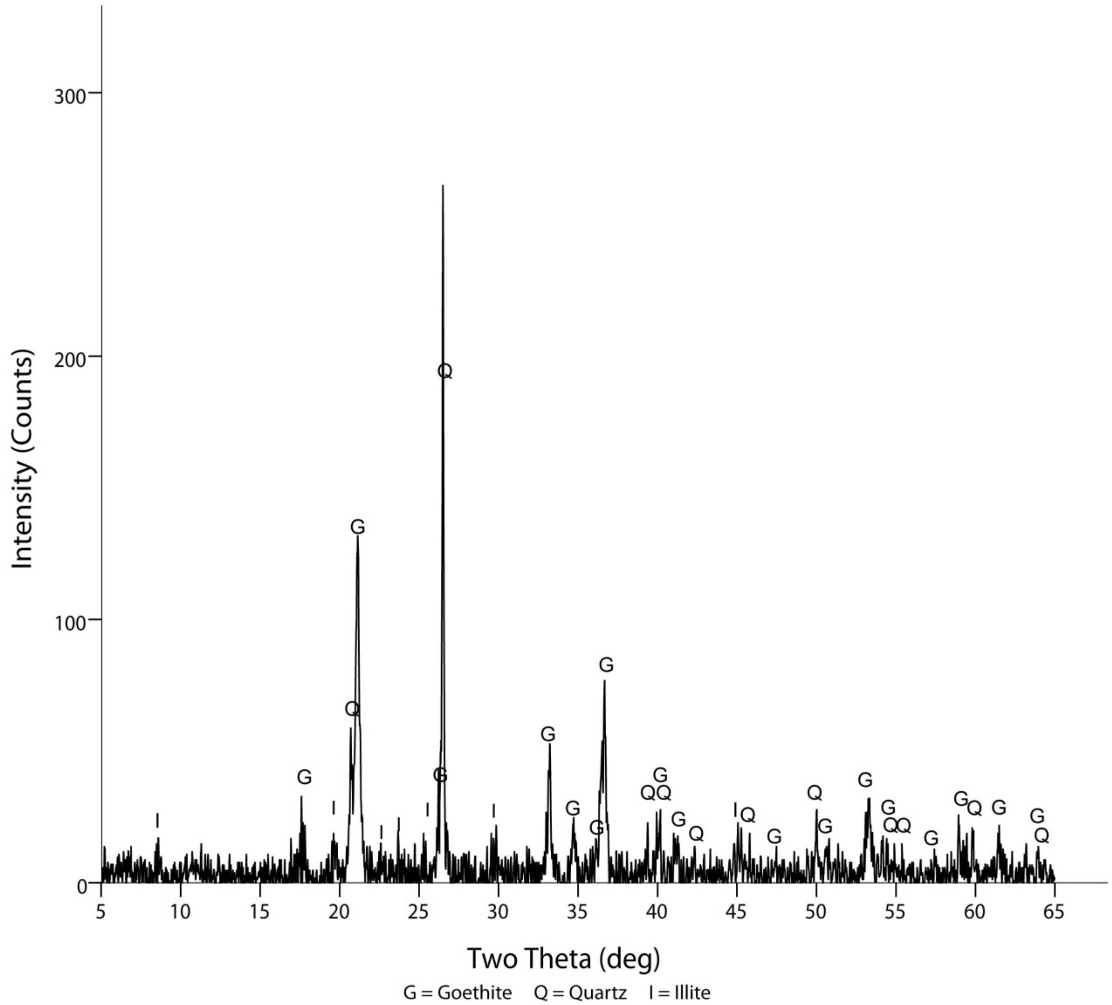


Fig. A.209. G38 Rooikoppie yellow

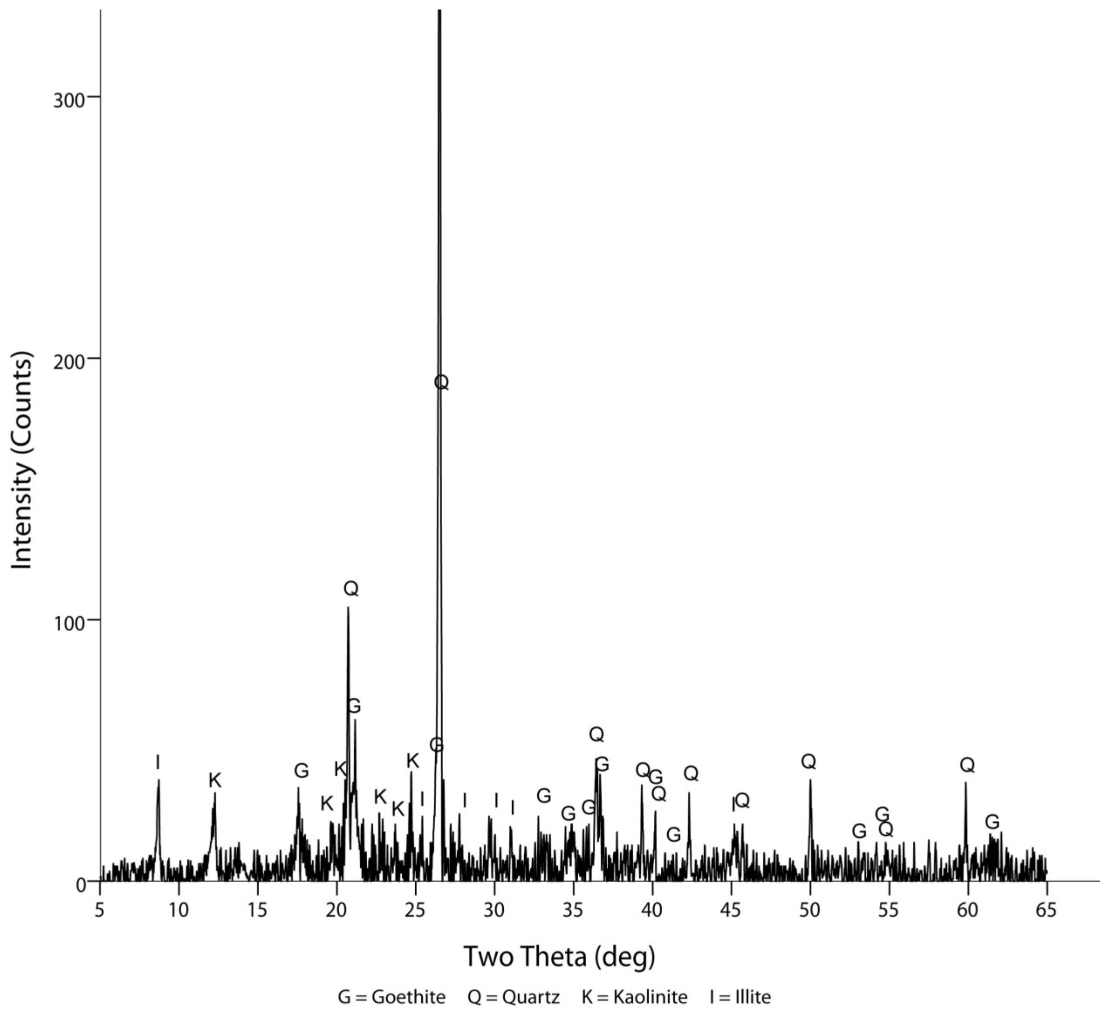


Fig. A.210. G40 Rooikoppie yellow

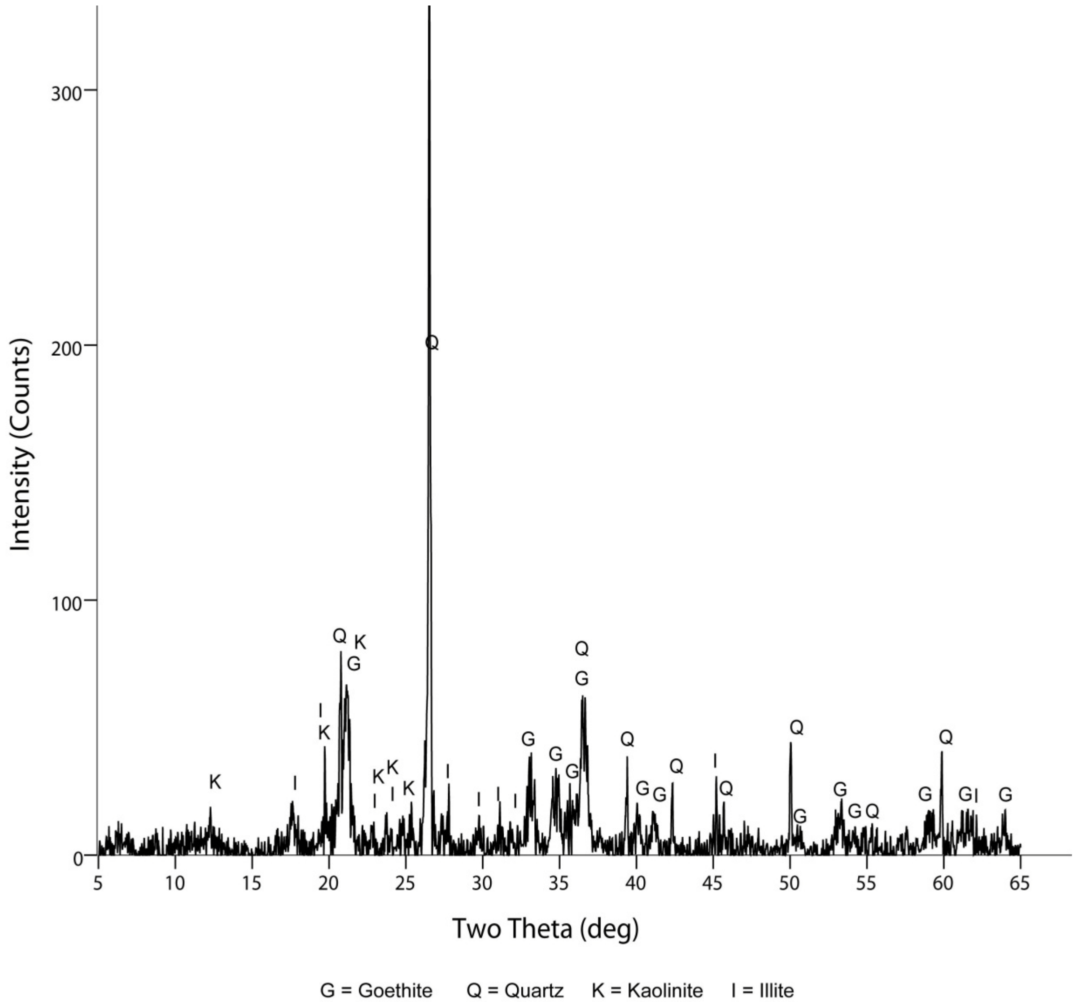


Fig. A.211. G44 Rooikoppie yellow

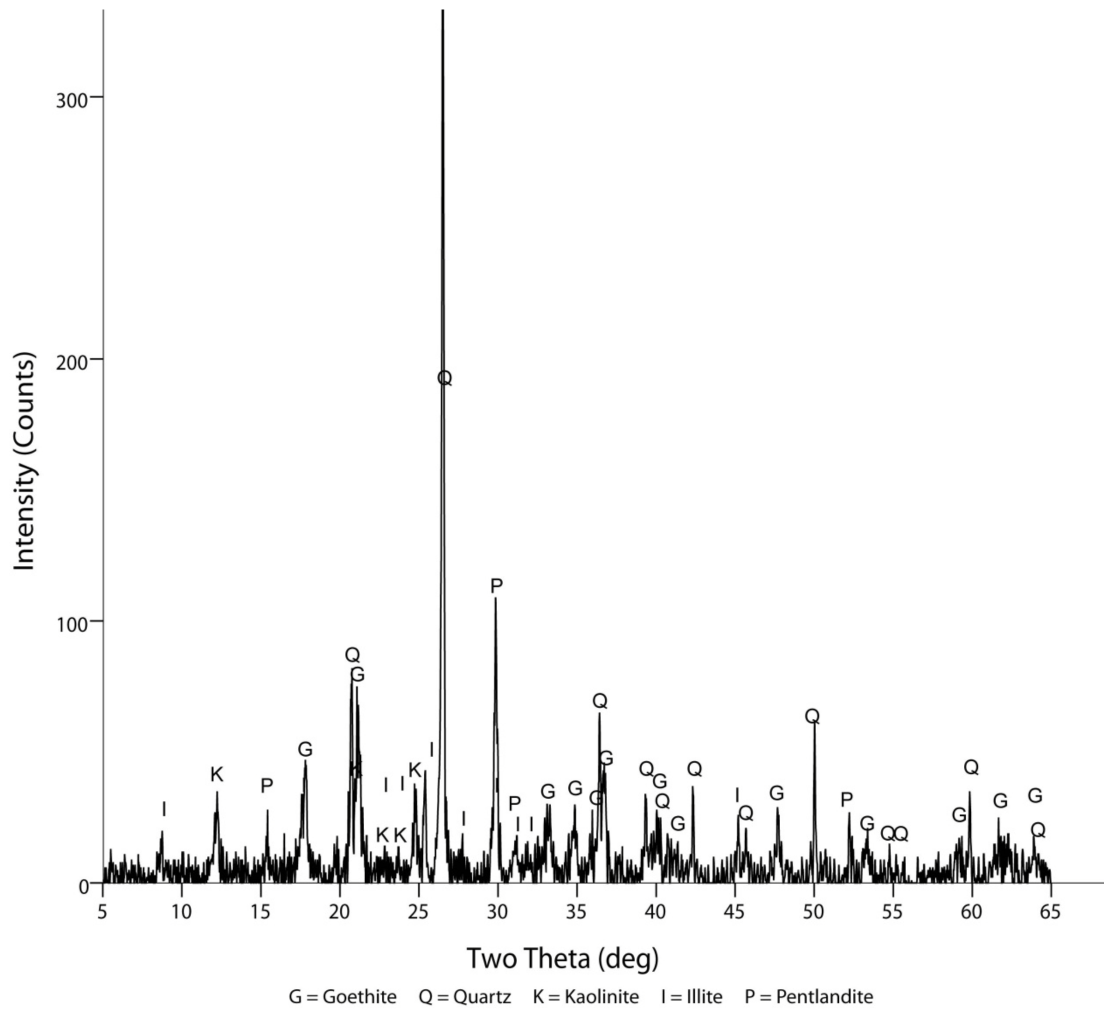


Fig. A.212. G45 Rooikoppie yellow

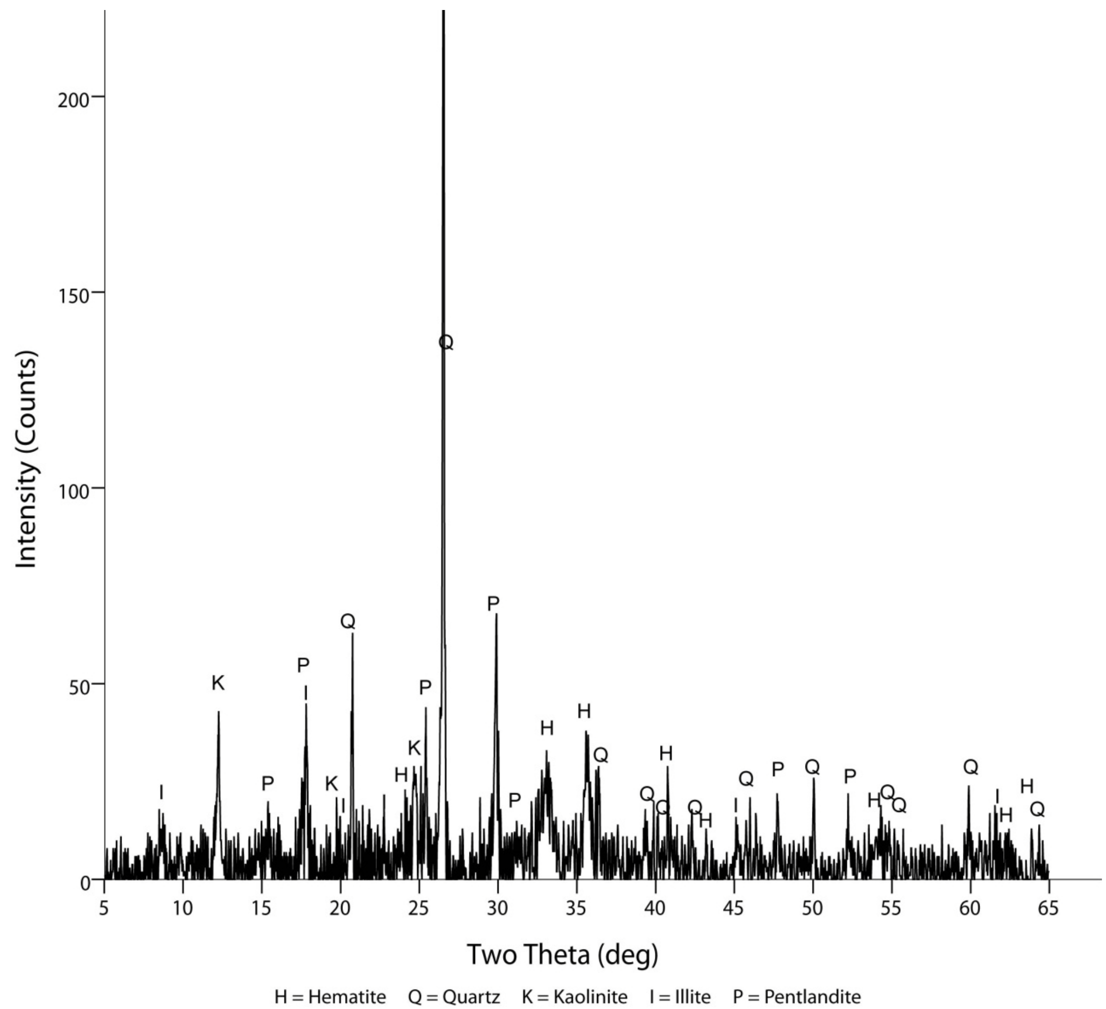


Fig. A.213. G9 Rooikoppie yellow heated

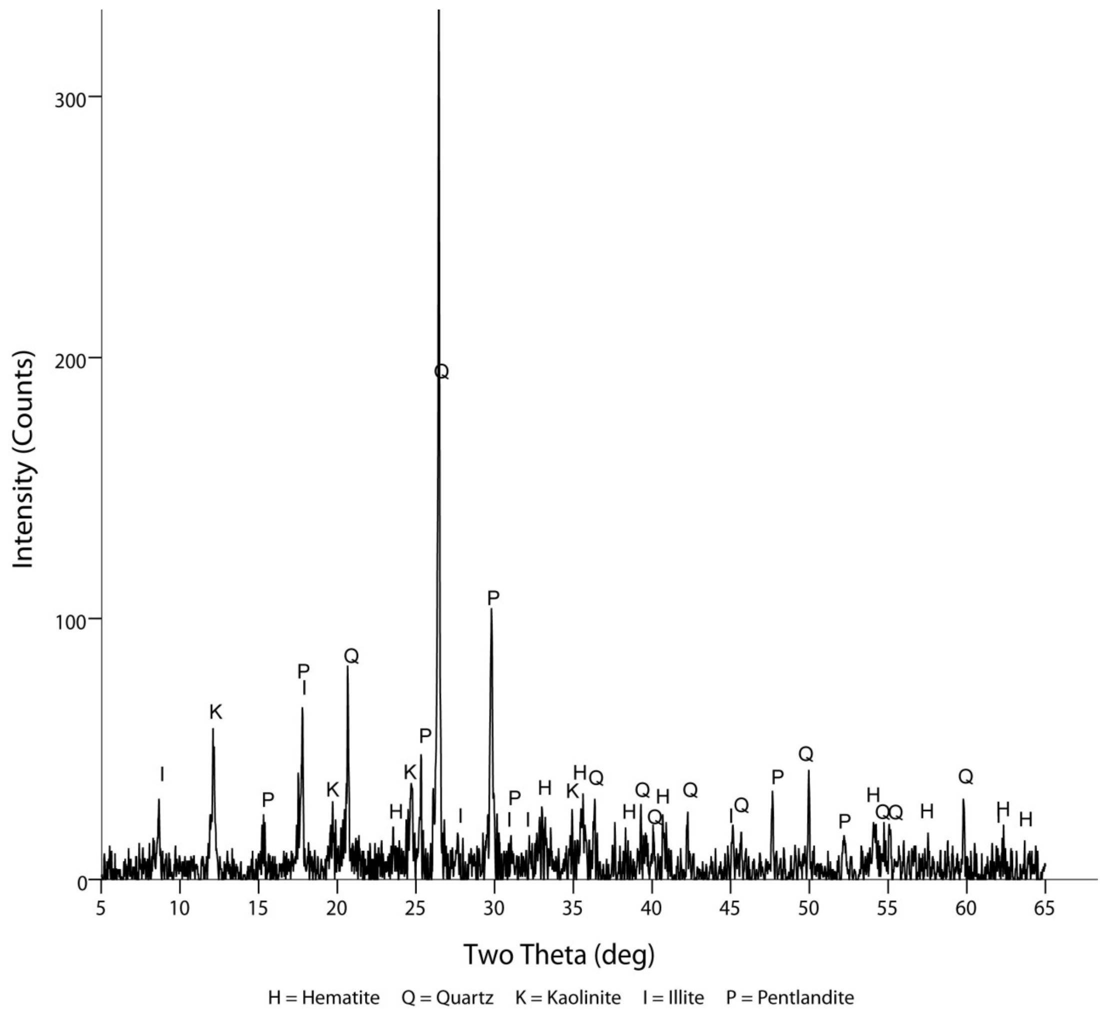


Fig. A.214. G10 Rooikoppie yellow heated

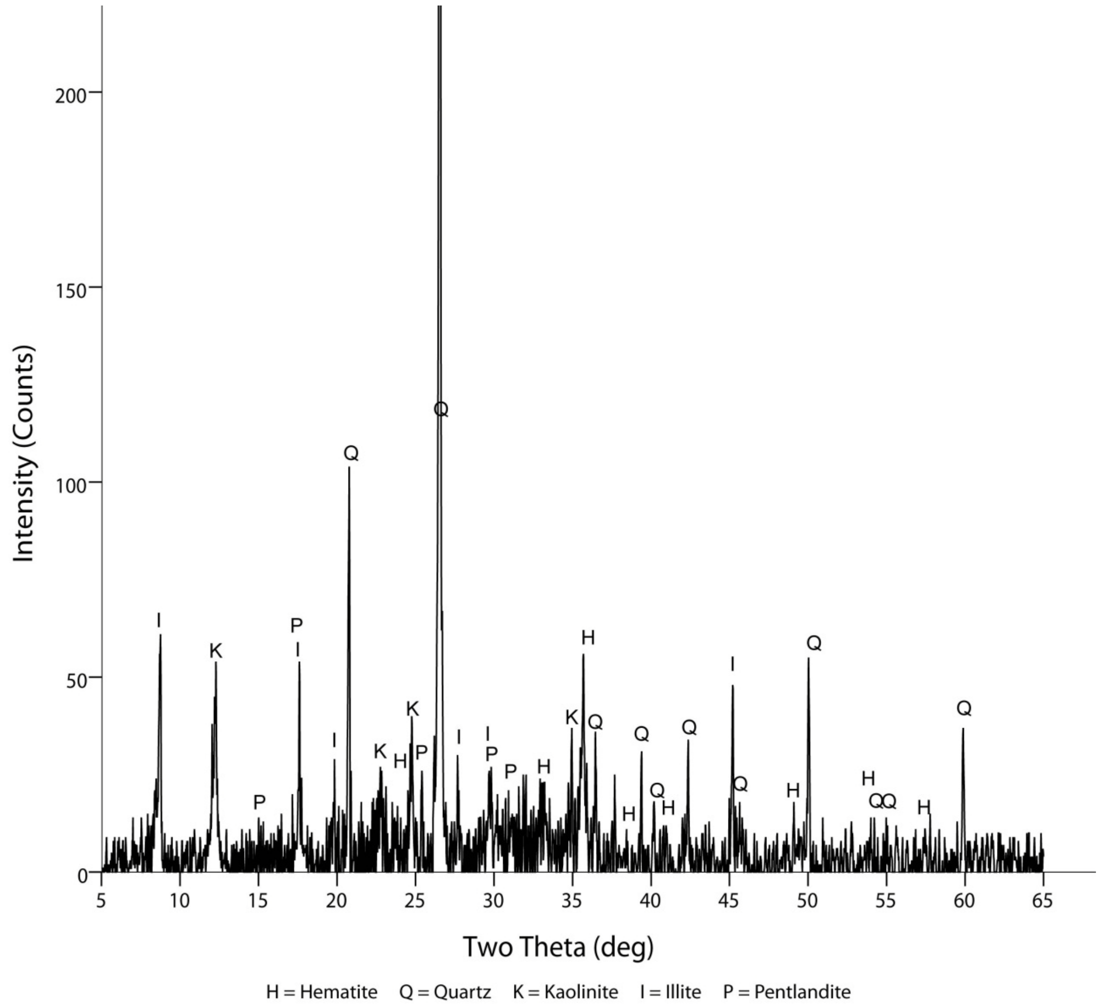


Fig. A.215. G13 Rooikoppie yellow heated

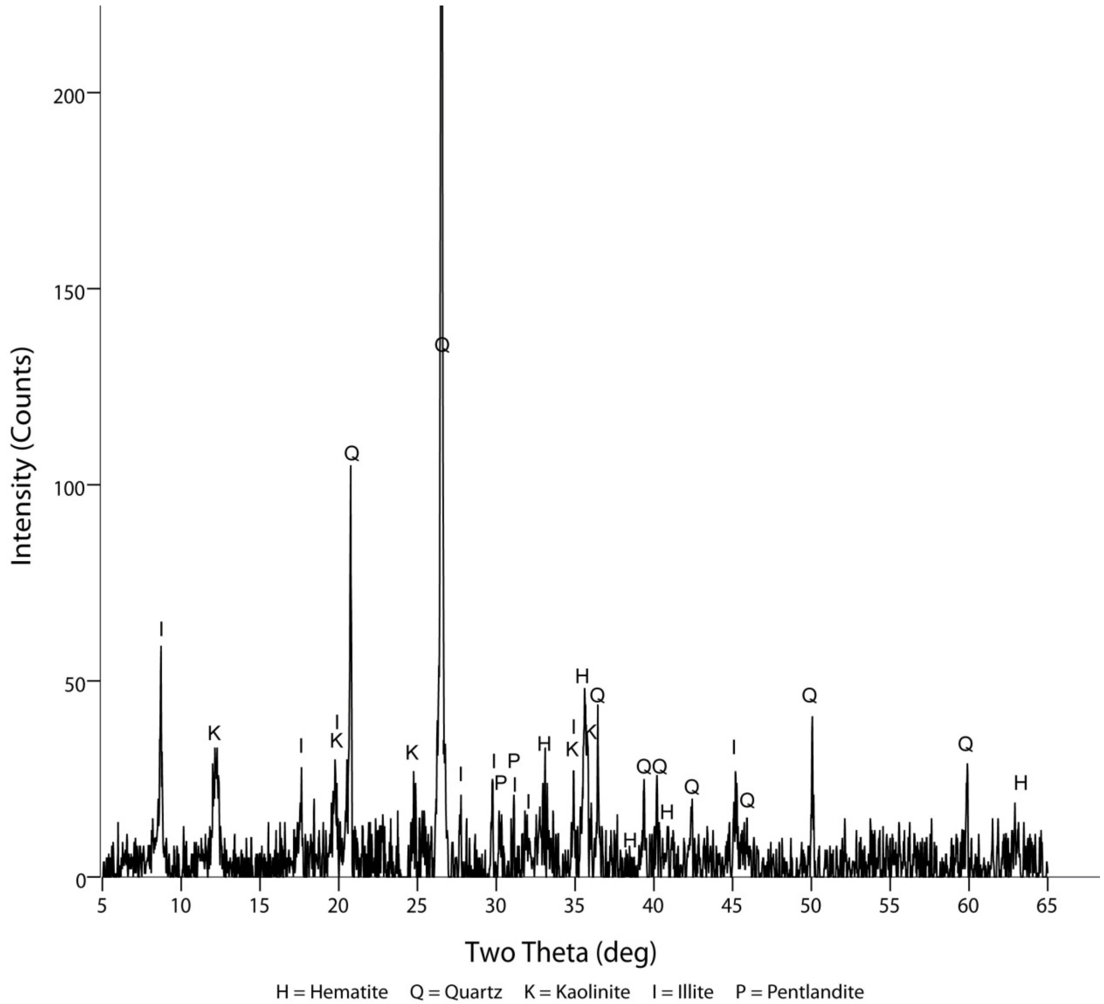


Fig. A.216. G14 Rooikoppie yellow heated

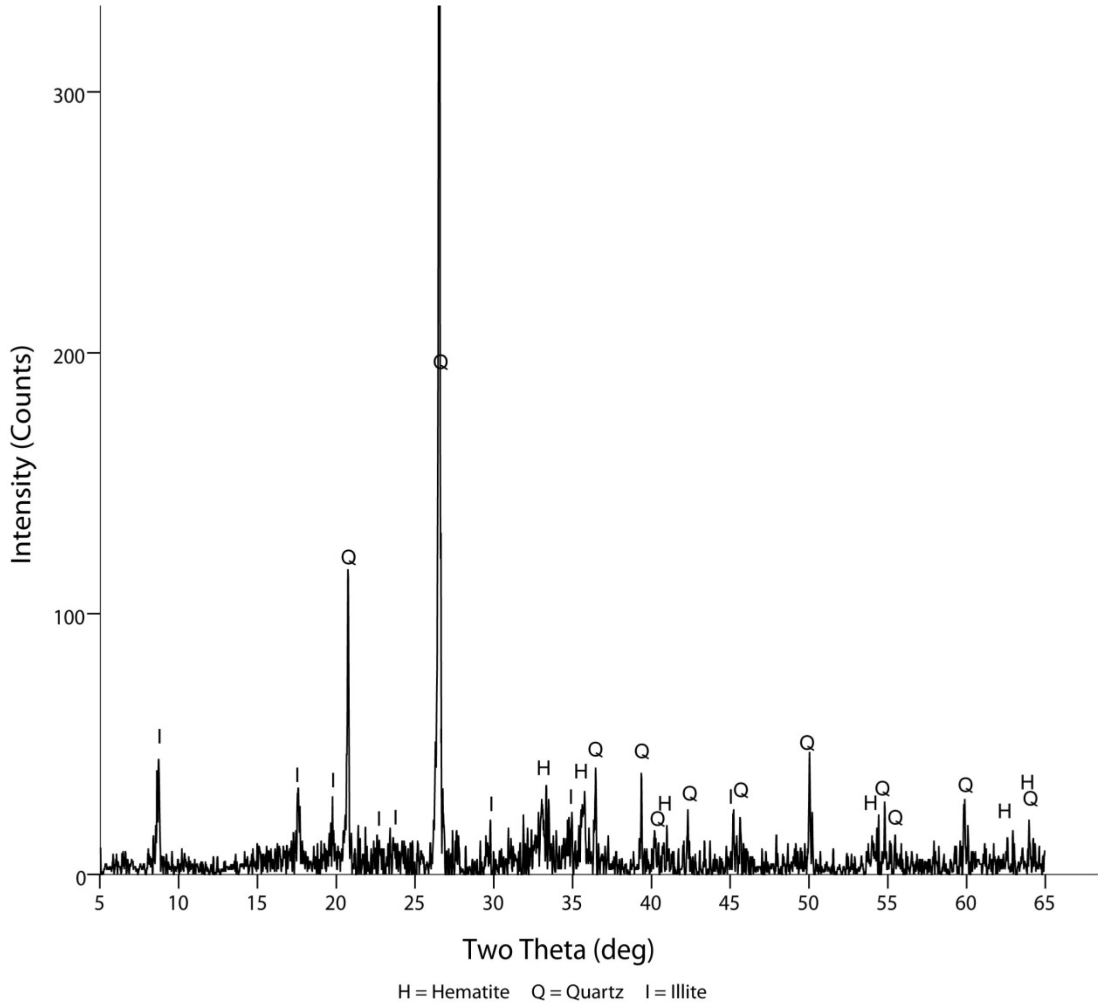


Fig. A.217. G207 Rooikoppie yellow heated

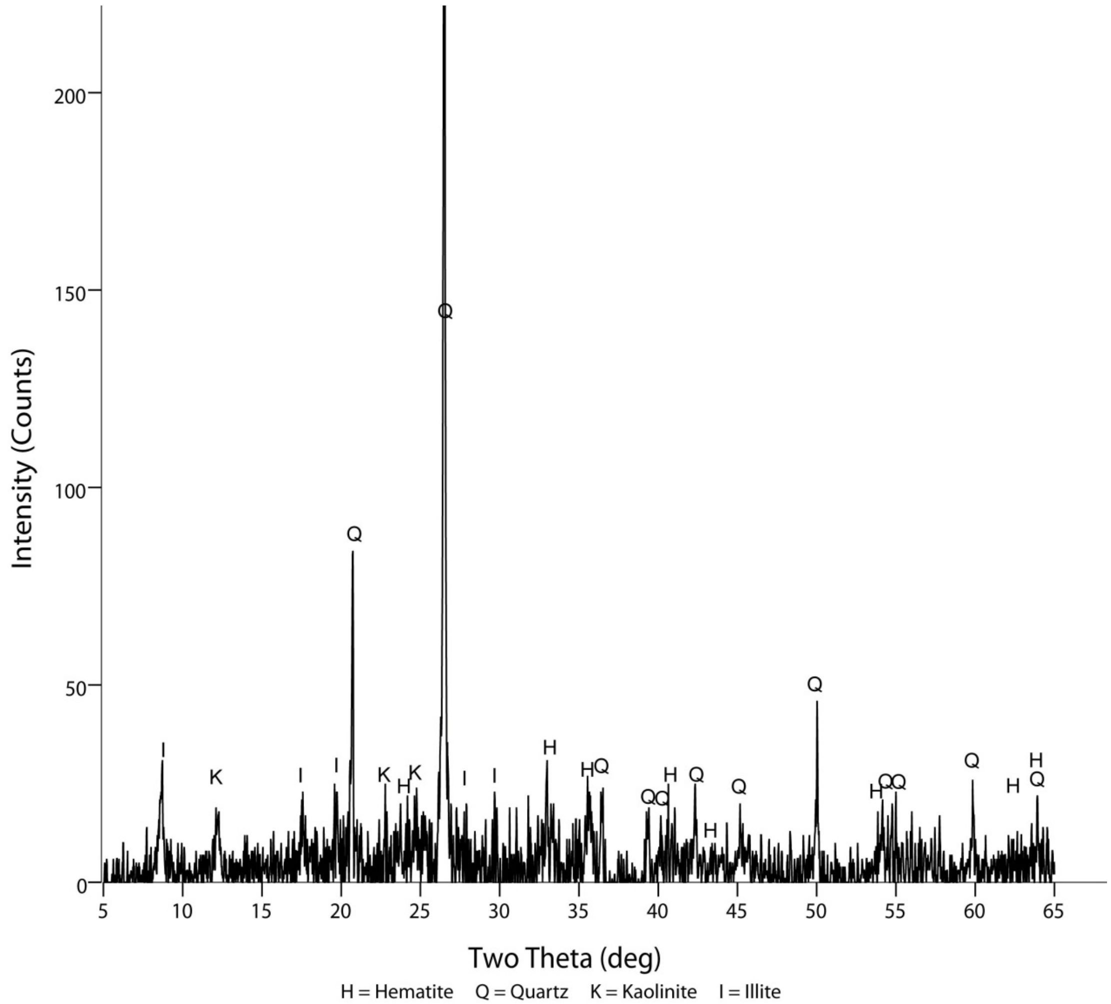


Fig. A.218. G208 Rooikoppie yellow heated

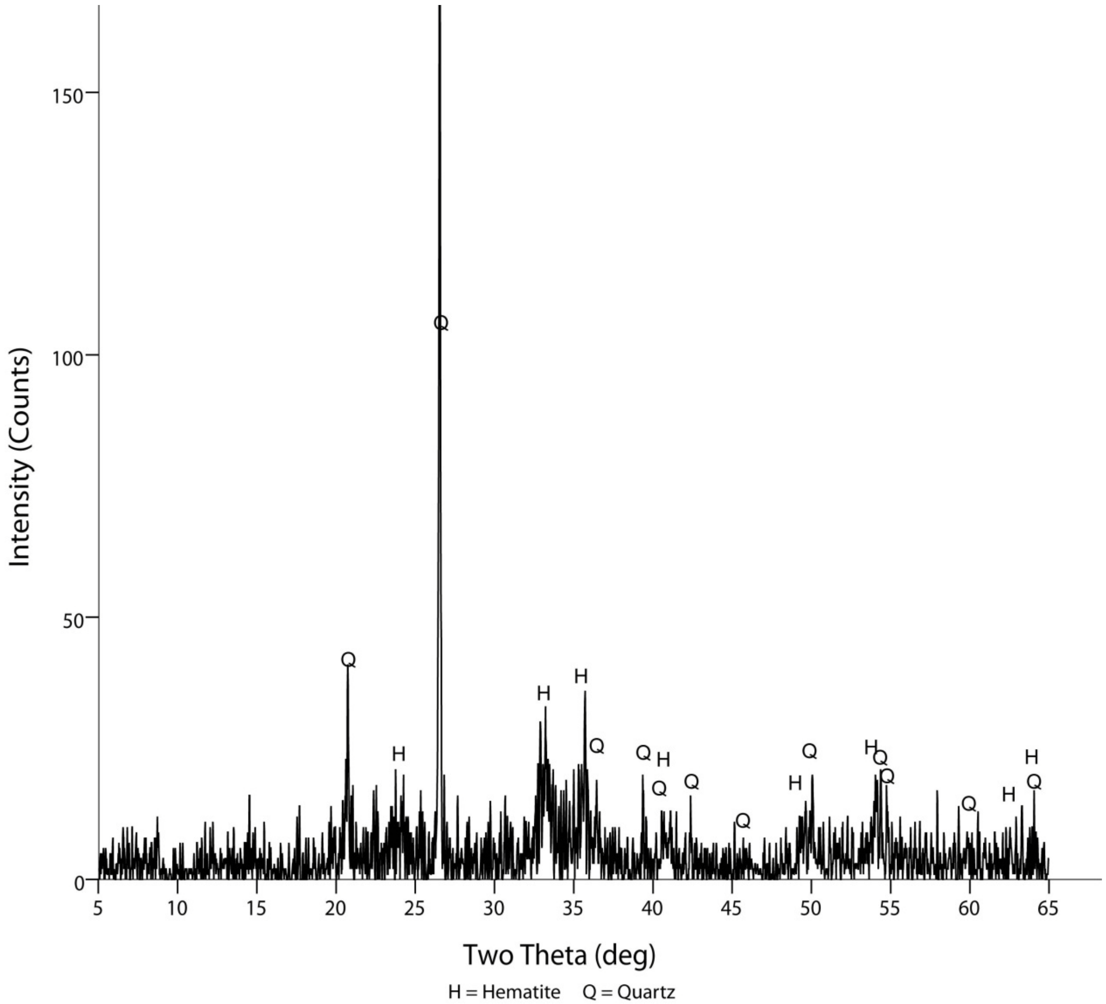


Fig. A.219. G209 Rooikoppie yellow heated

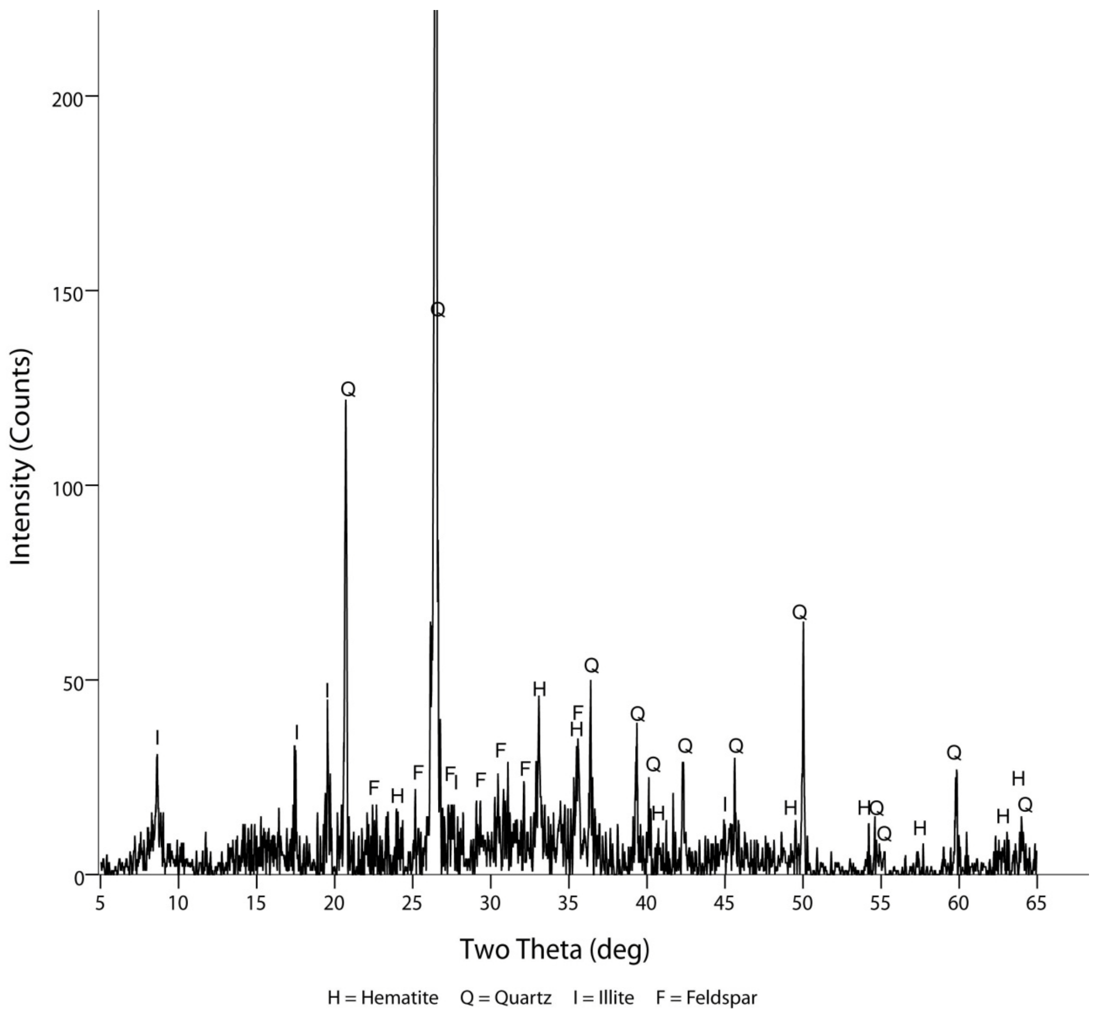


Fig. A.220. G269 Rooikoppi e yellow heated

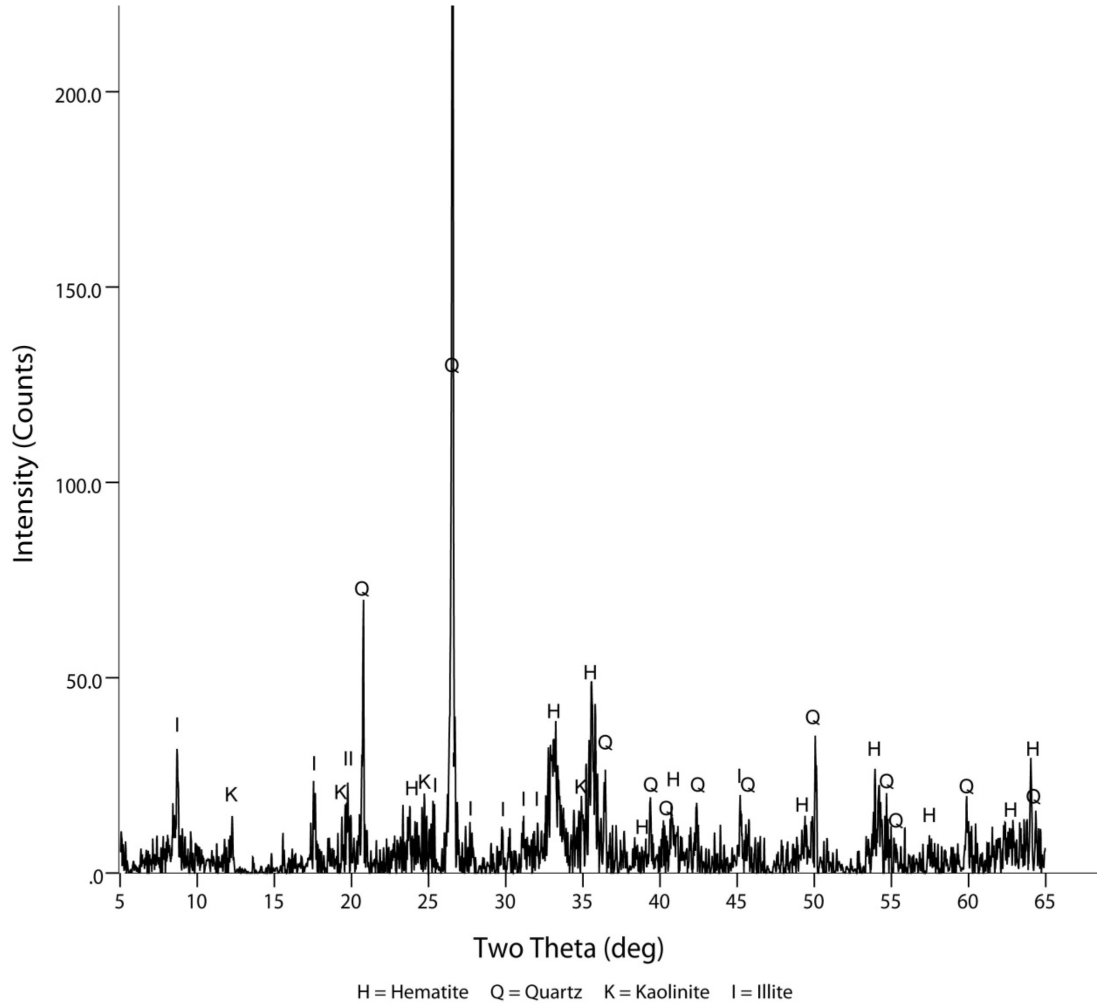


Fig. A.221. G270 Rooikoppie yellow heated

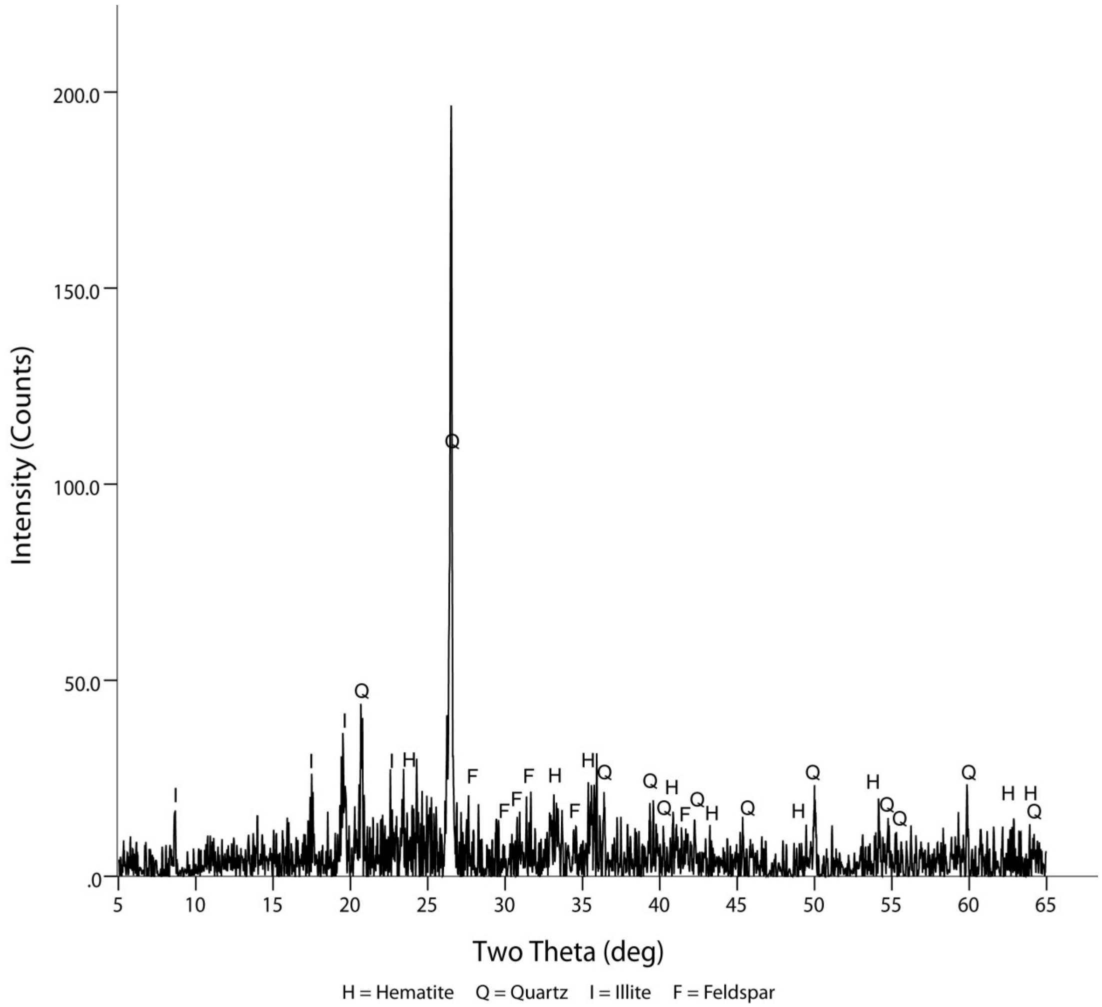


Fig. A.222. G272 Rooikoppie yellow heated

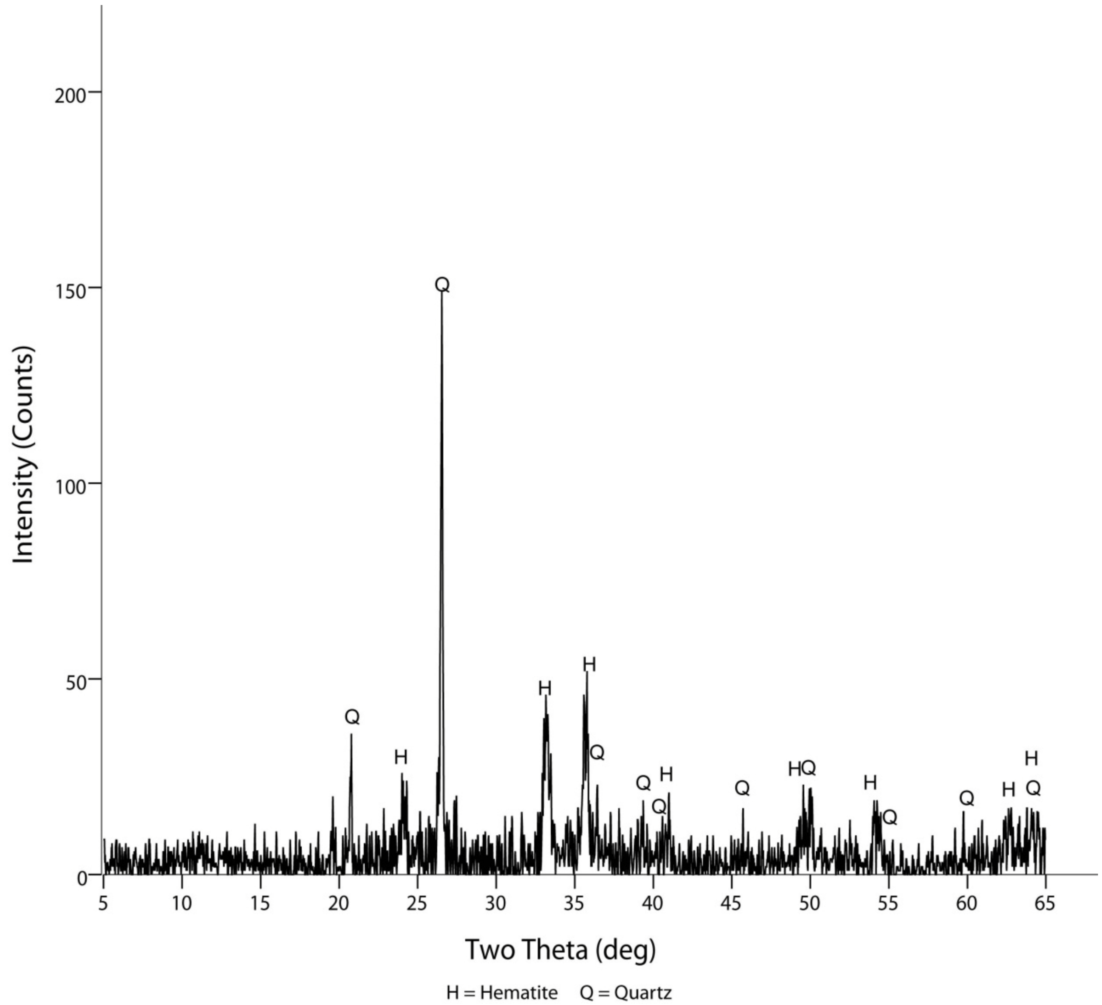


Fig. A.223. G273 Rooikoppie yellow heated

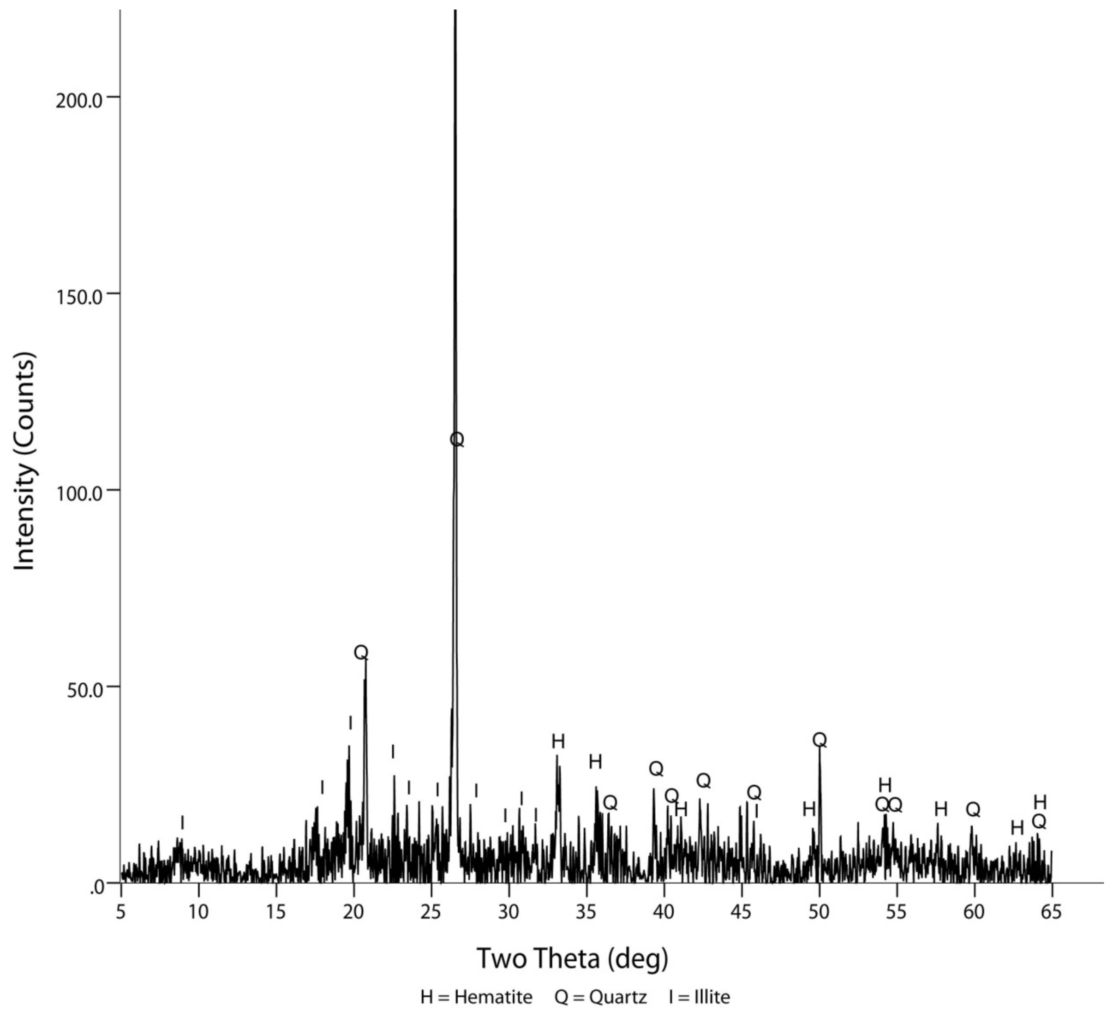


Fig. A.224. G274 Rooikoppie yellow heated

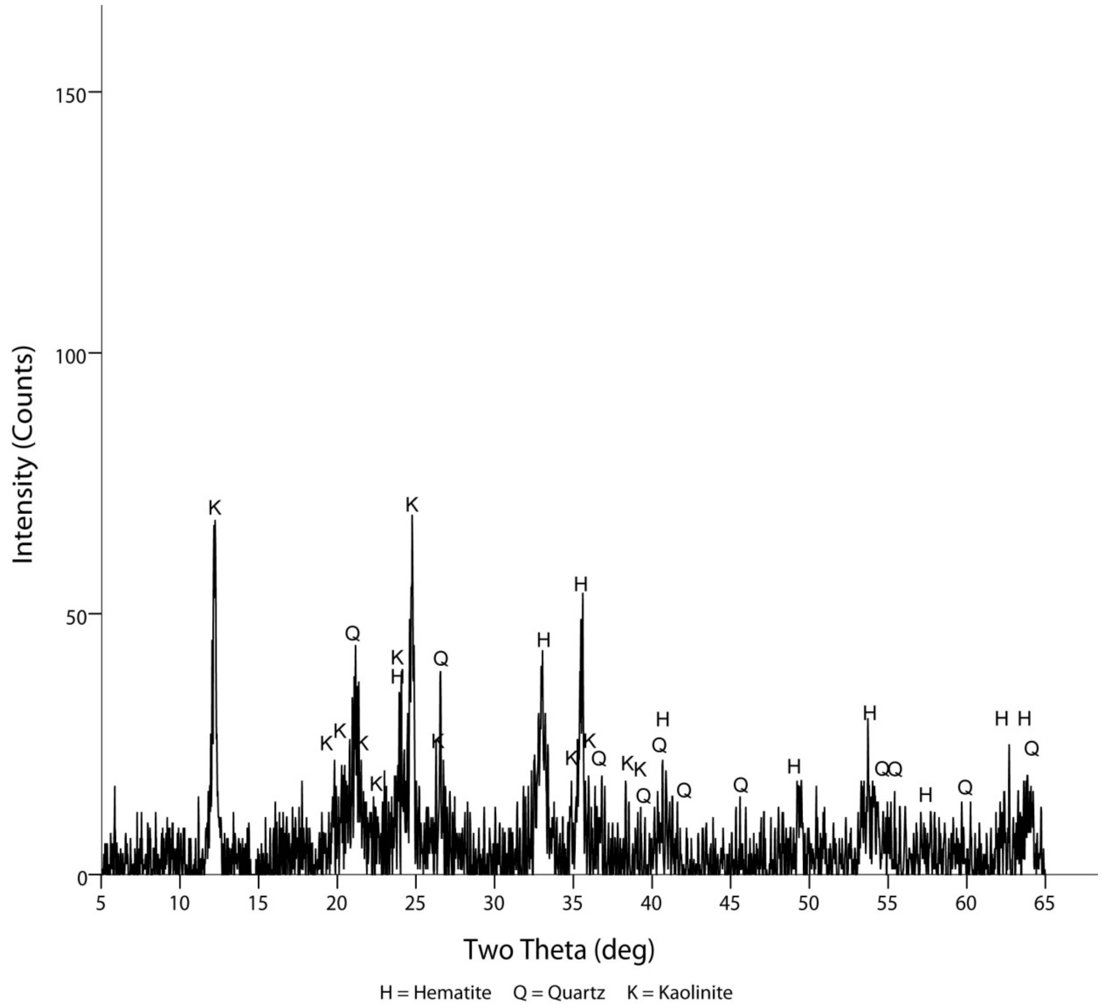


Fig. A.225. G134 Ruiterskraal red

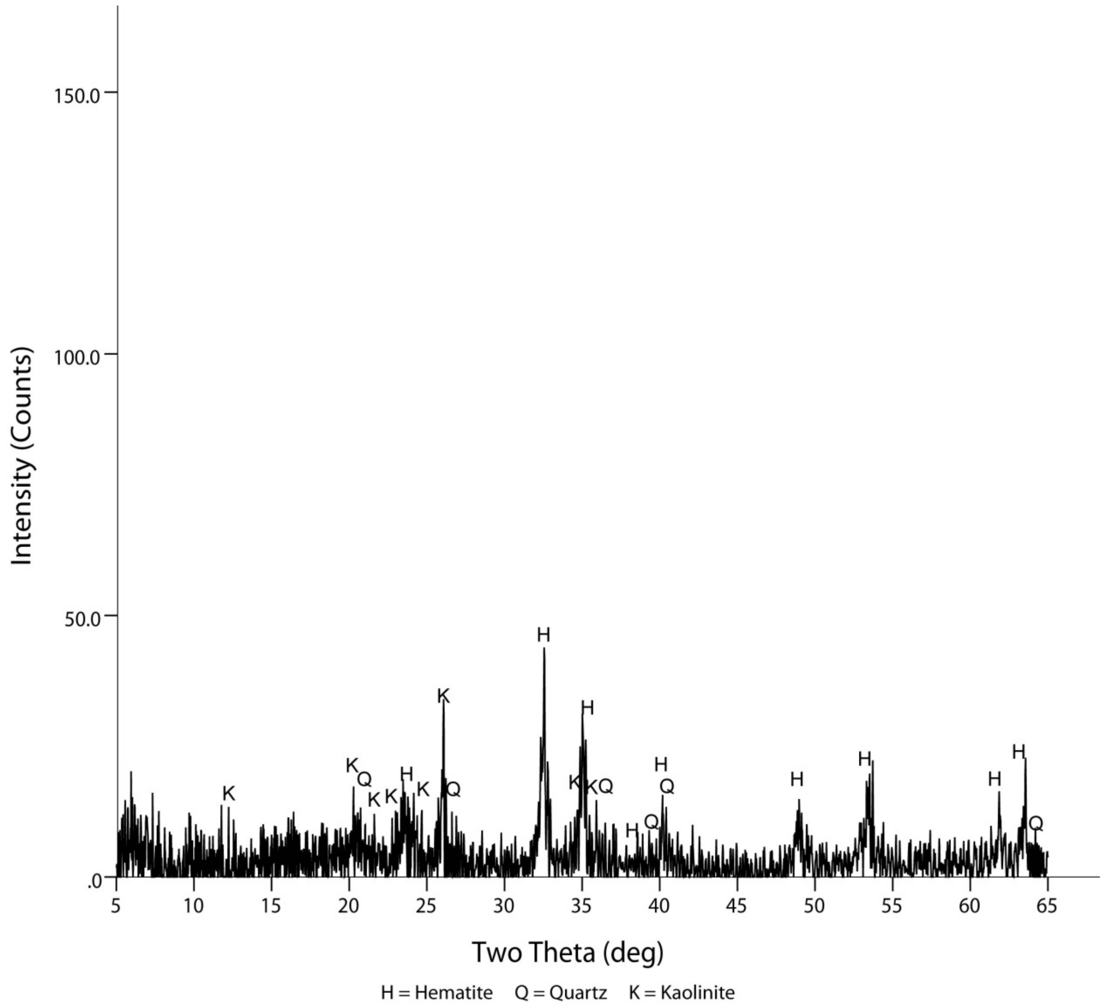


Fig. A.226. G136 Ruiterskraal red

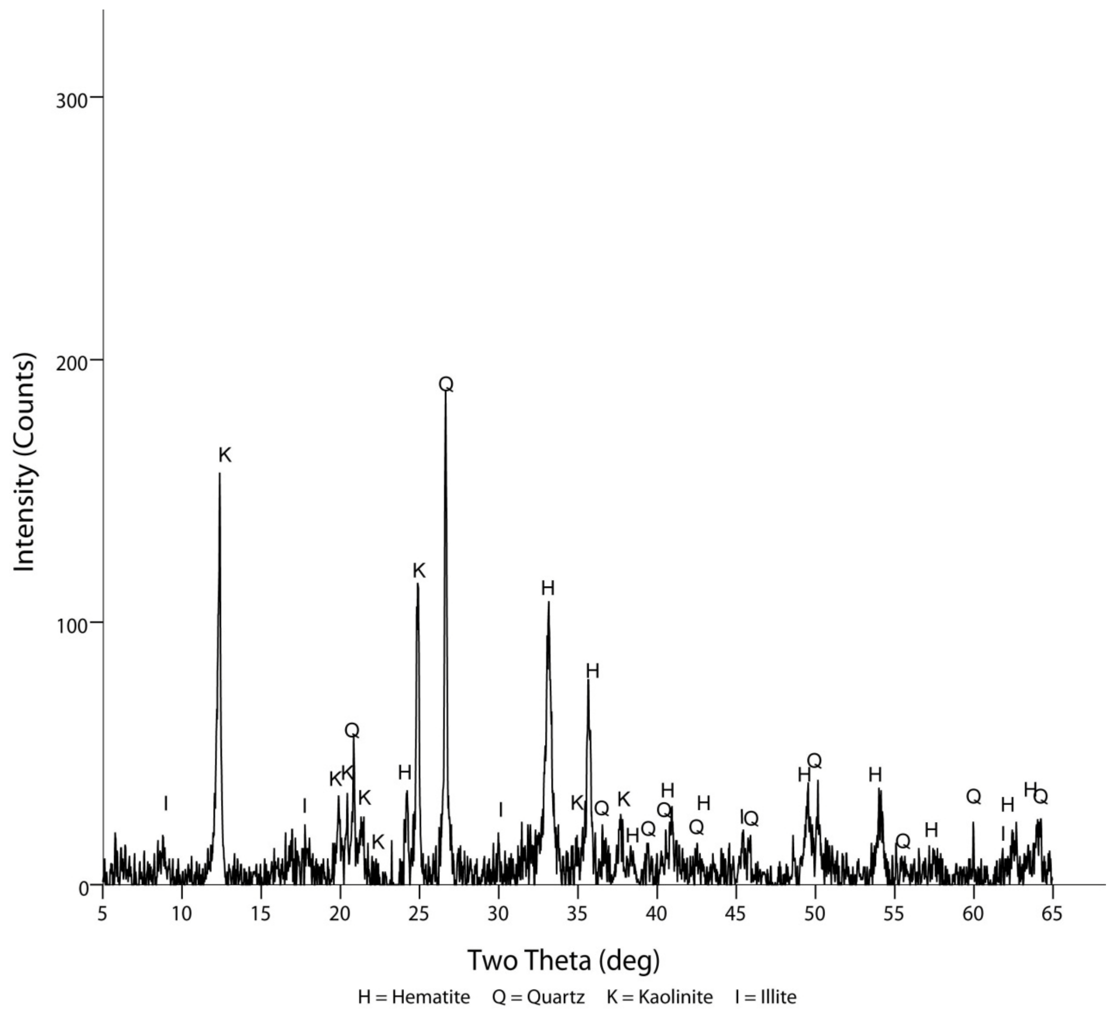


Fig. A.227. G138 Ruiterskraal red

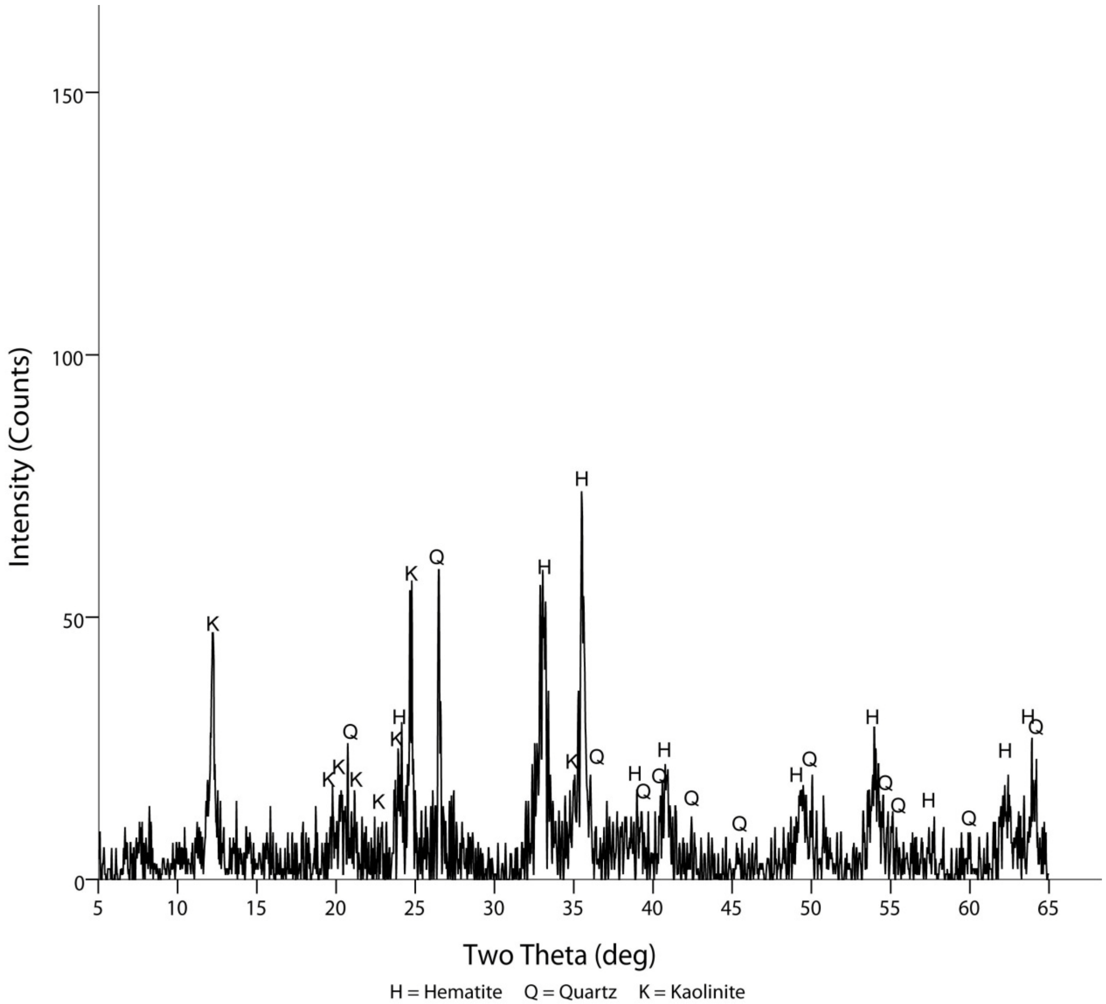


Fig. A.228. G135 Ruiterskraal red heated

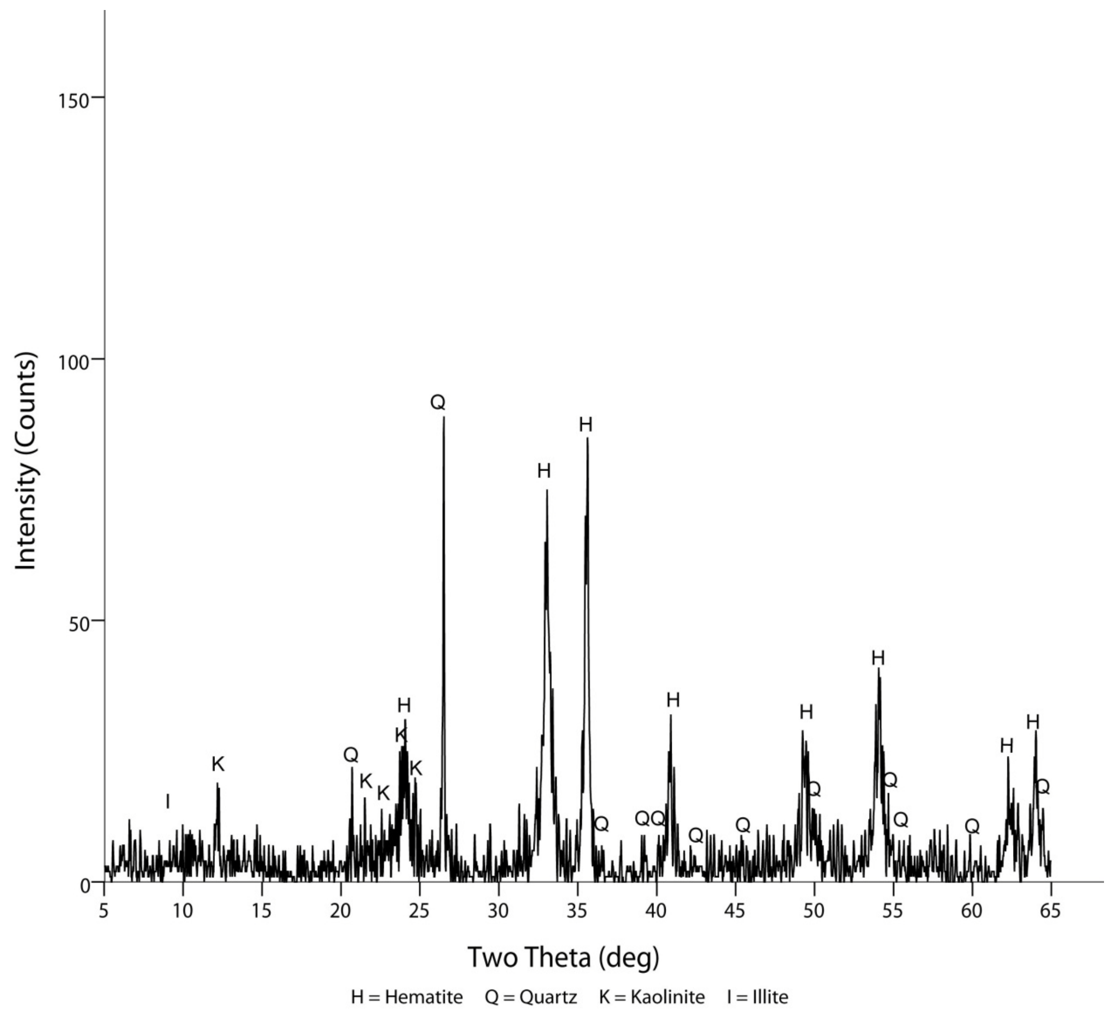


Fig. A.229. G137 Ruiterskraal red heated

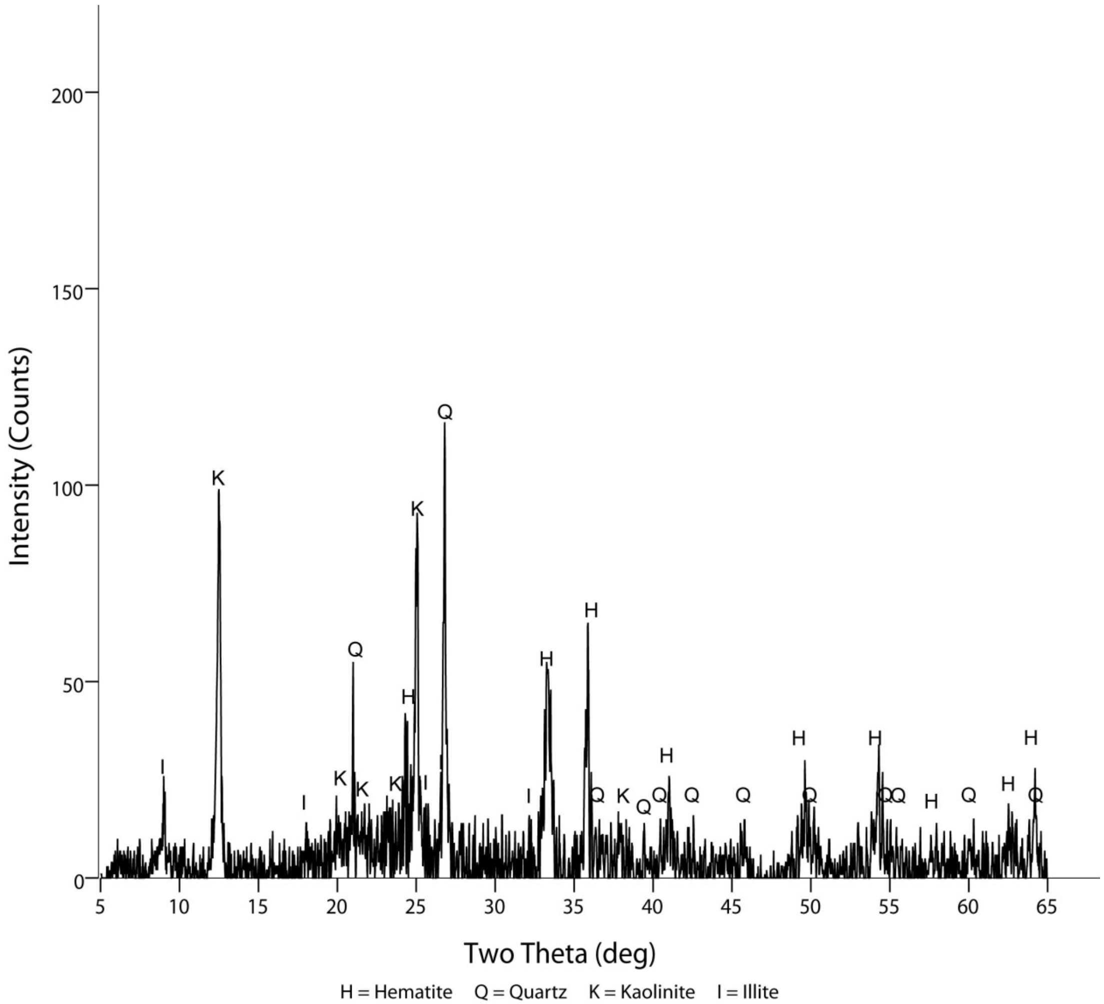


Fig. A.230. G139 Ruiterskraal red heated

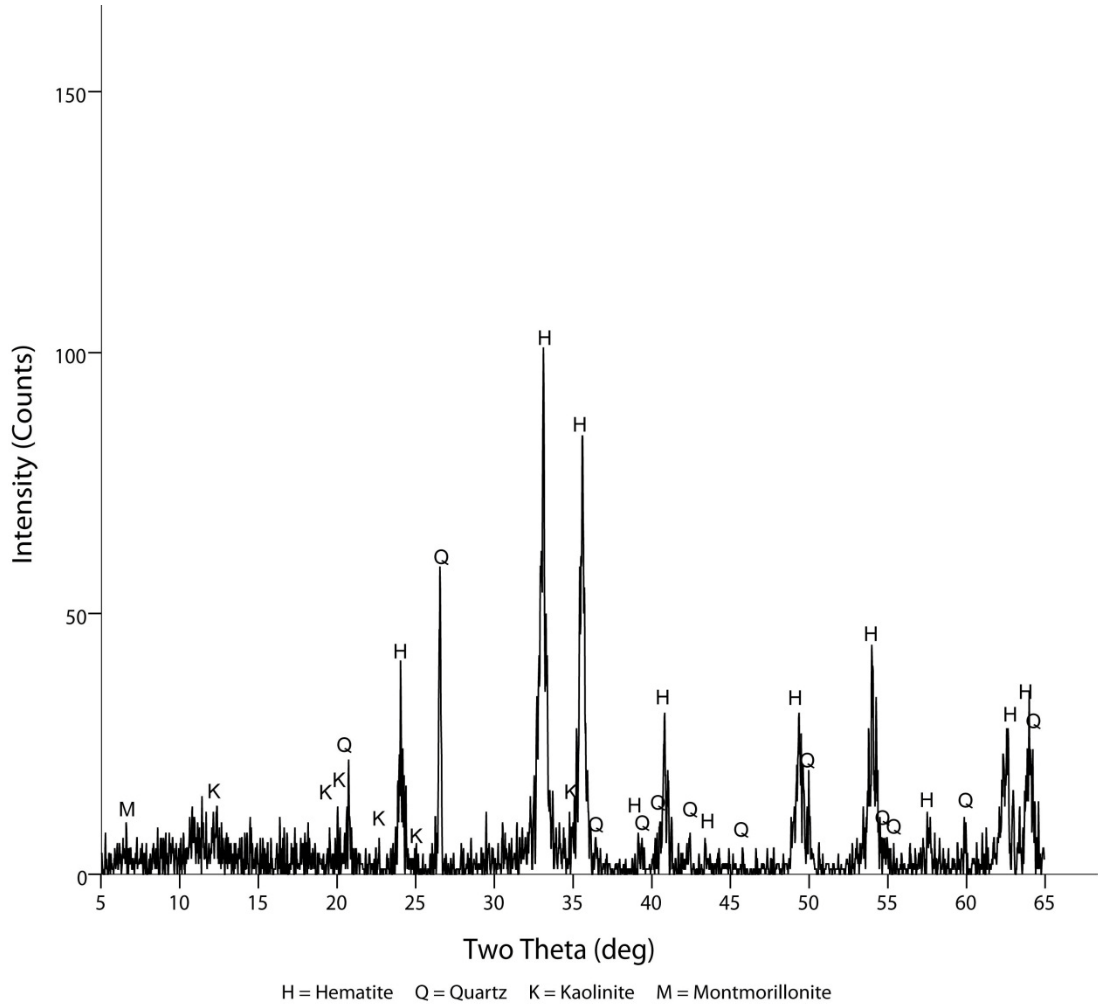


Fig. A.231. G223 Ruiterskraal red heated

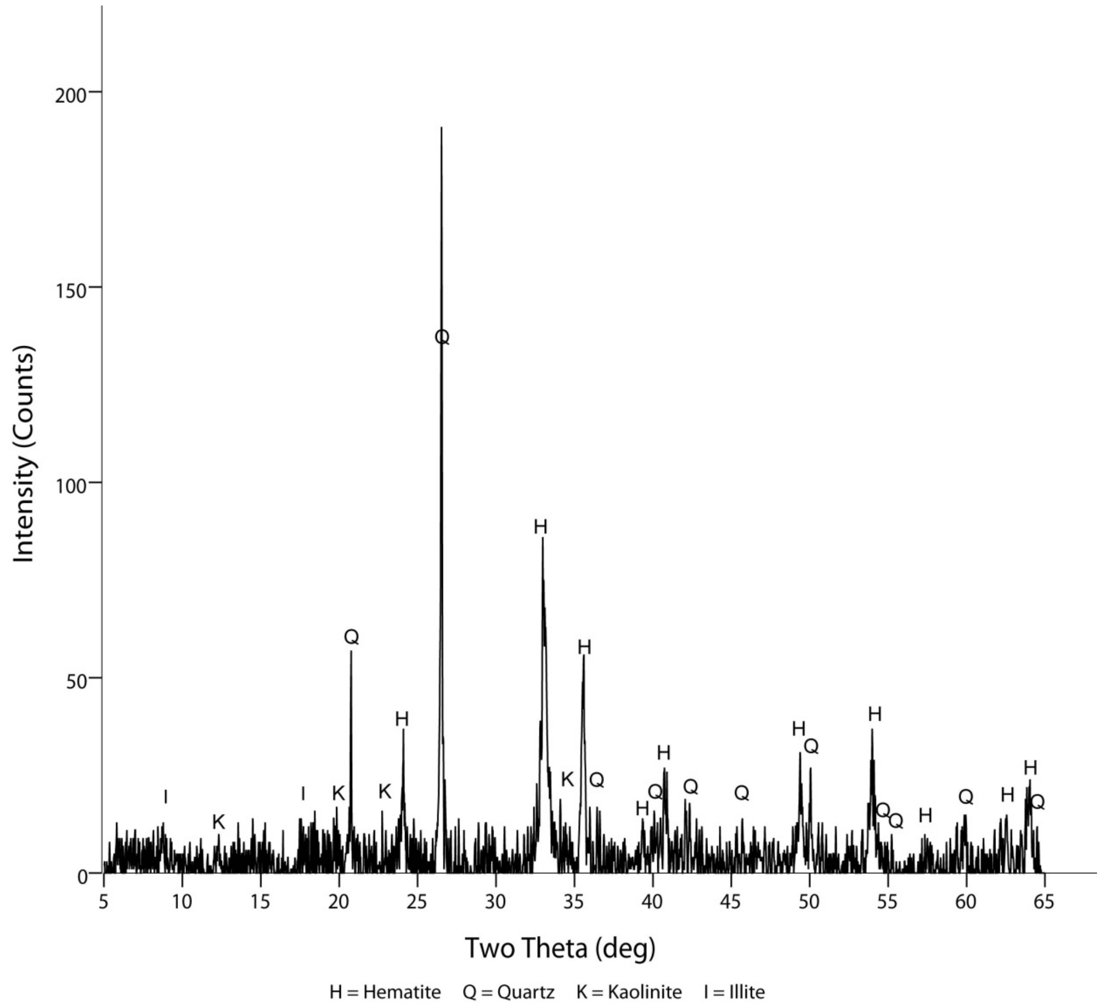


Fig. A.232. G224 Ruiterskraal red heated

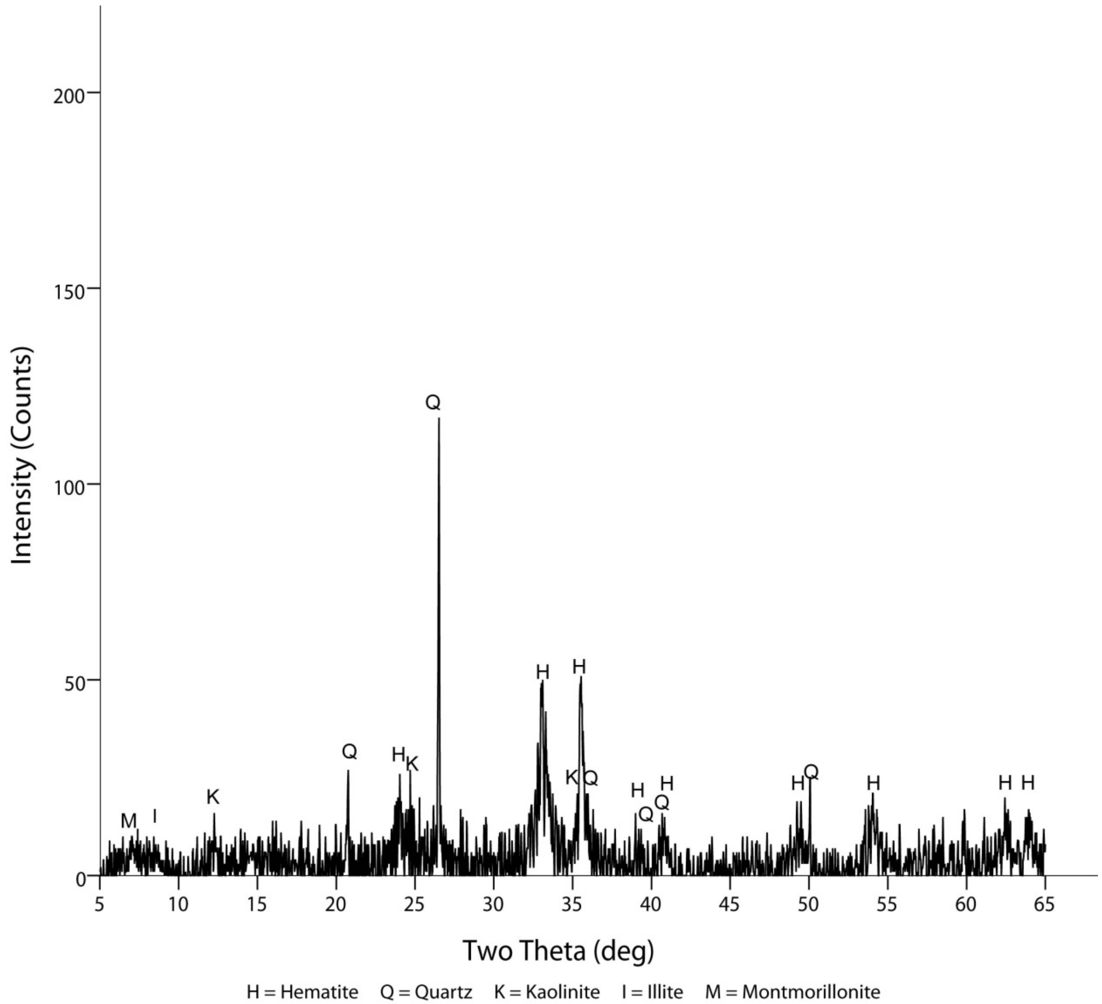


Fig. A.233. G225 Ruiterskraal red heated

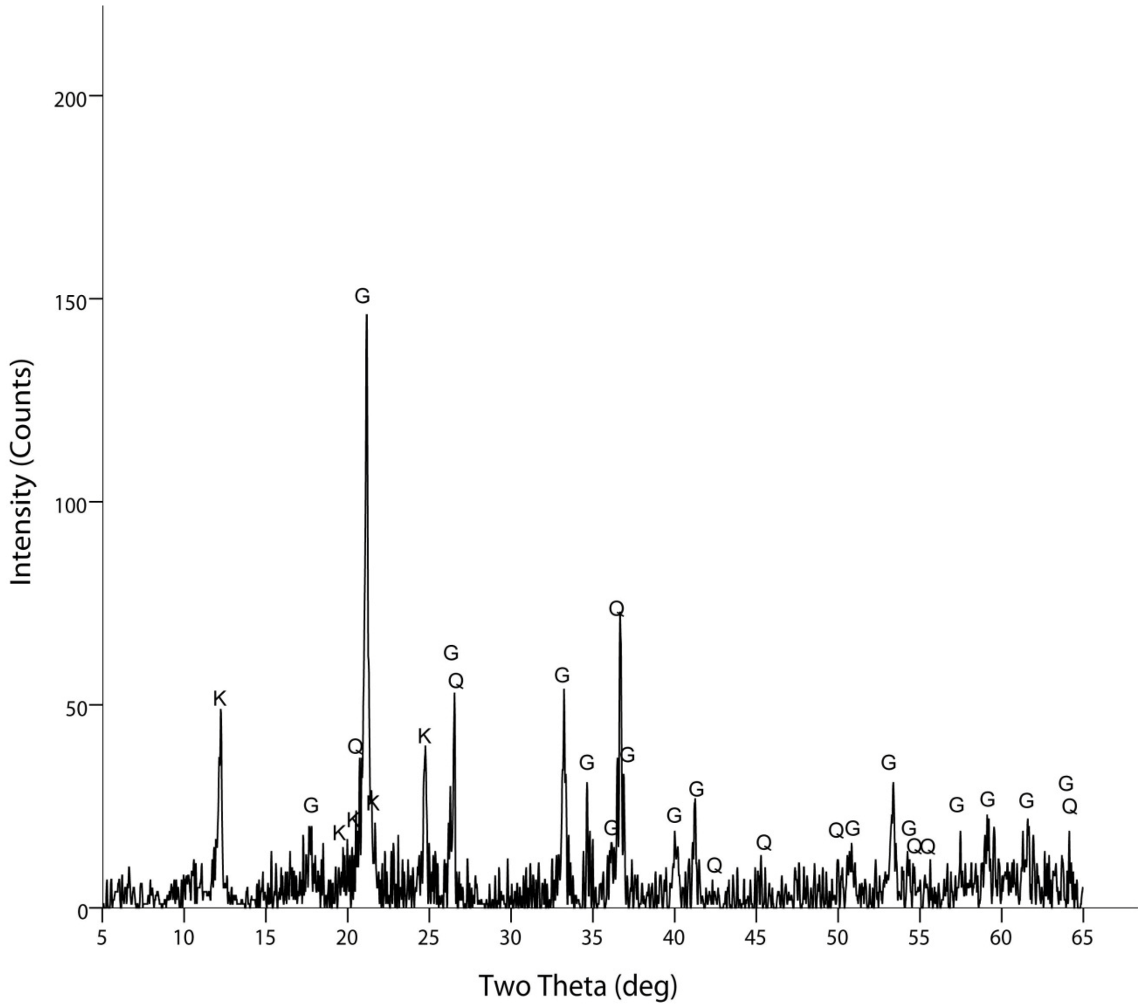


Fig. A.234. G130 Ruiterskraal yellow

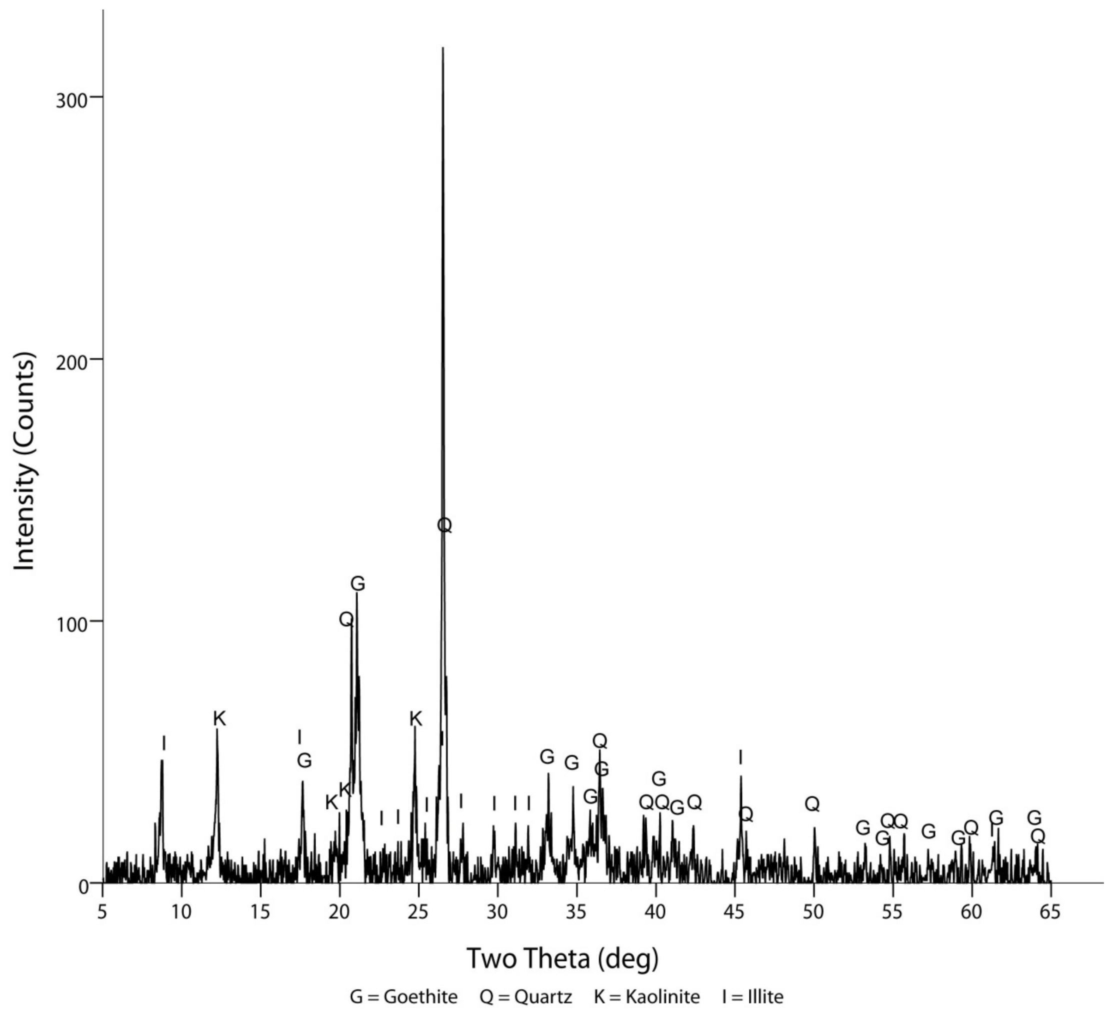


Fig. A.235. G132 Ruiterskraal yellow

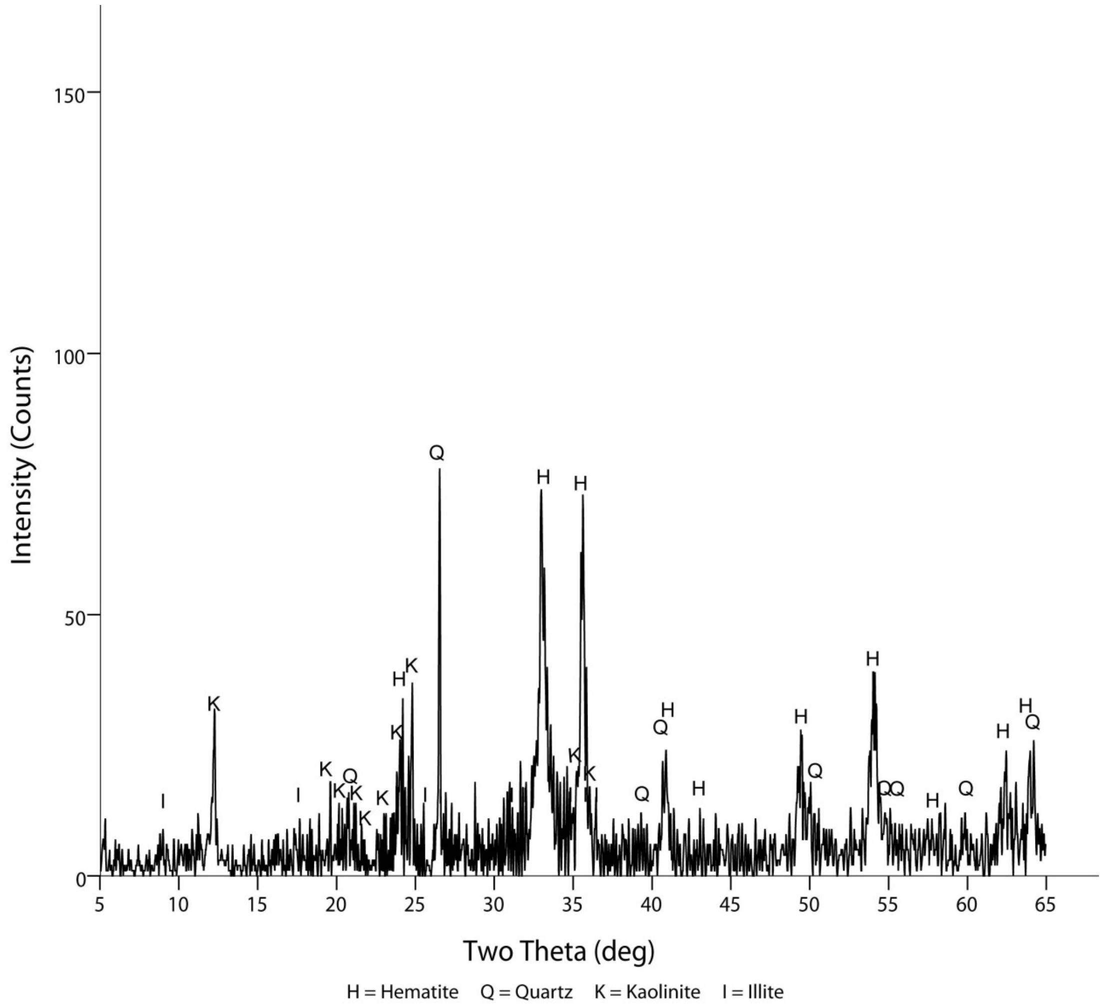


Fig. A.236. G131 Ruiterskraal yellow heated

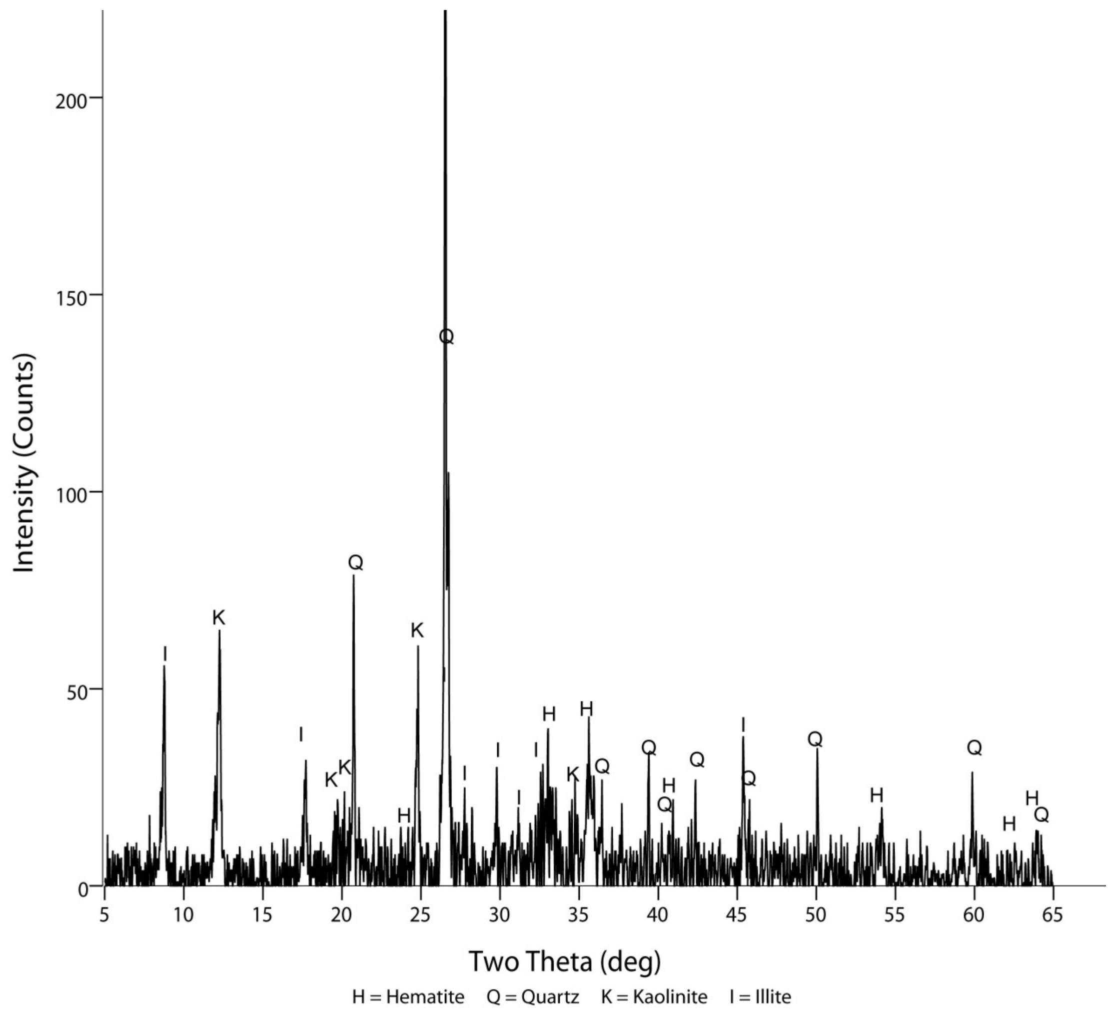


Fig. A.237. G133 Ruiterskraal yellow heated

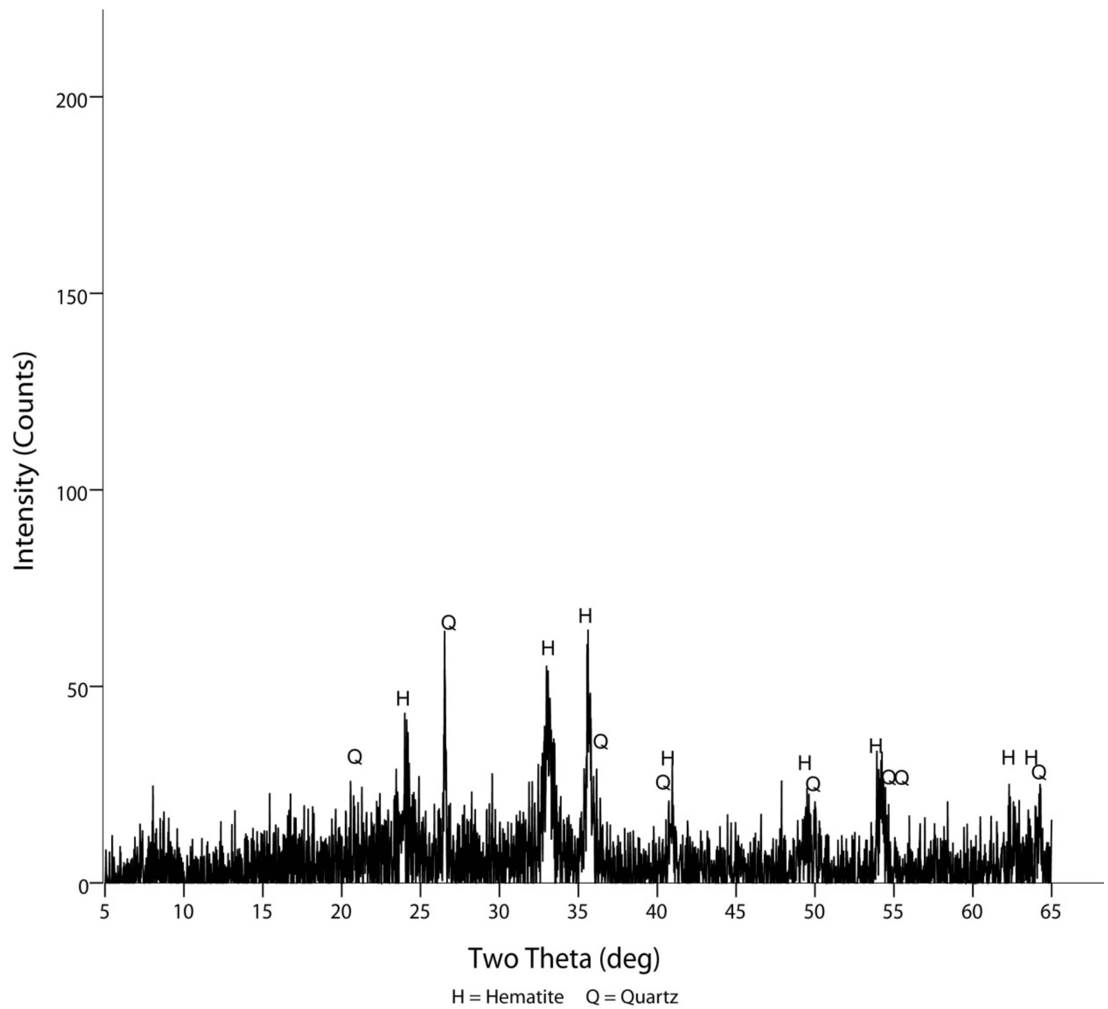


Fig. A.238. G221 Ruiterskraal yellow heated

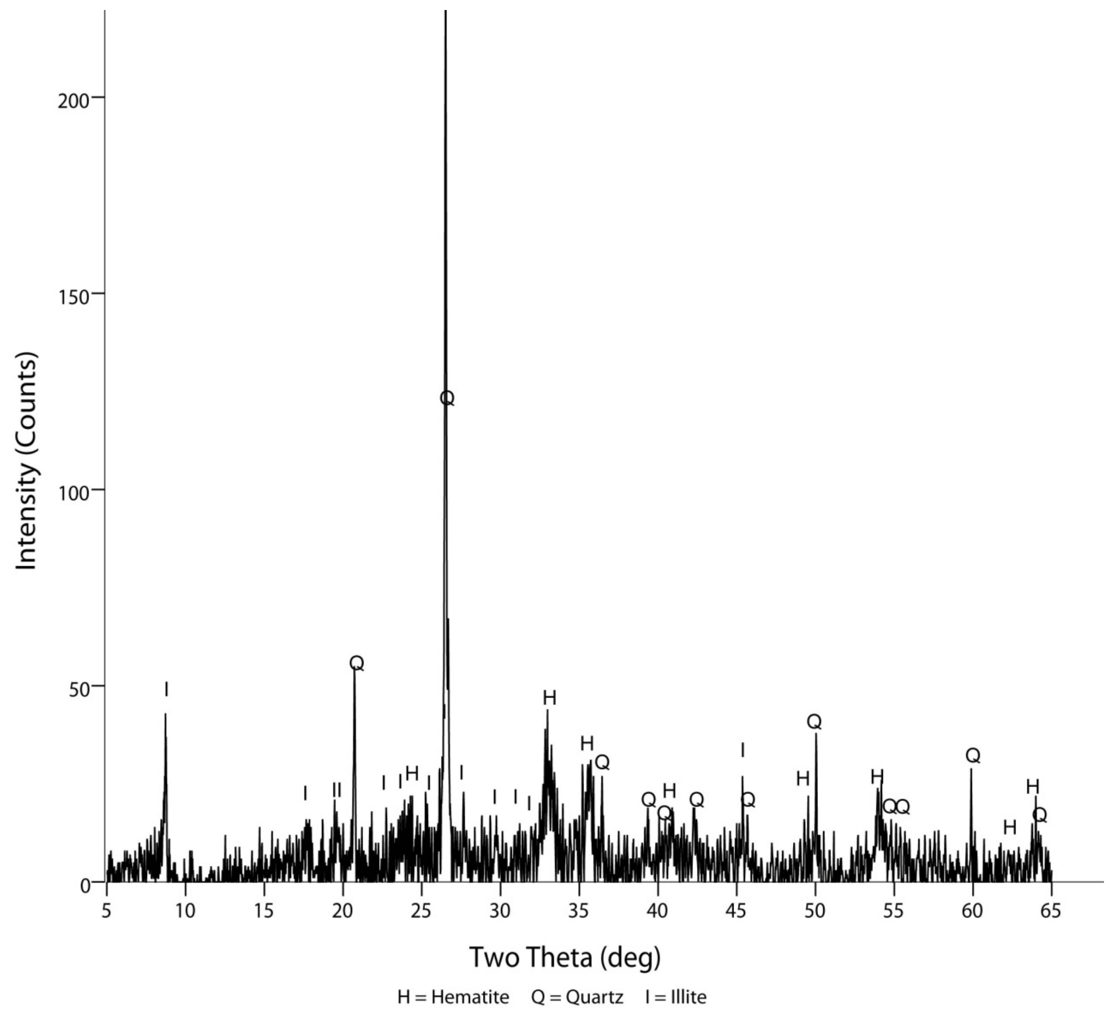


Fig. A.239. G222 Ruiterskraal yellow heated

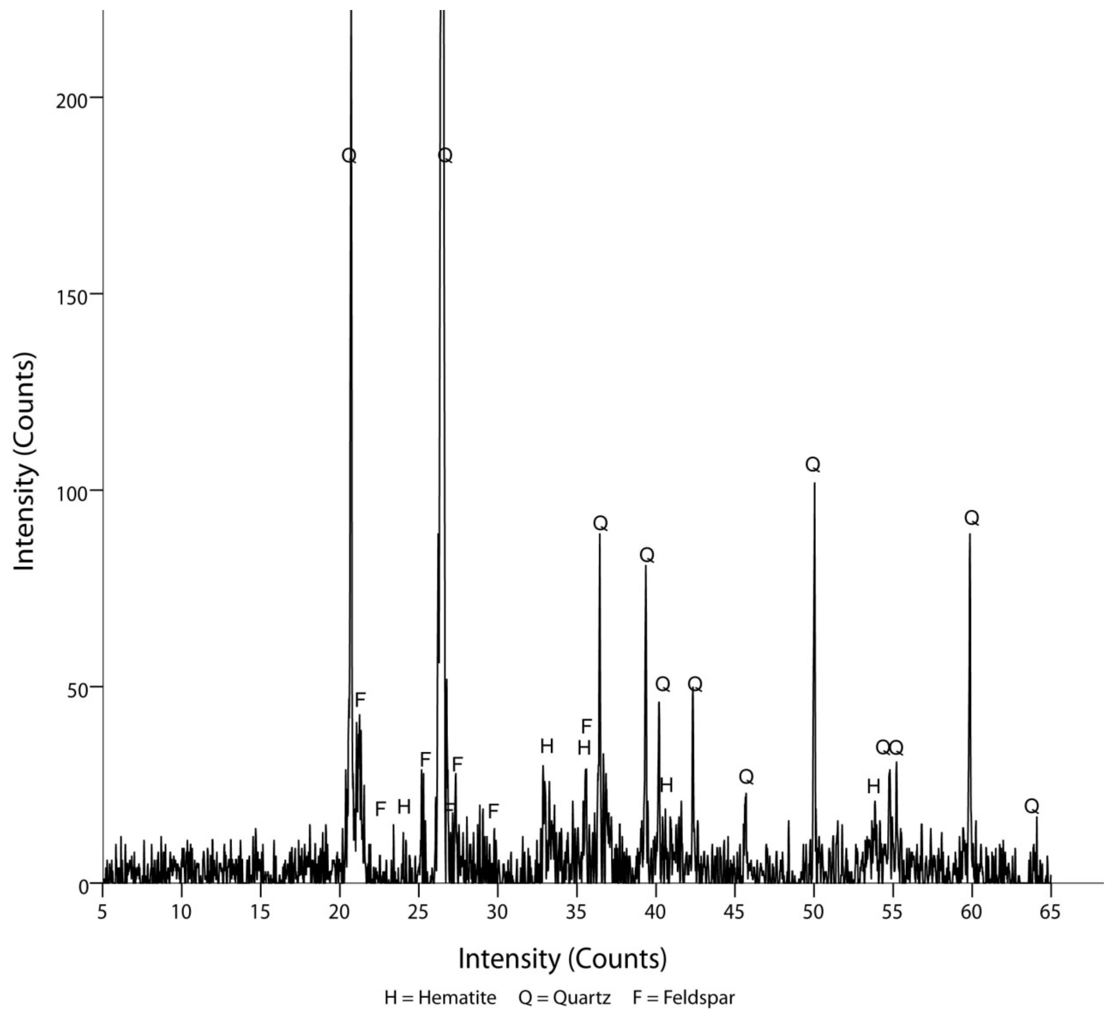


Fig. A.240. G150 R328A red

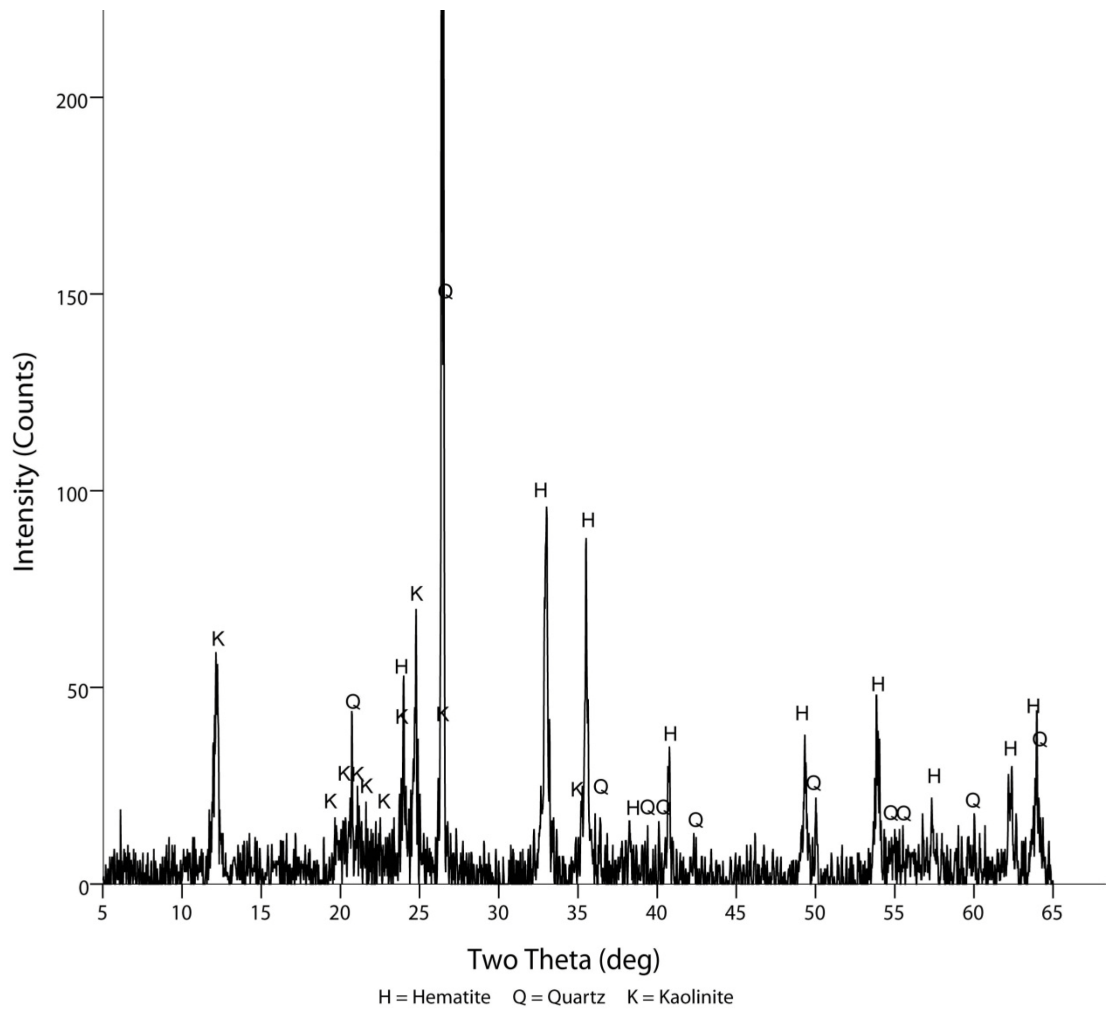


Fig. A.241. G156 R328A red

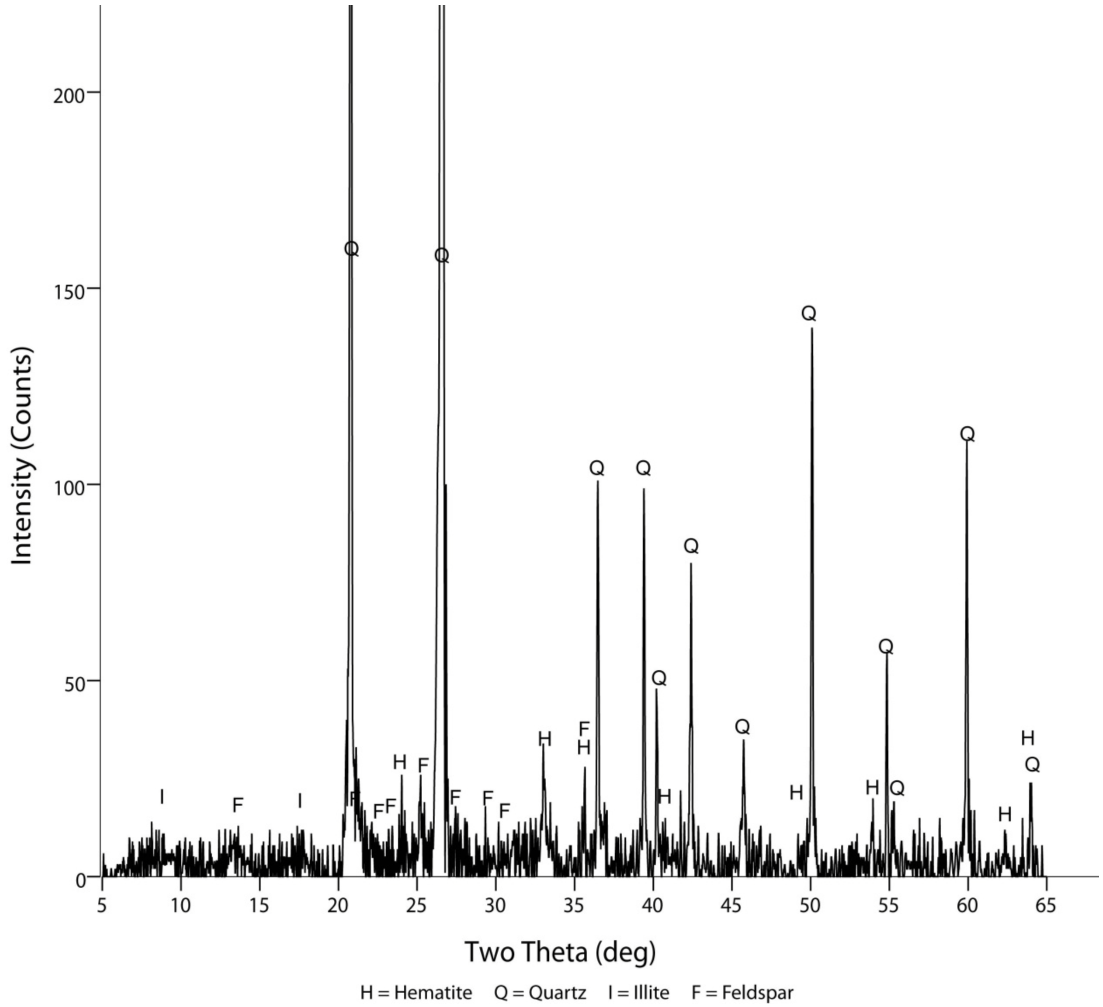


Fig. A.242. G161 R328A red

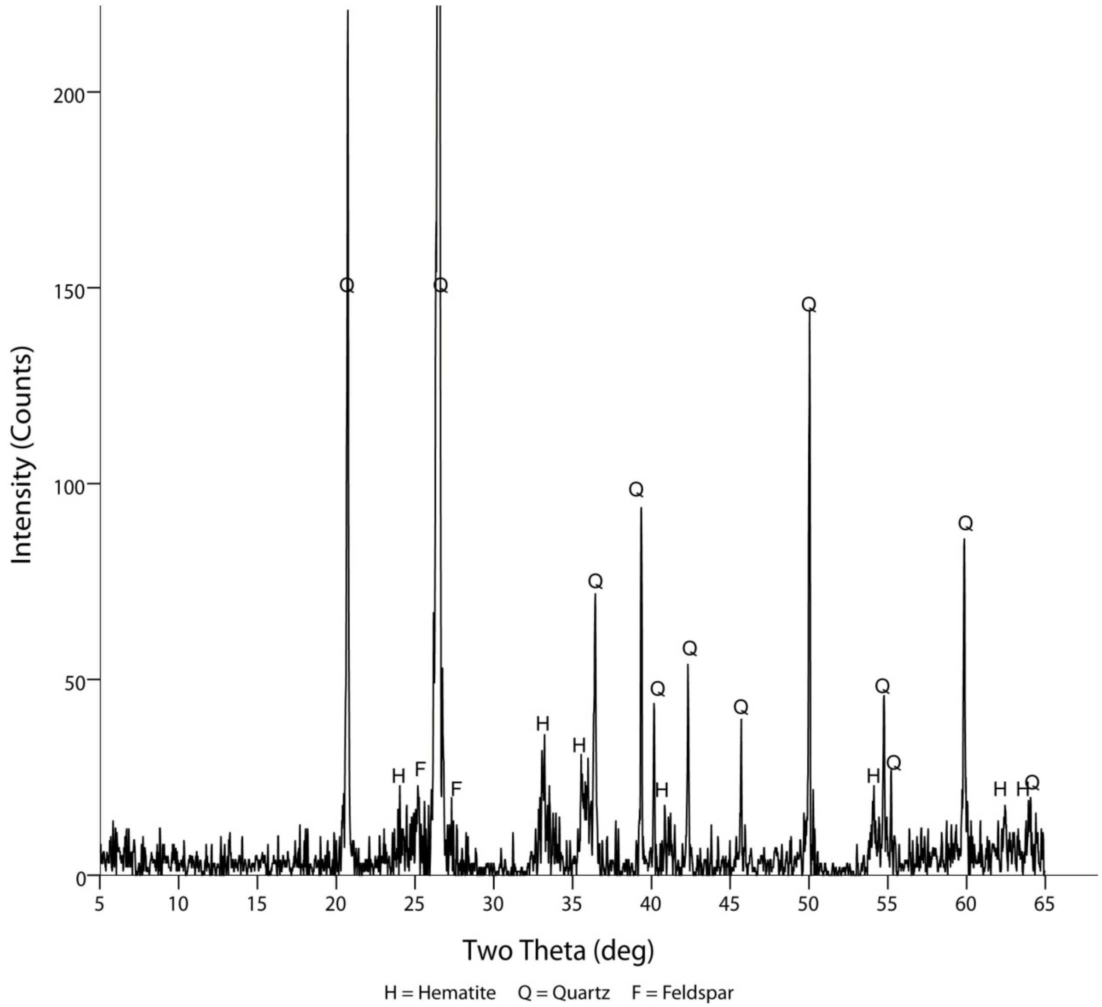


Fig. A.243. G151 R328A red heated

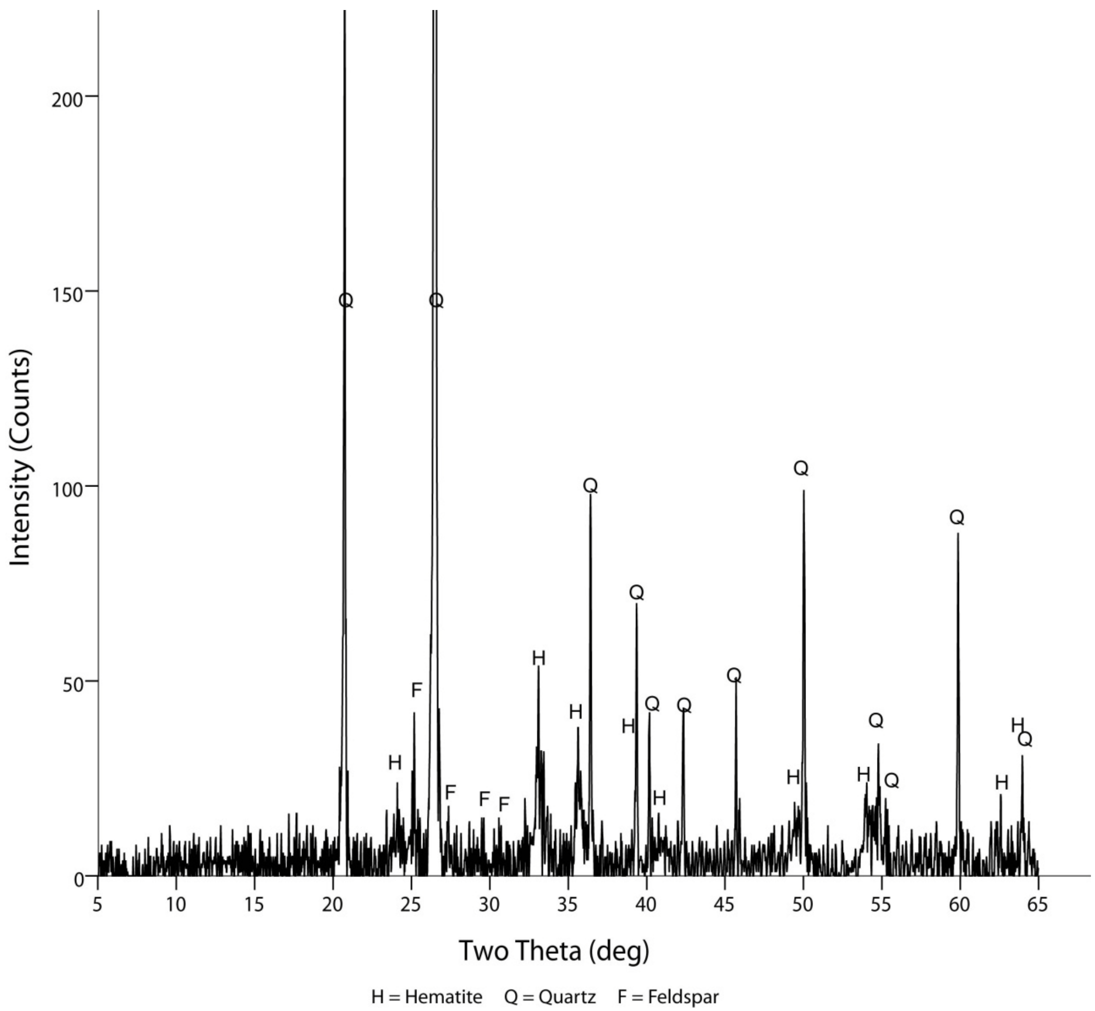


Fig. A.244. G152 R328A red heated

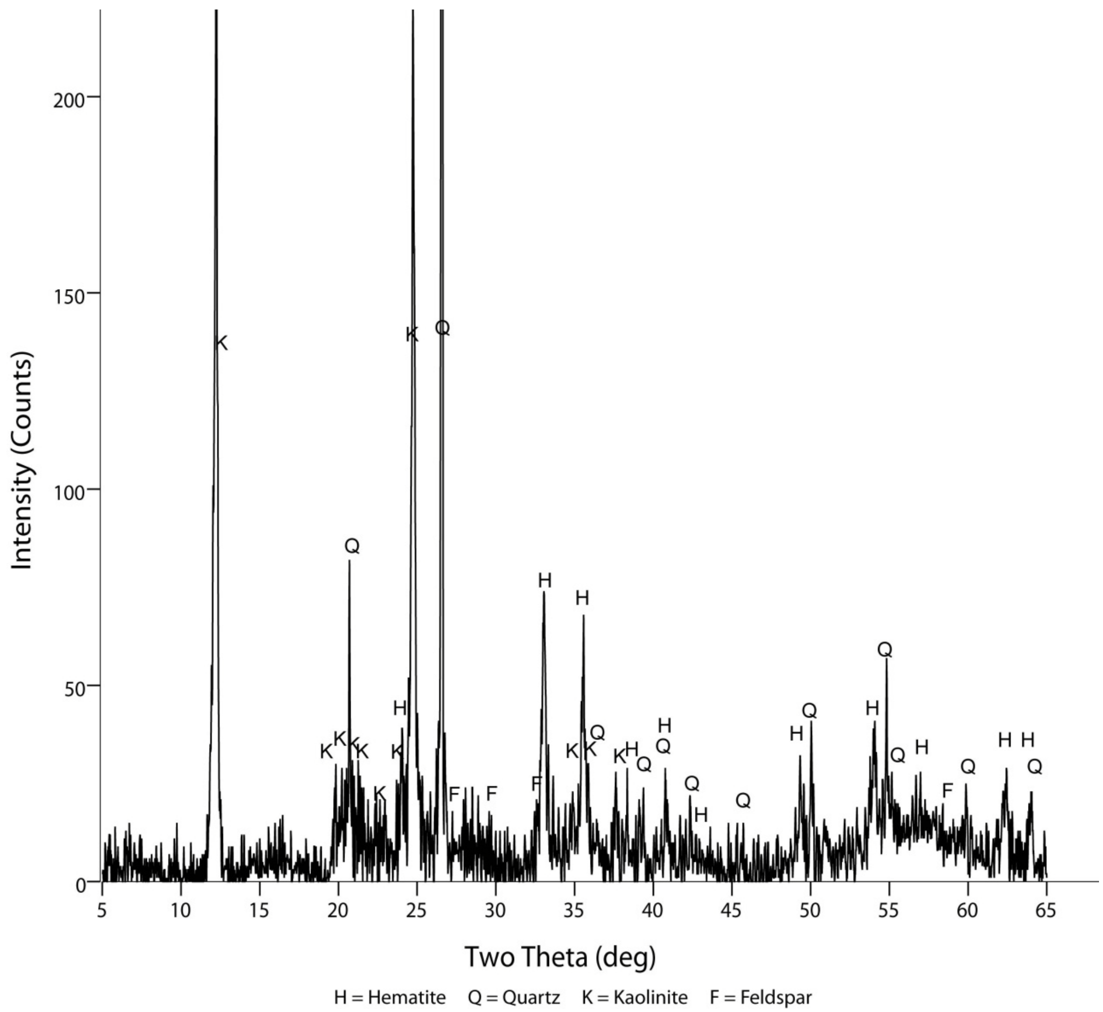


Fig. A.245. G157 R328A red heated

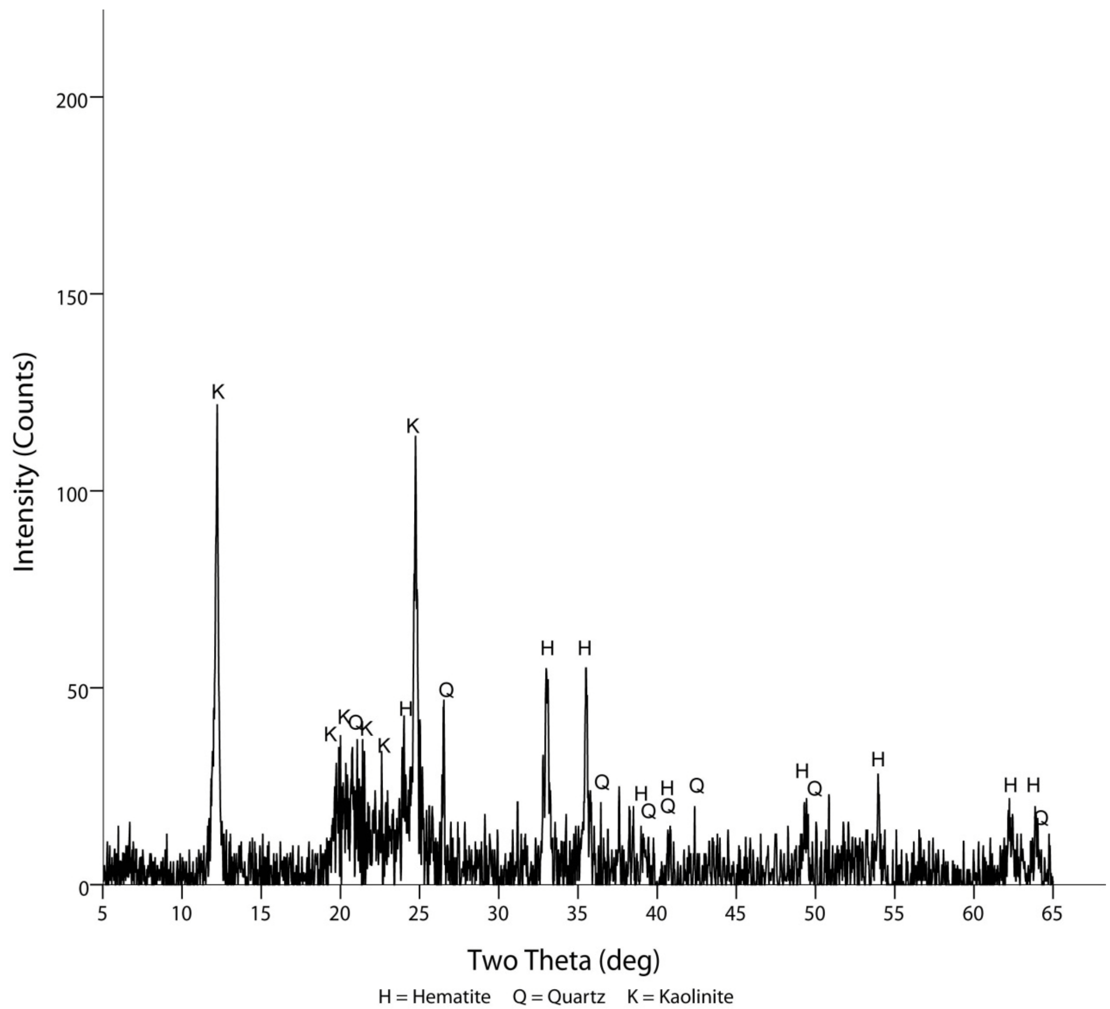


Fig. A.246. G158 R328A red heated

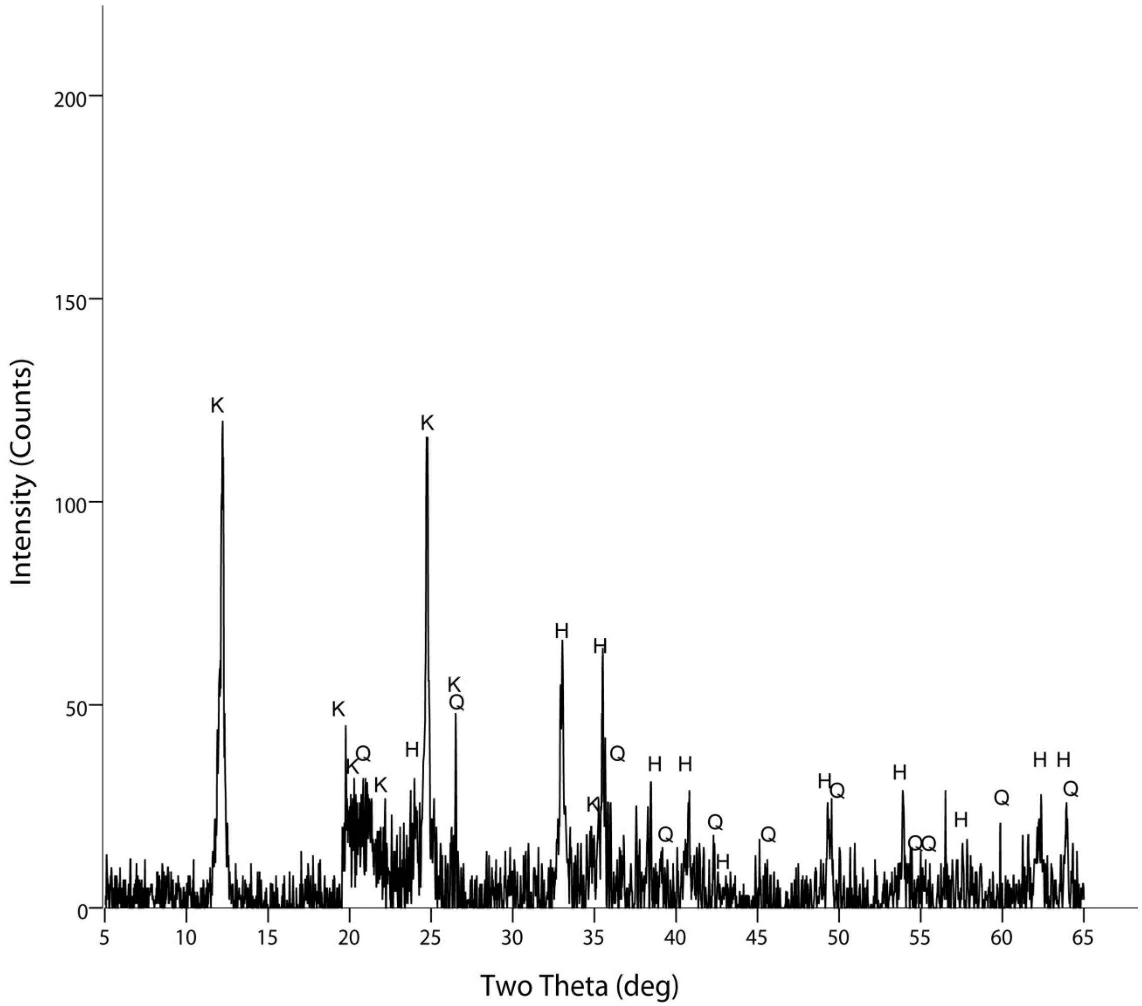


Fig. A.247. G159 R328A red heated

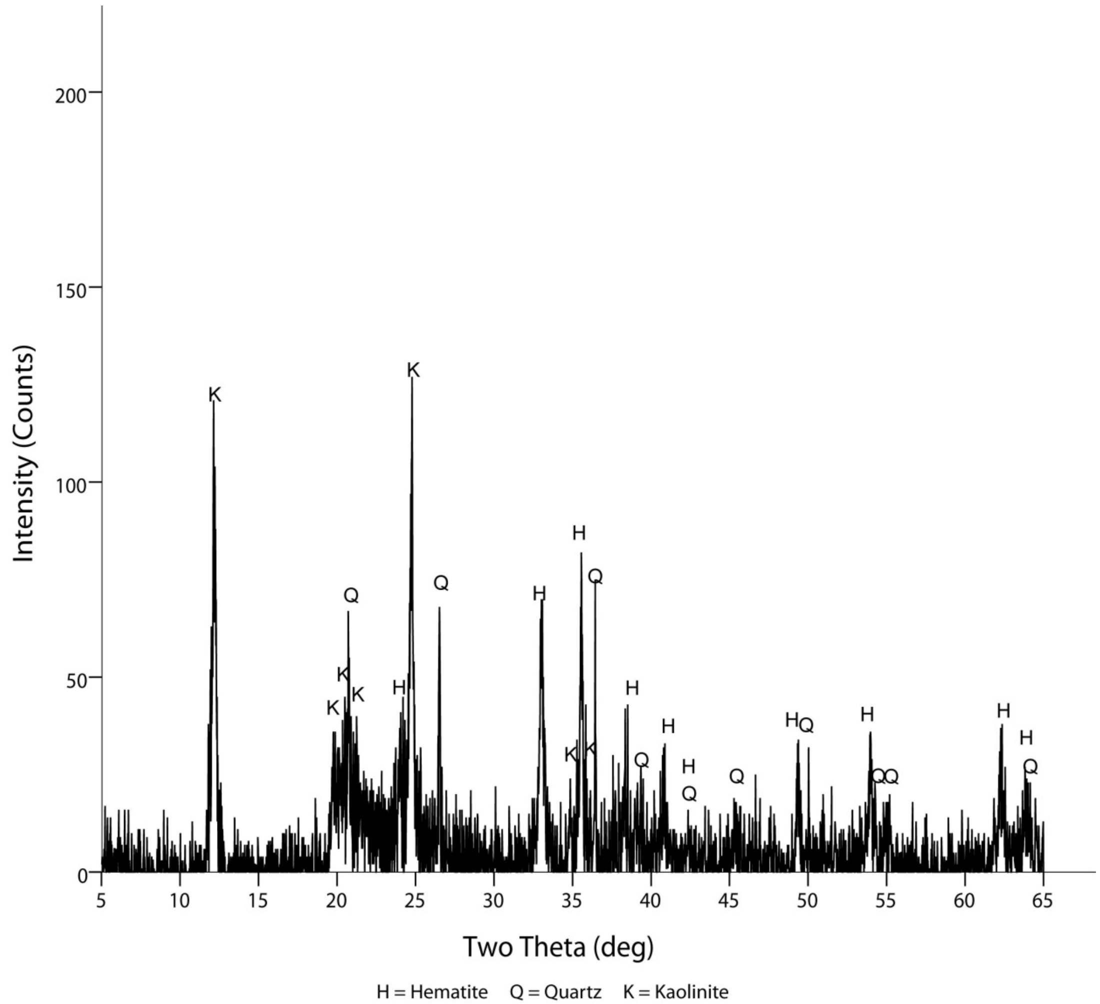


Fig. A.248. G160 R328A red heated

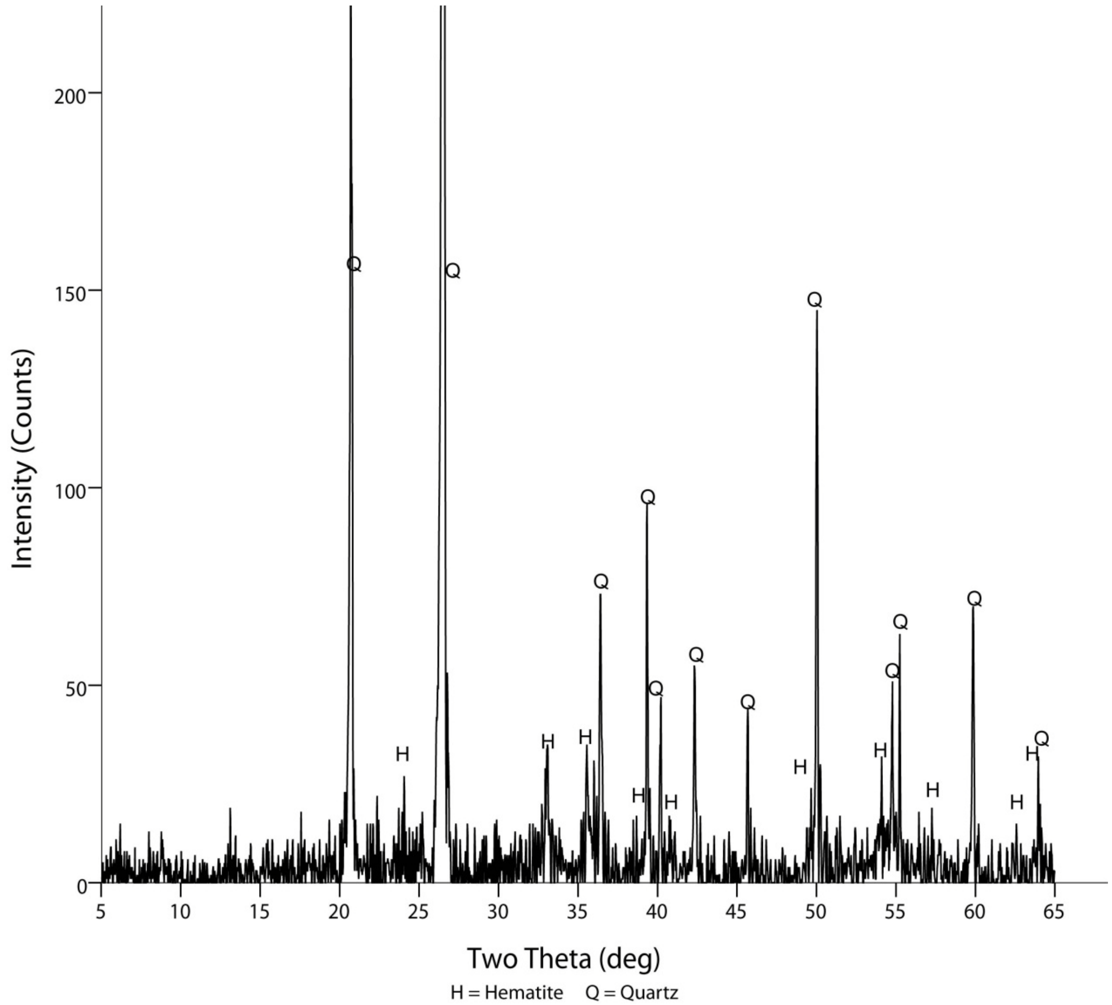


Fig. A.249. G162 R328A red heated

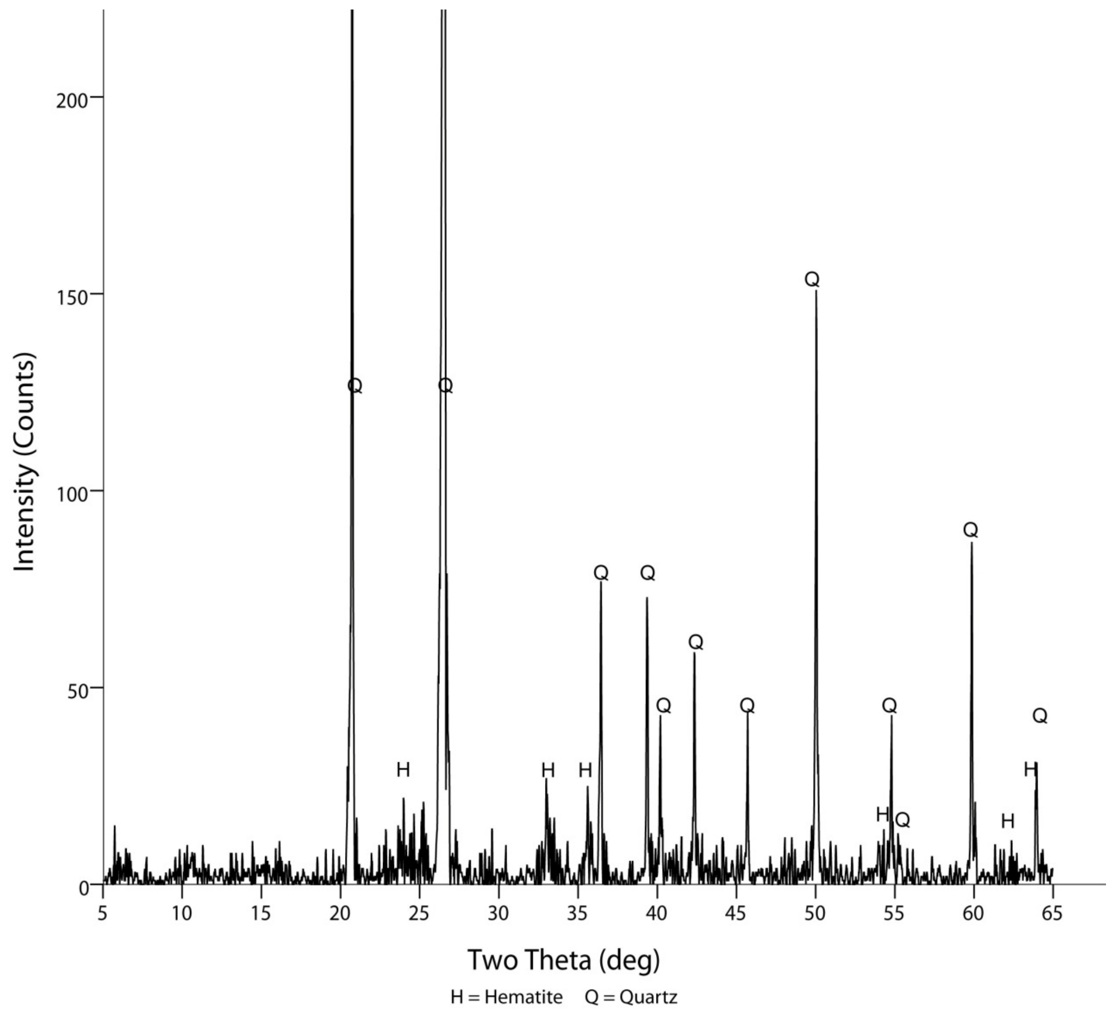


Fig. A.250. G247 R328A red heated

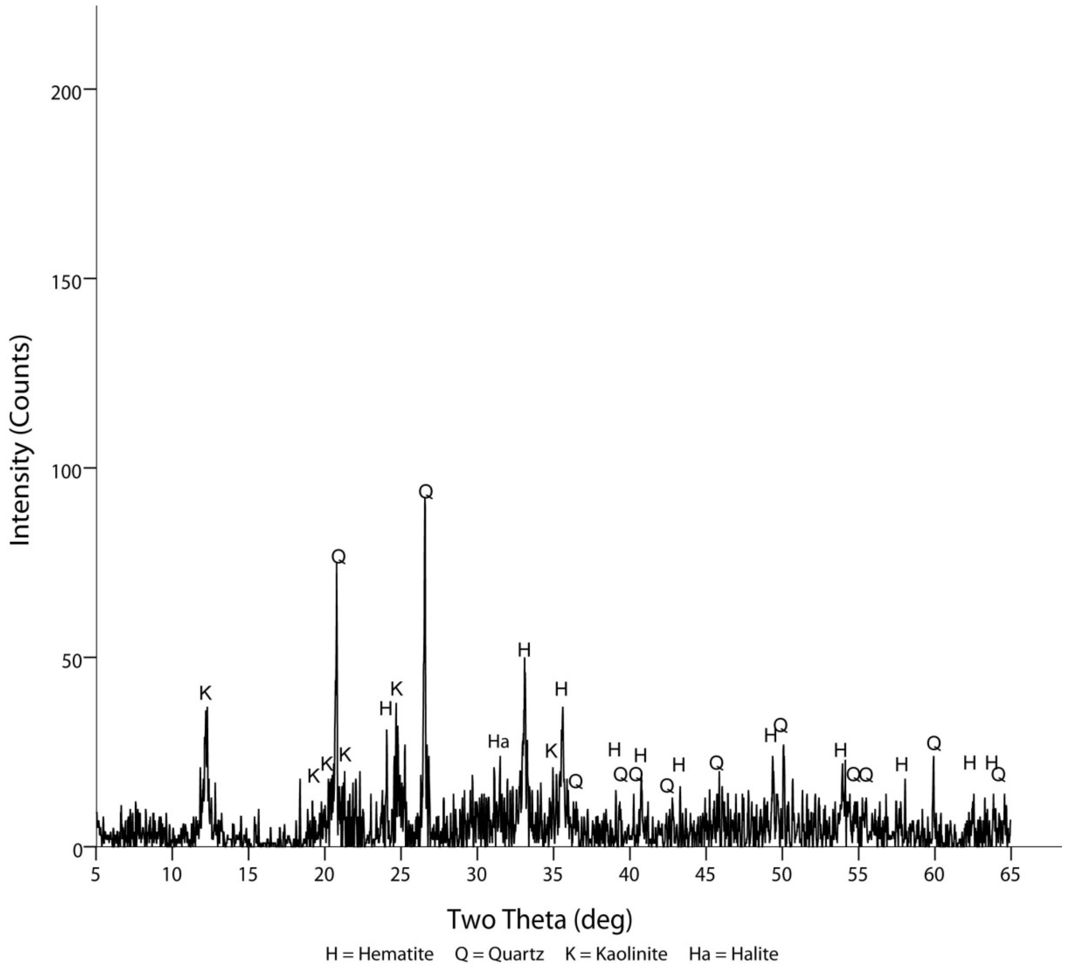


Fig. A.251. G248 R328A red heated

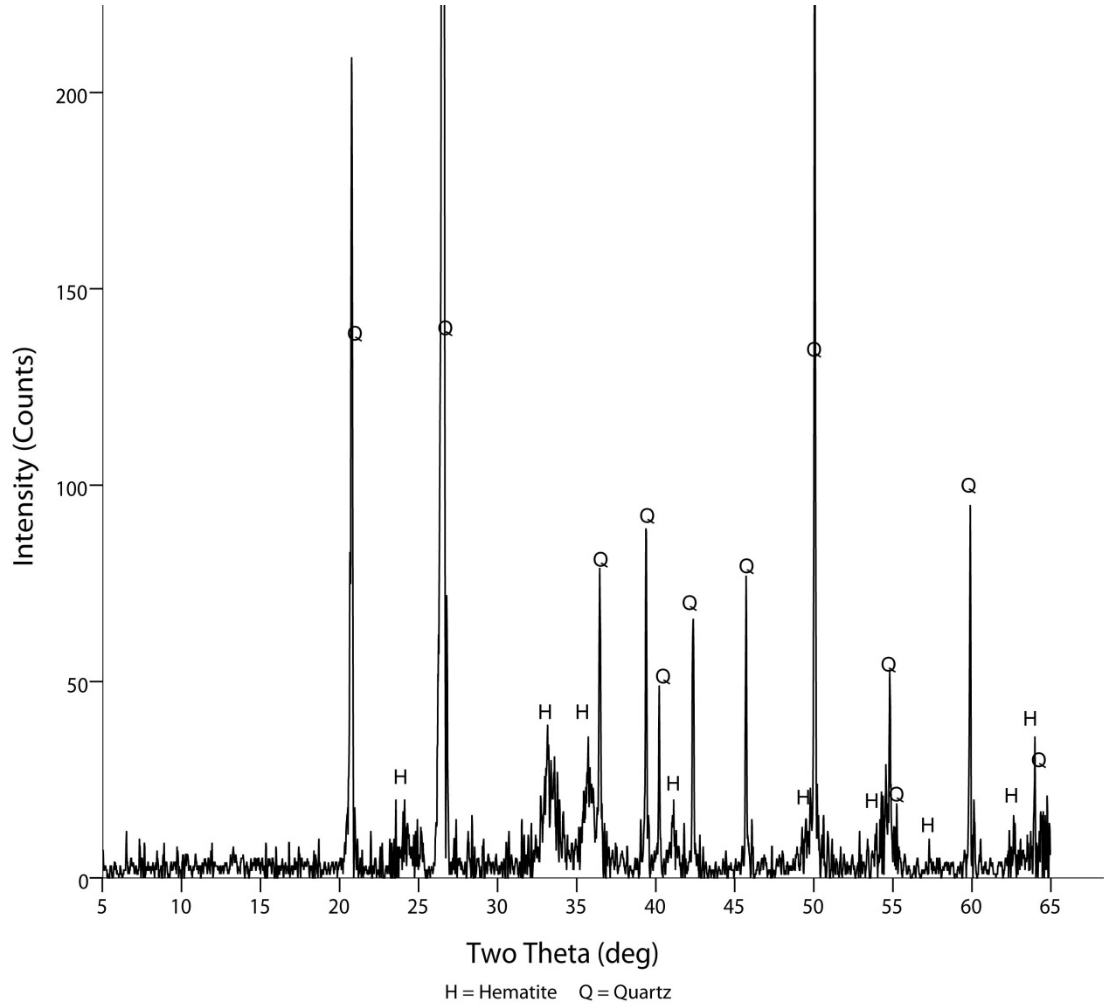


Fig. A.252. G249 R328A red heated

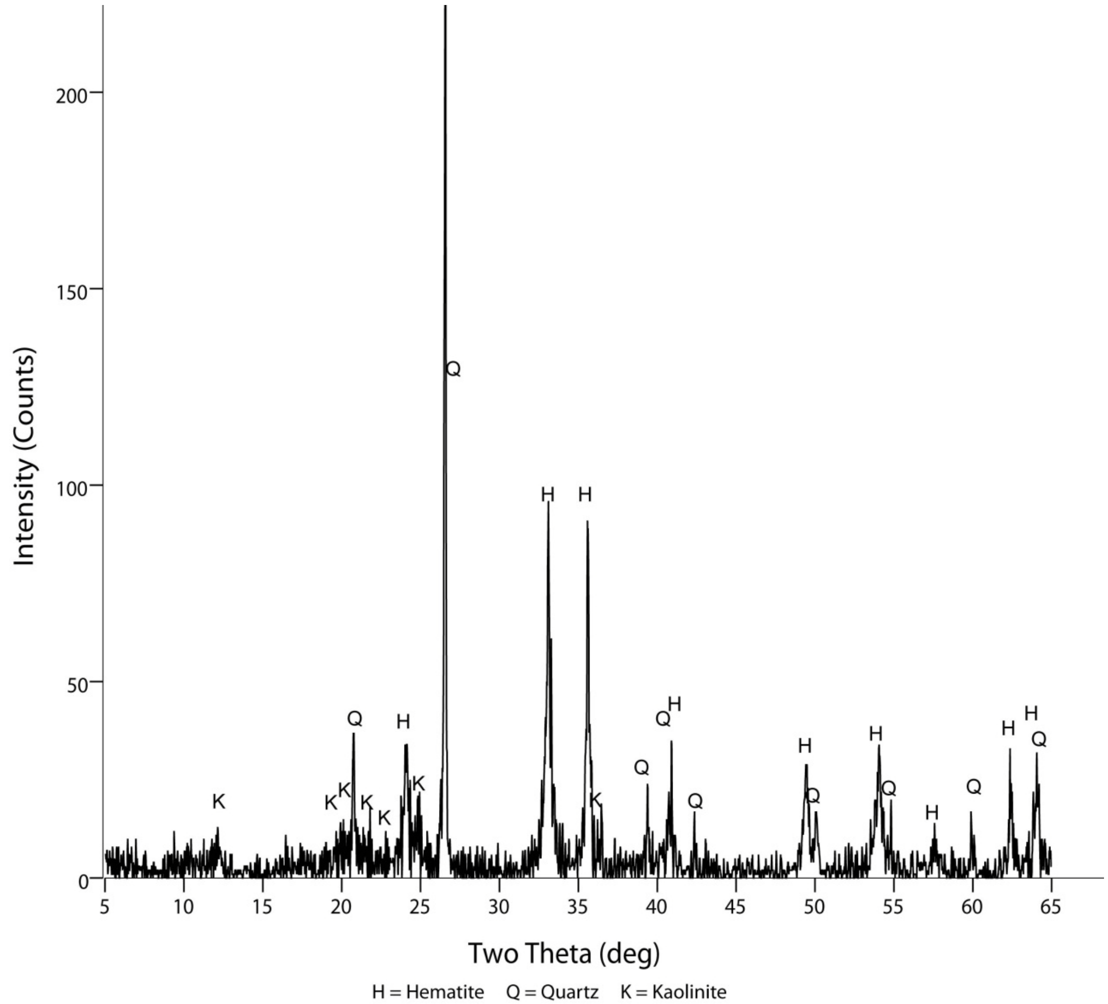


Fig. A.253. G250 R328A red heated

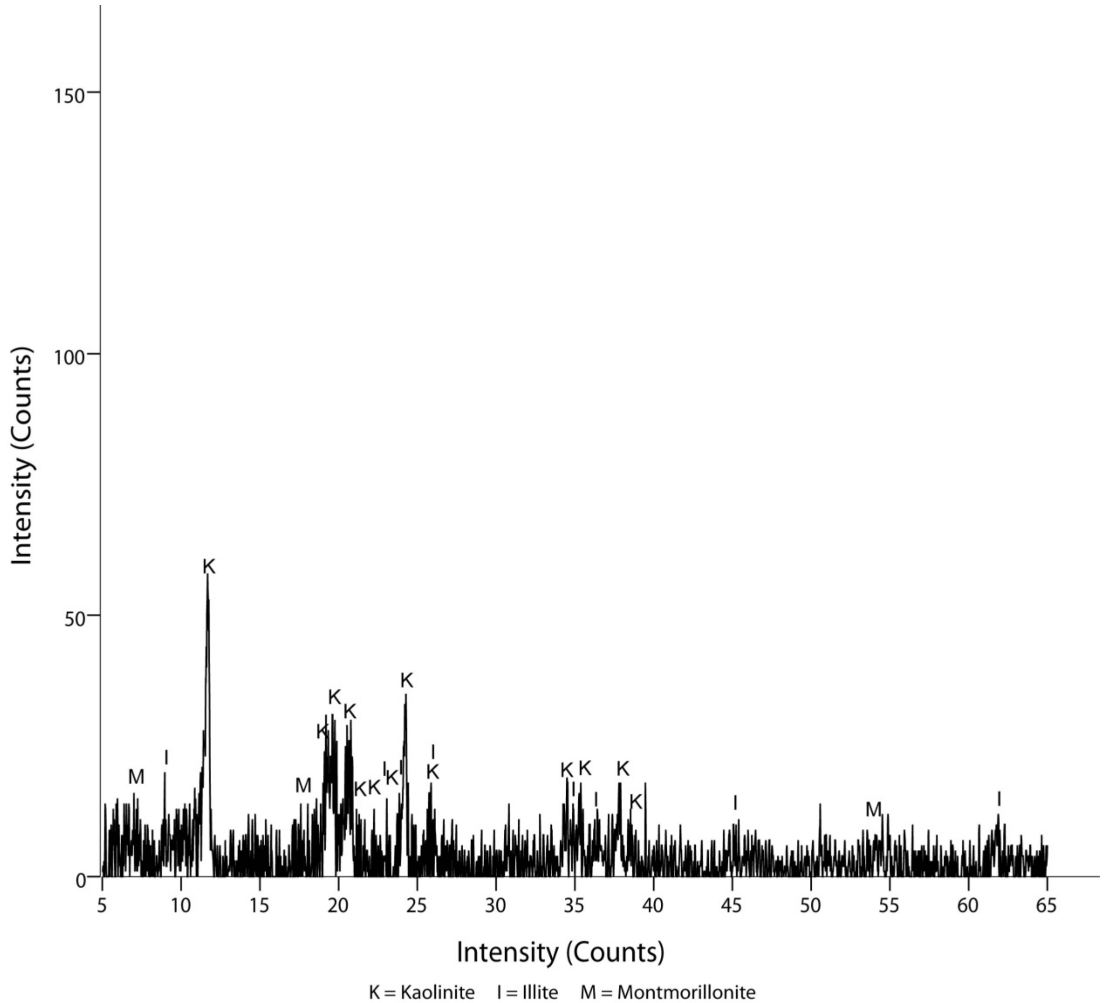


Fig. A.254. G153 R328A yellow

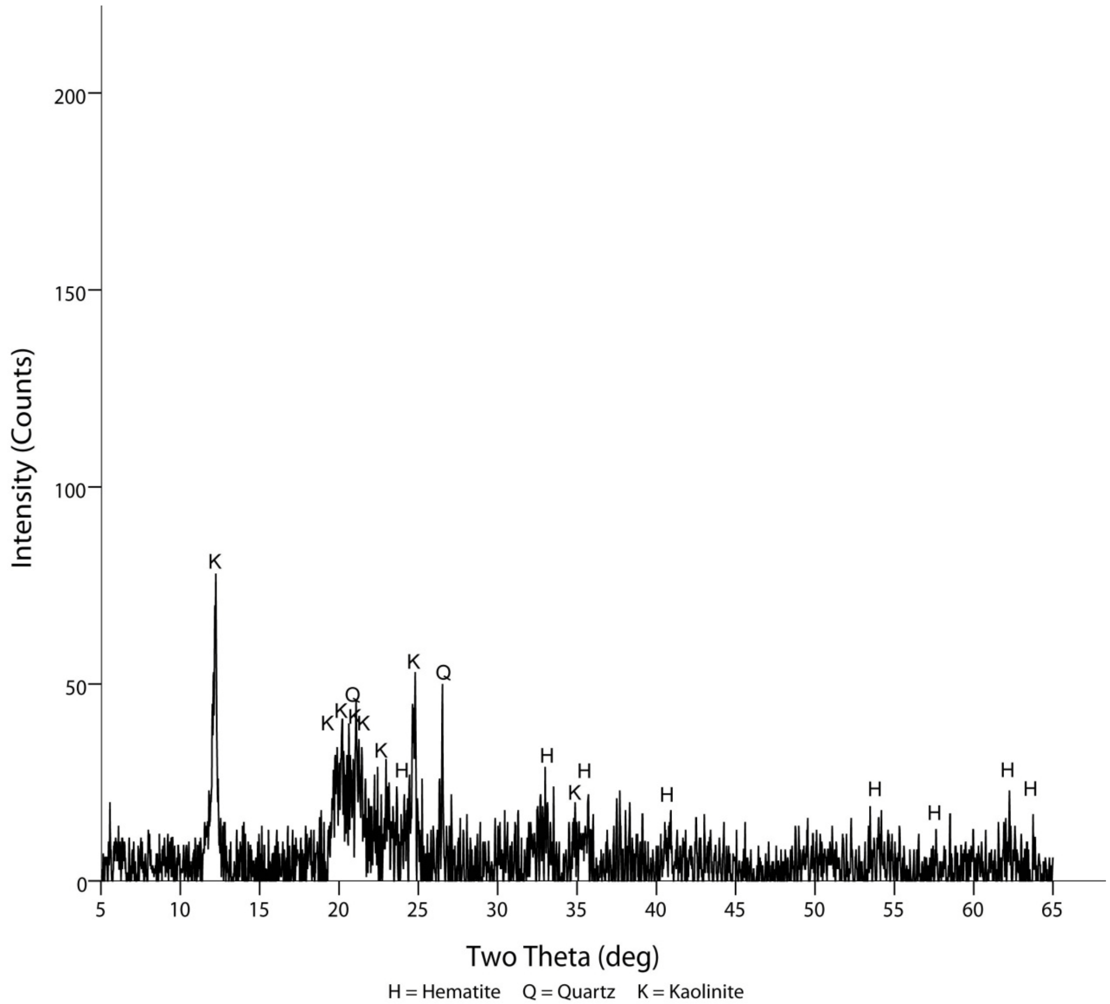


Fig. A.255. G154 R328A yellow heated

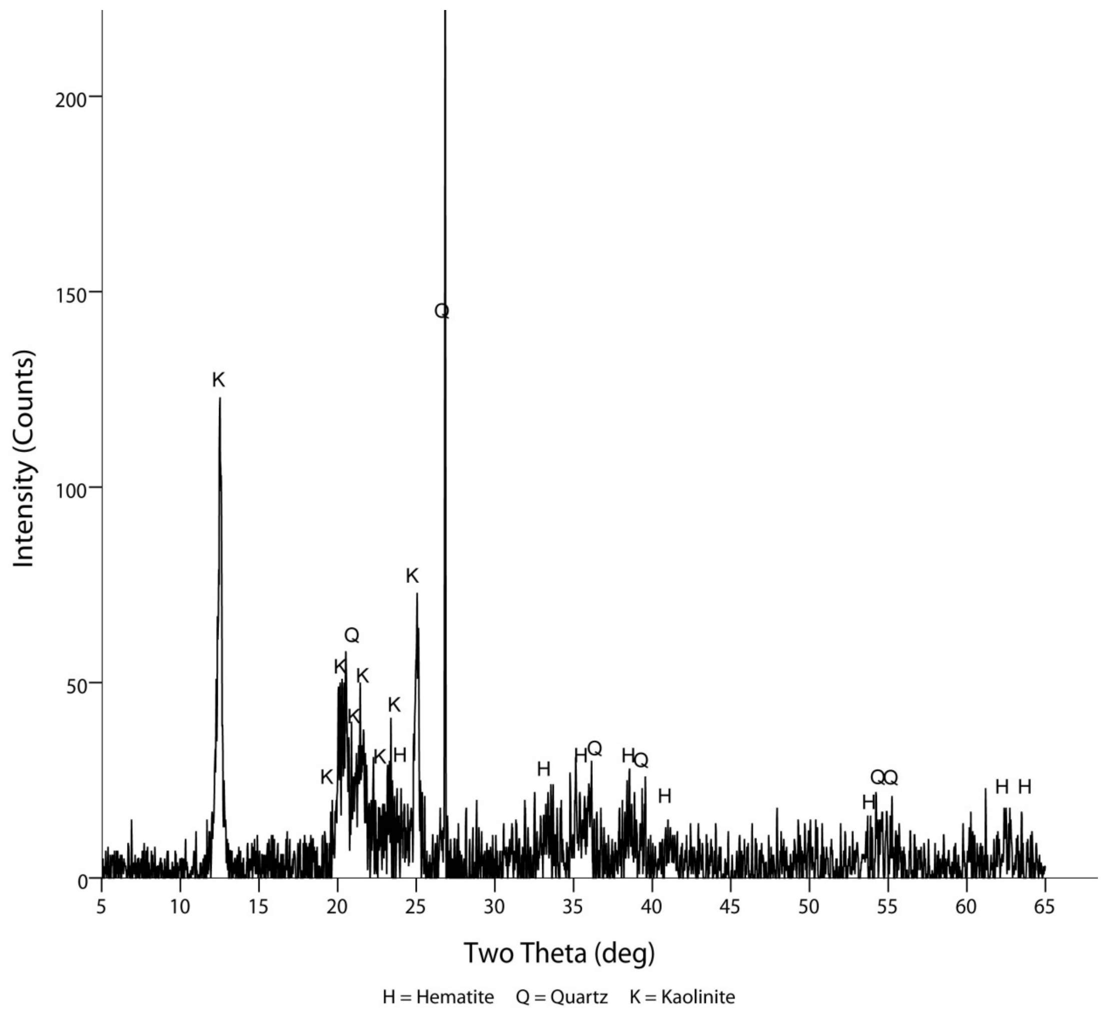


Fig. A.256. G155 R328A yellow heated

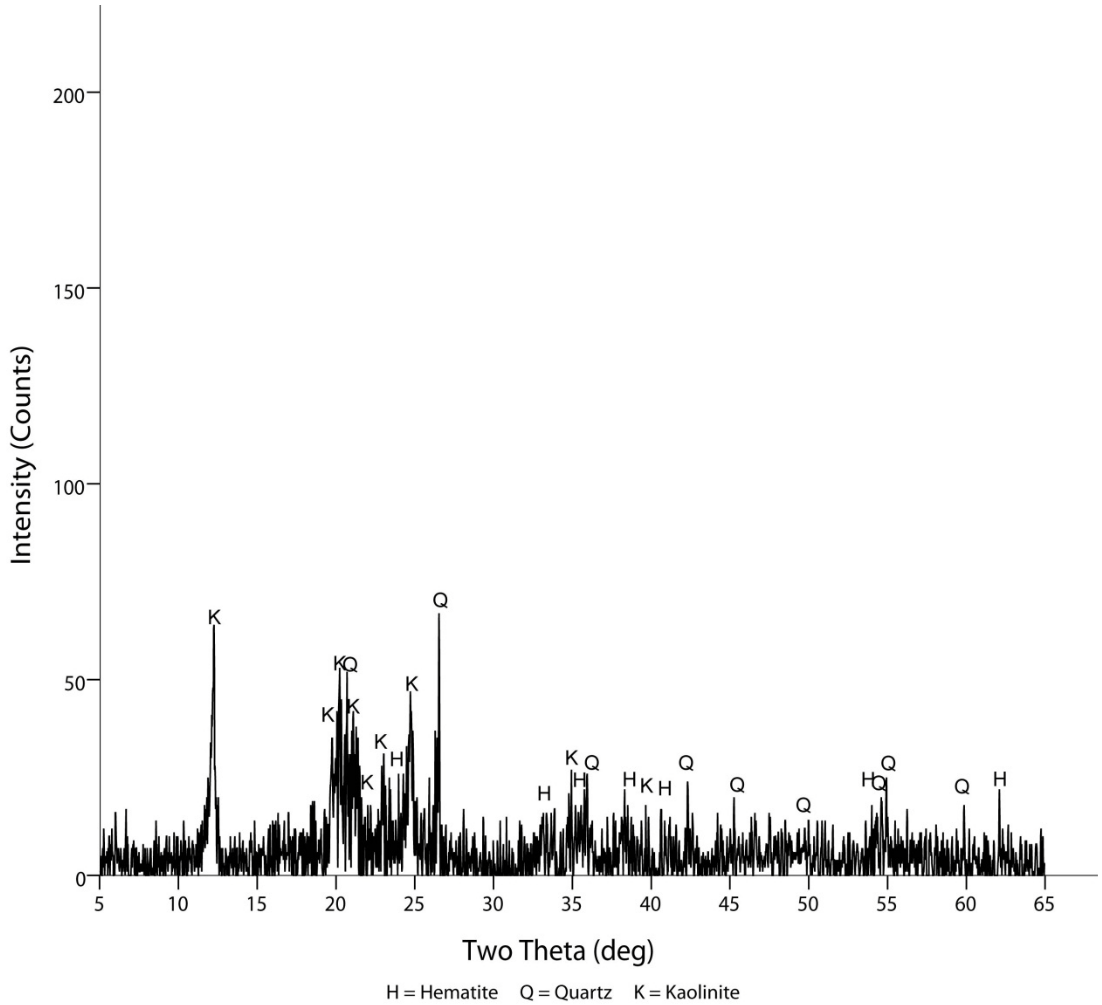


Fig. A.257. G246 R328A yellow heated

APPENDIX B

GEOLOGICAL SAMPLES PIXE RESULTS

Table B.1

LoE elemental concentration data for Albertina B

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*FeK*
1	G2	0.634	2.722	0.003	0.011	0.120	0.156	0.009	0.029	0.004	0.002	0.000	146139.3
1	G52	0.316	1.348	0.000	0.004	0.049	0.076	0.003	0.020	0.004	0.003	0.000	201543.2
1	G194	0.241	1.013	0.000	0.004	0.018	0.083	0.003	0.022	0.004	0.002	0.000	81038.6
2	G3	0.397	1.398	0.004	0.008	0.090	0.102	0.004	0.018	0.000	0.003	0.000	207192.3
2	G49	0.307	1.015	0.000	0.008	0.071	0.072	0.003	0.015	0.002	0.003	0.000	223492.6
2	G193	0.092	0.439	0.003	0.004	0.040	0.035	0.002	0.010	0.001	0.003	0.000	122870.8
3	G5	2.729	9.929	0.000	0.038	0.294	0.647	0.050	0.139	0.000	0.000	0.000	27571.8
3	G48	3.393	11.803	0.014	0.034	0.143	0.756	0.009	0.152	0.000	0.002	0.000	28165.4
3	G192	1.616	6.114	0.000	0.015	0.064	0.435	0.030	0.107	0.000	0.000	0.000	13705.3
4	G47	0.615	1.891	0.007	0.043	0.099	0.138	0.006	0.031	0.000	0.002	0.001	90924.7
5	G6	0.178	0.444	0.004	0.004	0.049	0.013	0.687	0.011	0.001	0.000	0.001	205882.9
5	G51	0.192	0.379	0.000	0.003	0.023	0.010	0.217	0.009	0.001	0.001	0.000	287930.5
5	G195	0.167	0.518	0.000	0.002	0.037	0.019	0.647	0.018	0.000	0.000	0.000	78812
6	G1	0.181	0.370	0.002	0.004	0.022	0.011	0.350	0.008	0.002	0.000	0.001	311216.7
6	G4	0.133	0.239	0.003	0.003	0.015	0.006	0.210	0.006	0.001	0.001	0.000	346973.4
6	G50	0.270	0.962	0.000	0.004	0.041	0.022	0.370	0.019	0.003	0.000	0.003	181599.4
6	G196	0.096	0.245	0.000	0.003	0.026	0.011	0.466	0.013	0.002	0.000	0.000	68420.5
6	G275	3.697	18.841	0.000	0.217	0.798	0.708	0.219	0.224	0.000	0.000	0.000	13130.5
6	G276	1.286	2.156	0.000	0.008	0.107	0.359	0.015	0.093	0.000	0.002	0.007	76087.7
6	G277	1.120	1.790	0.028	0.135	0.001	0.296	0.006	0.038	0.000	0.000	0.000	98278.3
6	G278	0.326	0.551	0.012	0.013	0.001	0.080	0.003	0.012	0.000	0.001	0.000	189709.6
7	G46	0.283	0.930	0.000	0.005	0.024	0.028	0.007	0.017	0.002	0.001	0.000	237544.4

Table B.2

LoE elemental concentration data for Albertinia C

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G261	0.784	1.863	0.019	0.005	0.246	0.192	0.011	0.030	0.002	0.001	0.001	66666
1	G262	1.041	2.278	0.017	0.008	0.364	0.254	0.012	0.040	0.000	0.001	0.000	100377.3
2	G263	0.349	0.693	0.003	0.006	0.110	0.092	0.003	0.015	0.000	0.001	0.000	82679.9
2	G264	0.312	0.689	0.003	0.005	0.093	0.077	0.003	0.015	0.000	0.001	0.000	198706.5
3	G265	1.148	2.600	0.000	0.004	0.073	0.204	0.004	0.040	0.000	0.002	0.000	96565.8
3	G266	0.828	1.878	0.005	0.003	0.177	0.159	0.006	0.031	0.000	0.001	0.000	203227
4	G267	0.368	1.007	0.003	0.004	0.105	0.075	0.005	0.017	0.002	0.001	0.000	101164.5
4	G268	0.239	0.833	0.000	0.004	0.032	0.028	1.073	0.021	0.002	0.002	0.000	154521.7

Table B.3

LoE elemental concentration data for Glentana

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G34	3.193	14.369	0.000	0.020	0.008	0.464	0.050	0.121	0.000	0.000	0.004	26587.7
1	G65	2.849	10.951	0.015	0.022	0.020	0.446	0.059	0.107	0.000	0.000	0.004	36299.4
1	G257	2.692	10.486	0.025	0.000	0.000	0.294	0.034	0.087	0.000	0.000	0.005	26445.7

Table B.4

LoE elemental concentration data for Gondwana A

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G27	0.429	1.609	0.000	0.003	0.008	0.026	0.009	0.019	0.001	0.003	0.000	269096
1	G70	0.634	1.864	0.000	0.010	0.044	0.019	0.004	0.034	0.002	0.002	0.000	185470
1	G201	0.162	0.574	0.000	0.002	0.004	0.021	0.002	0.020	0.001	0.002	0.000	99164
2	G26	0.125	0.984	0.003	0.002	0.001	0.006	0.002	0.031	0.002	0.000	0.000	52881.8
2	G66	0.161	0.900	0.003	0.001	0.001	0.010	0.003	0.030	0.002	0.000	0.000	245463
3	G28	0.141	3.473	0.000	0.003	0.001	0.003	0.013	0.161	0.005	0.000	0.000	67424.6
3	G68	0.154	3.965	0.000	0.002	0.002	0.005	0.002	0.228	0.000	0.000	0.000	82696.8
3	G202	0.271	6.228	0.011	0.004	0.004	0.007	0.003	0.332	0.000	0.002	0.000	77759.5
4	G29	0.374	7.522	0.015	0.009	0.007	0.014	0.015	0.348	0.000	0.000	0.002	141997
4	G67	0.372	5.672	0.006	0.006	0.003	0.012	0.006	0.194	0.000	0.000	0.000	75320.5
4	G203	1.164	1.173	0.002	0.005	0.005	0.045	0.004	0.022	0.002	0.001	0.001	36284.5
5	G69	2.285	2.683	0.000	0.009	0.019	0.097	0.013	0.050	0.000	0.002	0.000	114968

Table B.5

LoE elemental concentration data for Gondwana B

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G19	1.052	3.040	0.009	0.007	0.246	0.160	0.024	0.035	0.003	0.002	0.000	103586.1
1	G24	0.765	2.052	0.000	0.011	0.260	0.124	0.007	0.028	0.002	0.002	0.000	127172.4
1	G73	0.685	2.057	0.000	0.006	0.099	0.167	0.007	0.039	0.003	0.002	0.000	79785.1
1	G214	0.503	1.368	0.003	0.003	0.122	0.113	0.003	0.031	0.002	0.002	0.000	43278.4
2	G20	0.676	2.452	0.006	0.009	0.172	0.111	0.004	0.034	0.005	0.003	0.000	137174.4
2	G71	0.632	1.943	0.001	0.006	0.085	0.086	0.003	0.029	0.004	0.003	0.000	142054.8
2	G213	0.702	2.237	0.005	0.007	0.075	0.105	0.003	0.036	0.004	0.003	0.000	78391.2
3	G15	0.557	1.641	0.000	0.002	0.156	0.074	0.006	0.026	0.003	0.002	0.000	116571.2
3	G75	0.509	1.696	0.000	0.004	0.090	0.094	0.004	0.038	0.004	0.001	0.000	85476.4
3	G216	0.299	0.967	0.002	0.006	0.079	0.035	0.005	0.012	0.006	0.003	0.000	202488.9
4	G21	0.989	2.905	0.006	0.016	0.275	0.186	0.017	0.039	0.002	0.003	0.000	104690.7
4	G77	0.500	1.585	0.000	0.005	0.082	0.149	0.003	0.032	0.000	0.002	0.000	68710.9
4	G215	0.277	0.729	0.003	0.003	0.074	0.043	0.002	0.011	0.001	0.002	0.000	154596.7
5	G17	0.556	1.992	0.005	0.013	0.064	0.162	0.003	0.033	0.000	0.002	0.000	150332.5
5	G74	0.053	0.178	0.000	0.001	0.009	0.006	0.002	0.003	0.000	0.001	0.000	374995.1
5	G212	0.080	0.201	0.001	0.002	0.006	0.005	0.002	0.002	0.001	0.000	0.000	269155.4
6	G16	0.075	0.152	0.005	0.005	0.005	0.007	0.002	0.008	0.001	0.001	0.000	439308.9
6	G22	0.110	0.197	0.008	0.006	0.012	0.007	0.002	0.006	0.002	0.001	0.000	436965.3
6	G23	2.295	6.595	0.031	0.044	0.012	0.273	0.013	0.147	0.000	0.000	0.000	51171.6
6	G76	0.128	0.424	0.004	0.005	0.032	0.023	0.003	0.012	0.002	0.001	0.000	192631.3
6	G210	0.126	0.307	0.006	0.004	0.023	0.018	0.003	0.007	0.002	0.000	0.001	164659
7	G18	0.941	2.960	0.000	0.007	0.165	0.128	0.018	0.048	0.006	0.000	0.000	78305
7	G72	1.359	3.961	0.000	0.014	0.202	0.172	0.013	0.057	0.006	0.003	0.000	75126.9
7	G211	2.307	6.681	0.014	0.015	0.170	0.404	0.007	0.099	0.007	0.002	0.003	34970.7

Table B.6

LoE elemental concentration data for Gondwana C

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G25	24.598	48.097	0.000	0.087	1.624	3.124	0.172	0.777	0.000	0.018	0.000	6026
1	G78	13.477	27.750	0.050	0.067	1.067	2.571	0.069	0.668	0.000	0.013	0.010	5420.2
1	G256	23.783	41.453	0.126	0.092	0.643	4.004	0.160	0.846	0.000	0.013	0.011	4251.9

Table B.7

LoE elemental concentration data for Gondwana D

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G122	0.130	0.401	0.000	0.004	0.026	0.036	0.003	0.007	0.000	0.000	0.008	315977.6
1	G123	0.178	0.492	0.000	0.002	0.029	0.049	0.004	0.009	0.000	0.000	0.010	274613.1
2	G124	0.126	0.400	0.000	0.000	0.019	0.031	0.003	0.006	0.000	0.000	0.005	351467.1
2	G125	0.142	0.440	0.000	0.001	0.022	0.036	0.004	0.006	0.000	0.000	0.006	314260.9
3	G126	0.450	1.372	0.000	0.000	0.011	0.132	0.016	0.025	0.000	0.000	0.008	129444.9
3	G127	0.166	0.510	0.000	0.002	0.018	0.047	0.007	0.008	0.000	0.000	0.022	269472.3
4	G128	0.245	0.826	0.002	0.002	0.029	0.068	0.005	0.013	0.000	0.001	0.008	195570.9
4	G129	0.395	1.268	0.003	0.005	0.045	0.105	0.011	0.021	0.000	0.001	0.010	121754.9
2	G232	0.080	0.288	0.000	0.001	0.013	0.030	0.003	0.006	0.000	0.000	0.005	323314.3
3	G233	0.036	0.098	0.000	0.000	0.009	0.012	0.005	0.002	0.000	0.000	0.023	404429.5
1	G234	0.205	0.840	0.000	0.005	0.034	0.090	0.010	0.019	0.000	0.001	0.006	171880.1
4	G235	0.205	0.841	0.000	0.005	0.034	0.090	0.010	0.019	0.000	0.001	0.006	171872.7

Table B.8

LoE elemental concentration data for Herbertsdale

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G163	1.481	4.585	0.000	0.000	0.229	0.381	0.013	0.097	0.000	0.002	0.007	45614.6
2	G164	1.757	4.699	0.000	0.008	0.074	0.382	2.229	0.101	0.000	0.006	0.006	38948.1
2	G165	1.968	6.259	0.000	0.012	0.242	0.502	0.017	0.102	0.000	0.000	0.010	38979.7
3	G166	1.733	4.858	0.000	0.011	0.305	0.503	0.015	0.097	0.005	0.000	0.013	46358.7
3	G167	1.764	5.033	0.016	0.014	0.259	0.491	0.012	0.107	0.003	0.000	0.013	46564.6
2	G251	2.205	5.497	0.000	0.035	0.139	0.408	6.775	0.089	0.000	0.000	0.000	17188.4
1	G252	2.109	6.748	0.000	0.018	0.193	0.519	0.016	0.106	0.000	0.006	0.016	27361.1
3	G253	1.967	5.791	0.000	0.014	0.254	0.562	0.018	0.108	0.000	0.002	0.011	37183.3

Table B.9

LoE elemental concentration data for Kwa-Nonqaba

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
3	G35	1.793	4.342	0.000	0.000	0.048	0.376	0.017	0.092	0.000	0.002	0.005	65074.8
2	G36	1.934	3.469	0.000	0.010	0.108	0.433	0.019	0.091	0.000	0.003	0.003	88157.3
1	G37	2.414	5.257	0.000	0.007	0.063	0.614	0.034	0.140	0.000	0.003	0.002	52833.6
2	G59	1.837	2.928	0.000	0.000	0.046	0.408	0.011	0.093	0.000	0.002	0.003	83148.7
1	G60	1.999	4.344	0.000	0.000	0.095	0.480	0.028	0.112	0.000	0.004	0.005	64874.2
3	G61	1.680	4.468	0.000	0.000	0.075	0.361	0.010	0.093	0.000	0.002	0.005	65103.8
3	G182	0.997	2.430	0.004	0.000	0.017	0.217	0.004	0.065	0.005	0.000	0.004	71432.9
3	G199	0.753	2.120	0.000	0.000	0.015	0.217	0.006	0.066	0.000	0.001	0.007	26239.8
1	G200	0.873	1.796	0.004	0.000	0.038	0.305	0.000	0.087	0.000	0.000	0.006	23545.2
	G281	0.211	0.514	0.000	0.003	0.027	0.028	0.657	0.013	0.002	0.001	0.000	181045.5
	G284	0.643	0.964	0.006	0.003	0.069	0.144	0.005	0.037	0.000	0.000	0.001	165056.4
	G285	0.078	0.126	0.000	0.002	0.016	0.004	0.232	0.005	0.002	0.000	0.000	291604.7
	G286	0.574	0.891	0.000	0.003	0.092	0.052	0.006	0.012	0.002	0.001	0.003	166391.5
	G288	0.411	1.520	0.003	0.011	0.001	0.129	0.004	0.027	0.002	0.001	0.000	152459.2

Table B.10
LoE elemental concentration data for Matjesfontein

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G95	0.155	3.845	0.000	0.004	0.005	0.004	0.004	0.395	0.000	0.002	0.000	56535.7
1	G96	0.154	0.554	0.002	0.002	0.002	0.016	0.003	0.003	0.001	0.002	0.000	243412.4
2	G97	0.114	0.305	0.000	0.002	0.004	0.013	0.002	0.005	0.001	0.001	0.000	186703.4
2	G98	1.229	3.547	0.000	0.020	0.130	0.348	5.910	0.080	0.000	0.000	0.000	23402.6
3	G99	0.597	1.298	0.000	0.002	0.001	0.041	0.006	0.013	0.002	0.002	0.000	84321.9
3	G100	0.816	1.607	0.007	0.004	0.002	0.069	0.006	0.015	0.003	0.001	0.000	137147.7
4	G101	0.138	2.401	0.000	0.006	0.001	0.002	0.002	0.218	0.000	0.001	0.000	121606.1
4	G102	0.129	1.675	0.004	0.004	0.002	0.001	0.002	0.175	0.005	0.001	0.000	153734.7
5	G103	0.111	1.640	0.003	0.006	0.001	0.001	0.002	0.180	0.000	0.002	0.000	154767.9
5	G104	0.075	1.332	0.000	0.005	0.002	0.001	0.001	0.195	0.005	0.001	0.000	144825.2
6	G105	0.739	1.760	0.003	0.003	0.017	0.055	0.041	0.021	0.001	0.002	0.000	99552.7
6	G106	0.318	0.461	0.010	0.003	0.007	0.008	0.005	0.007	0.001	0.001	0.000	251309.5
3	G238	0.835	2.047	0.000	0.003	0.002	0.063	0.005	0.016	0.003	0.002	0.000	87665.5
4	G239	0.113	1.225	0.000	0.003	0.001	0.002	0.002	0.246	0.000	0.001	0.000	148057
5	G240	0.535	1.167	0.000	0.003	0.008	0.042	0.004	0.019	0.002	0.003	0.000	101486.3
1	G241	0.187	0.553	0.002	0.002	0.002	0.018	0.003	0.006	0.001	0.001	0.000	256523.5
2	G242	0.167	0.555	0.002	0.002	0.002	0.018	0.002	0.004	0.001	0.001	0.000	222257.3
6	G243	0.737	1.497	0.005	0.003	0.008	0.058	0.006	0.024	0.000	0.003	0.001	128127.9

Table B.11
LoE elemental concentration data for Oude Duinigt

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G179	0.397	2.785	0.000	0.000	0.002	0.108	0.005	0.066	0.002	0.001	0.000	24071.9
1	G180	0.371	3.364	0.000	0.000	0.006	0.130	0.004	0.086	0.003	0.000	0.000	67174.9
1	G181	0.356	3.615	0.000	0.003	0.002	0.134	0.004	0.076	0.000	0.000	0.000	72969.2
1	G217	0.195	2.112	0.000	0.003	0.004	0.004	0.004	0.023	0.003	0.001	0.000	85552.7
1	G218	2.911	4.065	0.000	0.007	0.000	0.049	0.048	0.032	0.000	0.000	0.012	97668

Table B.12

LoE elemental concentration data for Pinnacle Point A, B, and C

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G30	0.396	1.292	0.005	0.006	0.014	0.167	0.022	0.019	0.000	0.000	0.123	226235.7
1	G62	1.192	6.514	0.000	0.000	0.020	0.435	0.013	0.052	0.000	0.002	0.031	55015.2
4	G33	1.624	25.171	0.000	0.050	0.263	0.405	0.033	0.047	0.008	0.004	0.017	11330.3
2	G258	2.987	23.713	0.043	0.056	0.470	0.571	0.020	0.108	0.000	0.000	0.000	10589.1
2	G32	4.096	37.533	0.049	0.060	0.898	0.840	0.074	0.098	0.000	0.009	0.000	18937.3
3	G260	1.894	29.852	0.000	0.154	0.255	0.461	0.077	0.051	0.000	0.006	0.000	16834.1
2	G64	2.604	28.435	0.056	0.222	1.509	0.641	0.159	0.061	0.000	0.000	0.000	14571.8
3	G31	3.802	34.349	0.000	0.415	1.088	0.765	0.301	0.114	0.000	0.006	0.000	13022.2
3	G63	2.568	20.730	0.000	0.830	4.300	0.527	0.643	0.096	0.000	0.011	0.008	11218.7
5	G279	0.478	1.216	0.005	0.006	0.159	0.085	0.006	0.020	0.002	0.001	0.000	161588.6
6	G280	1.125	1.953	0.025	0.036	0.000	0.292	0.007	0.038	0.000	0.000	0.000	106959.2
6	G282	0.096	0.193	0.000	0.002	0.012	0.006	0.148	0.005	0.002	0.001	0.000	359251.7
6	G283	0.532	4.322	0.000	0.009	0.057	0.018	0.015	0.033	0.000	0.002	0.000	67154.5

Table B.13

LoE elemental concentration data for Rietvlei A

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G55	0.168	1.397	0.000	0.003	0.003	0.025	0.003	0.008	0.000	0.001	0.000	189755.4
2	G56	0.127	1.095	0.008	0.001	0.001	0.030	0.003	0.005	0.001	0.001	0.000	276494.5
3	G57	0.221	1.871	0.008	0.001	0.004	0.060	0.006	0.012	0.000	0.000	0.000	208282.9
3	G82	0.098	0.489	0.003	0.001	0.002	0.027	0.004	0.005	0.000	0.000	0.000	157908.5
2	G83	0.057	0.367	0.003	0.001	0.002	0.016	0.001	0.004	0.000	0.001	0.000	182530.7
1	G84	0.078	0.648	0.000	0.002	0.001	0.016	0.001	0.006	0.001	0.001	0.000	186271.5
4	G171	0.100	0.269	0.000	0.001	0.001	0.001	0.000	0.009	0.001	0.001	0.000	398731
1	G184	0.105	0.630	0.001	0.001	0.002	0.017	0.002	0.006	0.001	0.001	0.000	272716.1
2	G185	0.069	0.460	0.002	0.001	0.003	0.014	0.001	0.003	0.001	0.000	0.000	313151.3
3	G186	0.121	1.025	0.002	0.001	0.005	0.032	0.003	0.007	0.000	0.000	0.000	190941.5

Table B.14

LoE elemental concentration data for Rietvlei B

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G107	2.130	6.712	0.000	0.044	0.202	0.543	0.009	0.089	0.006	0.002	0.006	42329.3
1	G108	1.824	6.550	0.000	0.065	0.310	0.554	0.024	0.106	0.000	0.002	0.007	11154.7
1	G109	1.332	4.728	0.000	0.025	0.213	0.418	0.009	0.080	0.000	0.003	0.004	33345.5
2	G110	1.976	7.893	0.000	0.029	0.279	0.502	0.007	0.103	0.006	0.002	0.000	17700.8
2	G111	1.739	7.032	0.000	0.019	0.182	0.409	0.007	0.088	0.000	0.000	0.000	43211.2
2	G112	1.707	7.527	0.000	0.034	0.364	0.399	0.008	0.087	0.000	0.002	0.000	28824.7
3	G113	3.081	9.558	0.000	0.064	0.465	0.860	0.016	0.162	0.000	0.000	0.006	32089.3
3	G114	3.569	11.018	0.000	0.030	0.434	0.913	0.019	0.212	0.000	0.000	0.011	18581.4
3	G115	3.107	9.047	0.000	0.034	0.370	0.825	0.010	0.157	0.012	0.000	0.004	25961.5
4	G116	1.633	6.017	0.010	0.021	0.202	0.468	0.009	0.084	0.000	0.003	0.014	34652.2
4	G117	2.171	7.615	0.000	0.020	0.278	0.578	0.012	0.110	0.000	0.004	0.010	53785.6
4	G118	3.877	14.870	0.000	0.030	0.393	0.842	0.020	0.175	0.015	0.000	0.006	30294.2
5	G119	2.780	9.939	0.000	0.040	0.254	0.719	0.011	0.139	0.000	0.004	0.005	22905
5	G120	2.800	9.135	0.000	0.062	0.470	0.787	0.010	0.150	0.000	0.000	0.006	33179.4
5	G121	3.793	9.368	0.000	0.129	0.675	1.246	0.045	0.230	0.000	0.000	0.009	42303.6
2	G187	1.482	5.365	0.007	0.018	0.254	0.374	0.008	0.086	0.005	0.000	0.005	35169.5
3	G188	1.794	7.536	0.017	0.029	0.159	0.483	0.014	0.113	0.000	0.000	0.008	26509
4	G189	1.958	6.840	0.000	0.026	0.427	0.624	0.012	0.140	0.000	0.002	0.030	25617.7
5	G190	1.693	7.980	0.000	0.030	0.274	0.504	0.012	0.126	0.000	0.000	0.005	41006.1
1	G191	0.851	3.196	0.000	0.024	0.252	0.311	0.007	0.073	0.000	0.000	0.003	39123.8

Table B.15

LoE elemental concentration data for Rivercrossing

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G140	0.416	22.634	0.000	0.023	0.012	0.017	0.010	0.534	0.000	0.007	0.000	18547.2
1	G141	0.449	17.448	0.000	0.015	0.014	0.010	0.008	0.418	0.000	0.004	0.000	28195.6
2	G142	0.175	4.389	0.000	0.007	0.002	0.002	0.002	0.117	0.000	0.001	0.000	17680.2
2	G143	2.304	31.481	0.000	0.000	0.013	0.025	0.016	0.891	0.000	0.008	0.000	26467.4
3	G144	0.486	18.347	0.000	0.012	0.007	0.015	0.004	0.214	0.000	0.003	0.004	10708.9
3	G145	0.458	19.874	0.000	0.013	0.009	0.016	0.006	0.227	0.000	0.008	0.000	13291.7
4	G146	0.276	12.575	0.000	0.000	0.000	0.007	0.000	0.140	0.007	0.000	0.000	82355.9
4	G147	0.790	14.820	0.000	0.050	0.020	0.022	0.014	0.145	0.000	0.000	0.009	20291.6
5	G148	1.319	35.416	0.000	0.020	0.000	0.042	0.014	0.689	0.000	0.000	0.000	23120.9
5	G149	0.912	26.877	0.000	0.000	0.008	0.021	0.005	0.454	0.000	0.000	0.000	10219.9
1	G227	0.315	18.155	0.000	0.000	0.014	0.007	0.008	0.413	0.000	0.000	0.000	24770.8
2	G228	4.885	29.633	0.034	0.014	0.039	0.031	0.031	0.695	0.000	0.000	0.006	36164.1
4	G229	0.196	8.132	0.000	0.006	0.006	0.006	0.007	0.089	0.000	0.000	0.000	20755.6
3	G230	0.298	13.395	0.013	0.006	0.008	0.008	0.003	0.147	0.000	0.001	0.000	19600.5
5	G231	0.381	12.894	0.000	0.005	0.000	0.012	0.003	0.185	0.000	0.005	0.000	11712.9

Table B.16

LoE elemental concentration data for Riversdale

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G53	2.173	8.659	0.000	0.013	0.091	0.174	0.055	0.099	0.000	0.003	0.003	41153.6
2	G54	11.558	12.733	0.000	0.009	0.034	0.013	0.011	0.005	0.000	0.004	0.000	18357.9
1	G79	1.154	5.766	0.000	0.006	0.018	0.106	0.013	0.092	0.006	0.004	0.004	34532.8
2	G81	8.390	9.488	0.000	0.011	0.054	0.020	0.012	0.008	0.000	0.003	0.000	14663.6
1	G254	1.893	7.296	0.014	0.015	0.011	0.126	0.015	0.100	0.000	0.003	0.000	30615.1
2	G255	9.857	10.672	0.000	0.010	0.016	0.016	0.015	0.015	0.000	0.006	0.000	16229

Table B.17

LoE elemental concentration data for Roodekrans

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G175	0.157	5.173	0.000	0.000	0.000	0.005	0.002	0.161	0.000	0.002	0.000	64314.1
1	G176	0.185	6.374	0.000	0.003	0.005	0.005	0.000	0.208	0.000	0.000	0.000	55839.5
2	G177	1.231	40.337	0.000	0.022	0.012	0.045	0.022	0.881	0.000	0.010	0.000	8887.7
2	G178	1.524	23.042	0.000	0.000	0.012	0.047	0.019	0.576	0.000	0.006	0.000	15264.8
1	G244	0.101	4.378	0.000	0.005	0.000	0.005	0.003	0.210	0.000	0.002	0.002	70565.6
2	G245	0.837	26.138	0.000	0.033	0.046	0.025	0.013	0.775	0.000	0.011	0.000	12375.6

Table B.18

LoE elemental concentration data for Rooikoppie

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G8	0.133	0.473	0.006	0.003	0.003	0.049	0.004	0.010	0.000	0.000	0.000	130024.4
1	G42	0.205	0.716	0.005	0.005	0.006	0.056	0.003	0.012	0.000	0.001	0.000	275785.6
1	G205	0.124	0.488	0.007	0.002	0.005	0.039	0.003	0.009	0.000	0.000	0.000	135282
2	G7	0.065	0.169	0.011	0.005	0.001	0.010	0.001	0.003	0.000	0.000	0.000	554930.8
2	G12	0.078	0.282	0.007	0.007	0.008	0.018	0.004	0.004	0.000	0.000	0.000	157539.8
2	G43	0.067	0.176	0.005	0.008	0.013	0.011	0.004	0.002	0.000	0.000	0.000	299955.3
2	G204	0.078	0.306	0.005	0.005	0.006	0.020	0.001	0.004	0.000	0.000	0.000	119902.8
3	G11	0.241	0.806	0.012	0.007	0.010	0.064	0.006	0.011	0.001	0.000	0.000	333353
3	G41	0.157	0.465	0.007	0.005	0.015	0.038	0.002	0.008	0.001	0.000	0.000	463599
3	G206	0.112	0.415	0.006	0.004	0.009	0.036	0.001	0.008	0.000	0.000	0.001	335262.3
4	G10	0.899	1.992	0.029	0.303	0.014	0.207	0.008	0.027	0.002	0.002	0.000	193966.9
4	G13	0.552	1.769	0.013	0.007	0.003	0.171	0.025	0.034	0.000	0.000	0.001	71895.8
4	G44	0.357	1.018	0.013	0.005	0.002	0.089	0.003	0.015	0.001	0.000	0.001	225470.2
4	G269	0.752	3.449	0.013	0.008	0.003	0.227	0.016	0.043	0.000	0.000	0.000	36133.6
4	G270	0.248	0.687	0.009	0.003	0.002	0.075	0.002	0.015	0.000	0.000	0.001	468803.6
5	G9	0.435	1.068	0.018	0.135	0.005	0.110	0.003	0.017	0.000	0.001	0.000	132593.9
5	G45	0.781	1.648	0.023	0.210	0.011	0.166	0.004	0.026	0.000	0.000	0.000	81910.1
5	G272	0.914	3.981	0.026	0.915	0.503	0.345	1.160	0.063	0.000	0.000	0.006	95222.2
5	G273	1.382	4.040	0.000	0.011	0.203	0.340	0.021	0.073	0.000	0.002	0.005	40396.7
5	G274	0.364	1.514	0.018	0.032	0.135	0.130	0.174	0.039	0.000	0.000	0.004	427250.3
6	G14	0.517	1.817	0.015	0.009	0.004	0.158	0.003	0.035	0.000	0.002	0.000	187010
6	G40	0.585	1.974	0.010	0.011	0.020	0.138	0.004	0.032	0.003	0.000	0.000	282658.7
6	G207	0.515	2.064	0.021	0.005	0.003	0.154	0.005	0.029	0.000	0.000	0.001	136784.7
6	G208	0.494	1.617	0.017	0.015	0.031	0.147	0.004	0.029	0.002	0.001	0.000	374574.1
6	G209	0.175	0.415	0.006	0.051	0.001	0.057	0.001	0.011	0.000	0.000	0.000	270538.8
7	G39	0.260	0.908	0.015	0.018	0.109	0.069	0.009	0.014	0.000	0.000	0.000	290031.5
8	G38	0.209	0.669	0.020	0.008	0.005	0.058	0.002	0.011	0.000	0.000	0.000	121148.3

Table B.19

LoE elemental concentration data for Ruiterskraal

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G130	0.159	0.233	0.000	0.002	0.001	0.011	0.002	0.004	0.000	0.001	0.000	270657.8
1	G131	0.115	0.201	0.002	0.001	0.001	0.009	0.002	0.004	0.000	0.001	0.000	325563.3
2	G132	0.339	0.818	0.000	0.004	0.001	0.112	0.003	0.021	0.003	0.001	0.000	163454.7
2	G133	0.303	0.817	0.002	0.004	0.003	0.093	0.002	0.017	0.003	0.001	0.000	209384.7
3	G134	0.264	0.319	0.003	0.001	0.001	0.007	0.001	0.002	0.000	0.001	0.000	302245.5
3	G135	0.205	0.279	0.000	0.001	0.003	0.007	0.001	0.002	0.000	0.001	0.000	330199.9
4	G136	0.069	0.226	0.000	0.001	0.002	0.006	0.001	0.005	0.000	0.001	0.000	410105.2
4	G137	0.052	0.144	0.000	0.002	0.003	0.002	0.001	0.003	0.000	0.001	0.000	437306.9
5	G138	0.380	0.787	0.001	0.000	0.001	0.043	0.003	0.012	0.000	0.001	0.000	221819
5	G139	0.311	0.662	0.000	0.001	0.001	0.040	0.003	0.010	0.000	0.001	0.000	255972.1
1	G221	0.121	0.213	0.002	0.002	0.001	0.007	0.003	0.003	0.000	0.000	0.000	237266.3
2	G222	0.359	0.932	0.002	0.006	0.004	0.096	0.005	0.020	0.002	0.002	0.000	192542.1
4	G223	0.065	0.206	0.000	0.002	0.003	0.005	0.001	0.003	0.000	0.001	0.000	411265.9
5	G224	0.353	0.798	0.004	0.001	0.001	0.038	0.003	0.010	0.001	0.000	0.000	225996.3
3	G225	0.264	0.475	0.003	0.002	0.001	0.010	0.001	0.003	0.000	0.001	0.000	271364.1

Table B.20

LoE elemental concentration data for R328A

Fragment	*Sample*	*Al/Fe*	*Si/Fe*	*P/Fe*	*S/Fe*	*Cl/Fe*	*K/Fe*	*Ca/Fe*	*Ti/Fe*	*V/Fe*	*Cr/Fe*	*Mn/Fe*	*Fe*
1	G150	0.166	4.476	0.000	0.004	0.002	0.004	0.004	0.184	0.005	0.001	0.000	72097.1
1	G151	0.163	2.836	0.000	0.004	0.004	0.001	0.001	0.163	0.000	0.000	0.000	103017.8
1	G152	0.165	3.620	0.000	0.009	0.008	0.005	0.011	0.201	0.000	0.002	0.000	95287.1
2	G153	3.077	3.273	0.000	0.004	0.004	0.005	0.000	0.024	0.003	0.002	0.000	50590.8
2	G154	1.044	1.106	0.000	0.004	0.004	0.011	0.003	0.018	0.003	0.001	0.001	125141
2	G155	2.819	3.052	0.000	0.003	0.004	0.012	0.003	0.049	0.000	0.003	0.000	52573.8
3	G156	0.210	0.606	0.000	0.001	0.001	0.001	0.000	0.015	0.003	0.002	0.000	264850.9
3	G157	0.611	1.349	0.000	0.001	0.005	0.005	0.001	0.030	0.002	0.003	0.000	155595.5
3	G158	0.513	0.981	0.000	0.000	0.002	0.002	0.002	0.043	0.000	0.002	0.000	154327.4
4	G159	0.919	1.252	0.000	0.002	0.004	0.002	0.001	0.073	0.000	0.003	0.000	122398.8
4	G160	0.791	1.240	0.000	0.000	0.004	0.003	0.001	0.067	0.004	0.001	0.000	149541.4
5	G161	0.108	5.170	0.000	0.000	0.000	0.003	0.001	0.206	0.000	0.000	0.000	71102.8
5	G162	0.137	5.006	0.000	0.000	0.005	0.003	0.002	0.166	0.000	0.000	0.001	69073.5
2	G246	2.489	2.564	0.000	0.004	0.002	0.015	0.003	0.031	0.002	0.002	0.000	54851.7
5	G247	0.138	6.649	0.000	0.006	0.004	0.004	0.004	0.225	0.000	0.003	0.000	48596.3
4	G248	0.963	1.549	0.000	0.003	0.002	0.004	0.002	0.080	0.000	0.002	0.000	115205.6
1	G249	0.153	2.607	0.004	0.004	0.002	0.002	0.002	0.074	0.000	0.000	0.000	118838.1
3	G250	0.320	0.661	0.002	0.001	0.001	0.002	0.003	0.022	0.003	0.003	0.000	193318.9

APPENDIX C

ARCHAEOLOGICAL SAMPLES XRD PATTERNS

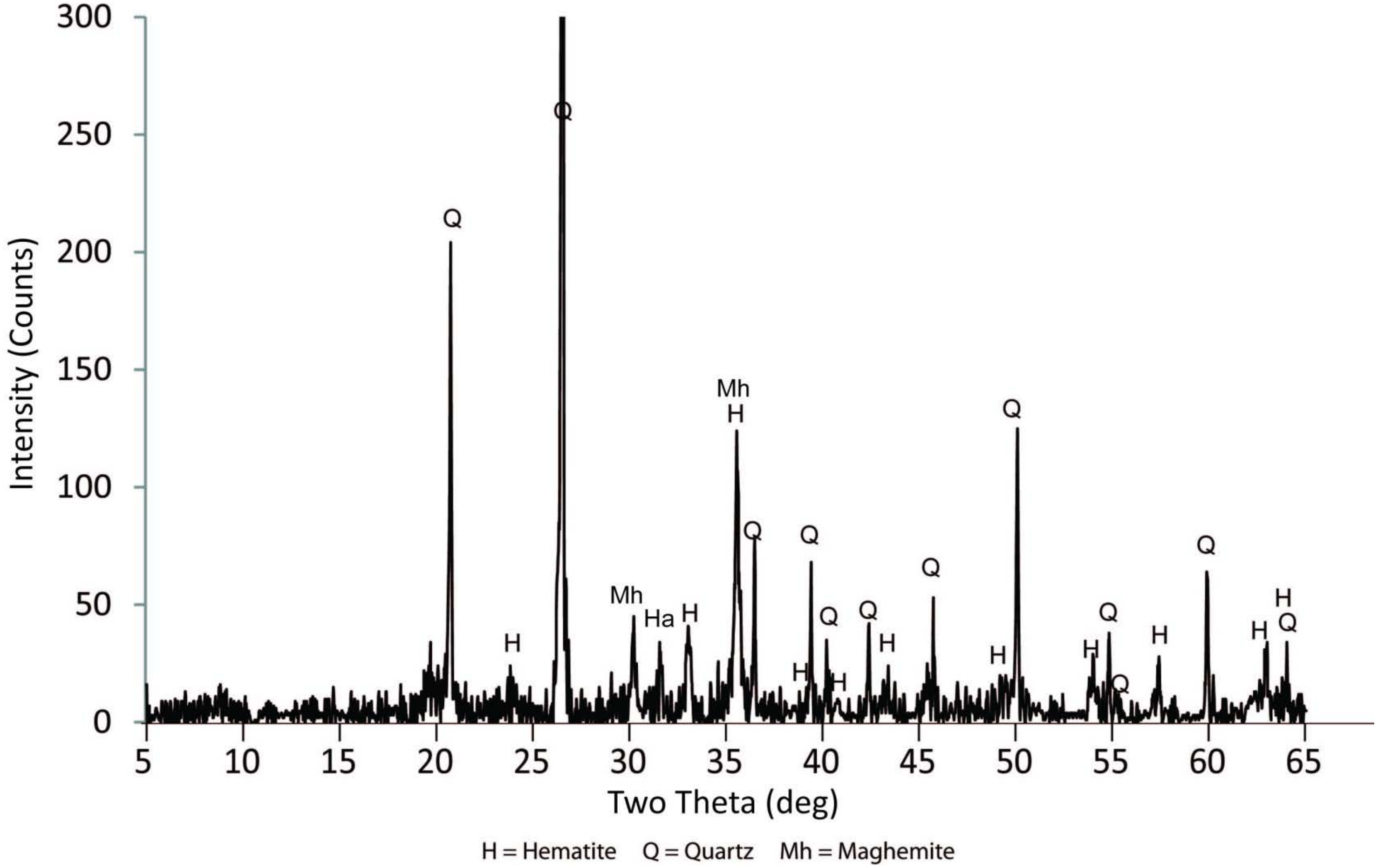


Fig. C.1. LC-MSA Lower 5950

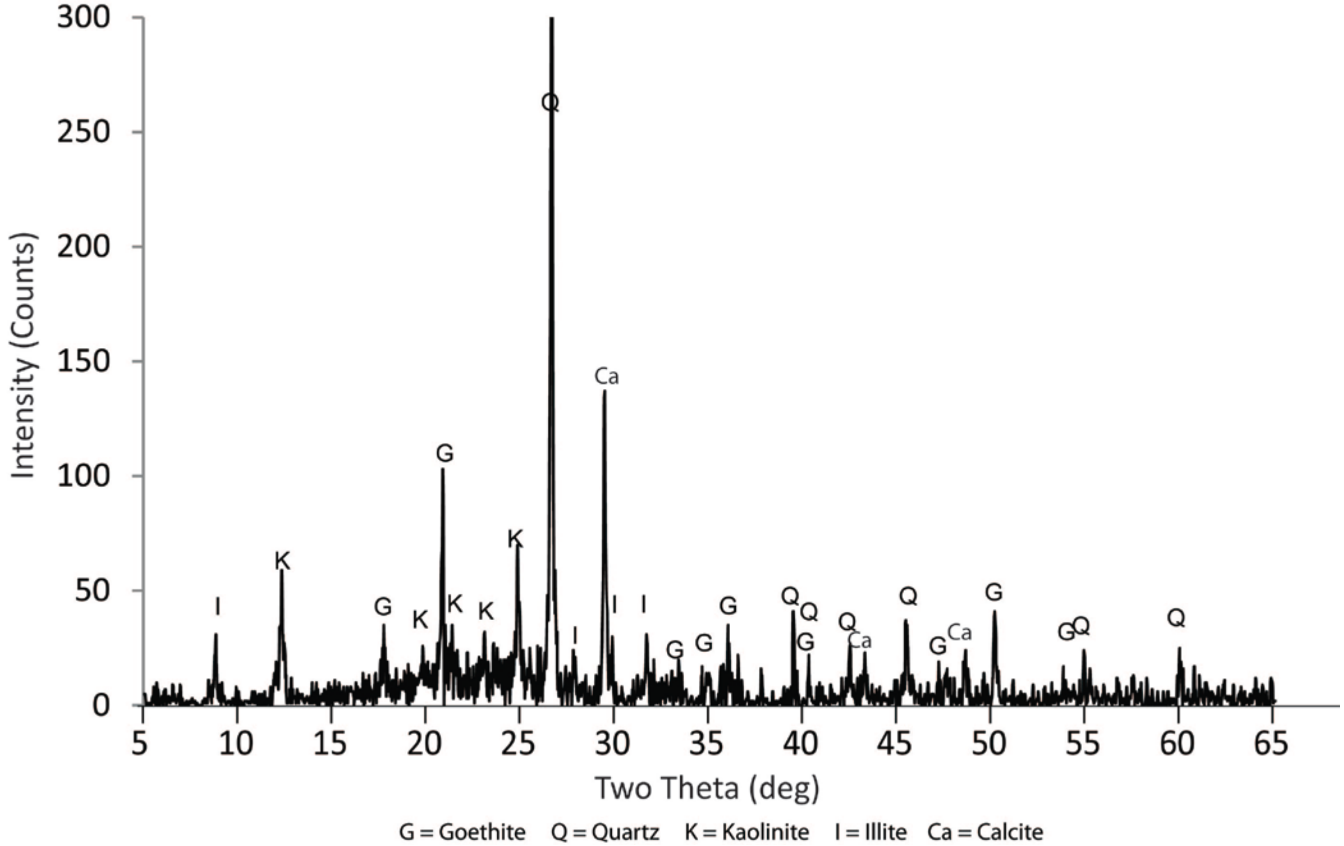


Fig. C.2. LC-MSA Lower 80427

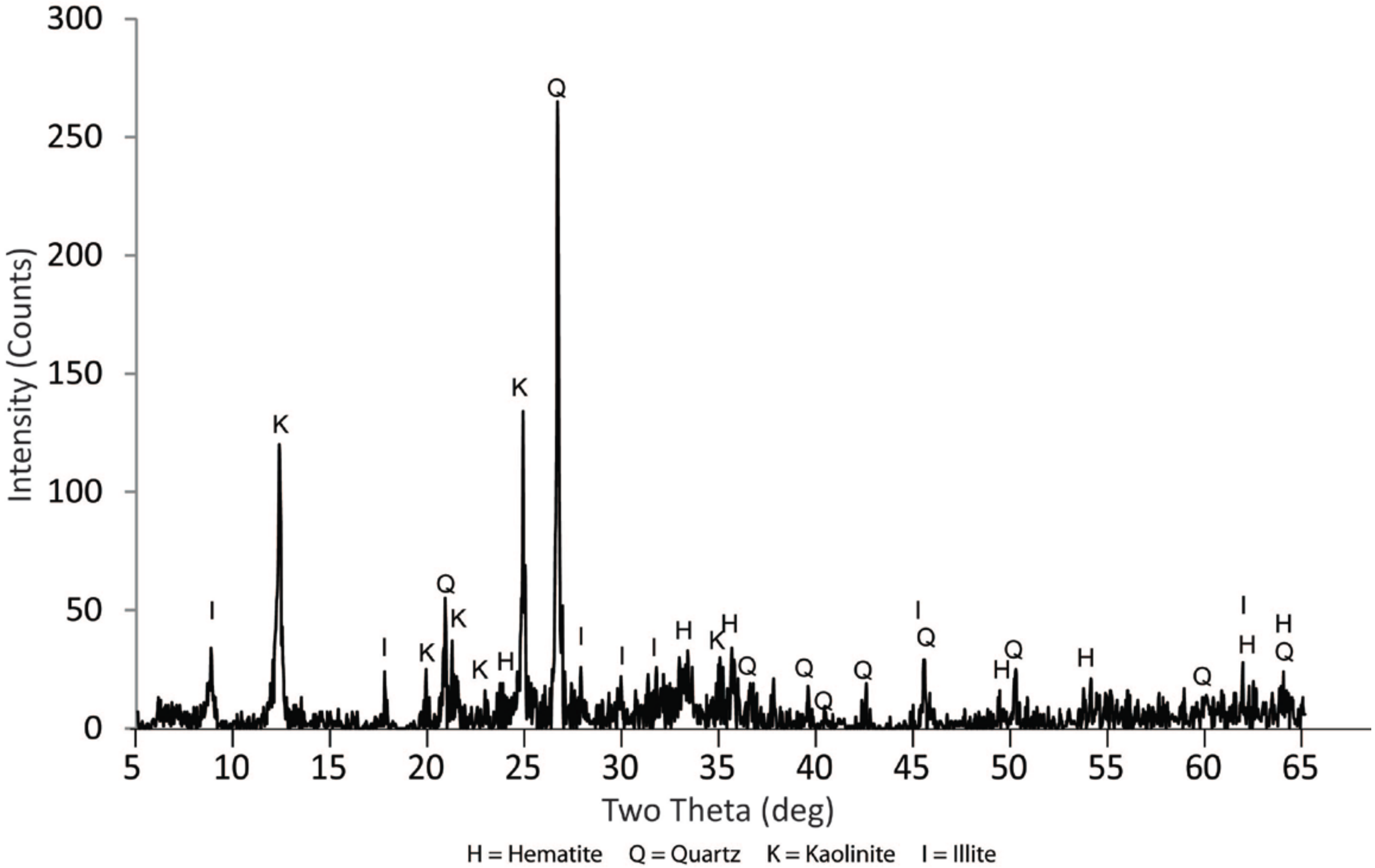


Fig. C.3. LC-MSA Lower 81745

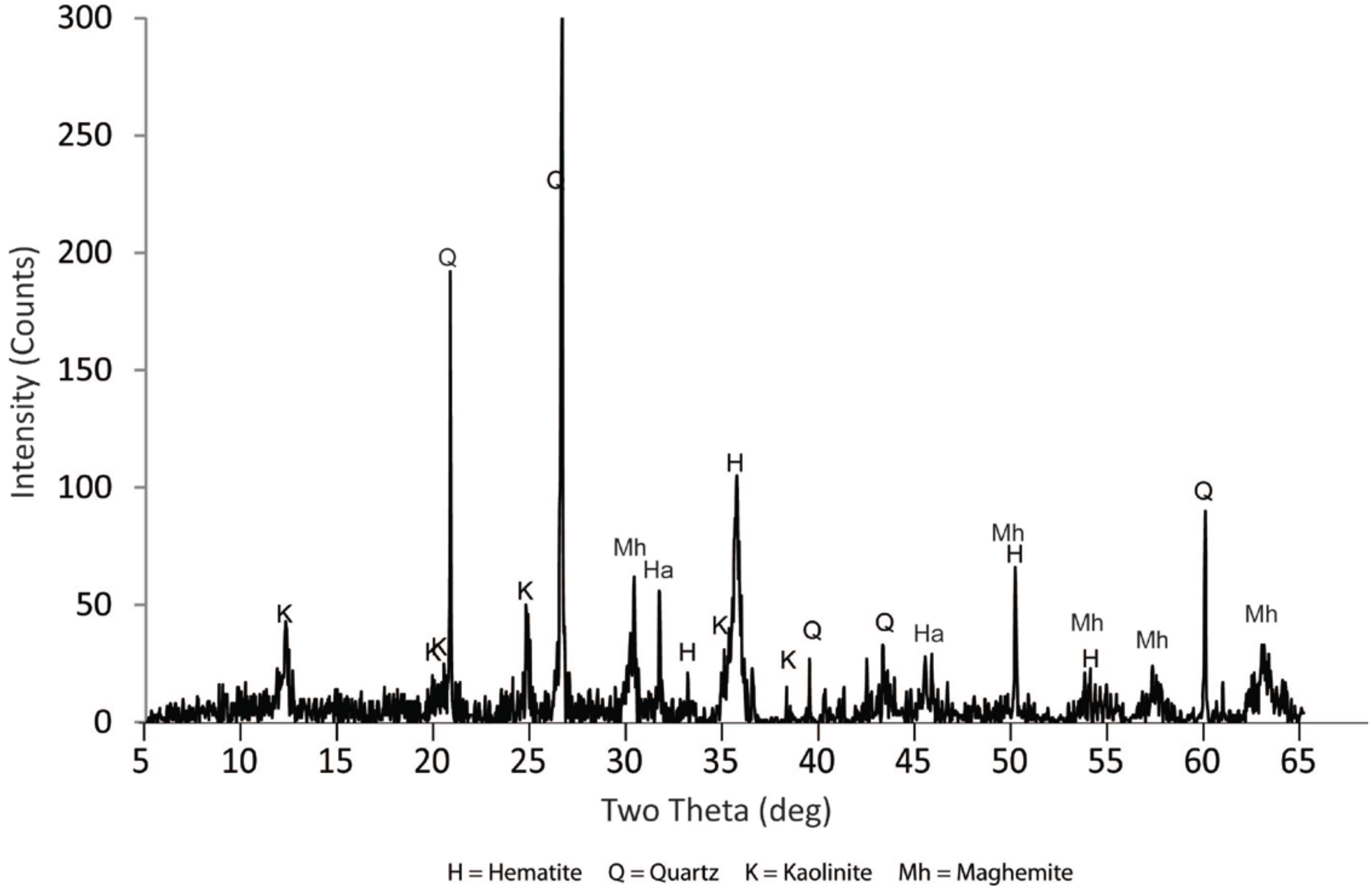


Fig. C.4. Upper Roofspall 59549

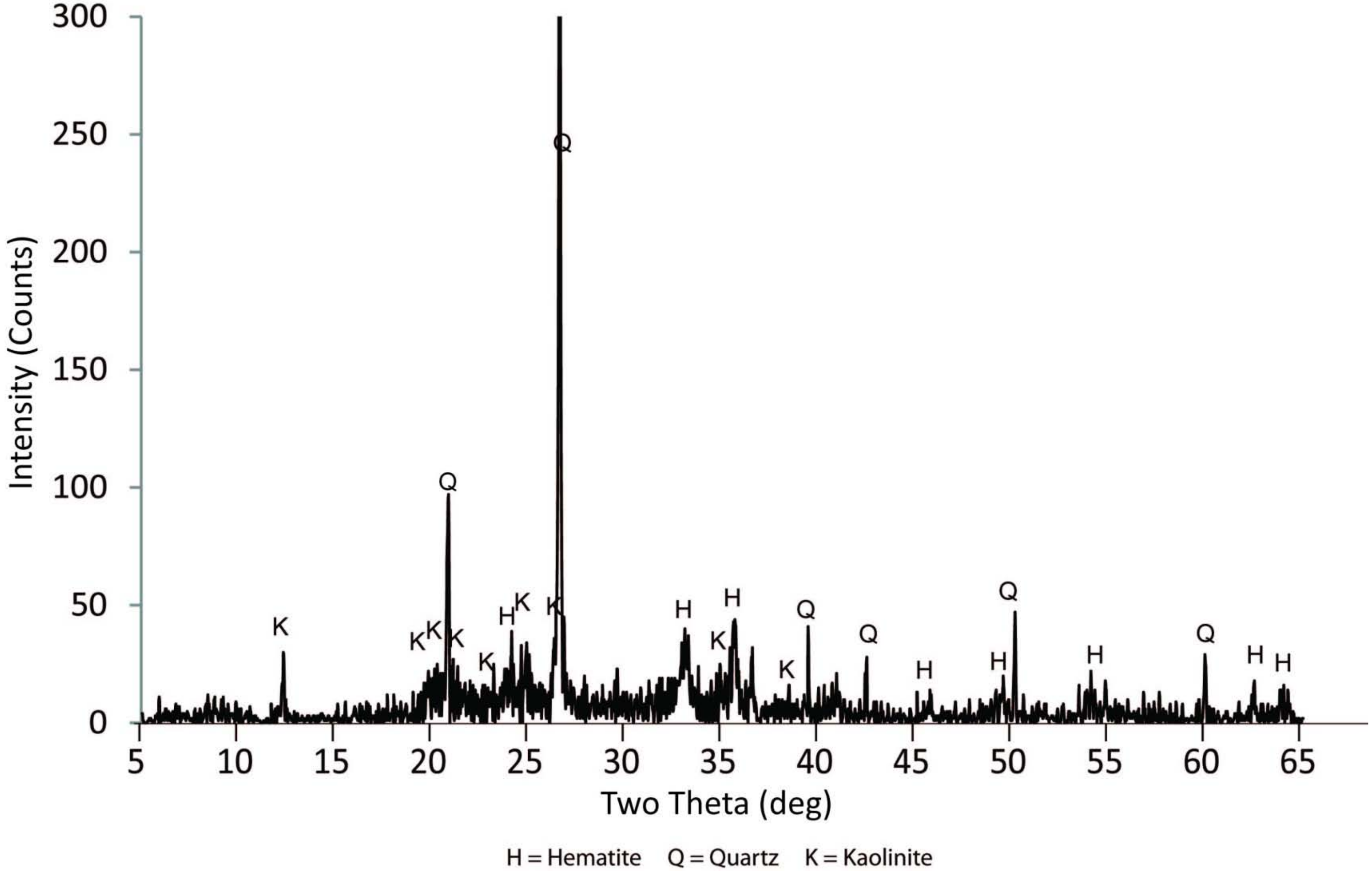


Fig. C.5. Upper Roofspall 111483

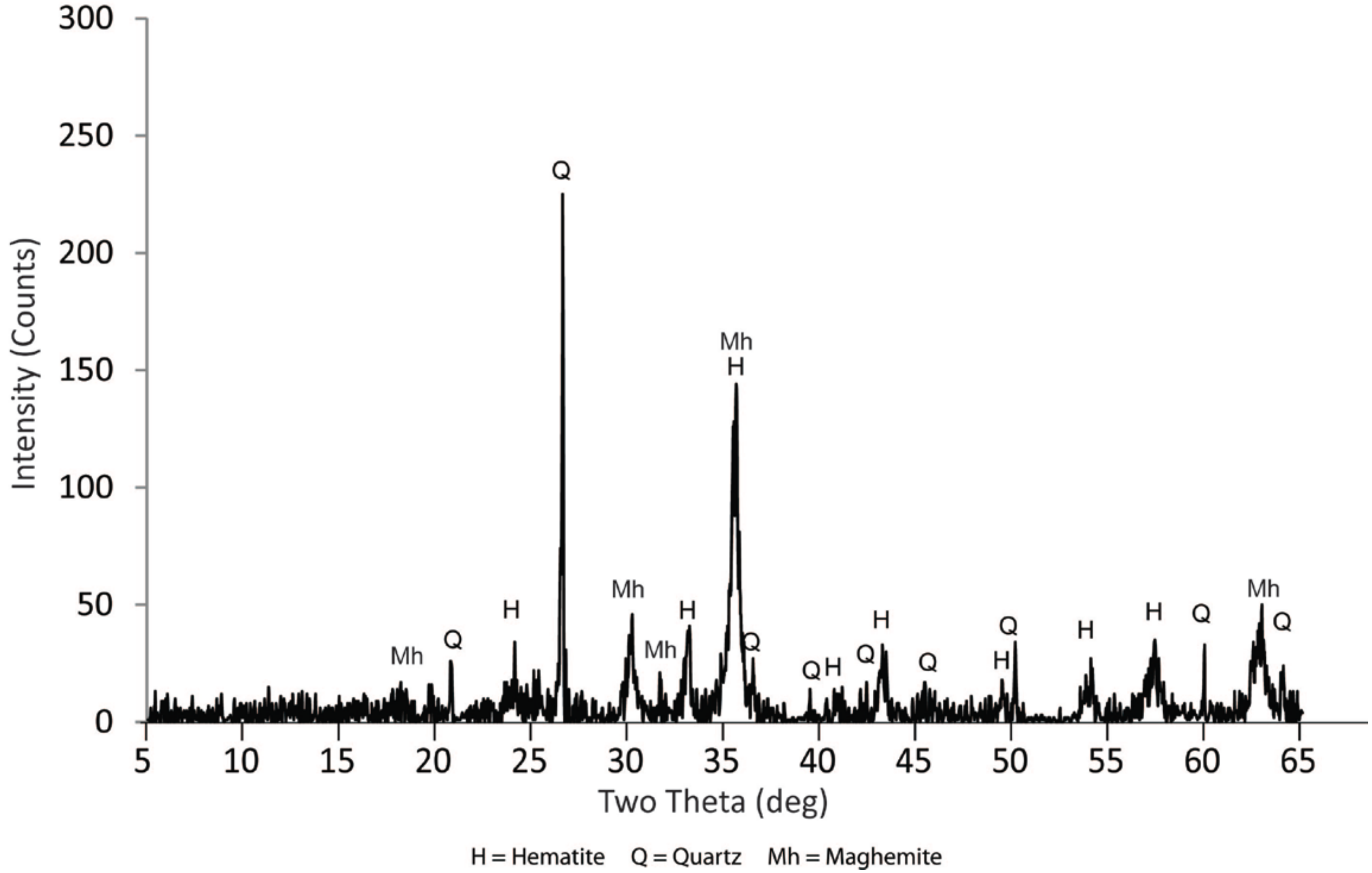


Fig. C.6. Shelly Brown Sand 52493

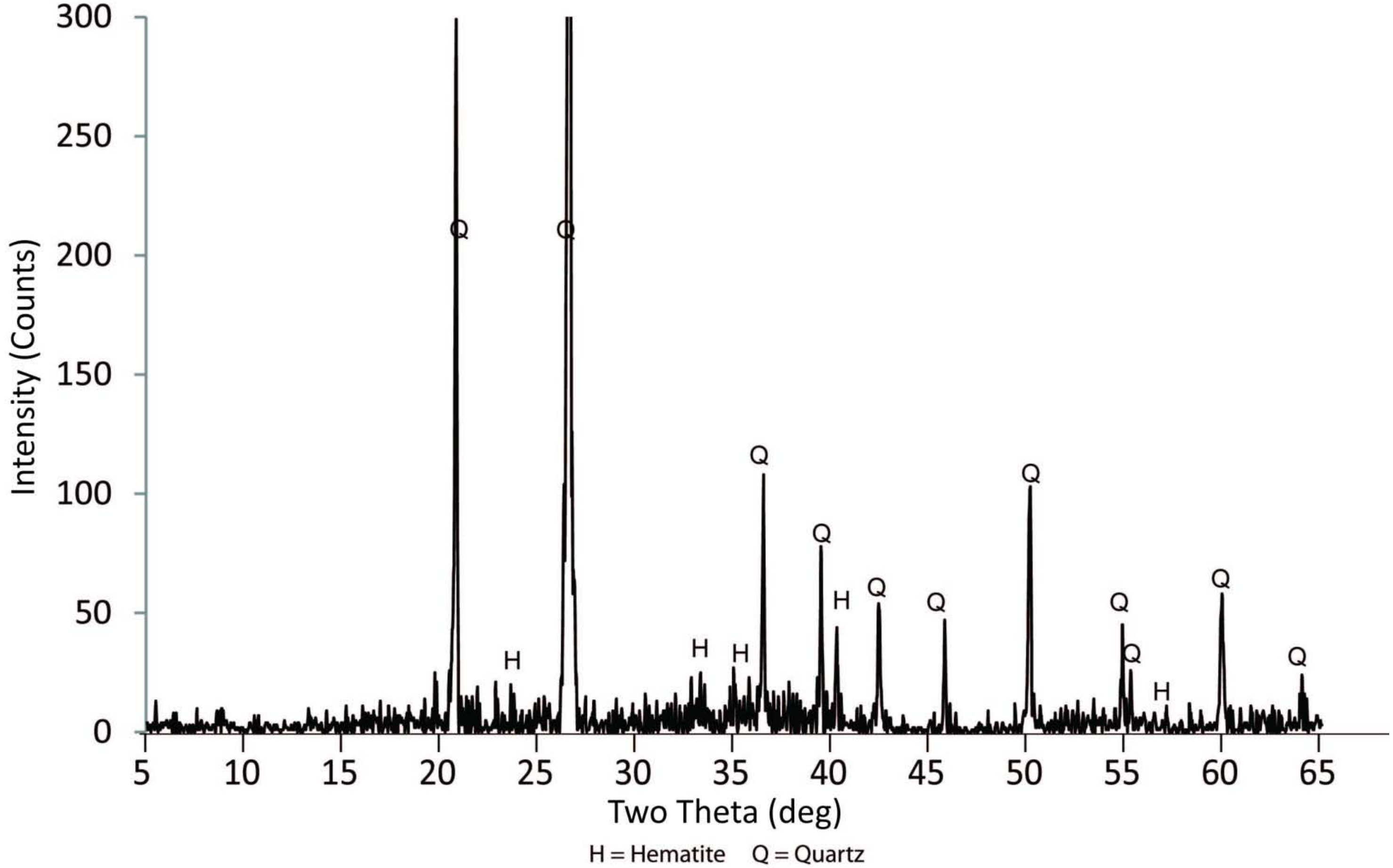


Fig. C.7. Shelly Brown Sand 56924

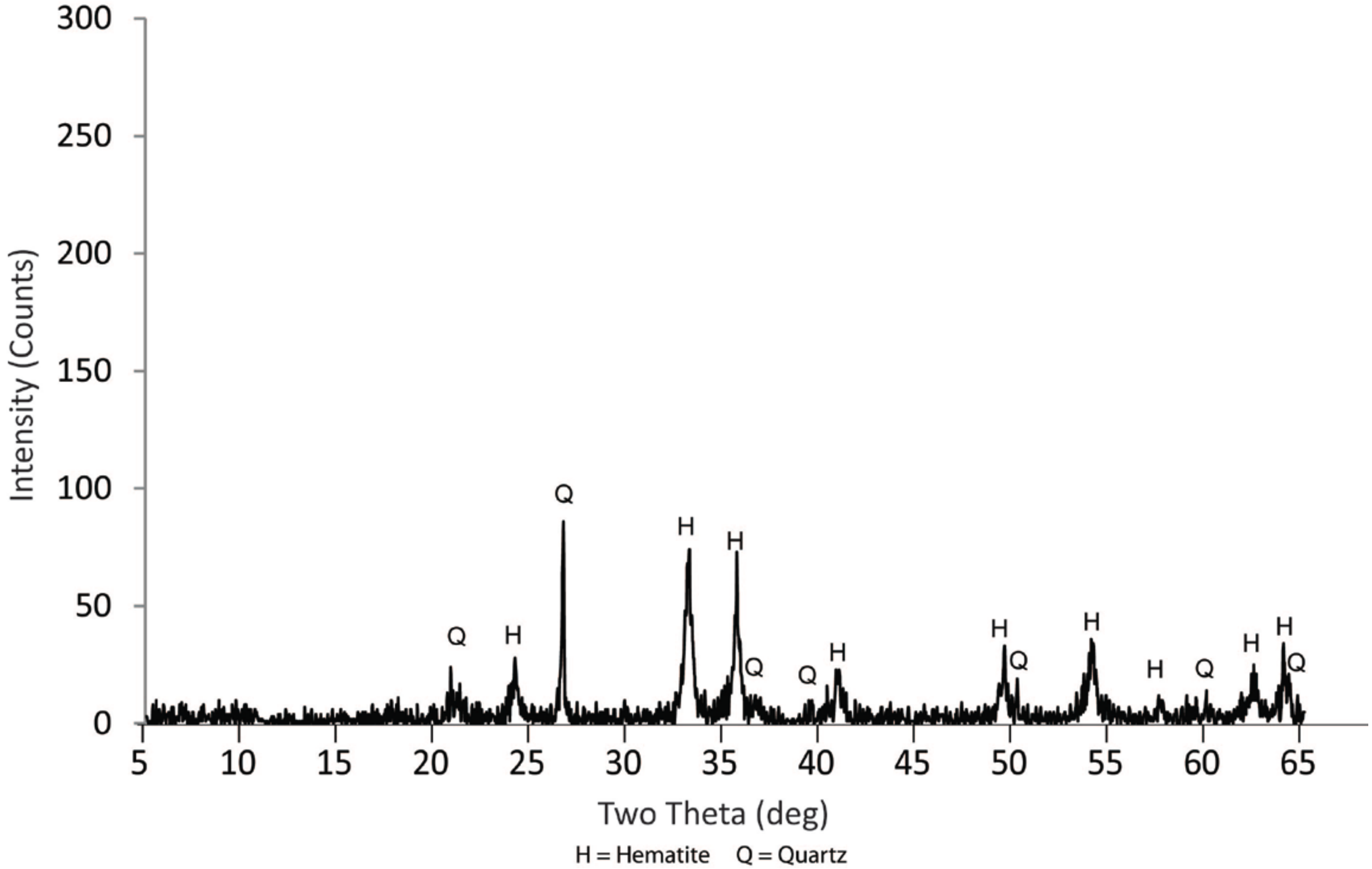


Fig. C.8. Shelly Brown Sand 57070

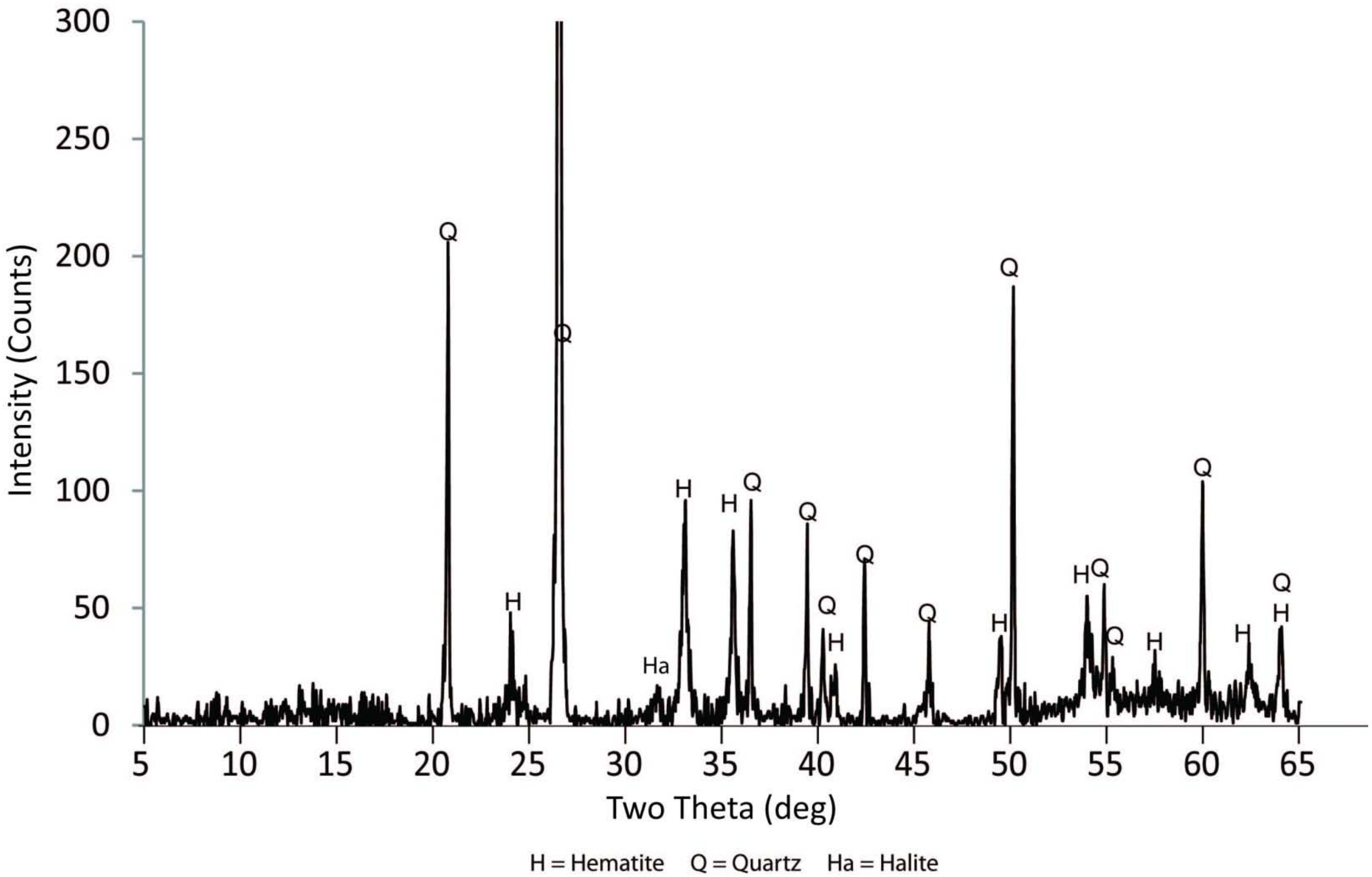


Fig. C.9. Truncation Fill 31404

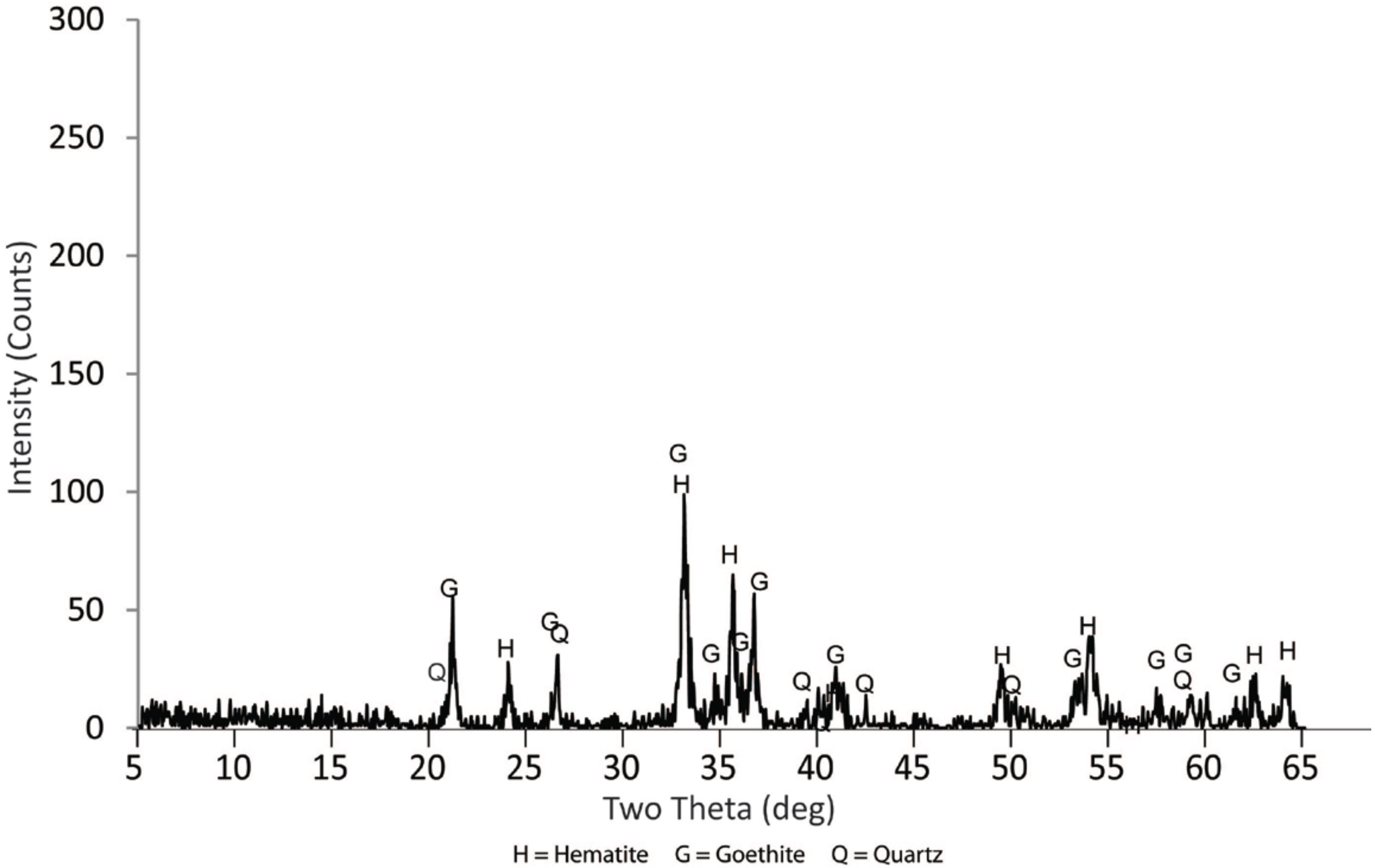


Fig. C.10. Truncation Fill 59548

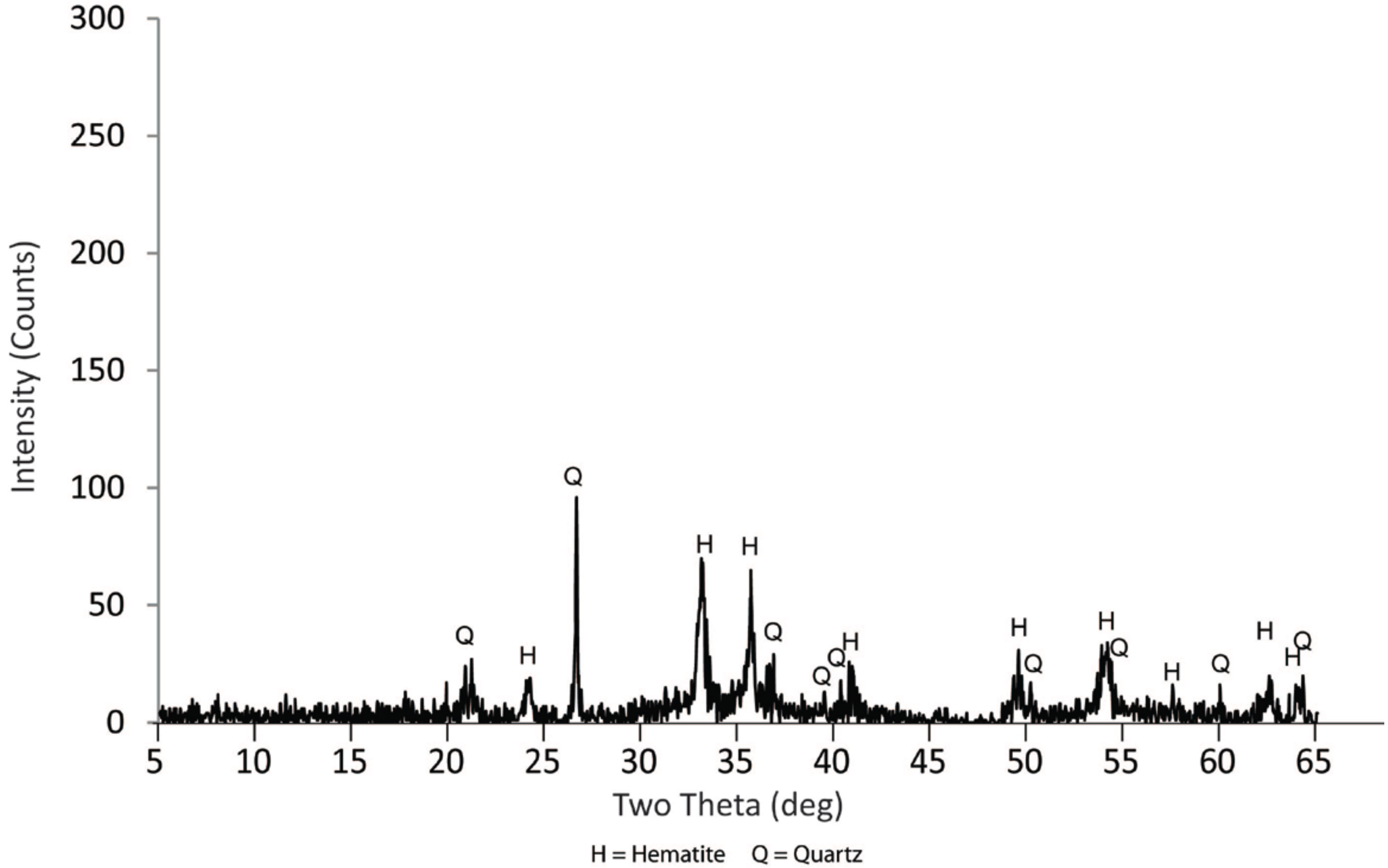


Fig. C.11. Redeposited Disturbance 25992

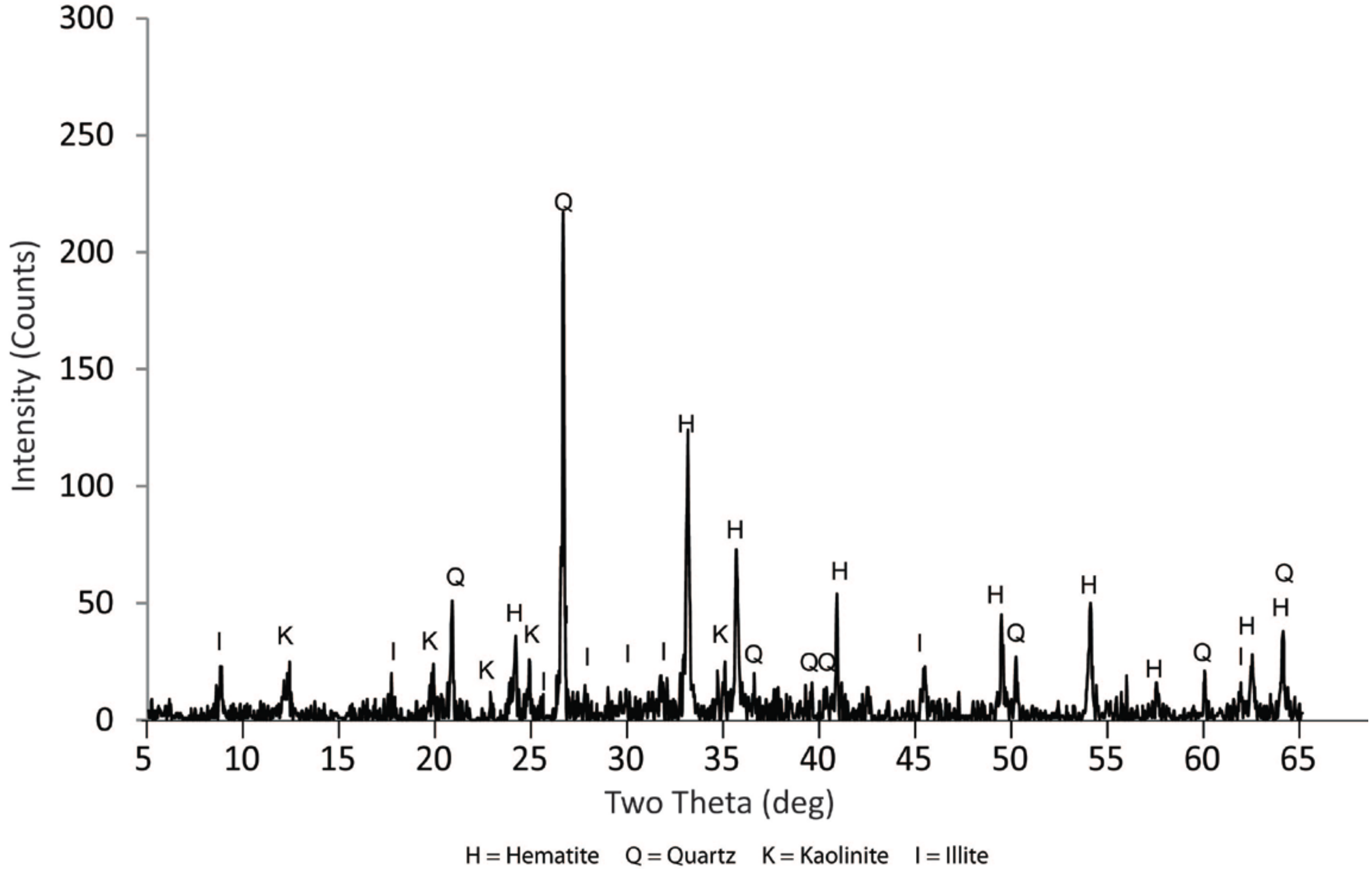


Fig. C.12. Redeposited Disturbance 30255

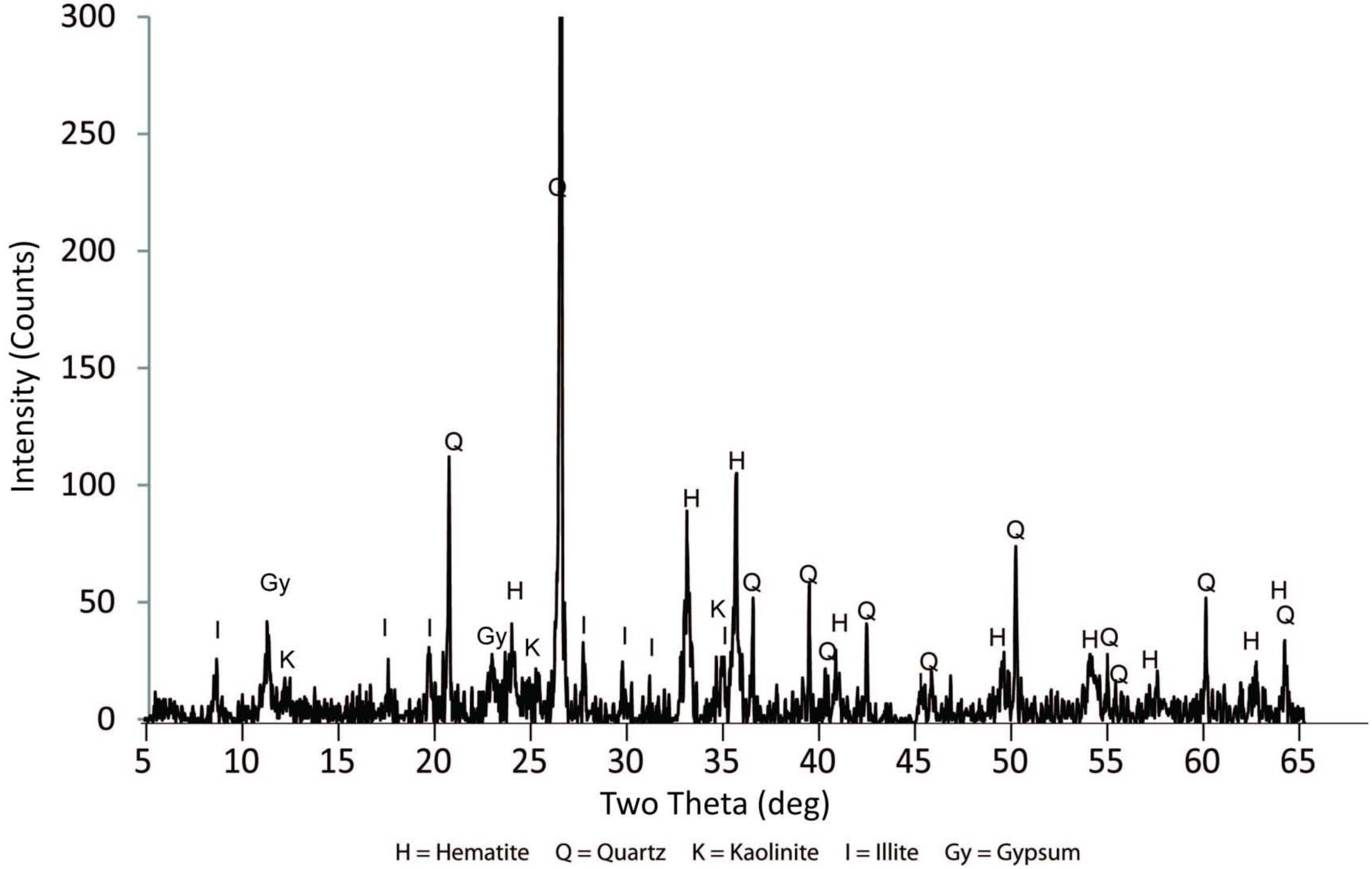


Fig. C.13. Eastern Surface 26091

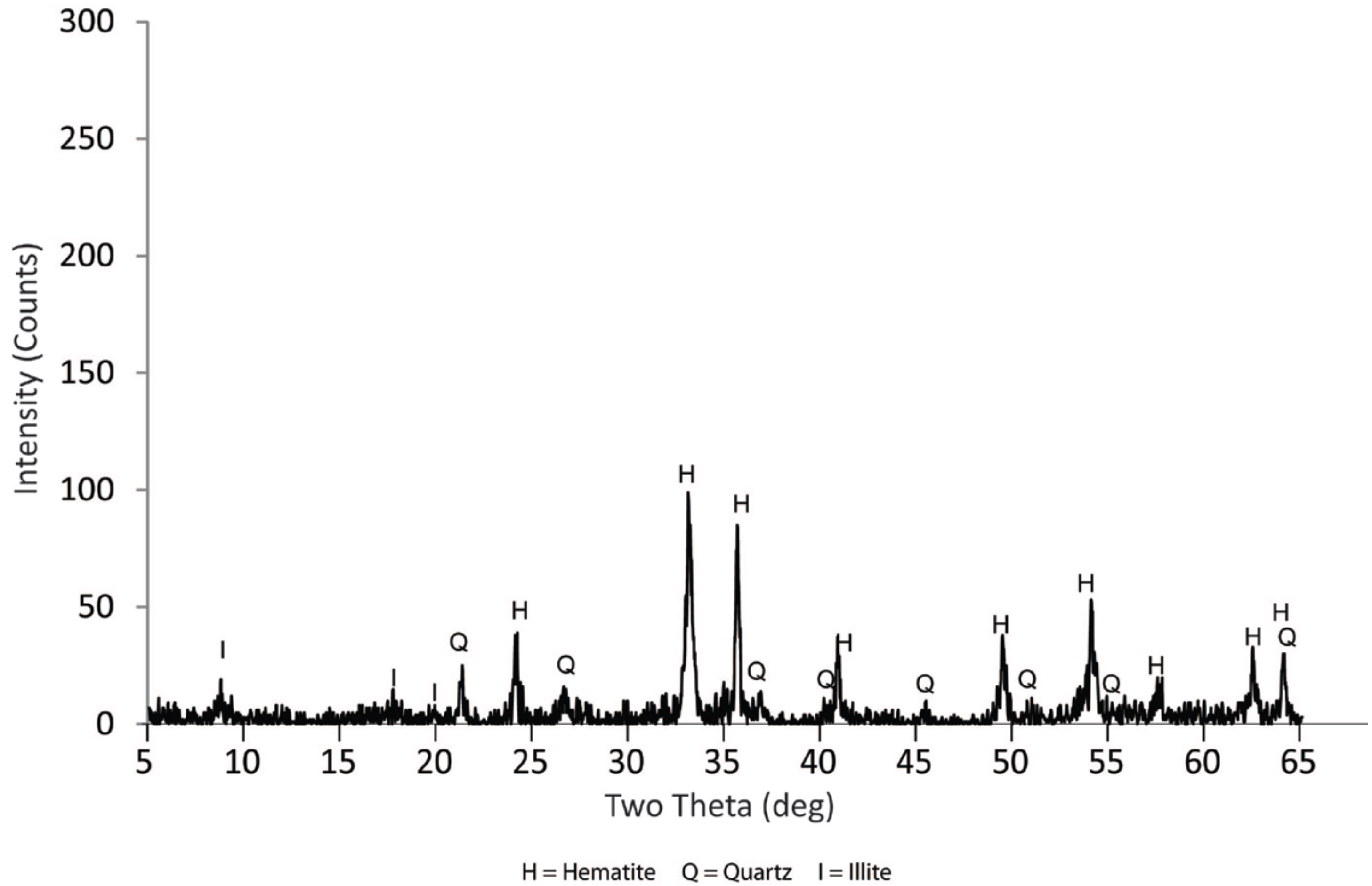


Fig. C.14. Eastern Surface 59519

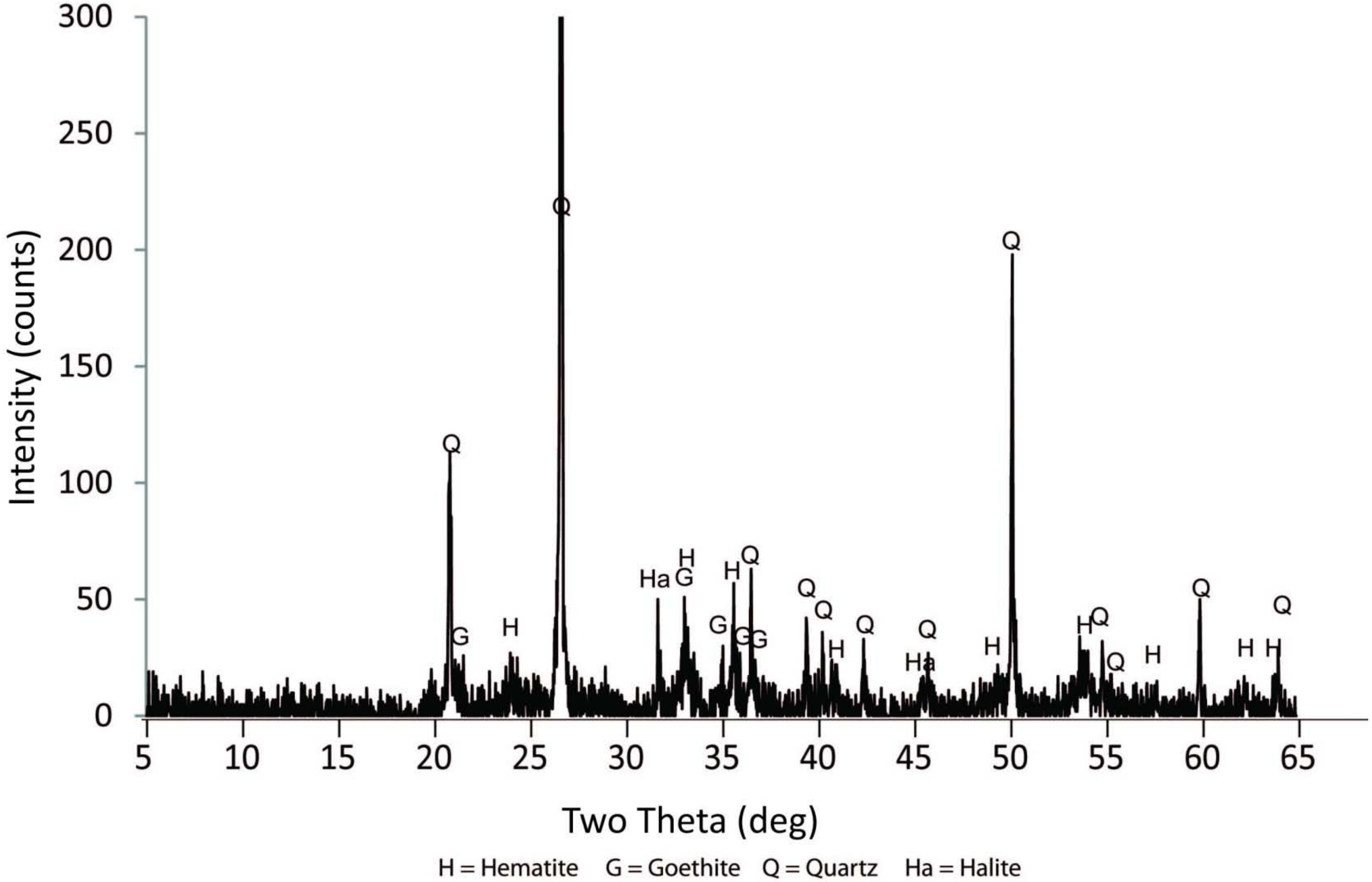


Fig. C.15. DB Sand 2 22873

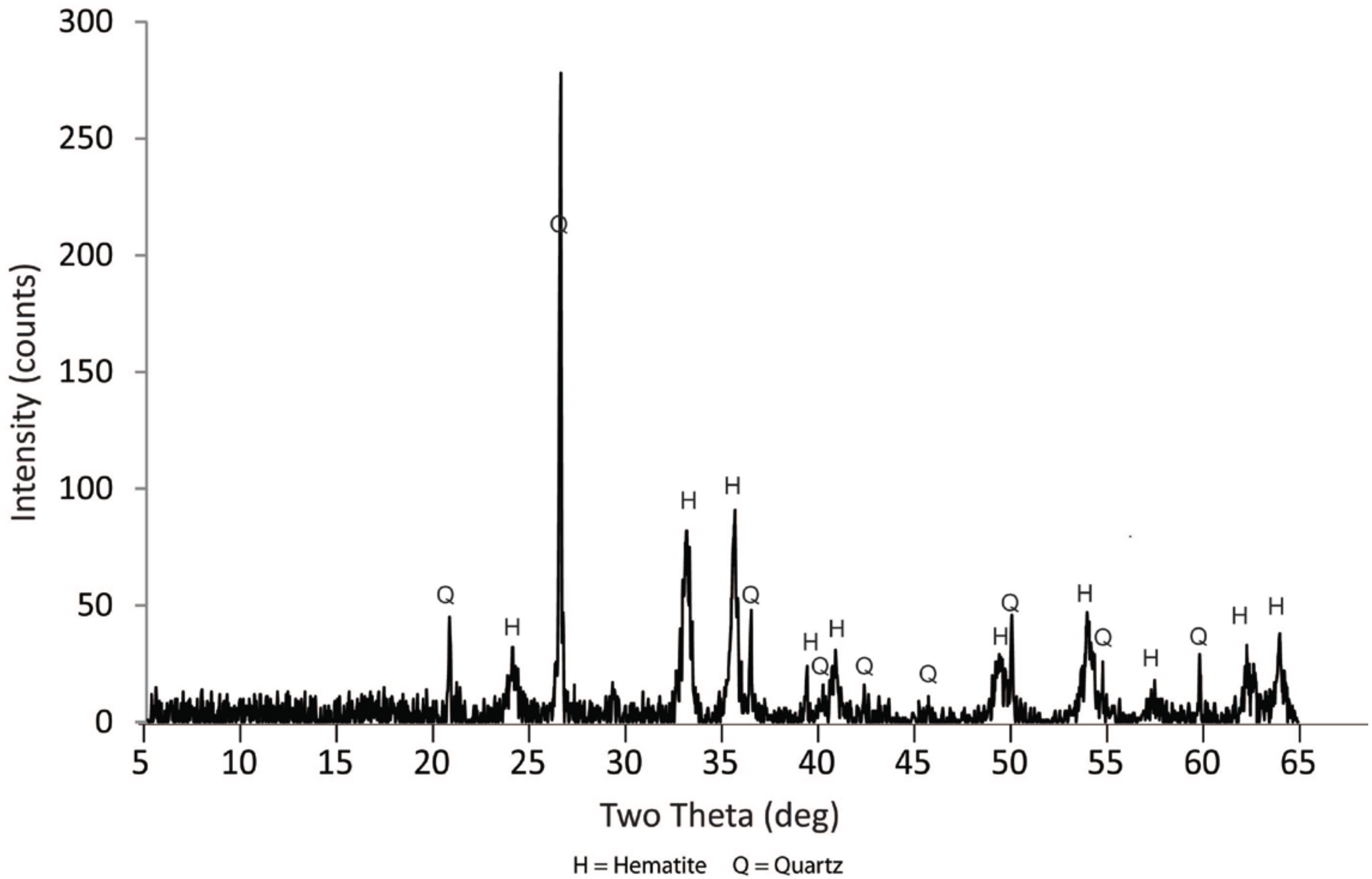


Fig. C.16. DB Sand 3 22109

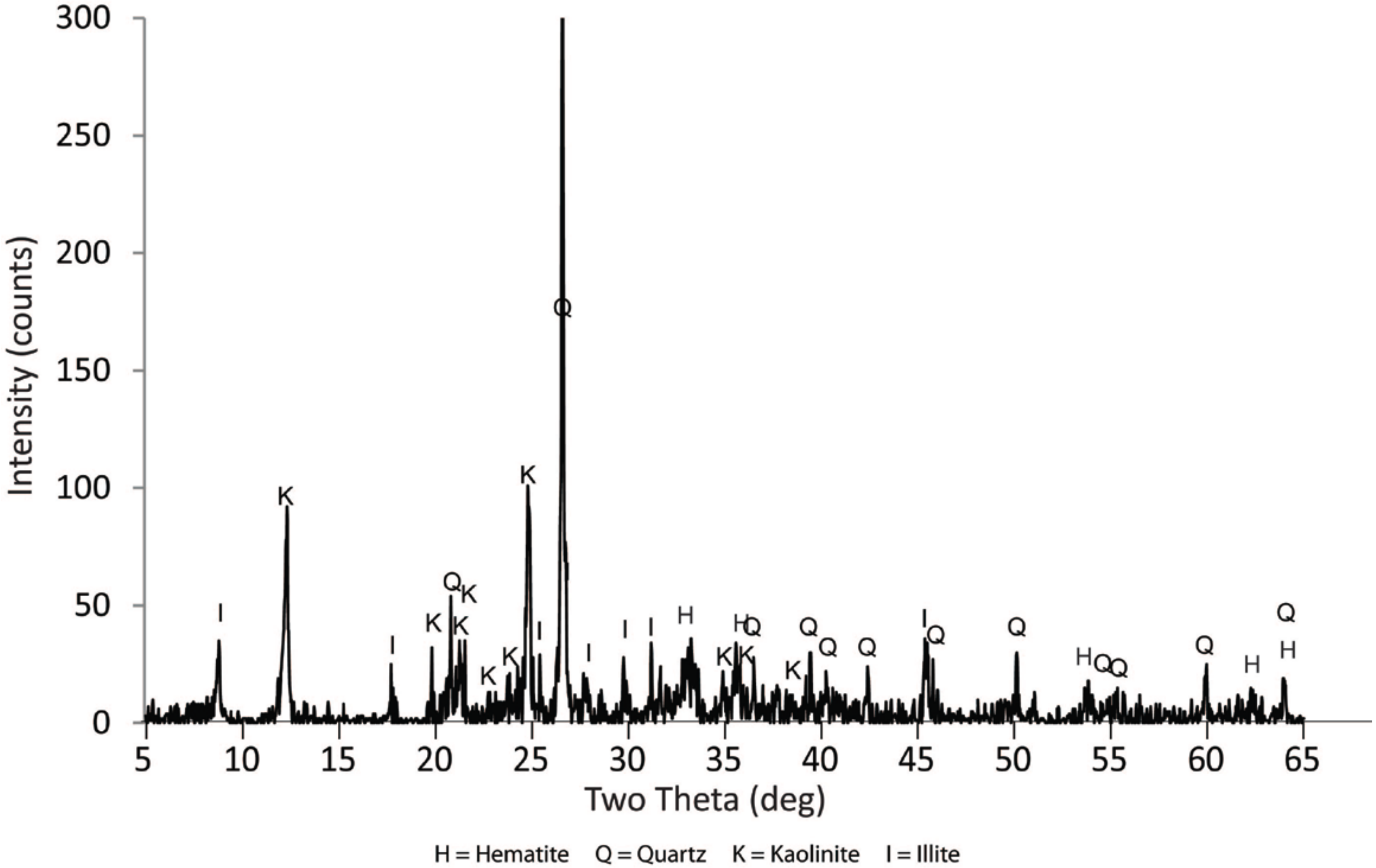


Fig. C.17. DB Sand 3 34674

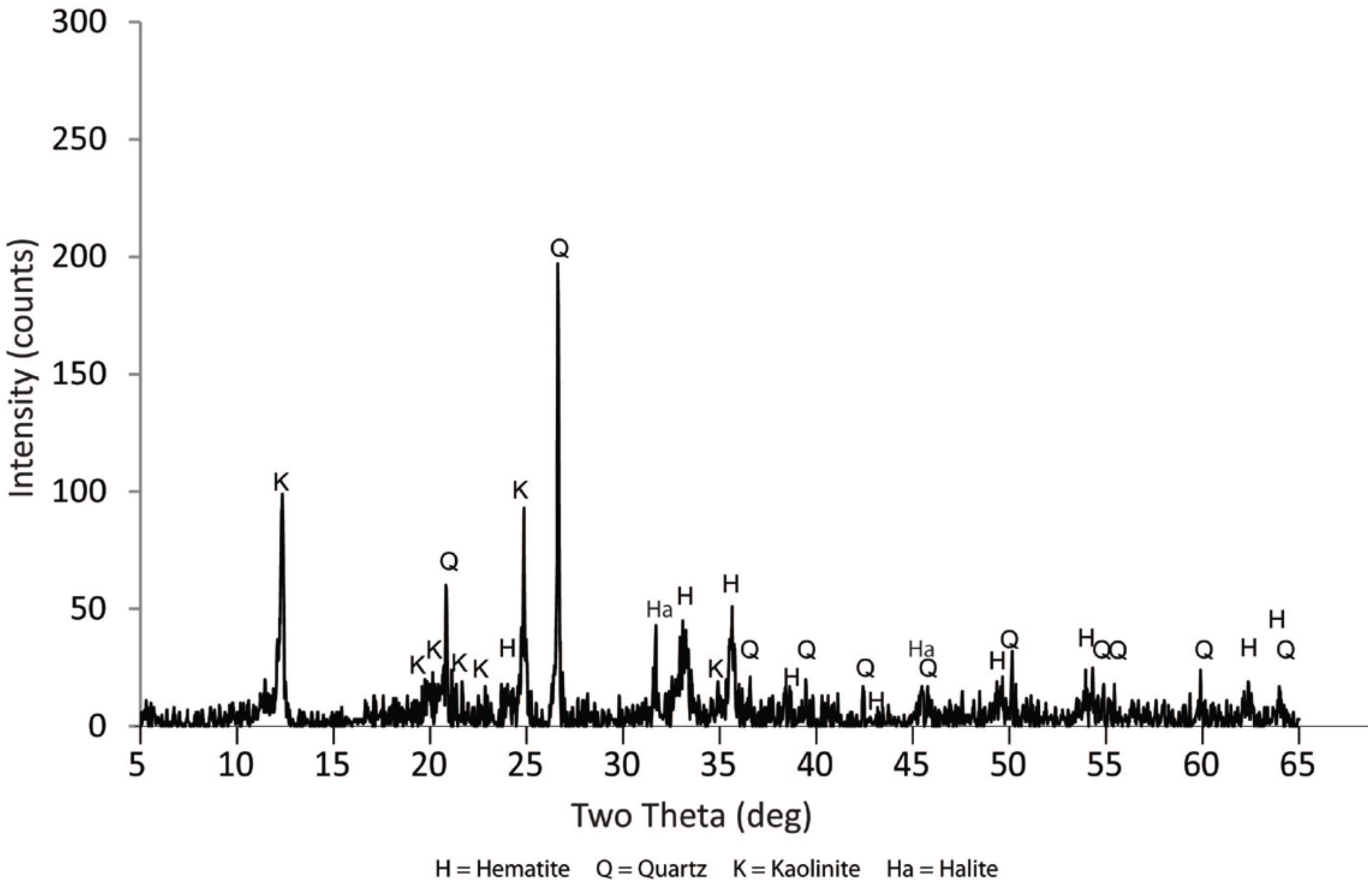


Fig. C.18. DB Sand 3 22151

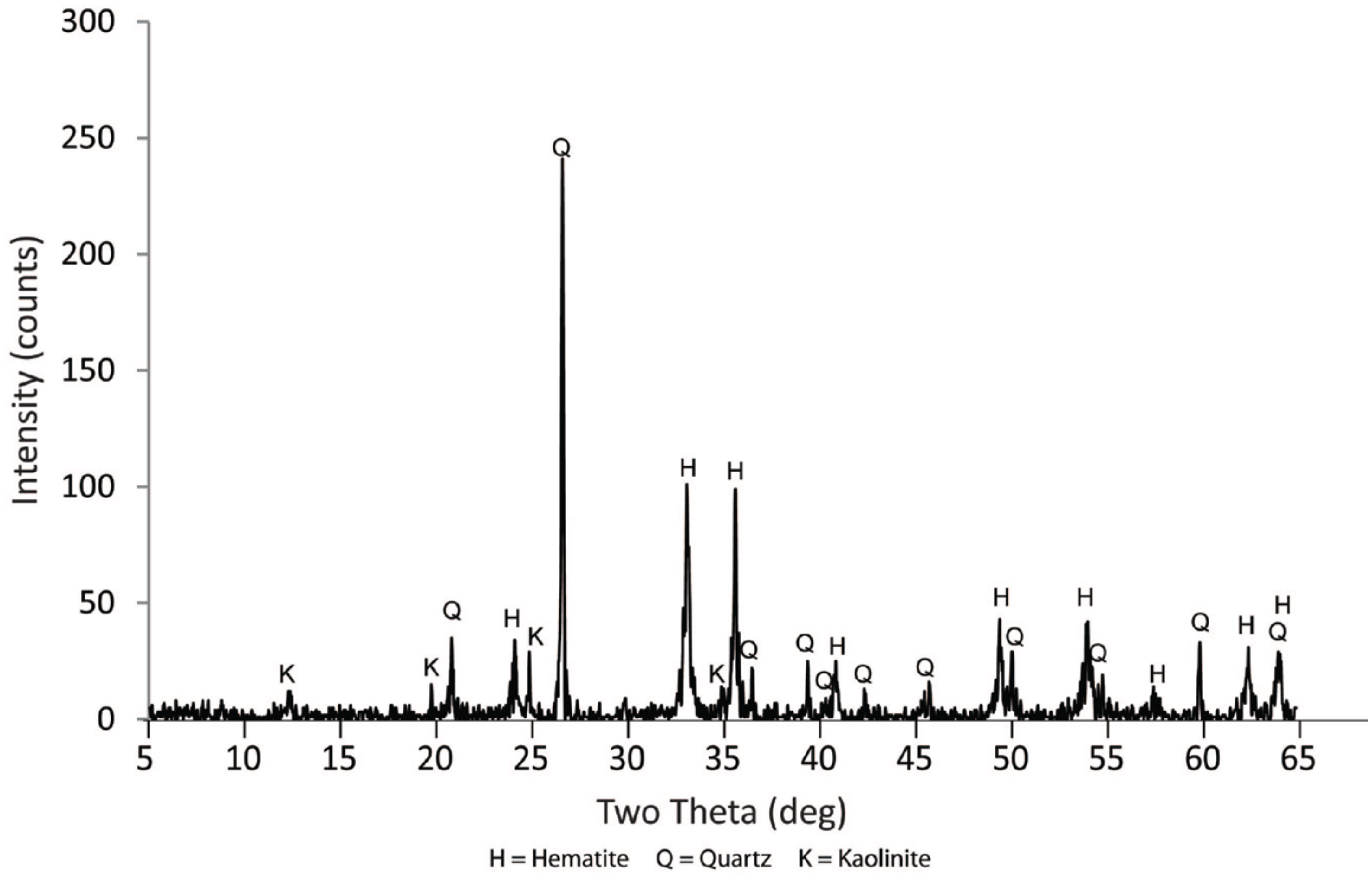


Fig. C.19. DB Sand 3 82307

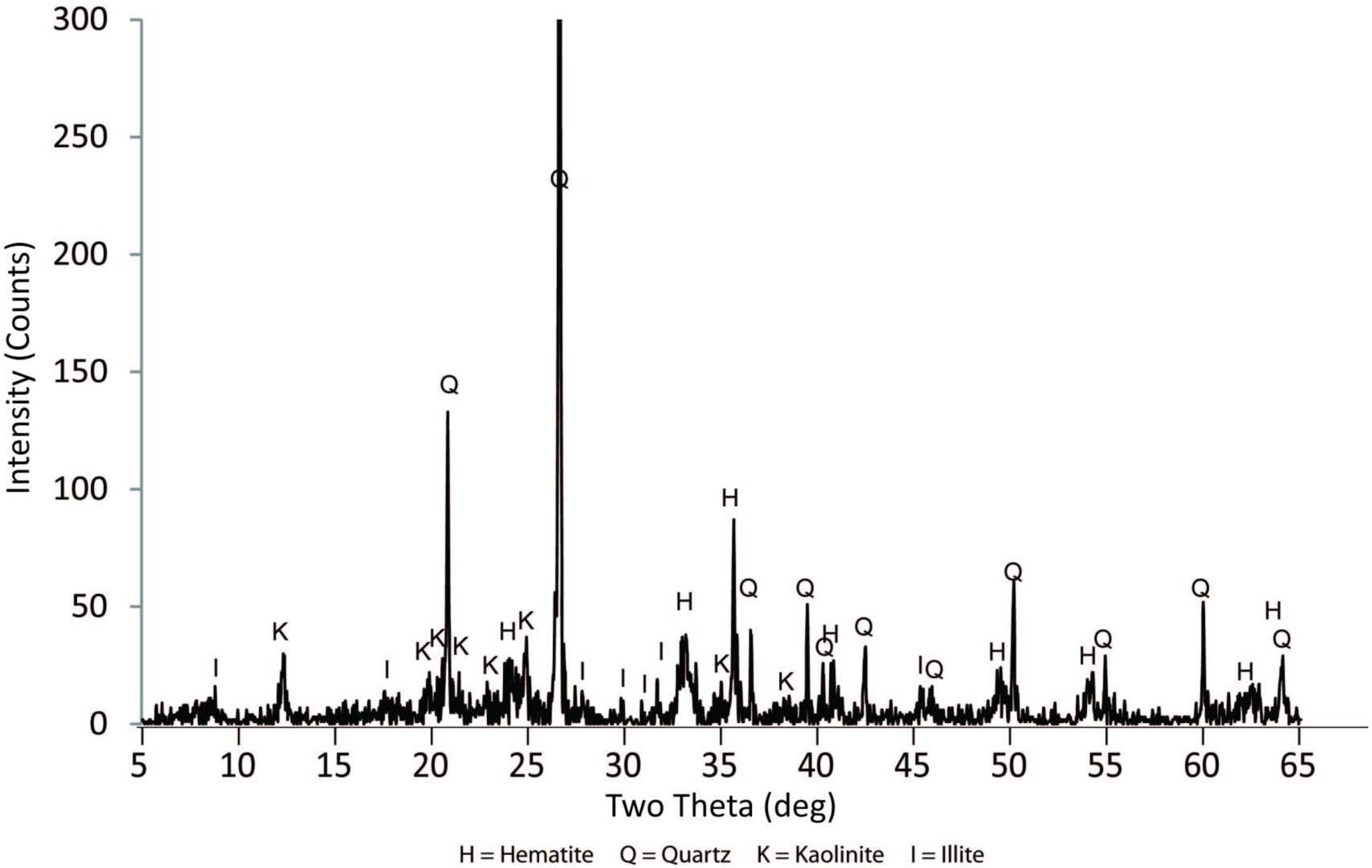


Fig. C.20. LBG Sand 53348

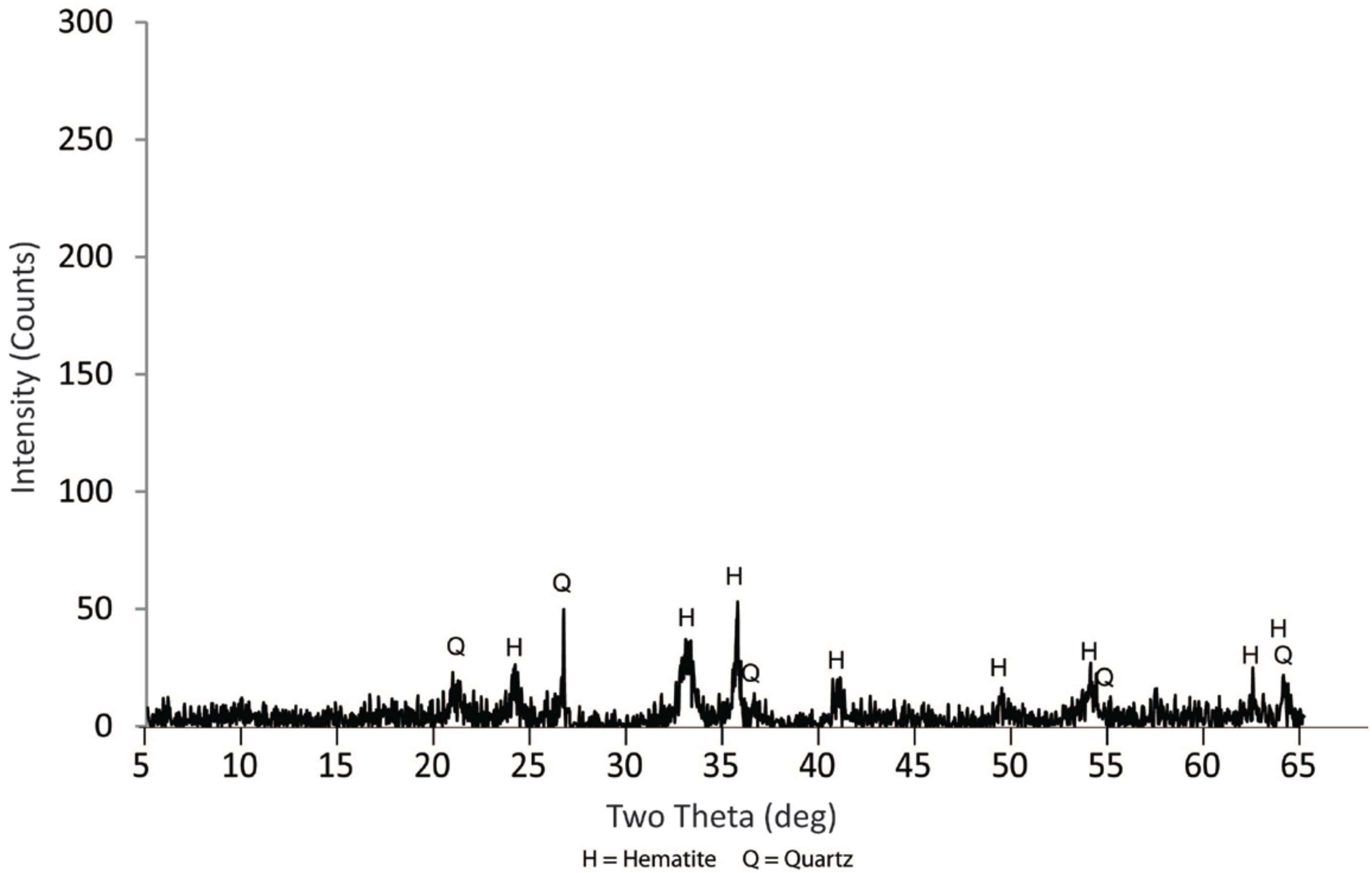


Fig. C.21. LBG Sand 53738

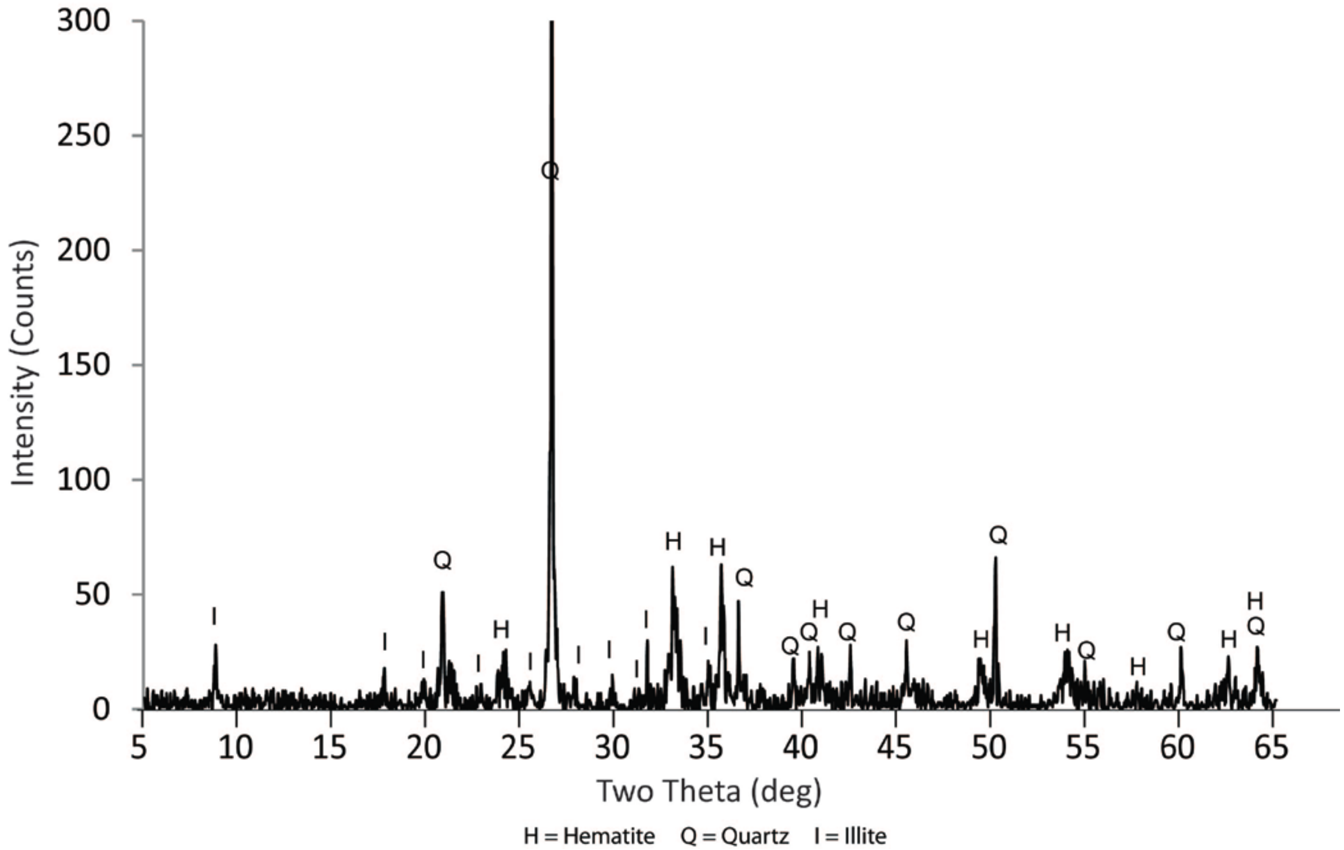


Fig. C.22. LB Sand 45739

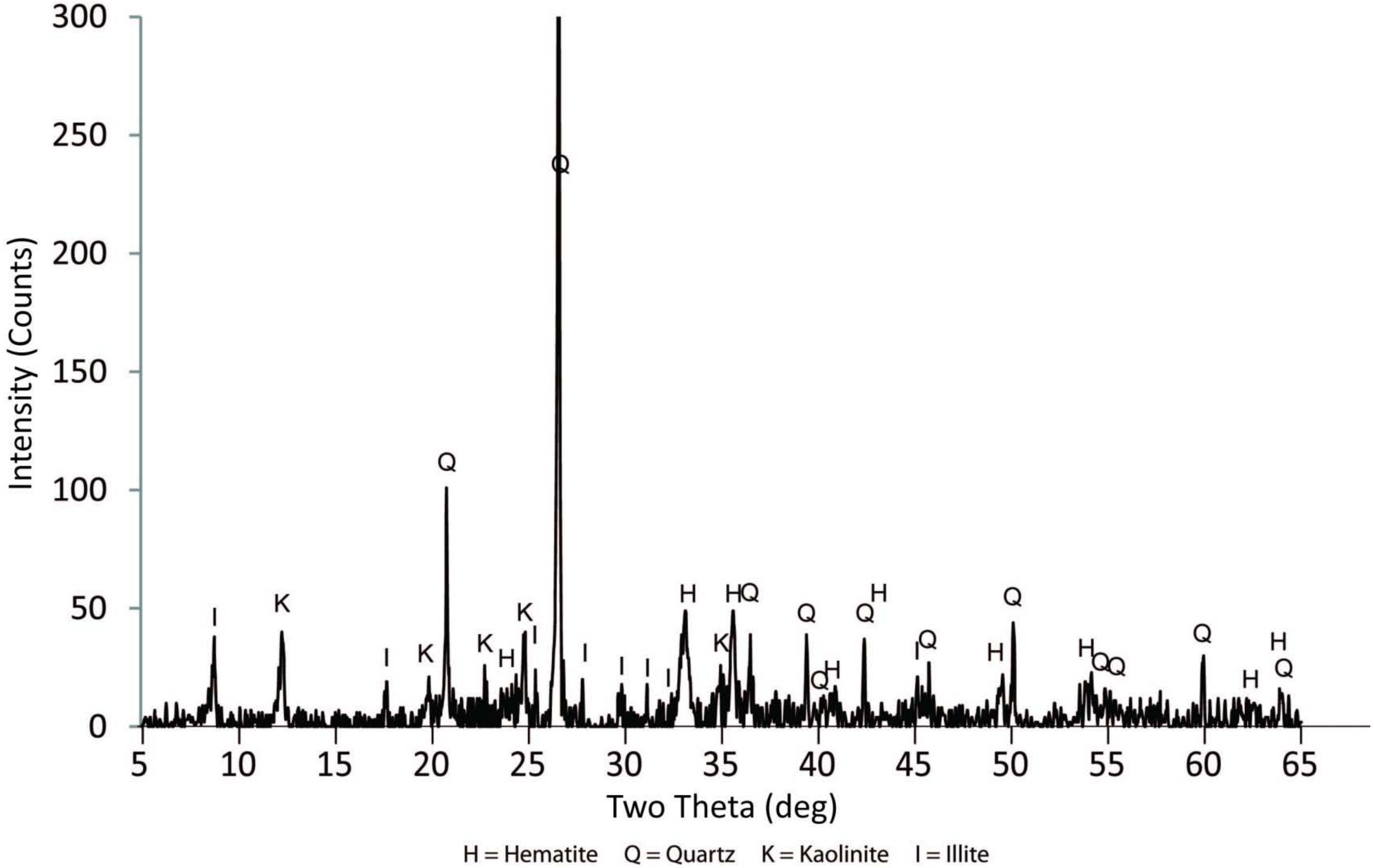


Fig. C.23. DBSS 103053

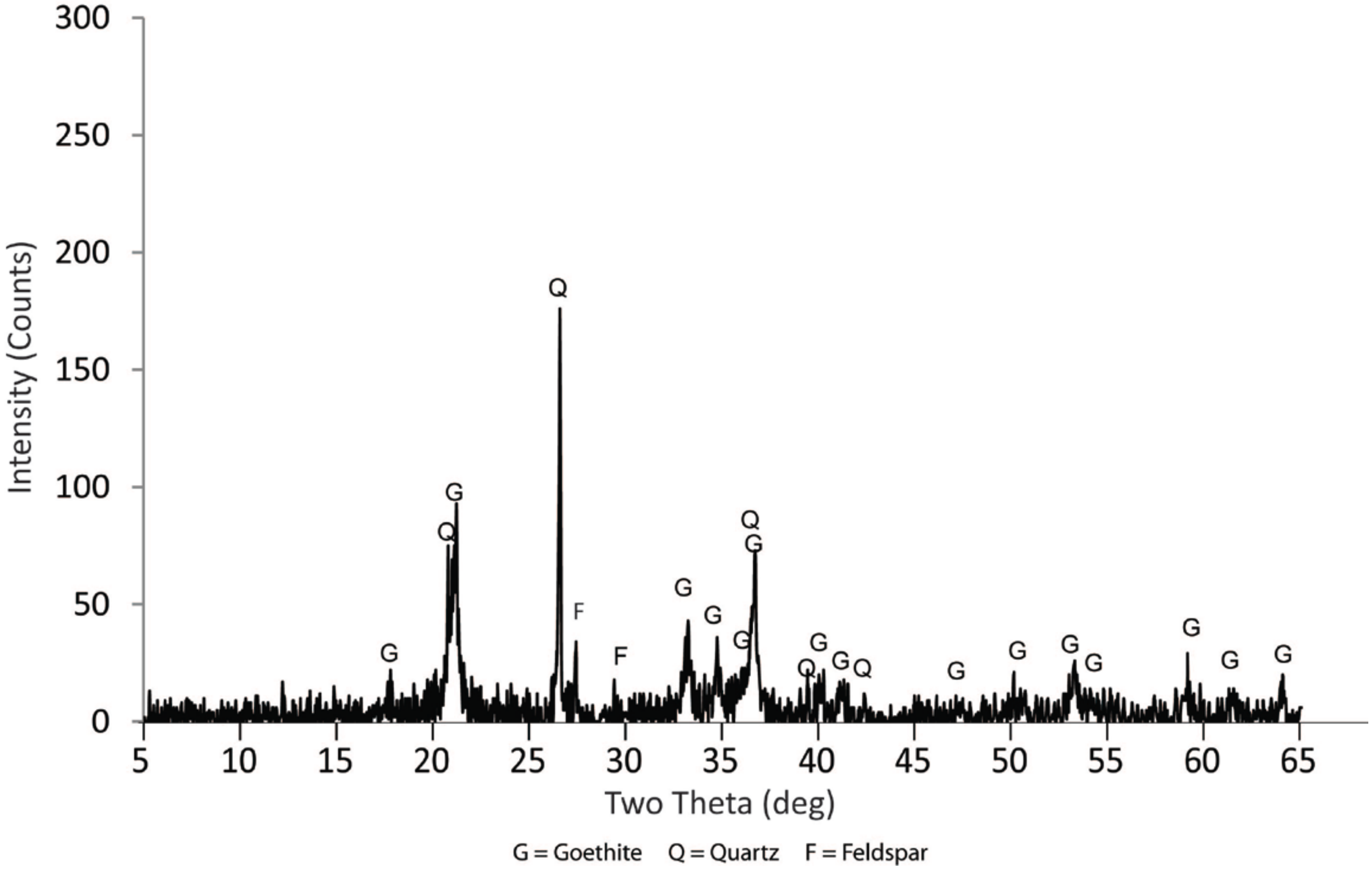


Fig. C.24. DBSS 103234

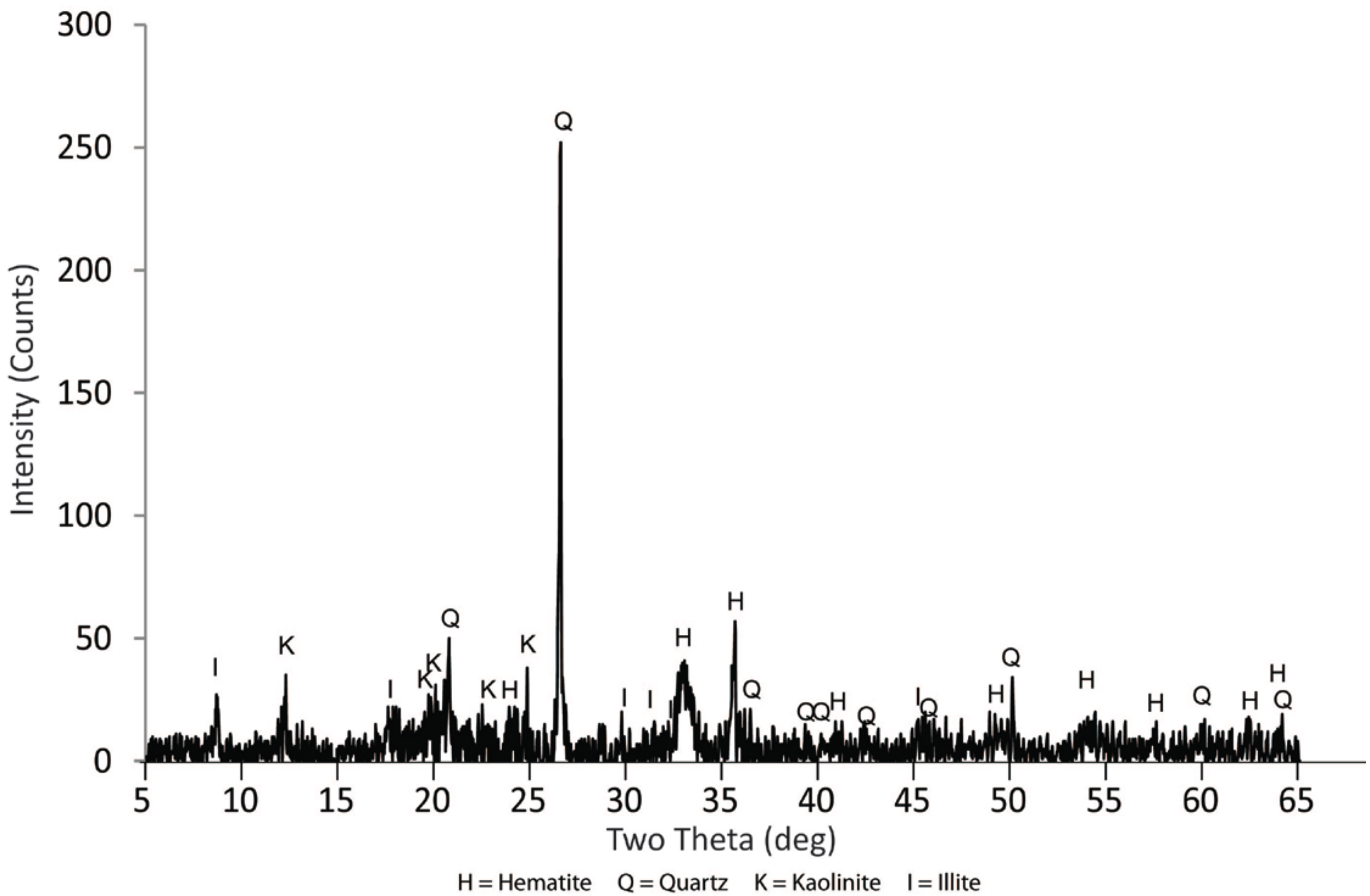


Fig. C.25. DBSS 103512

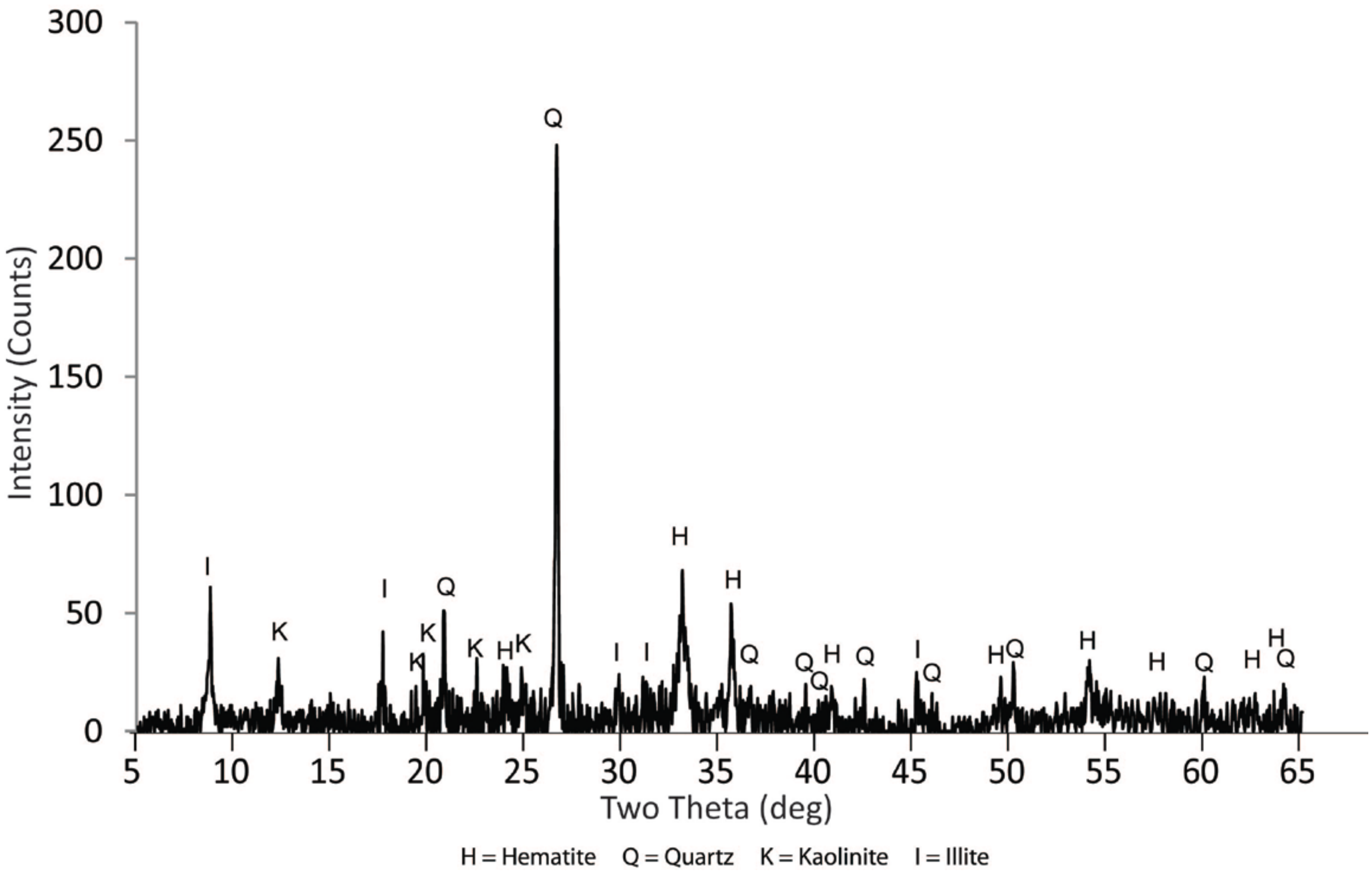


Fig. C.26. DBSS 103759

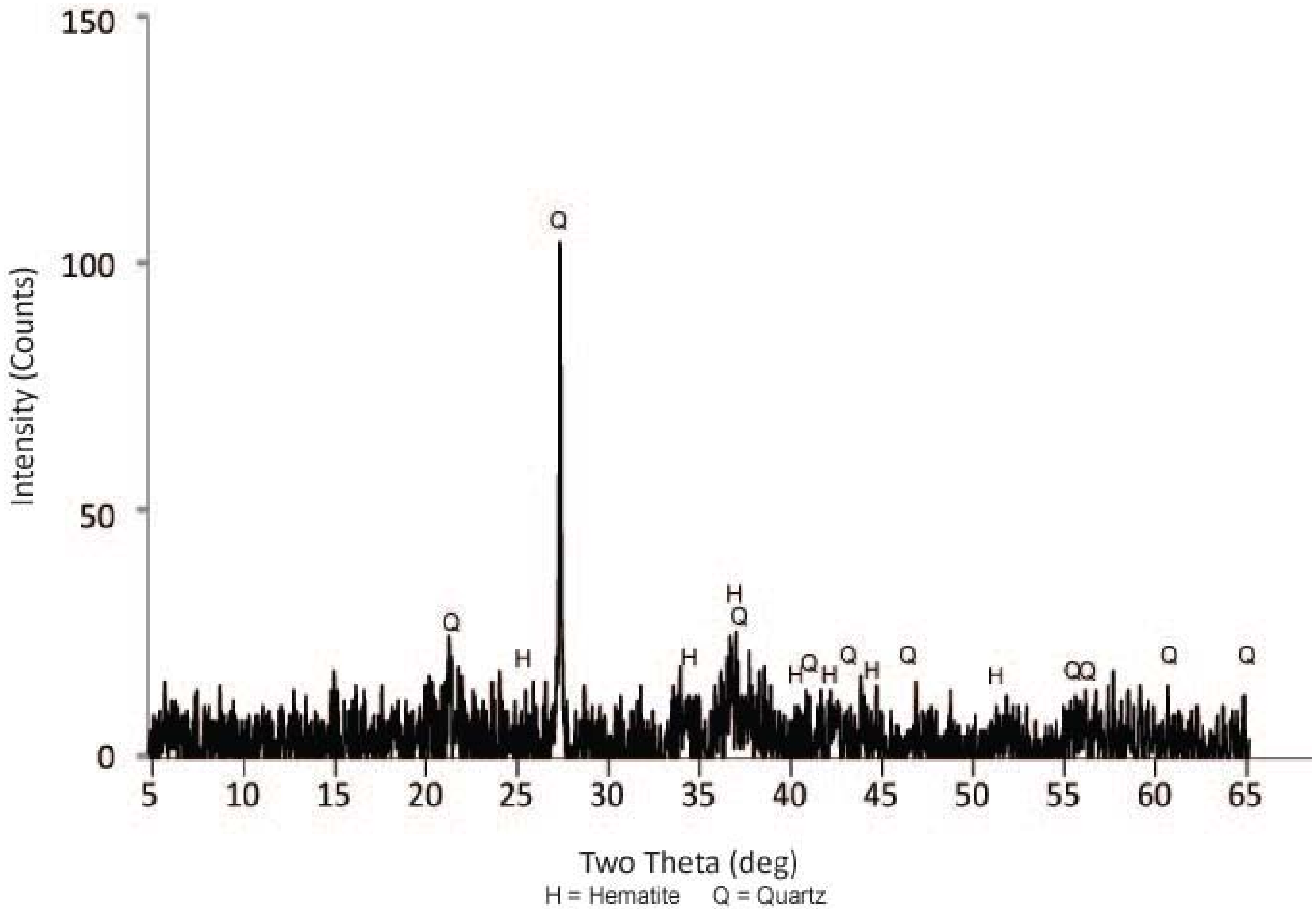


Fig. C.27. BCSR 257436

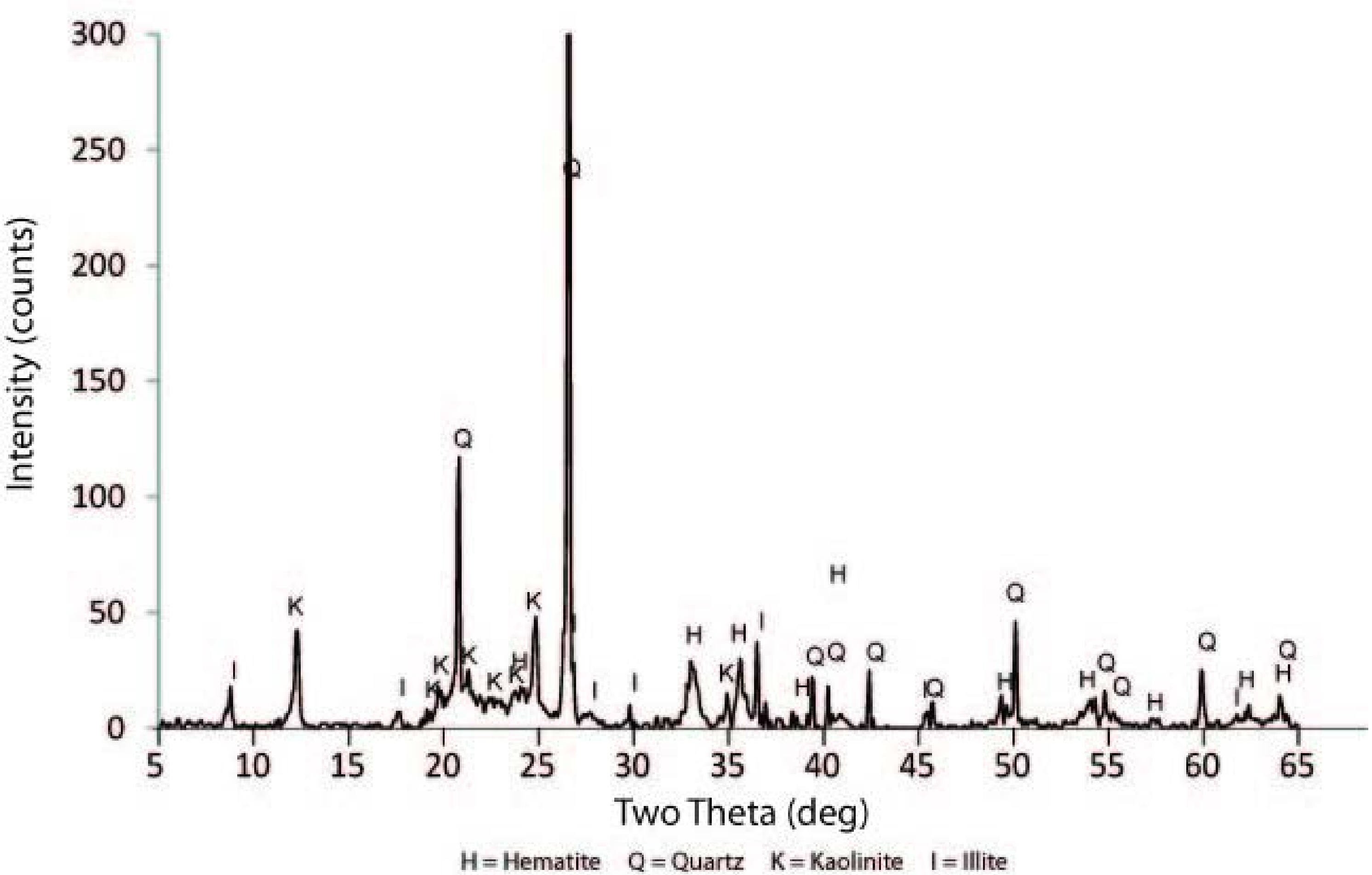


Fig. C.28. BCSR 257438

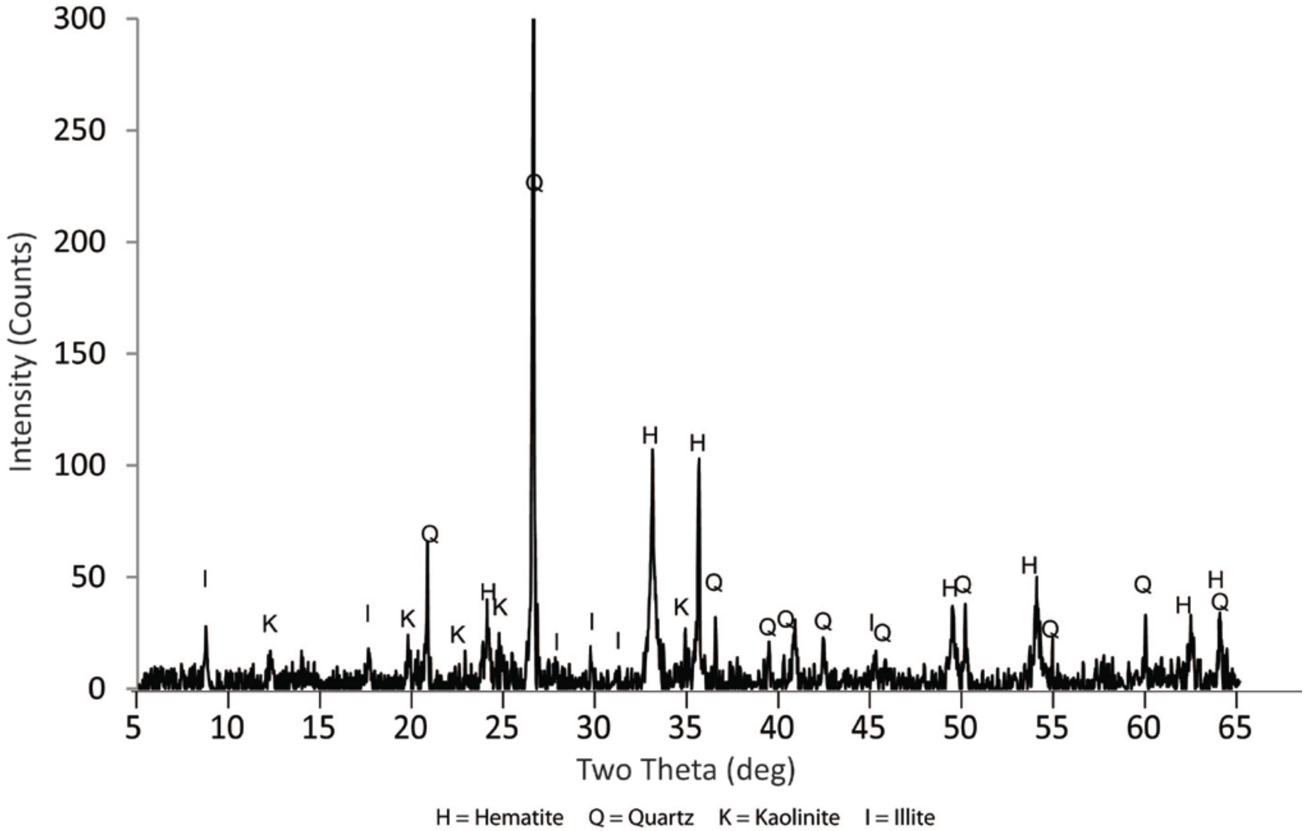


Fig. C.29. RBSR 153642

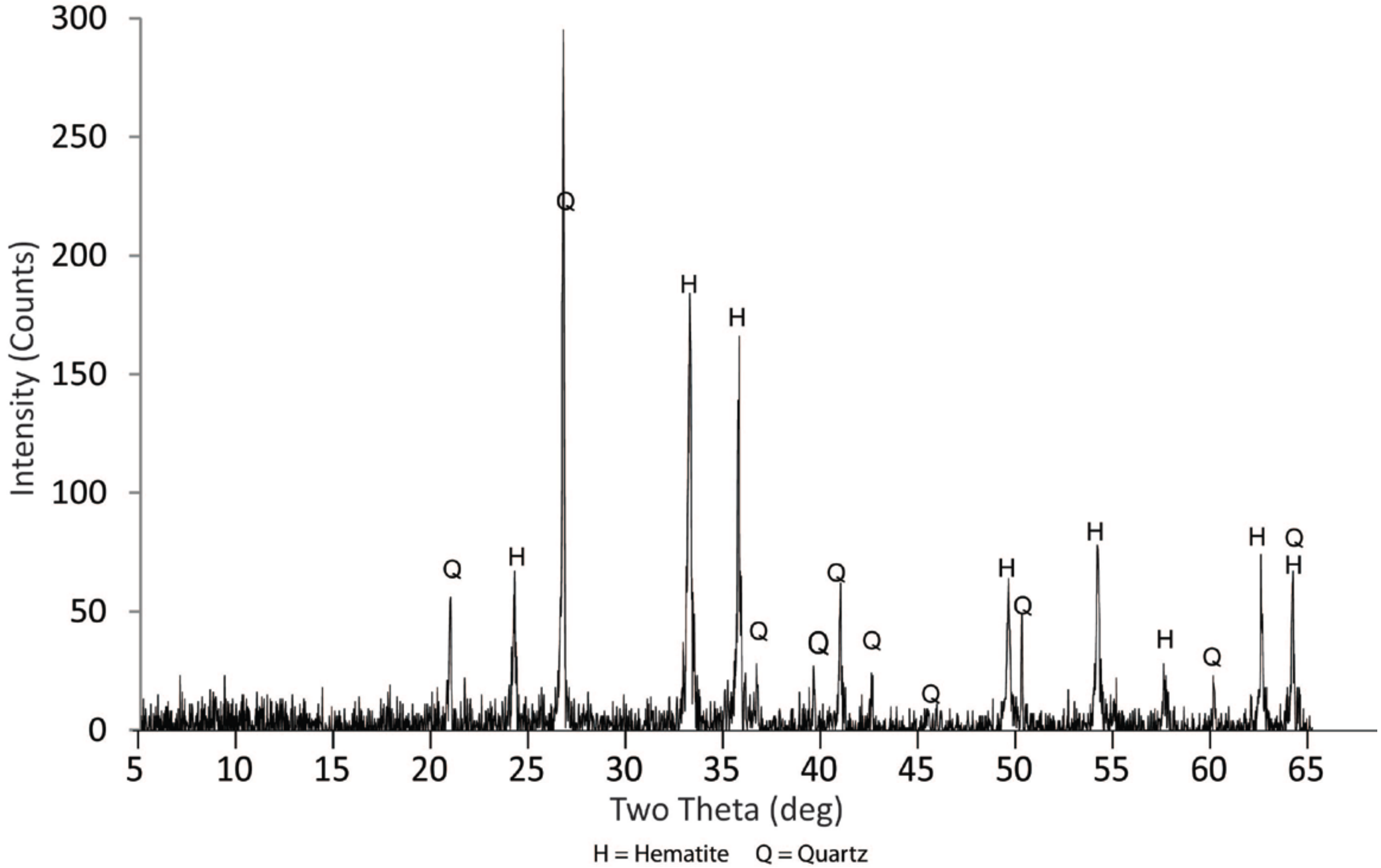


Fig. C.30. RBSR 257250

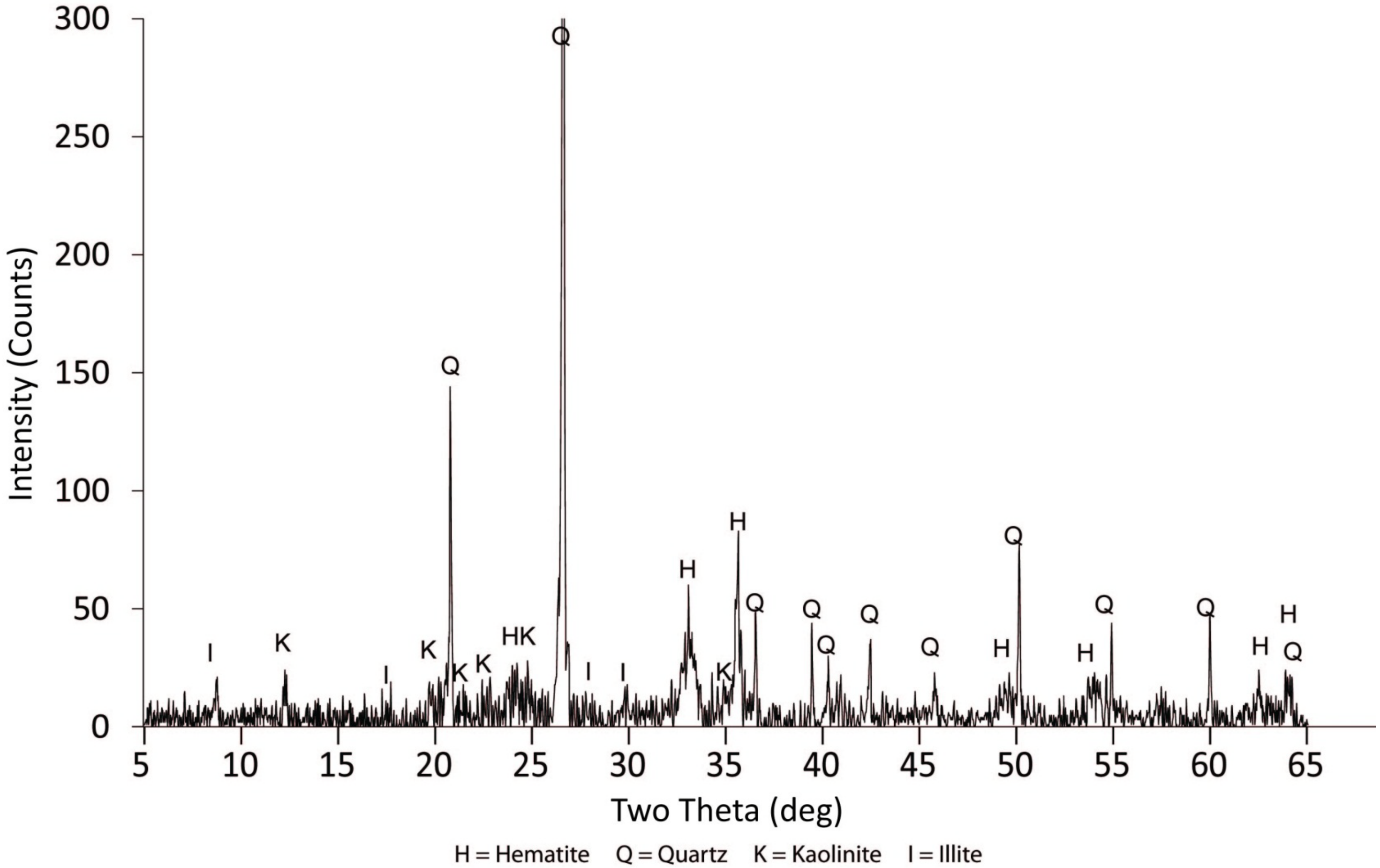


Fig. C.31. RBSR 257271

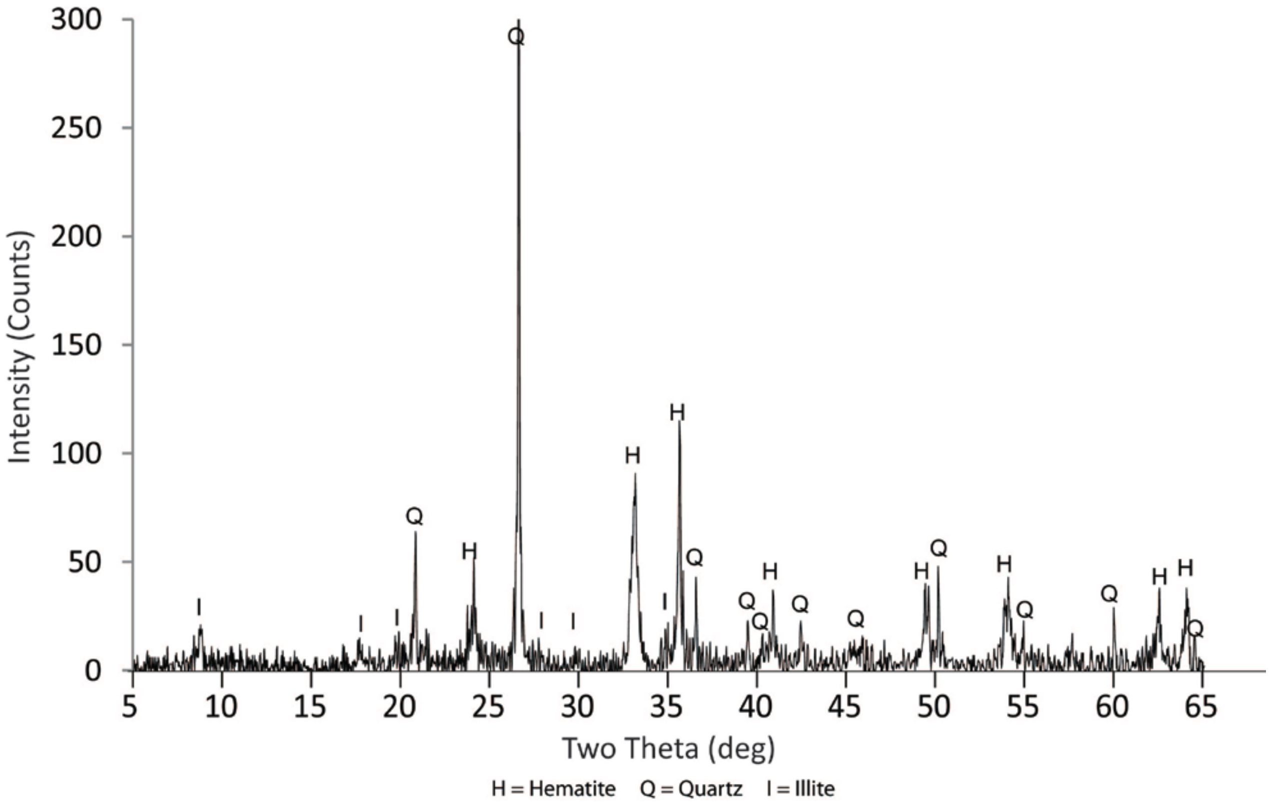


Fig. C.32. RBSR 257297

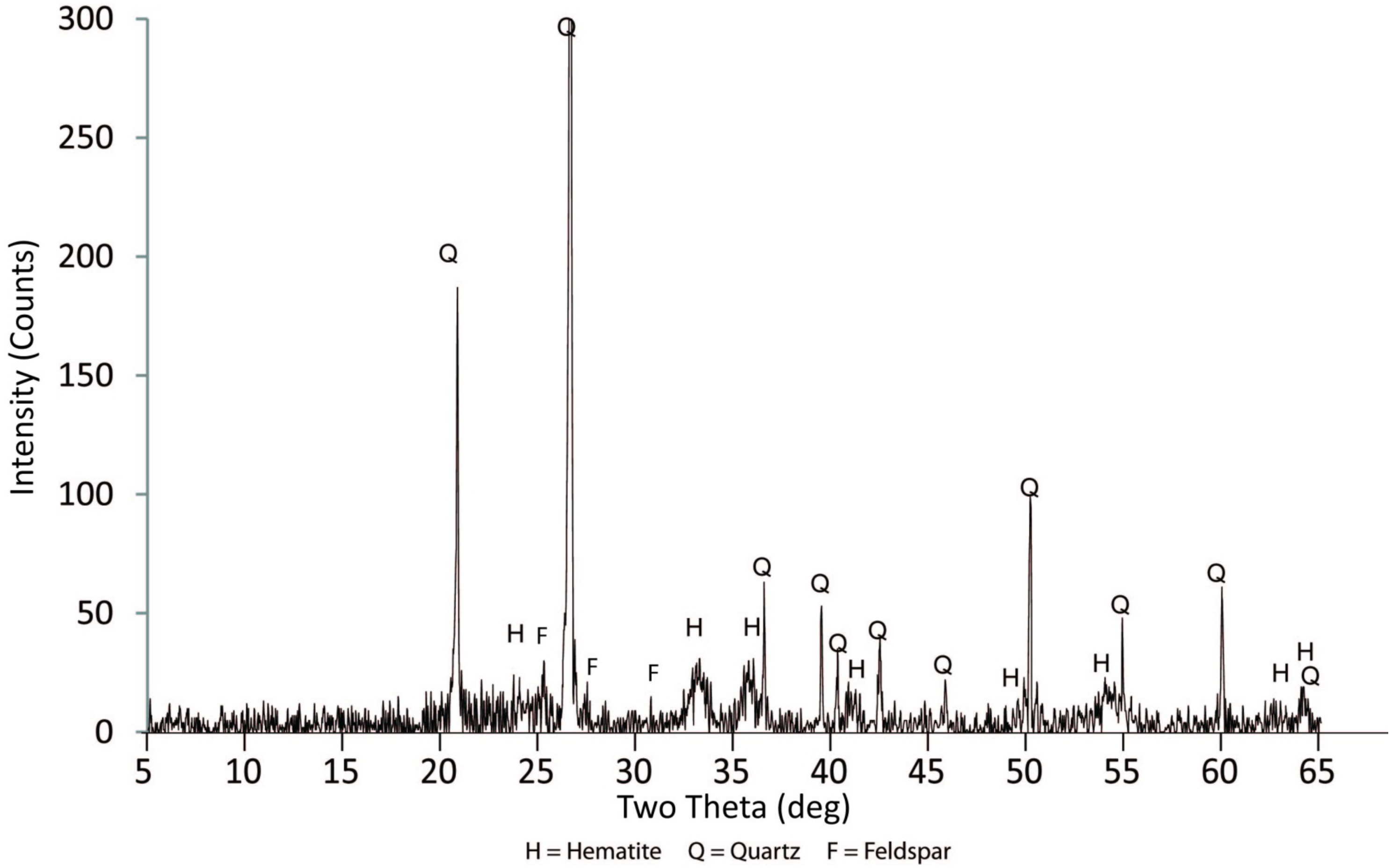


Fig. C.33. RBSR 257318

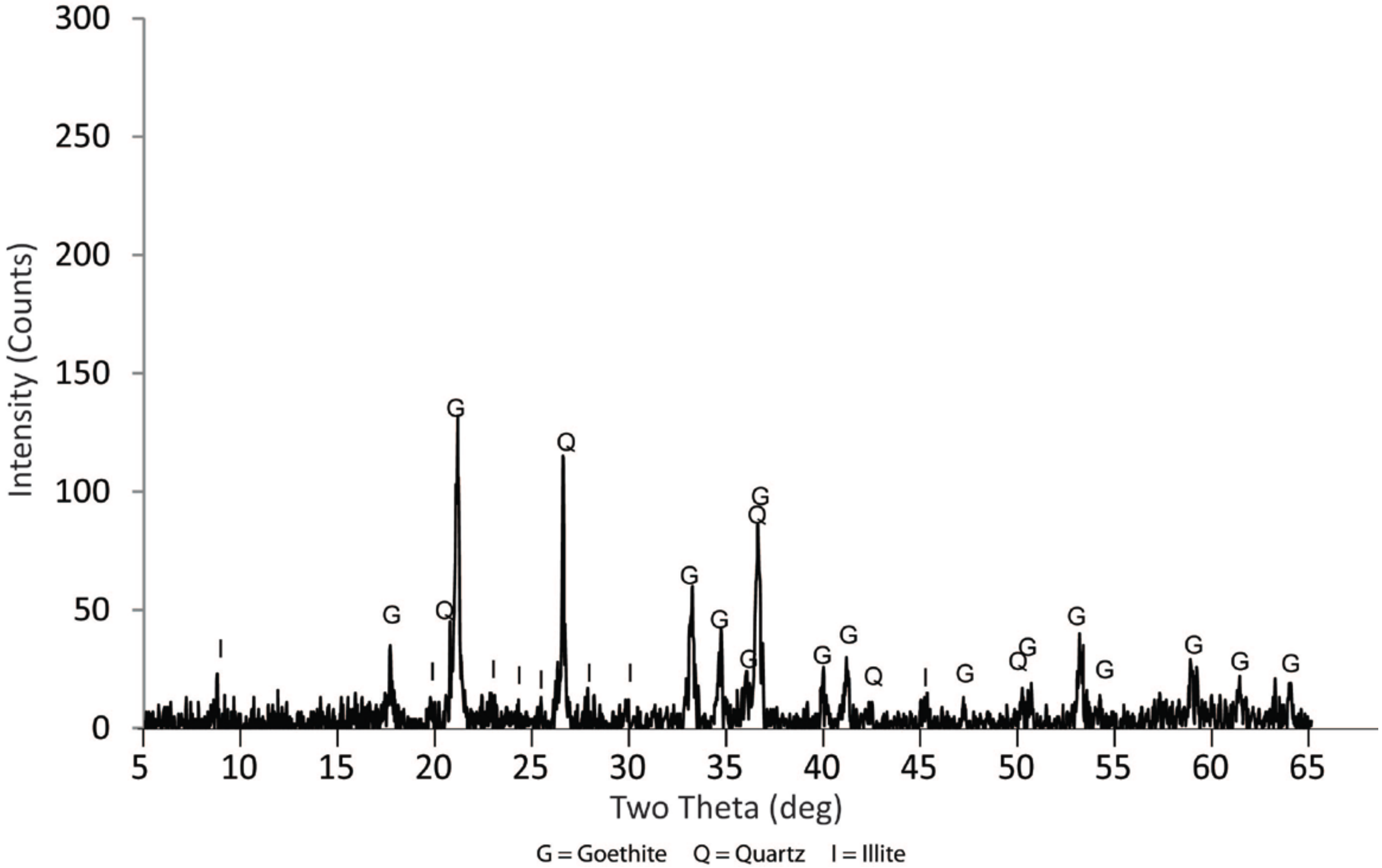


Fig. C.34. RBSR 257324

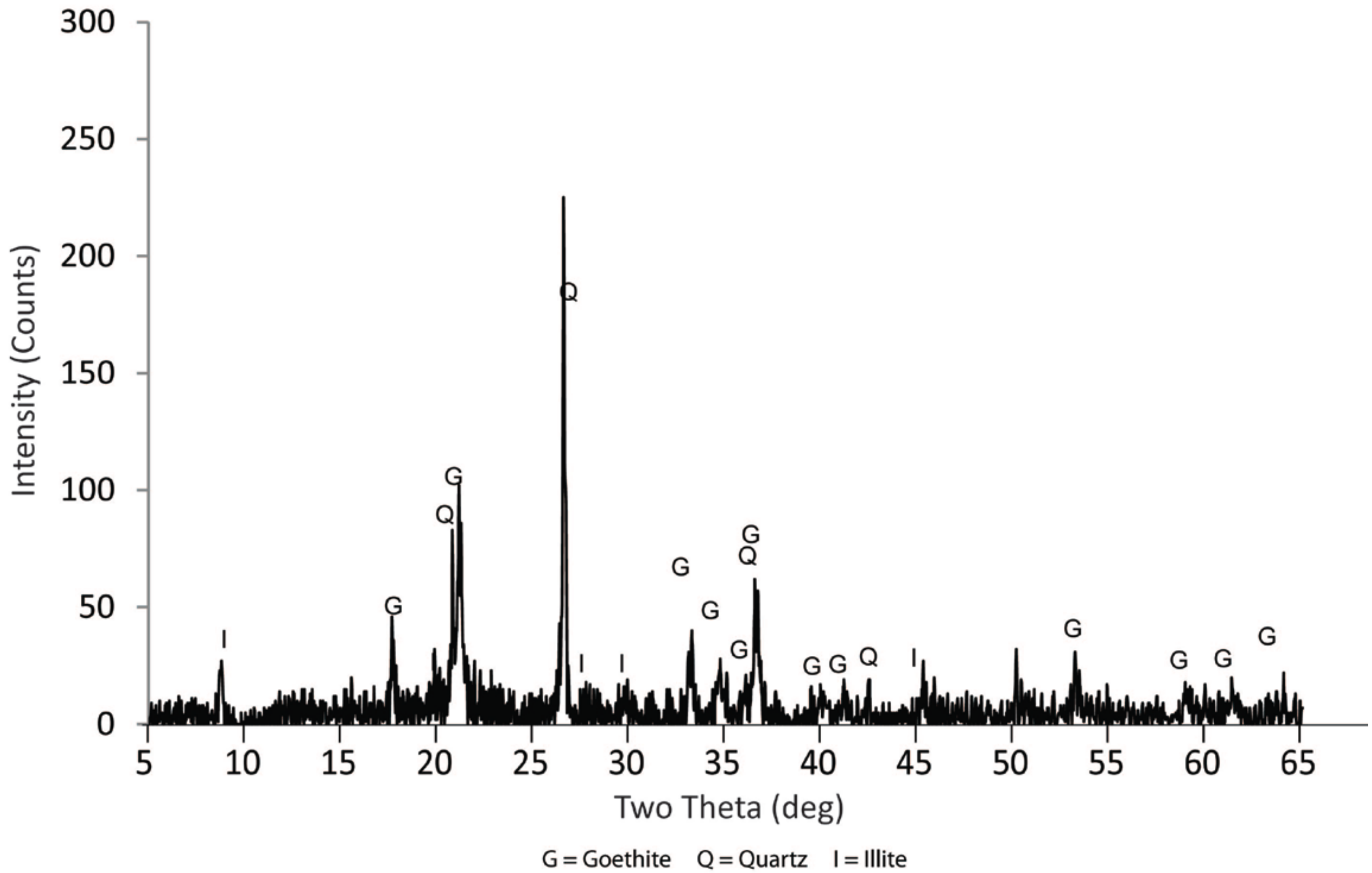


Fig. C.35. RBSR 257326

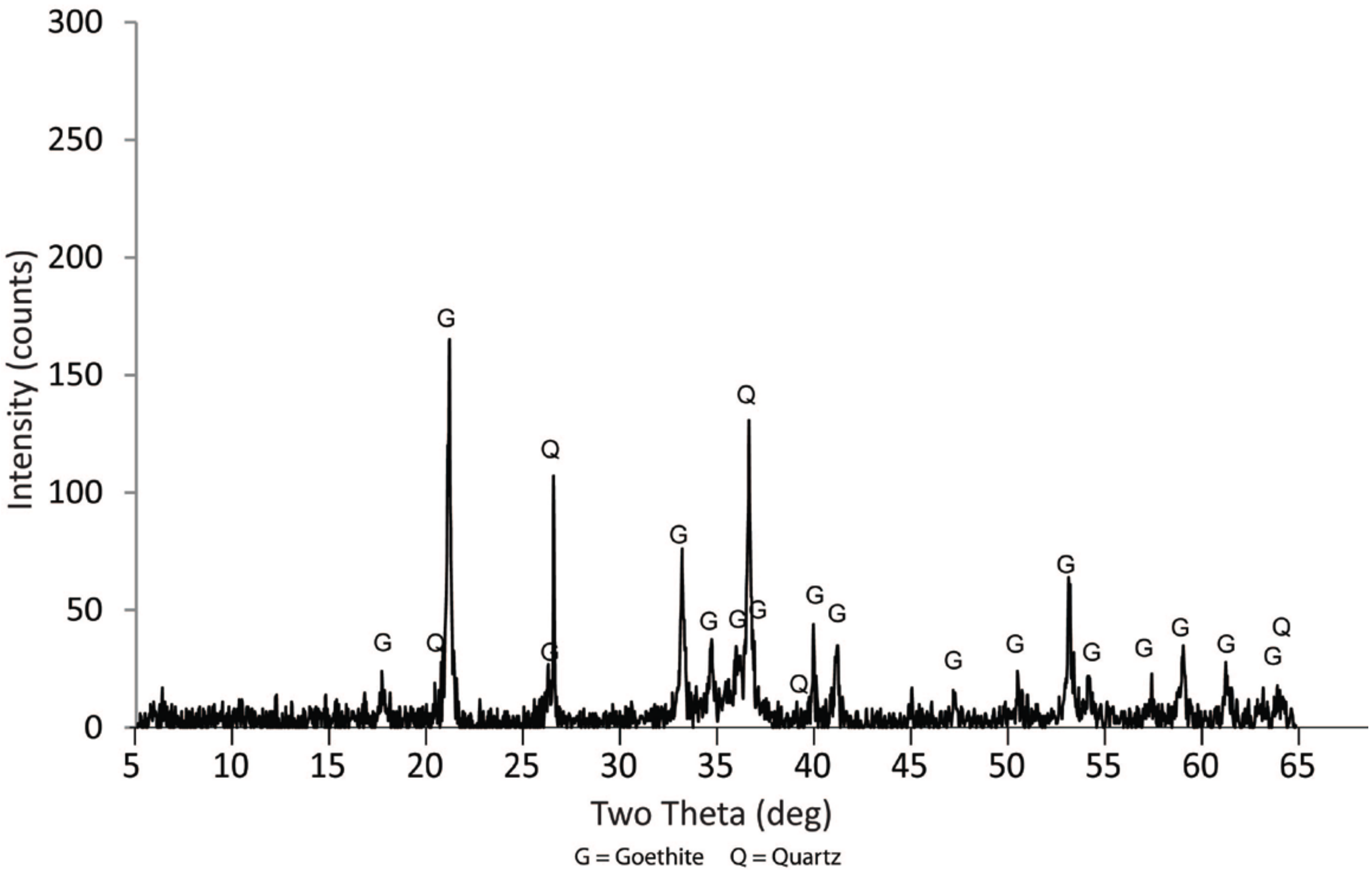


Fig. C.36. DBCS 119208

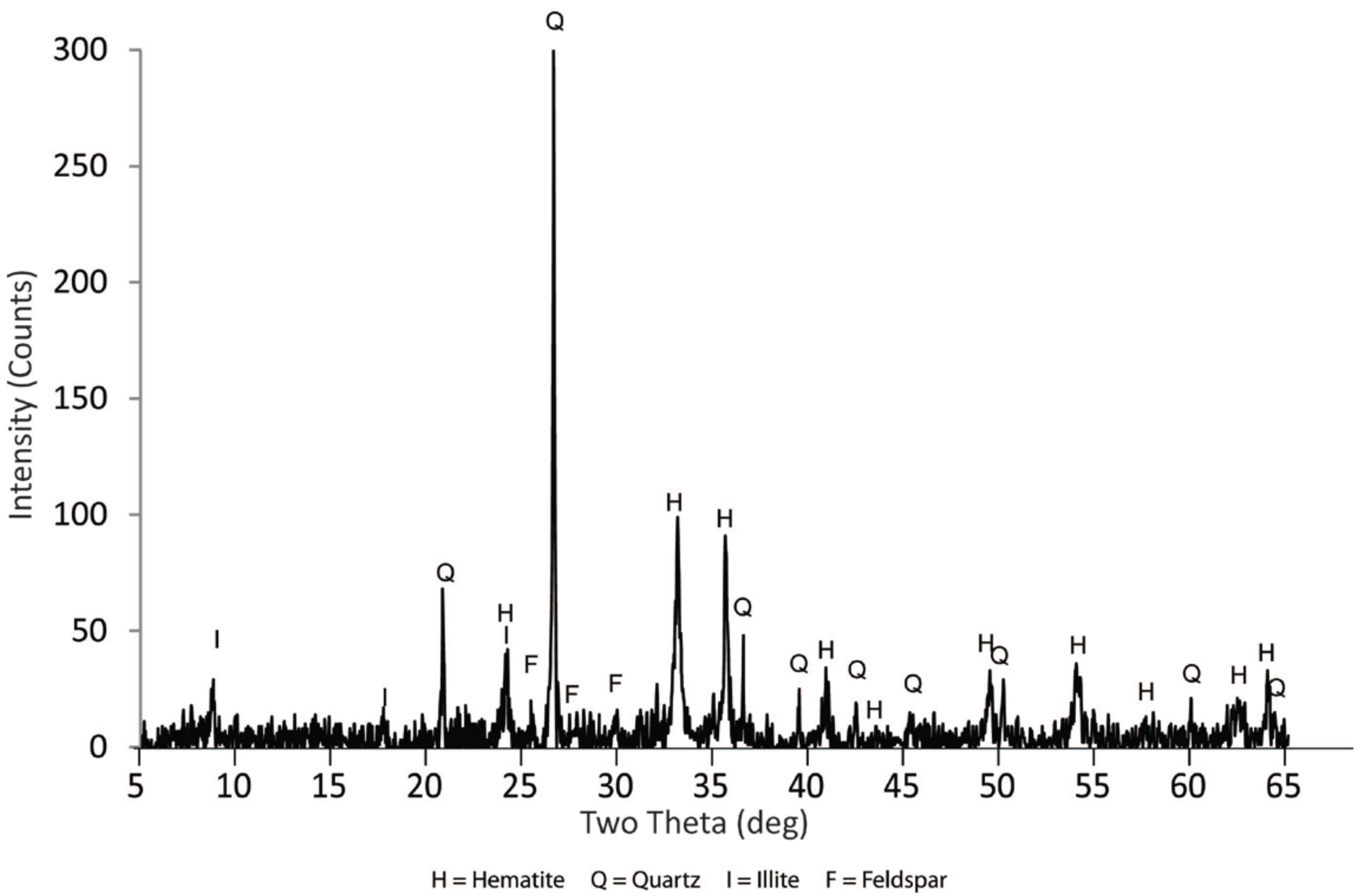
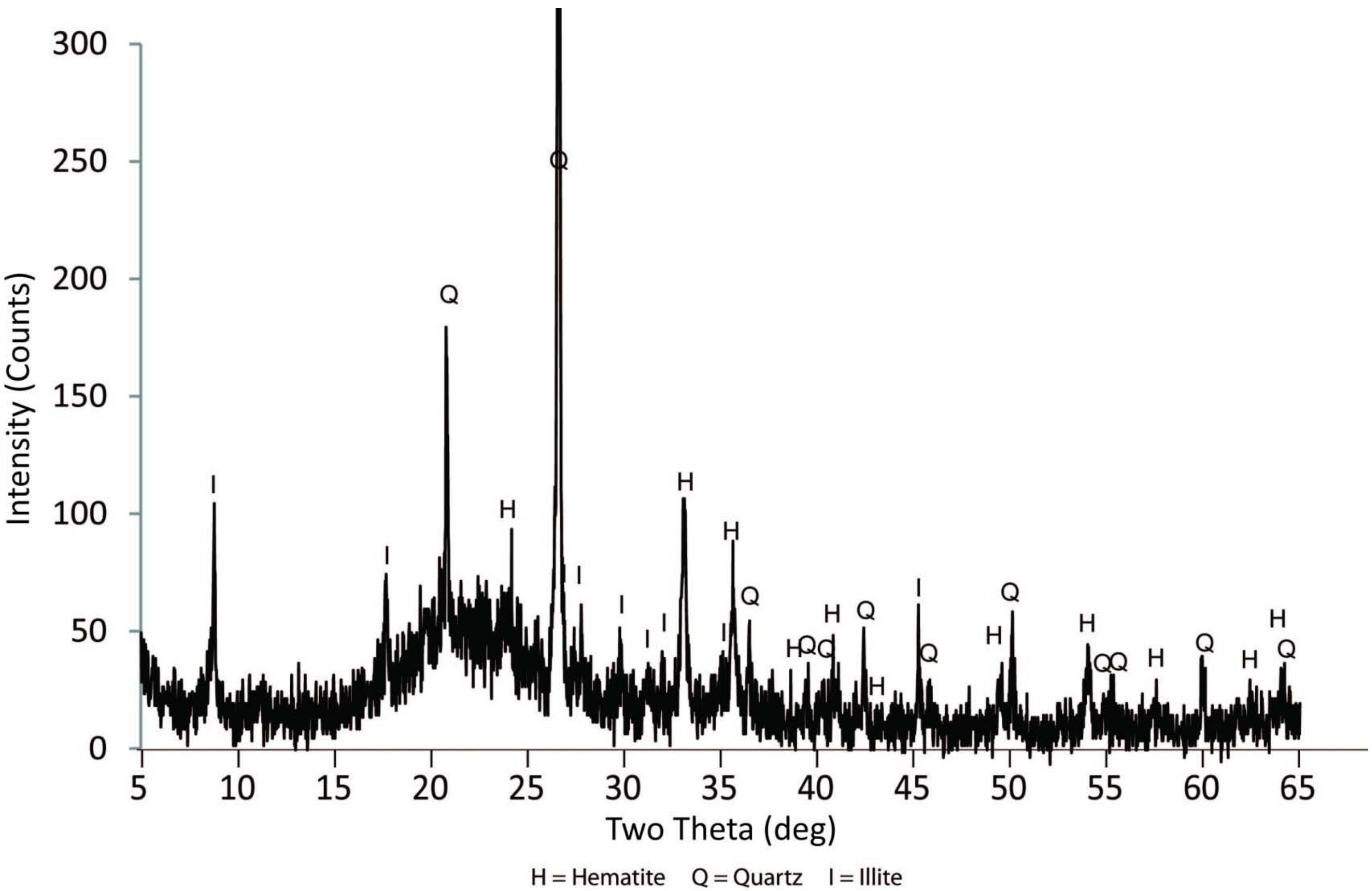


Fig. C.37. DBCS 120449



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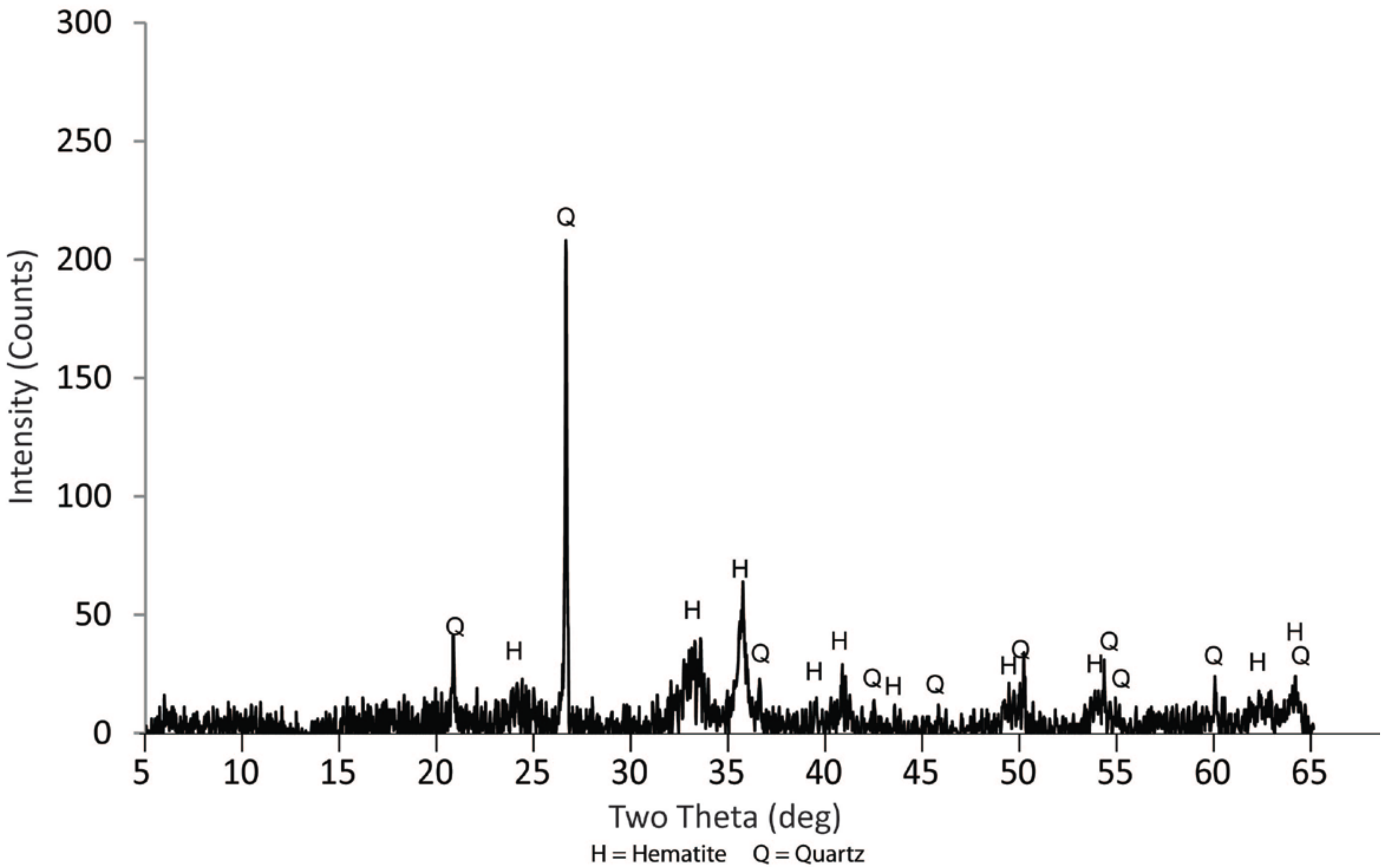

Fig. C.39. DBCS 121931

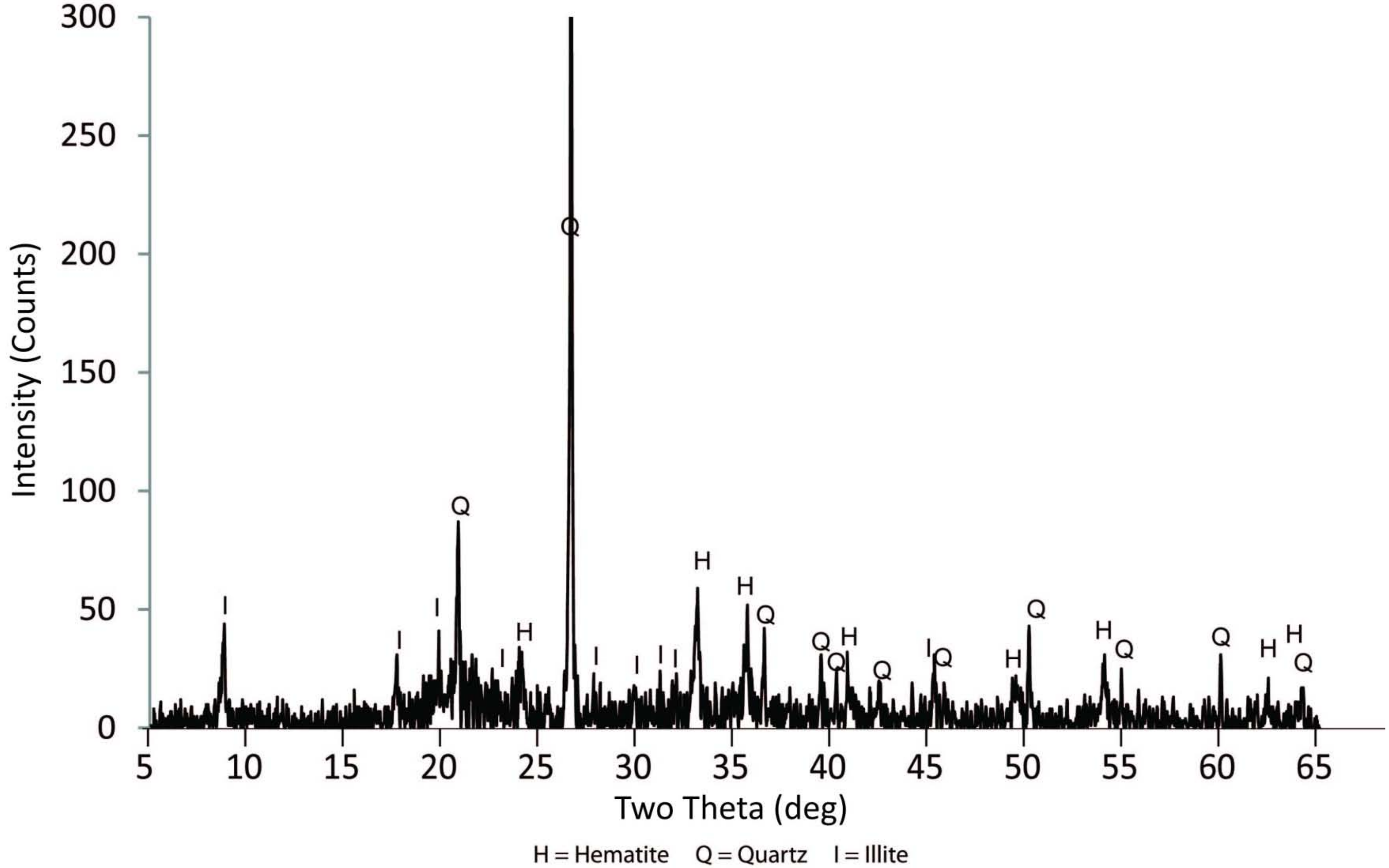

Fig. C.40. DBCS 122709

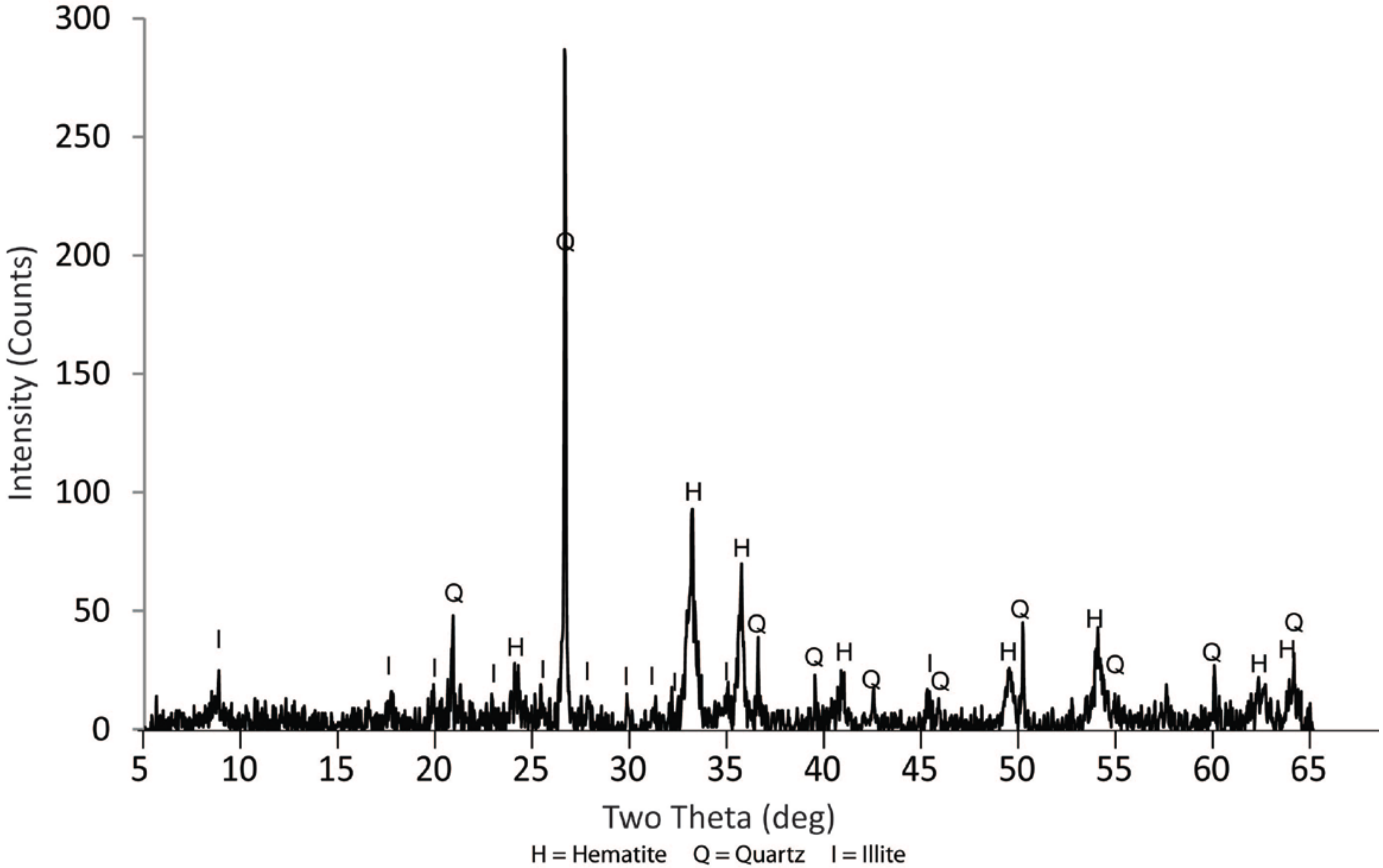

Fig. C.41. DBCS 133123

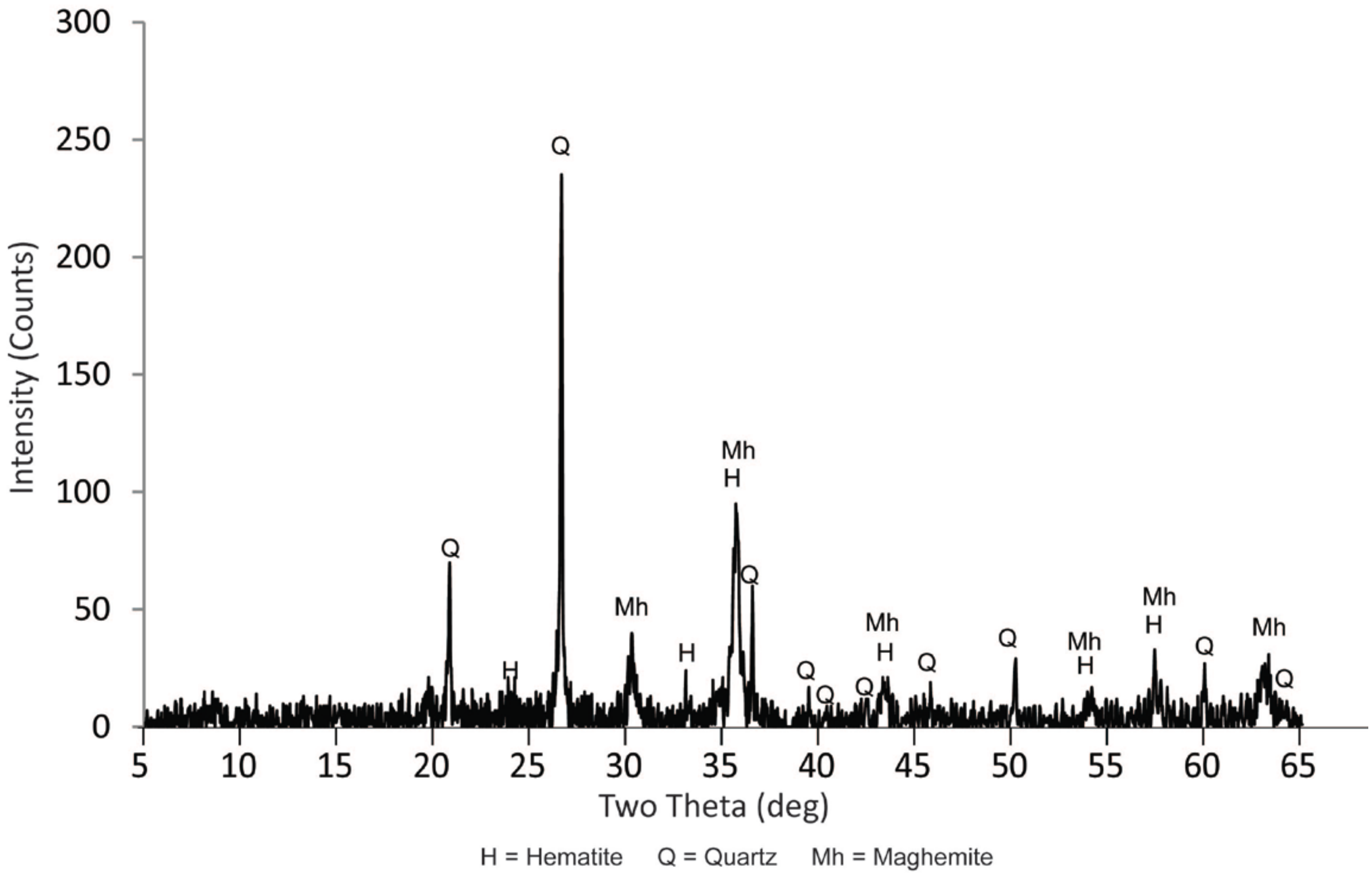

Fig. C.42. DBCS 138351

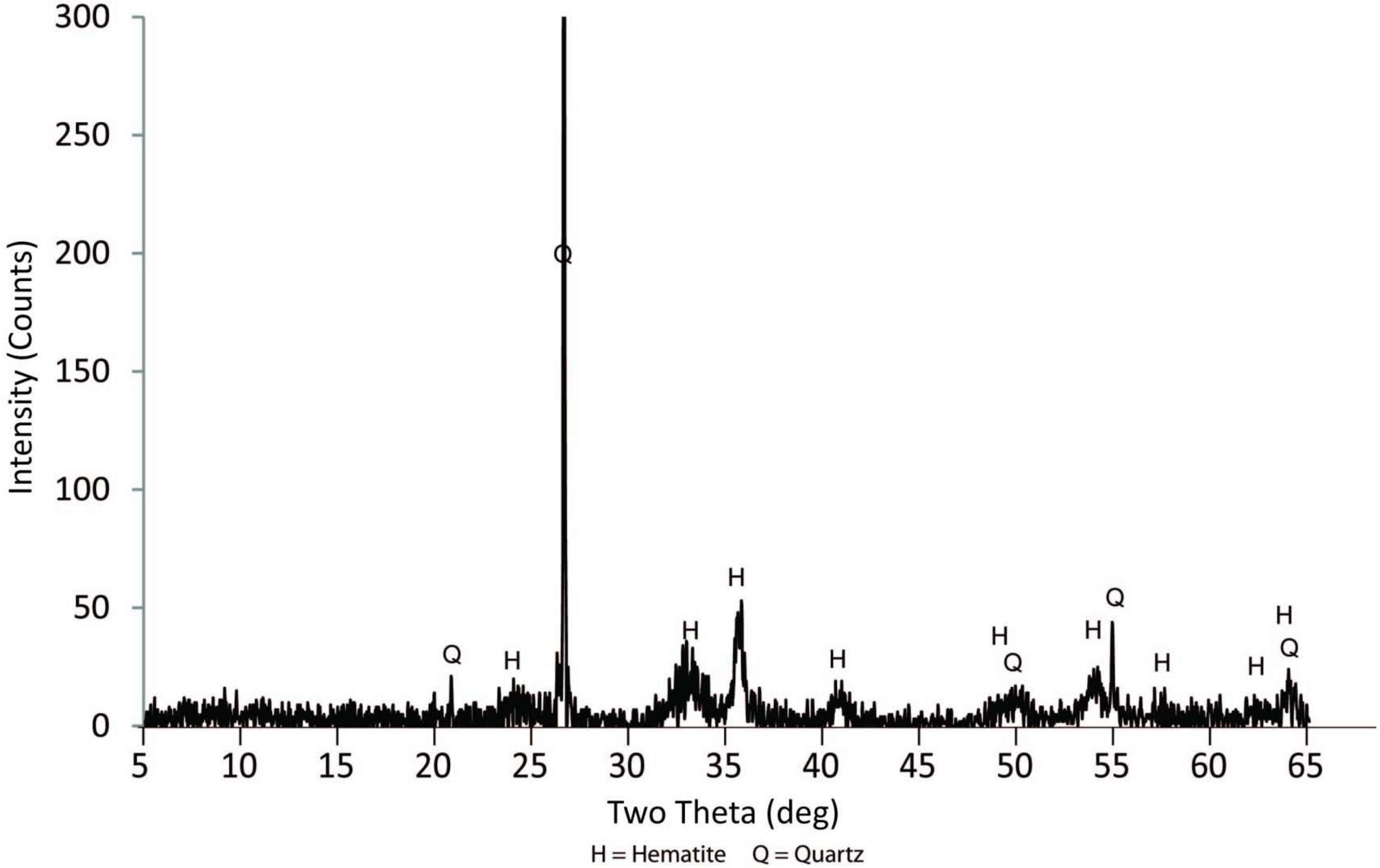

Fig. C.43. DBCS 168843

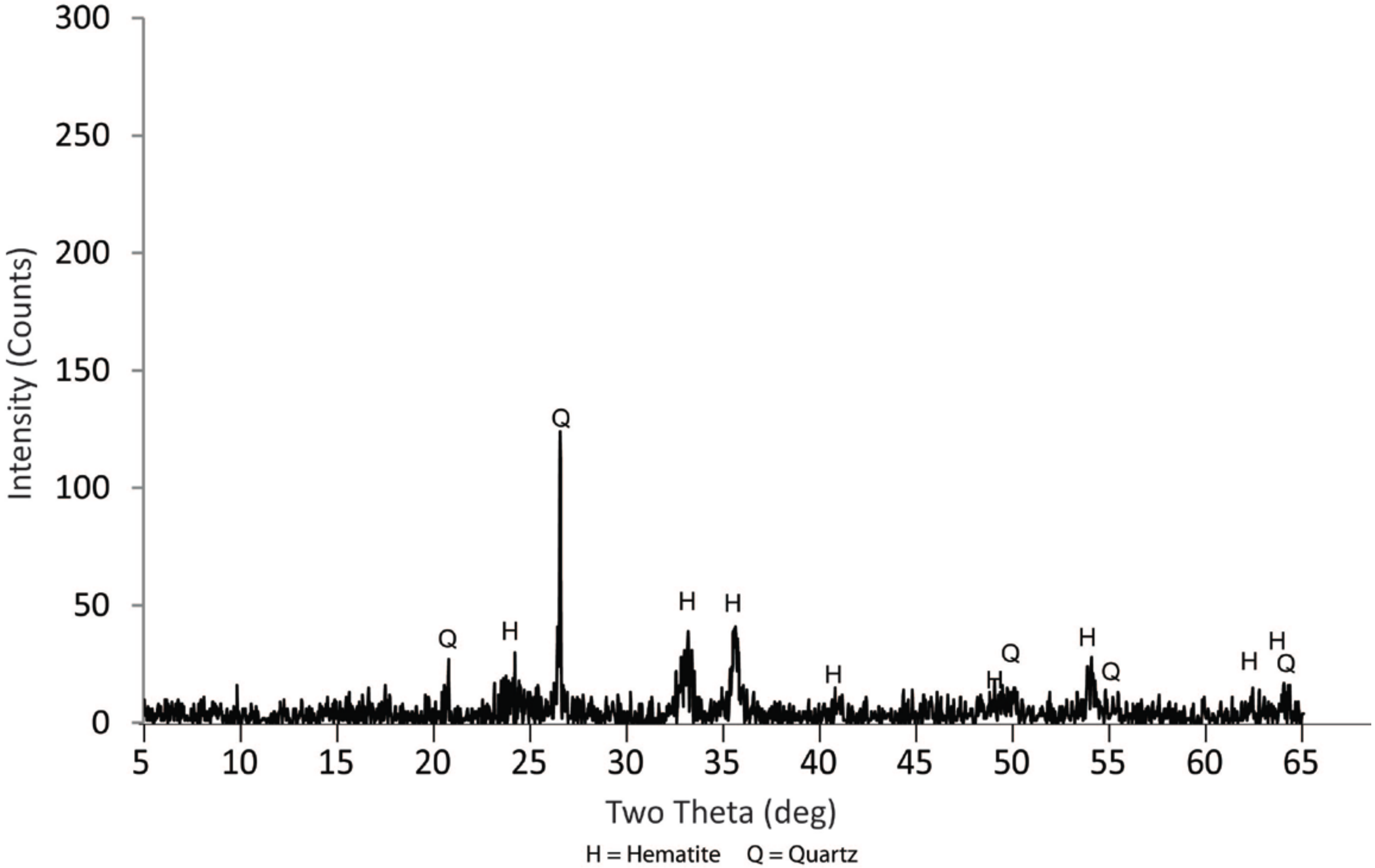

Fig. C.44. DBCS 170199

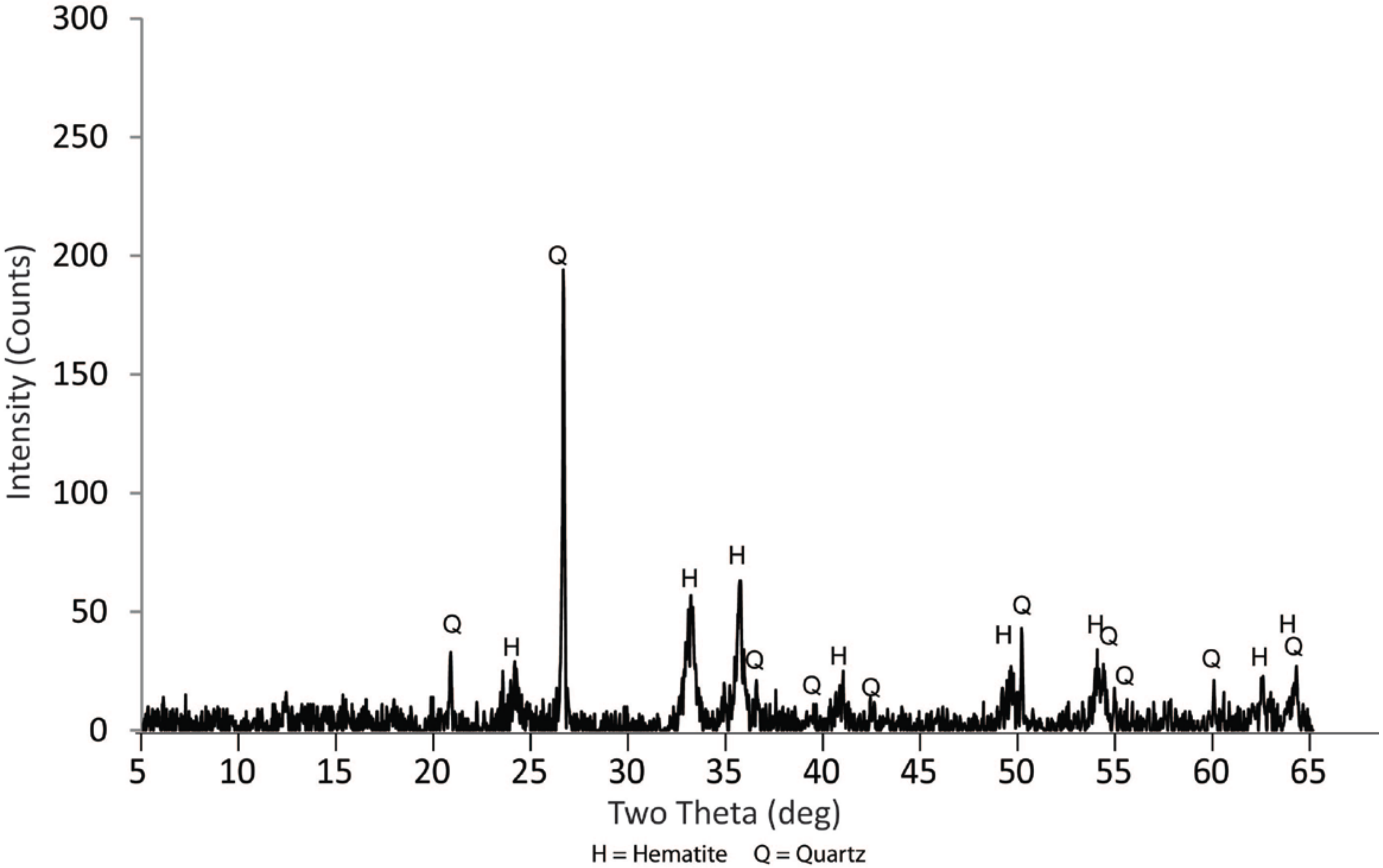

Fig. C.45. DBCS 181724

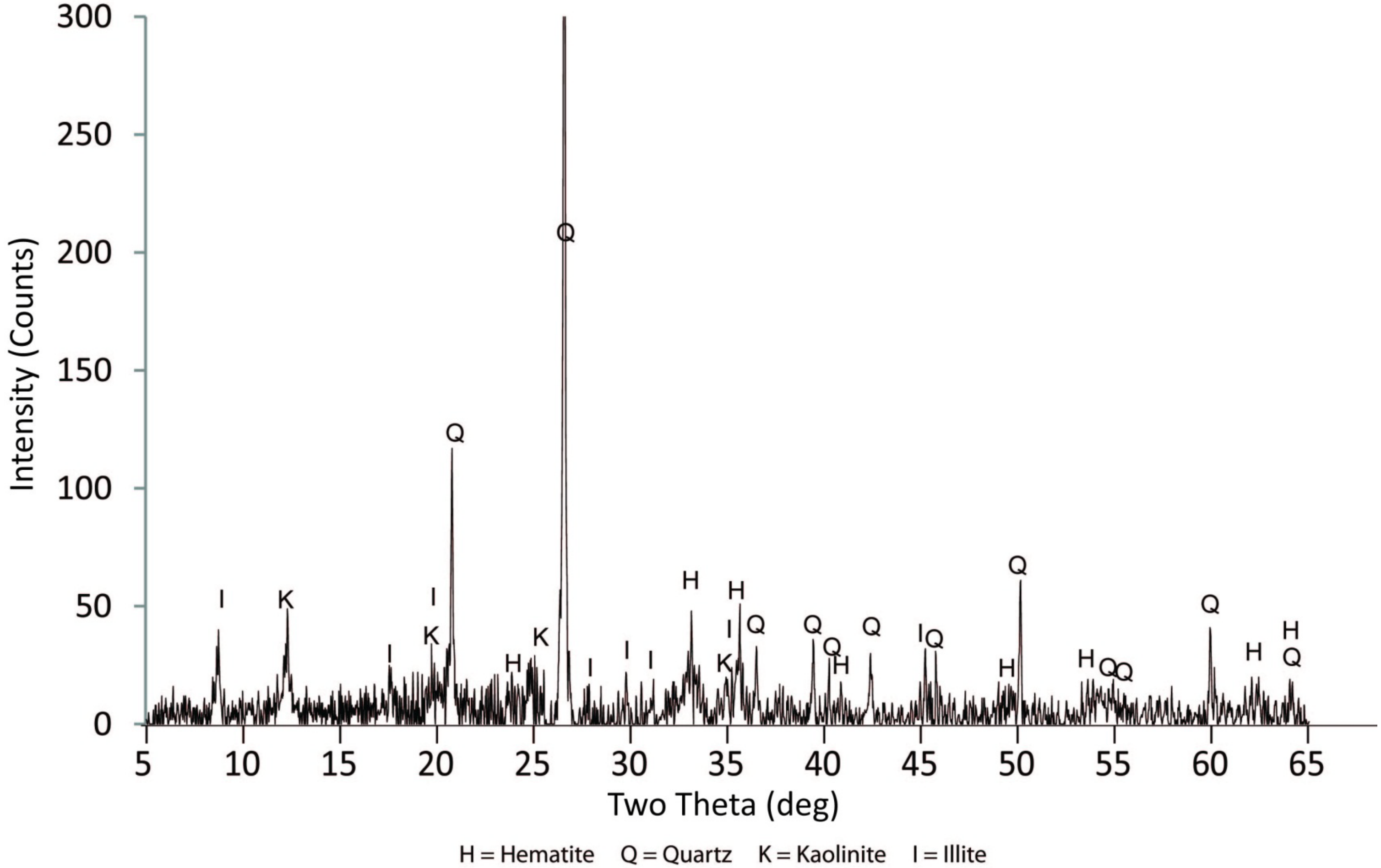

Fig. C.46. DBCS 257335

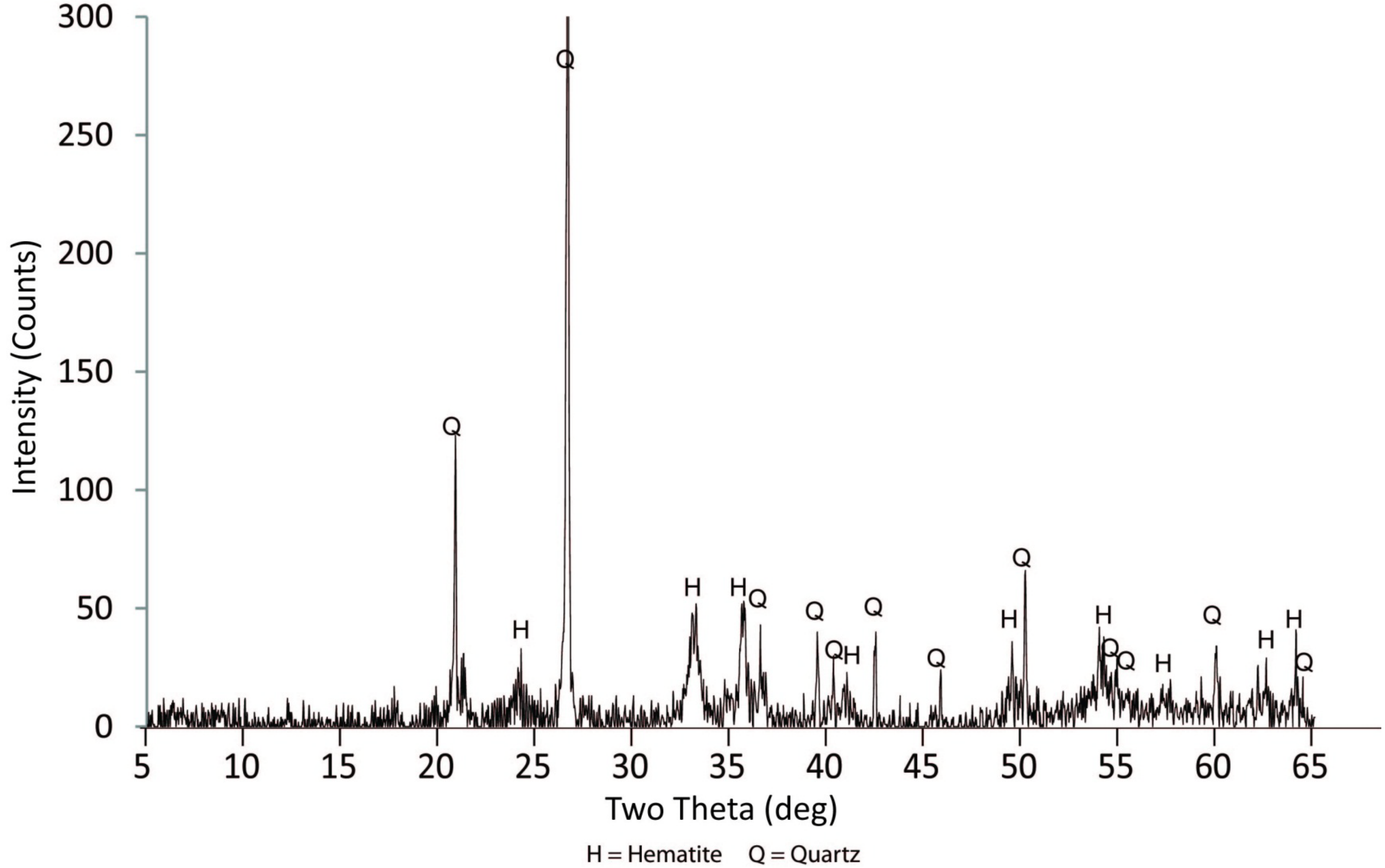

Fig. C.47. SGS 257347

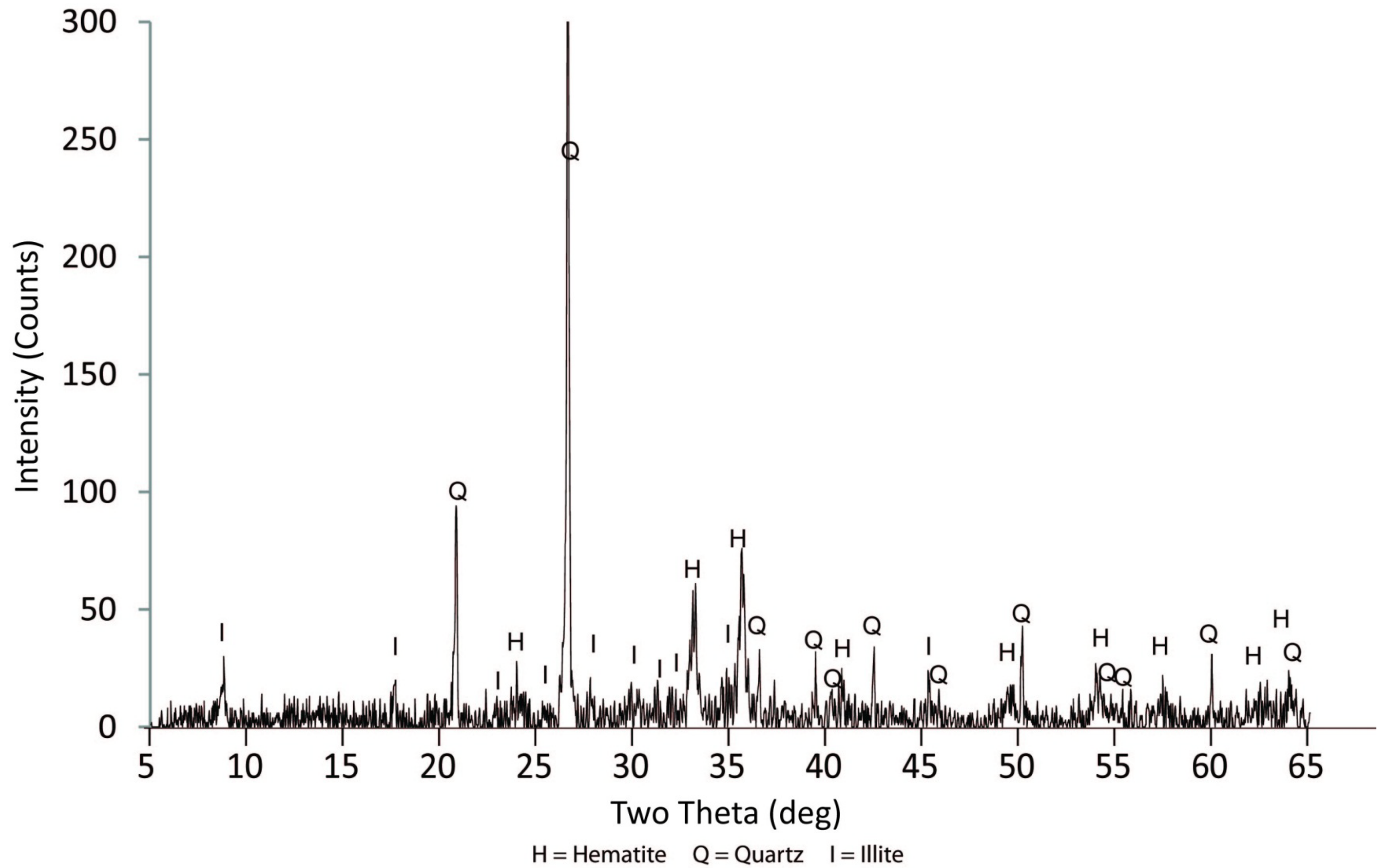

Fig. C.48. OBS1 257329

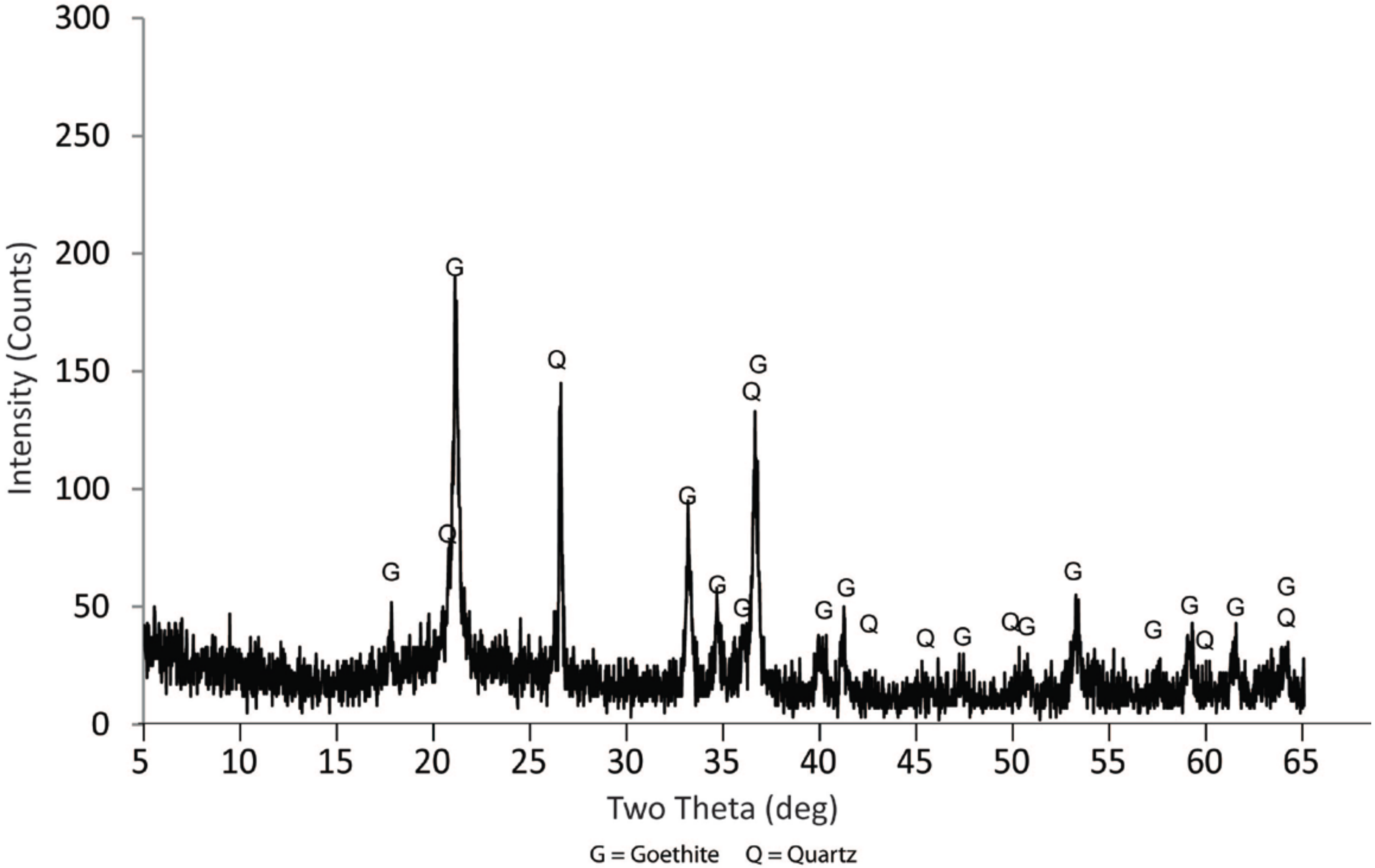

Fig. C.49. OBS1 257330

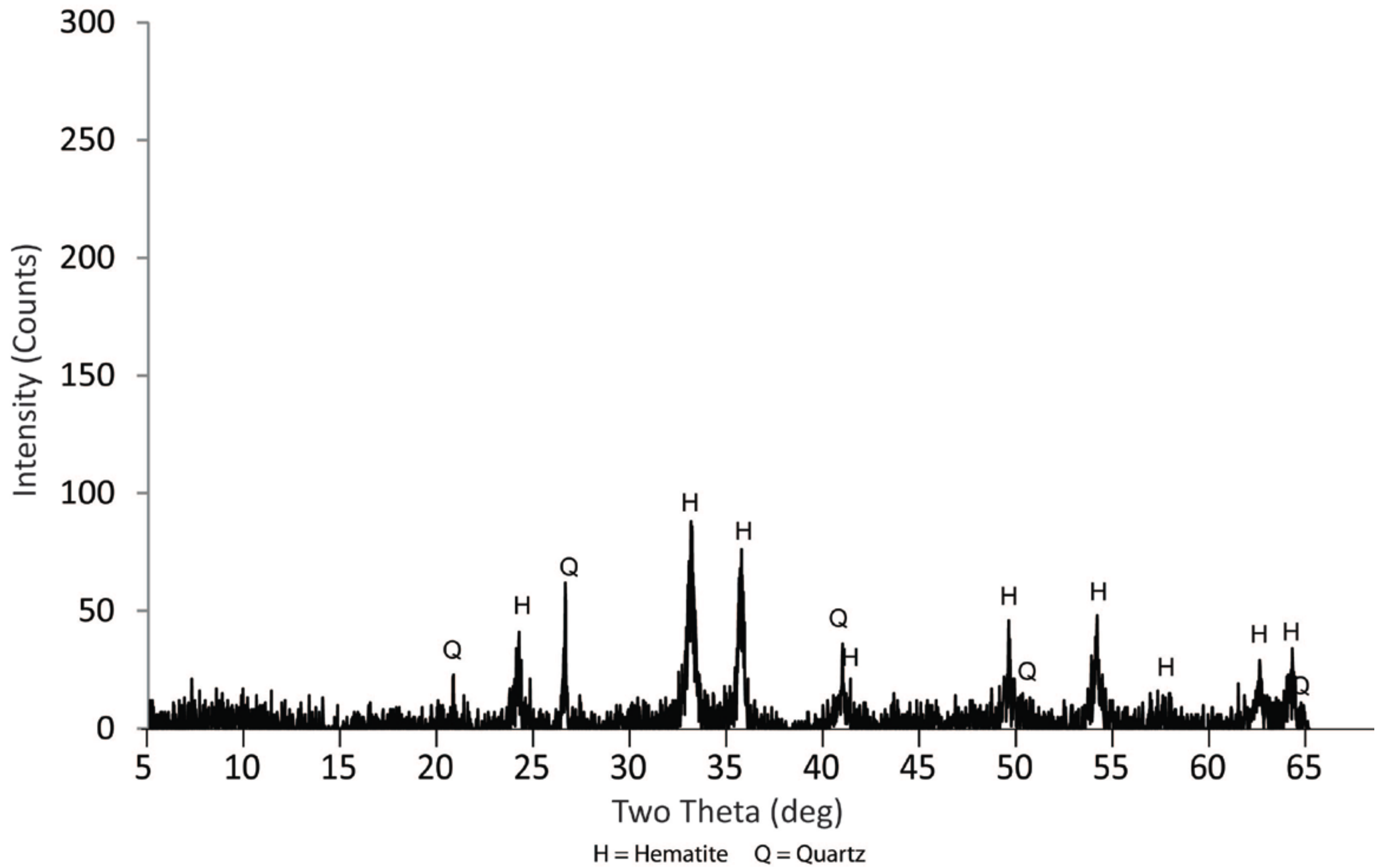

Fig. C.50. OBS1 257357

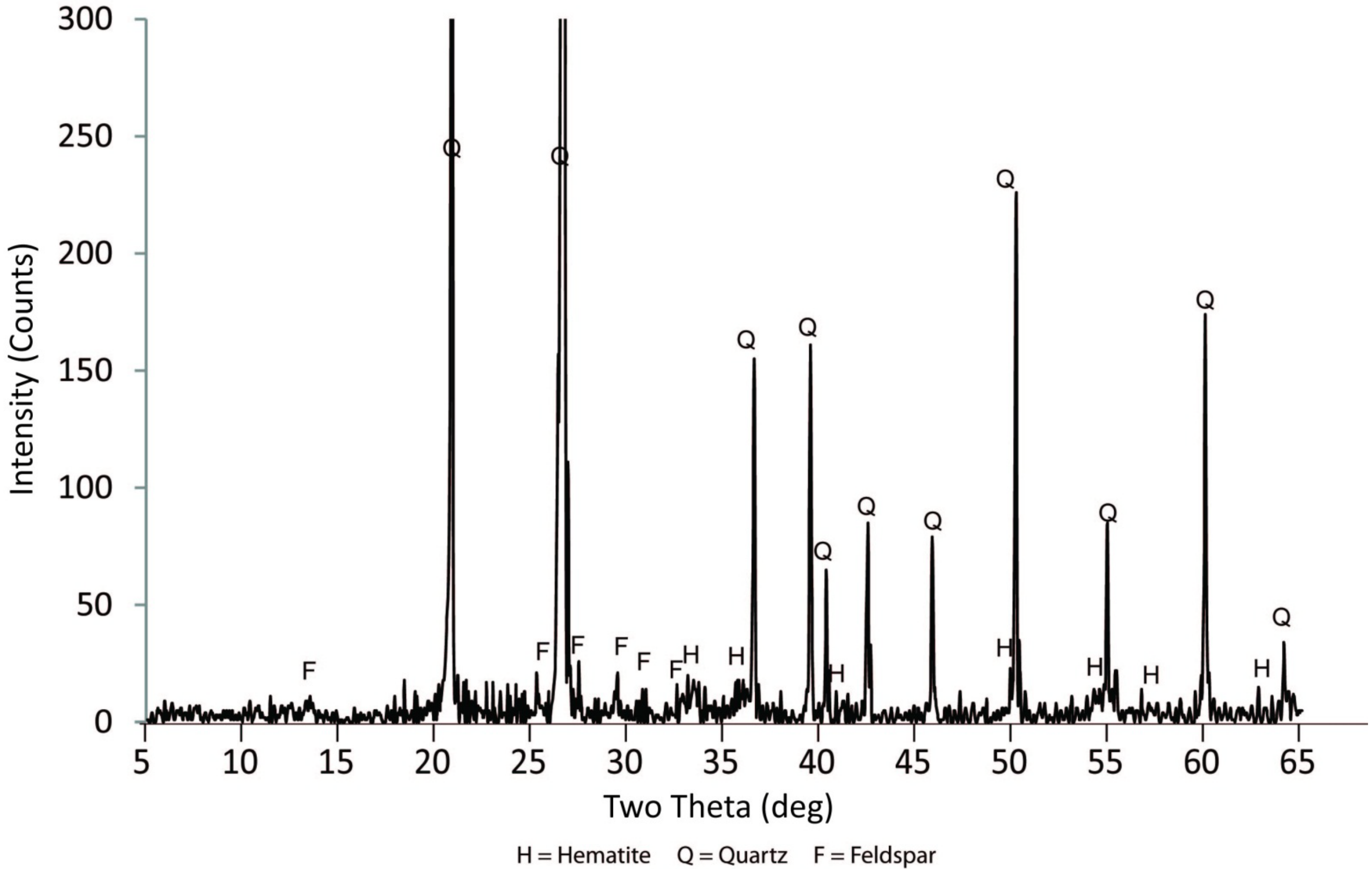

Fig. C.51. SADBS 131583

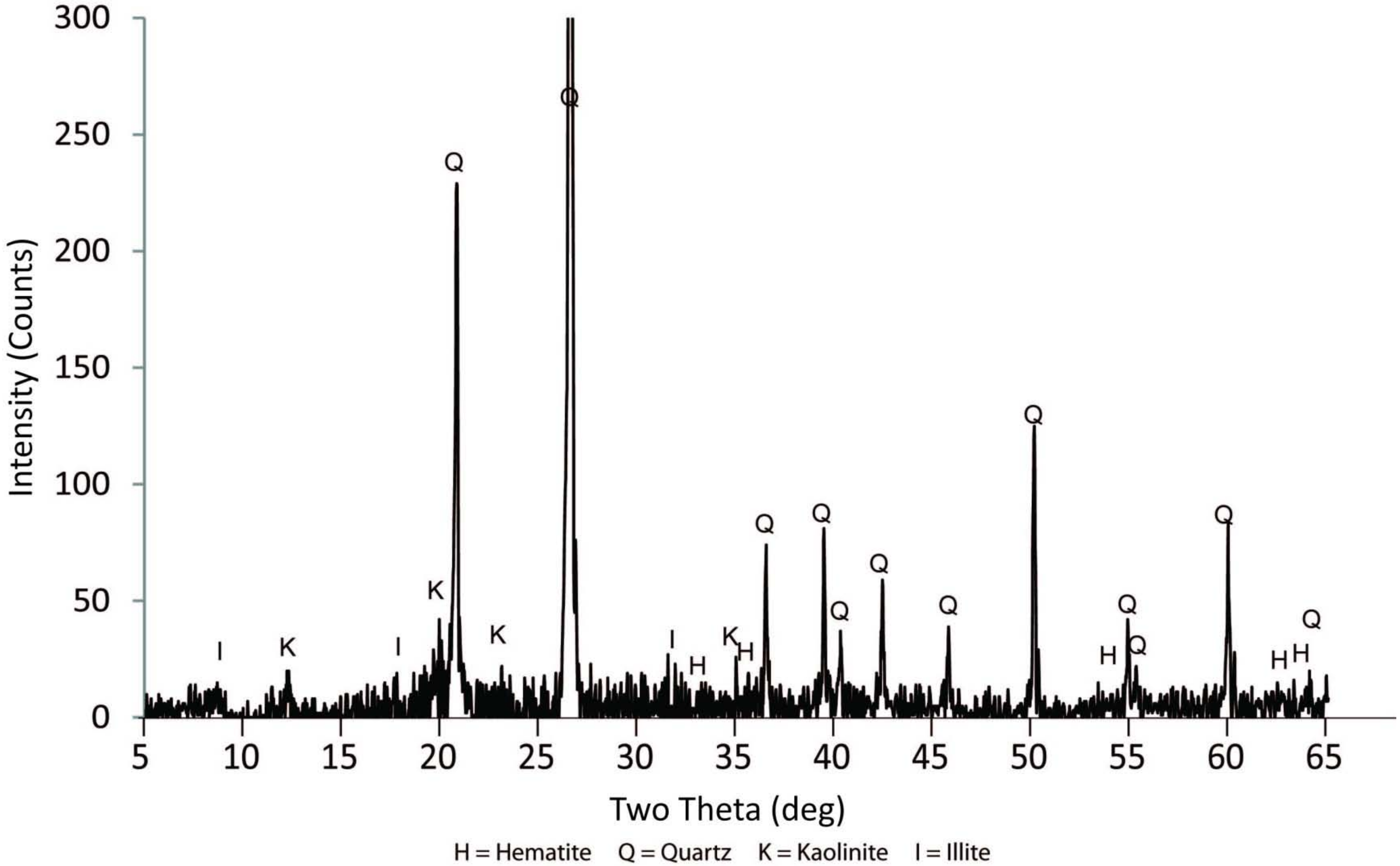

Fig. C.52. SADBS 135335

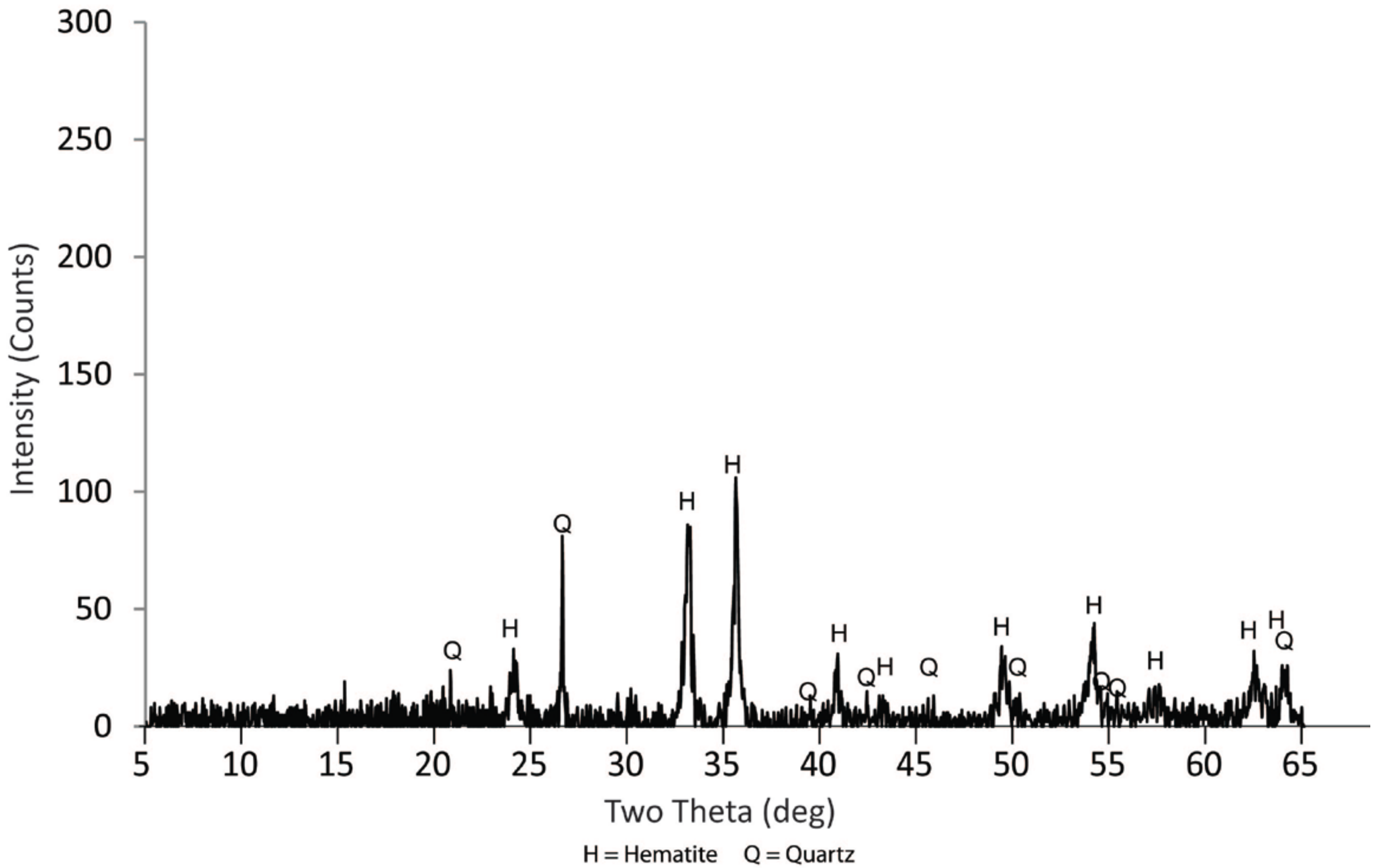

Fig. C.53. SADBS 135670

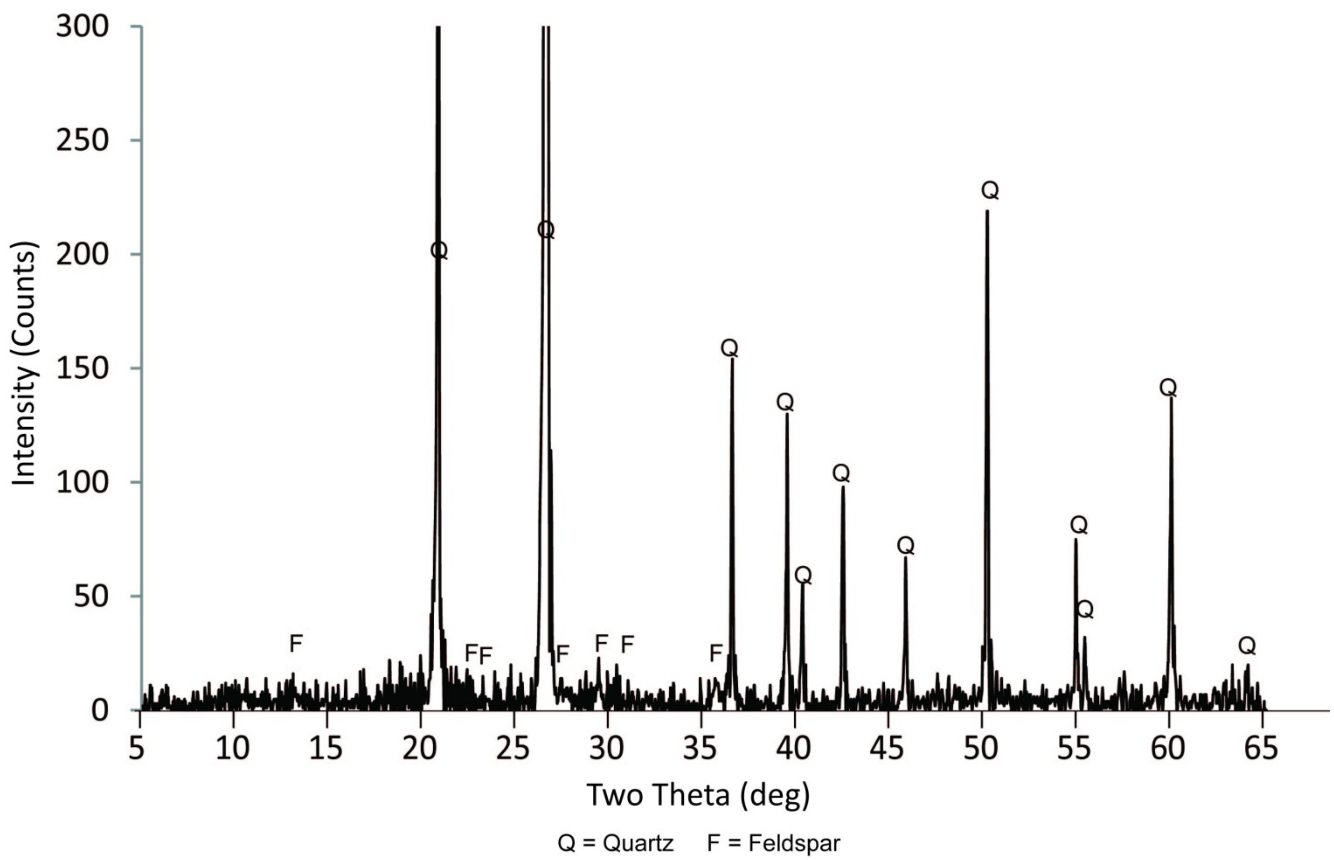

Fig. C.54. SADBS 151183

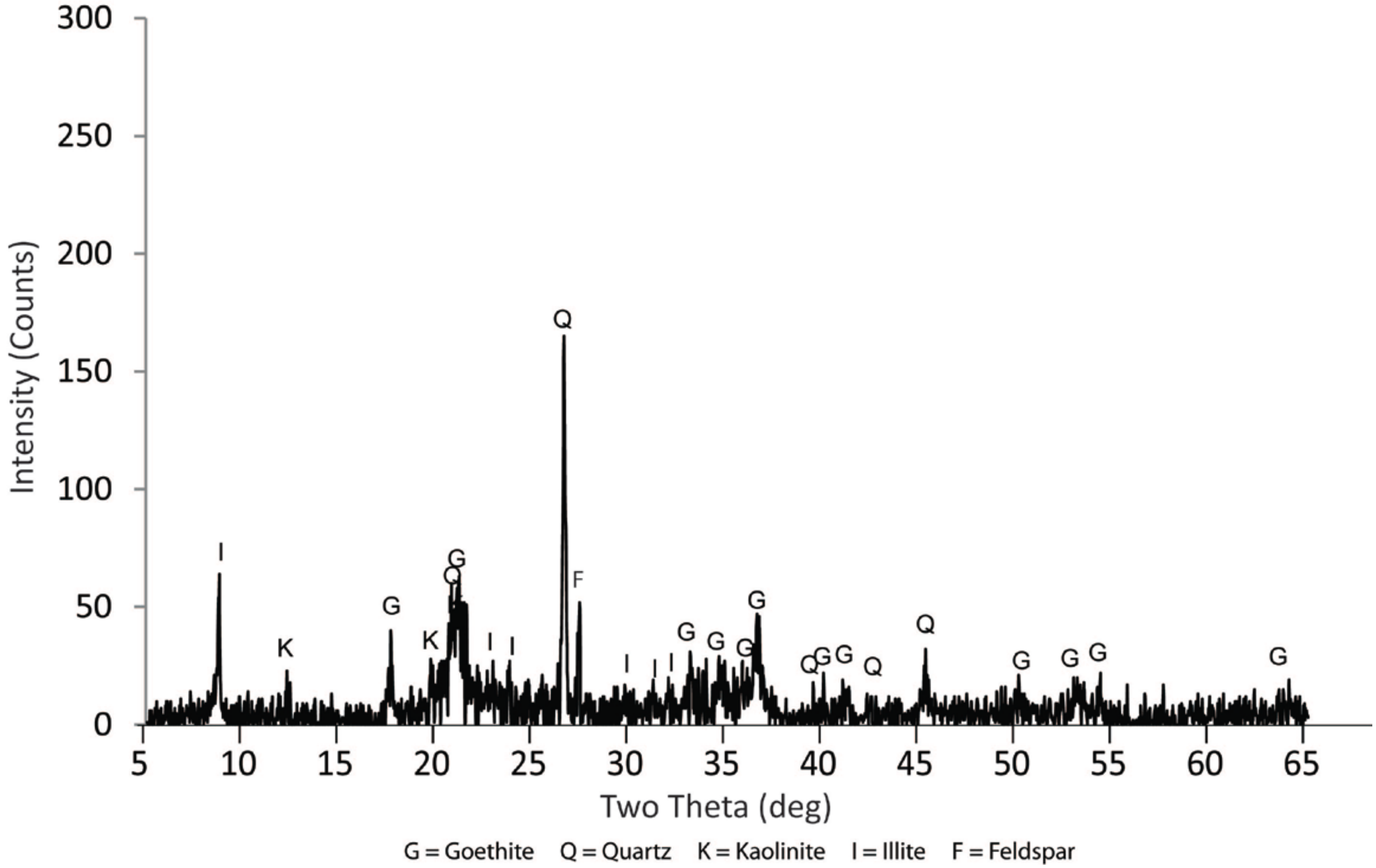

Fig. C.55. SADBS 257362

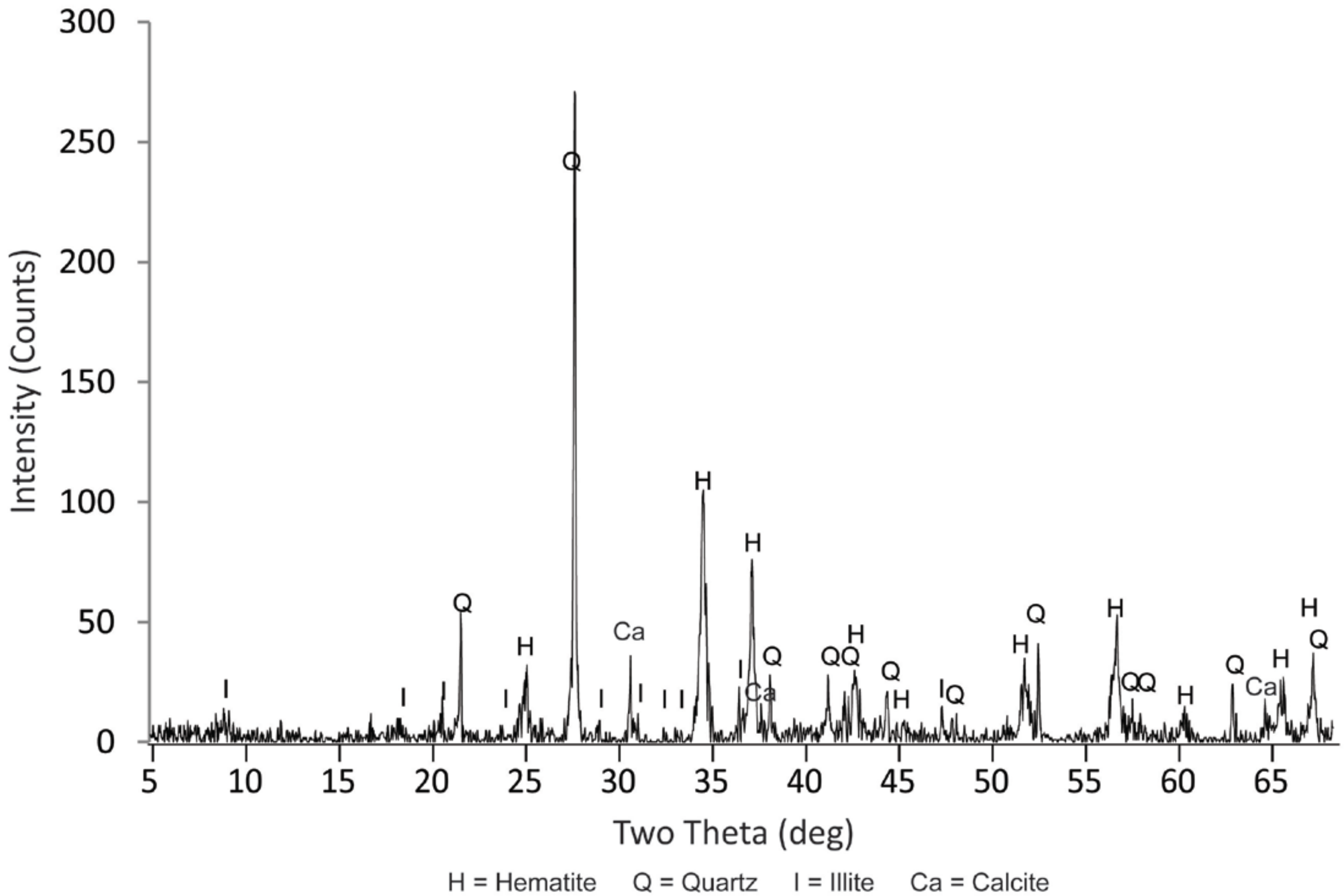

Fig. C.56. ALBS 172814.2

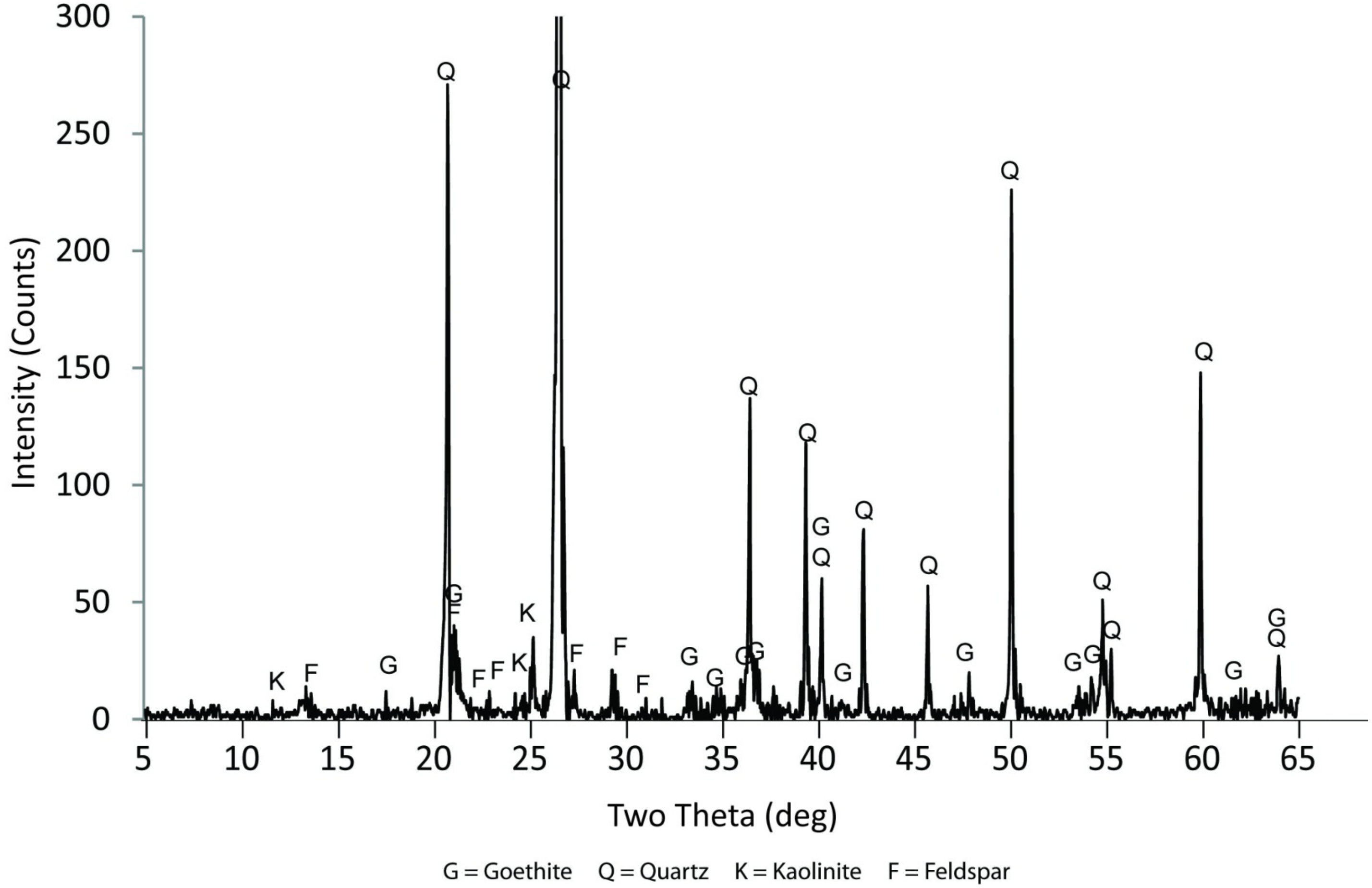

Fig. C.57. ALBS 181100.3

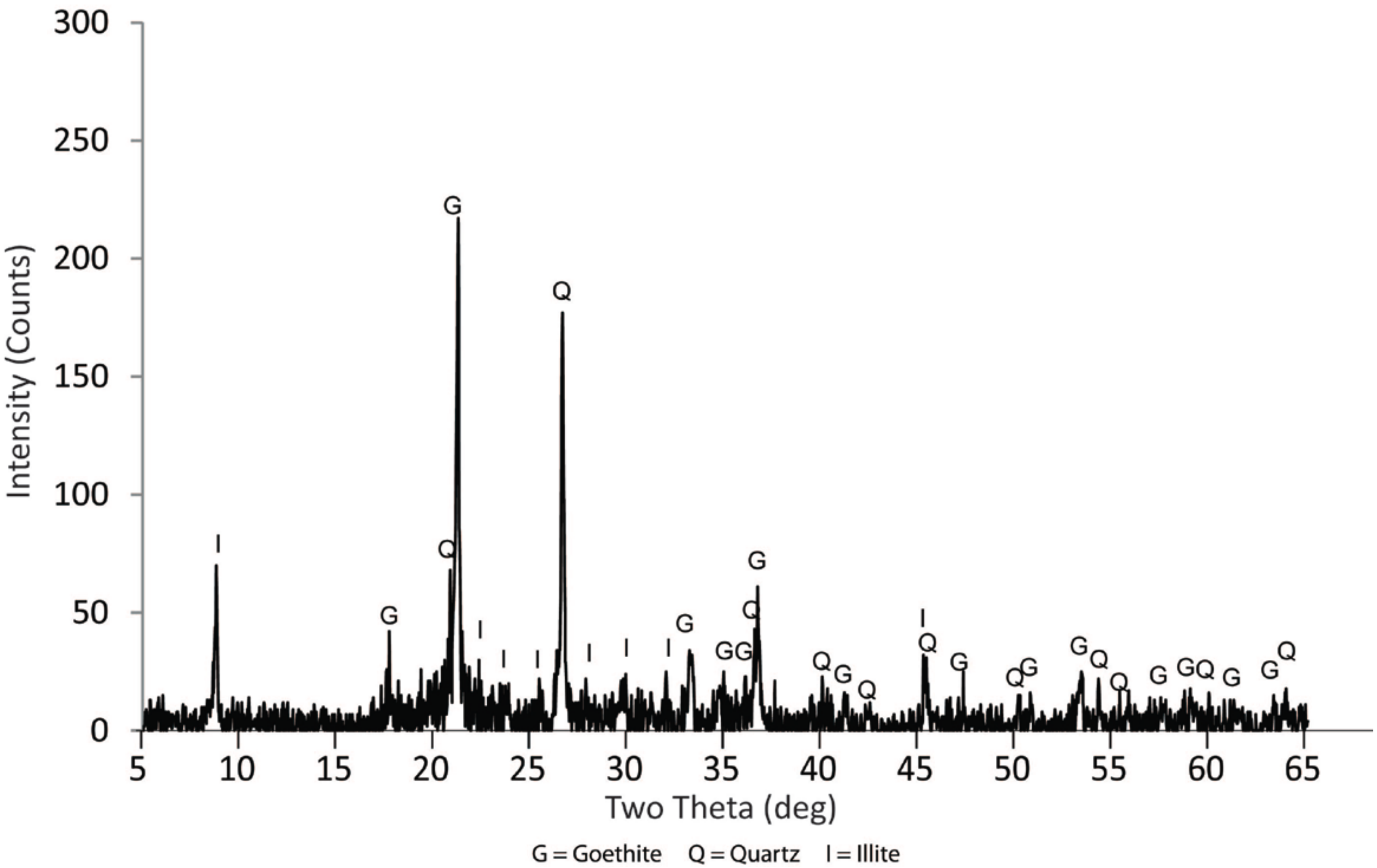

Fig. C.58. LBSR 257247

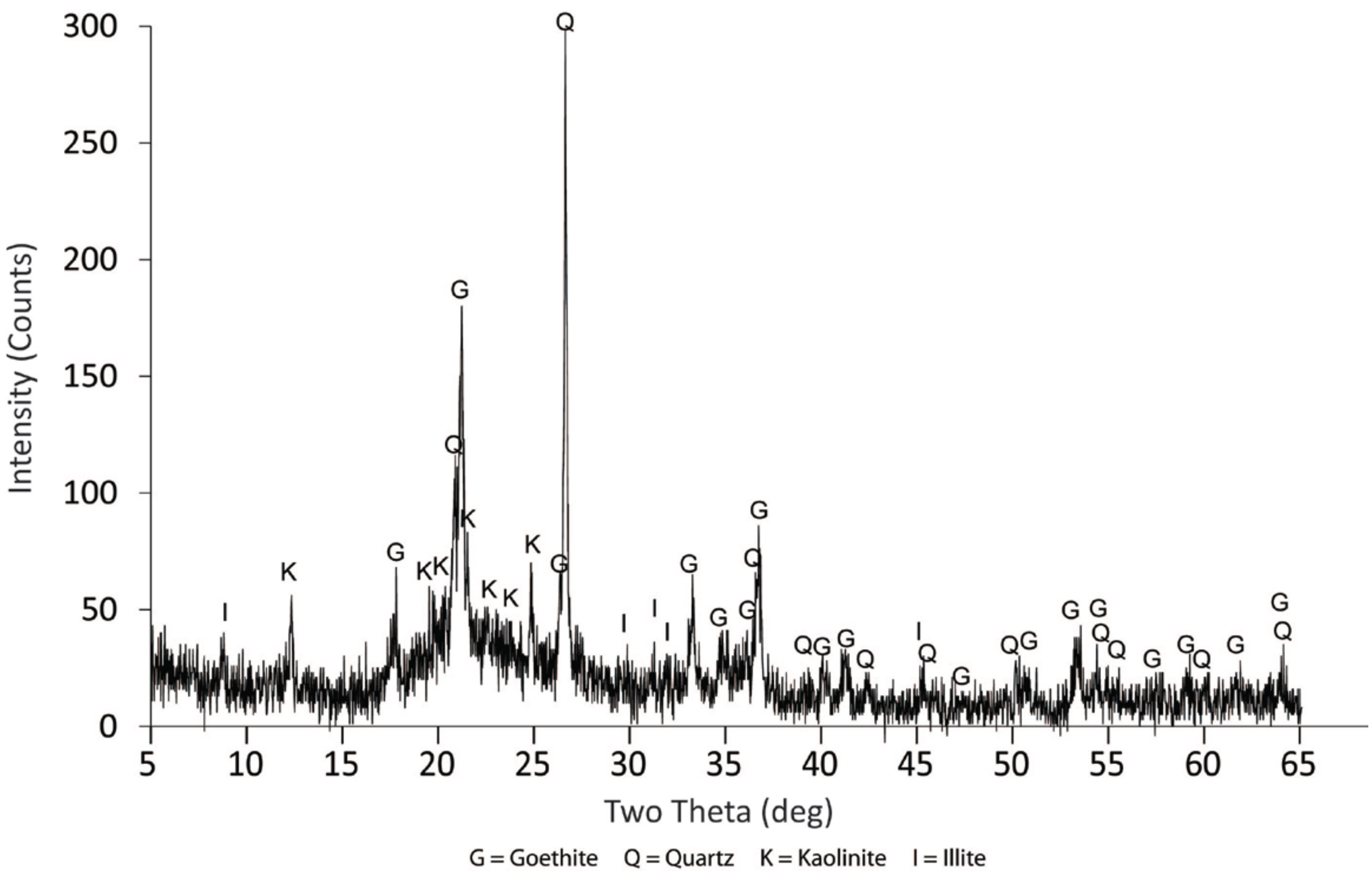

Fig. C.59. LBSR 257272

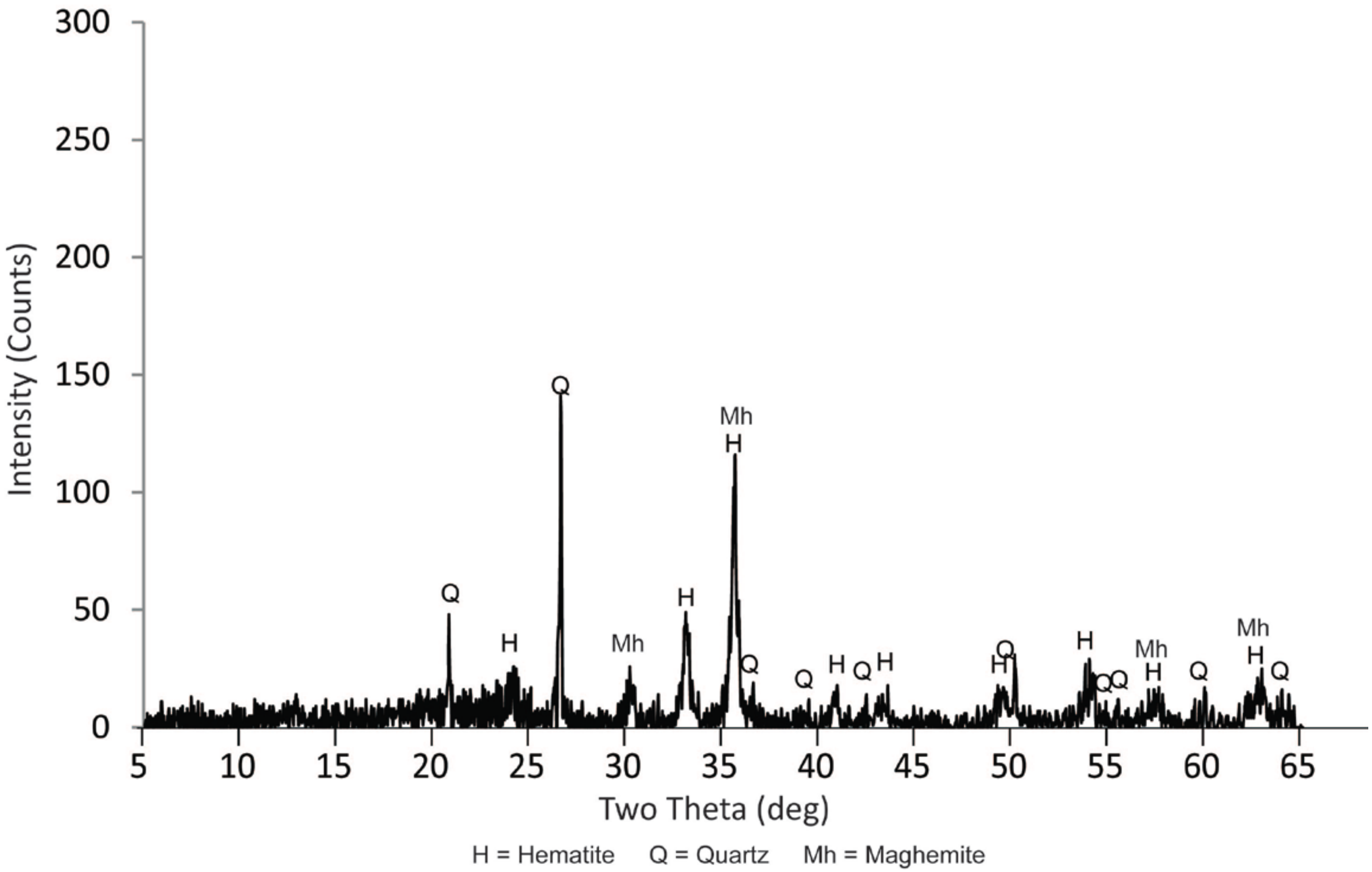

Fig. C.60. LBSR 257349

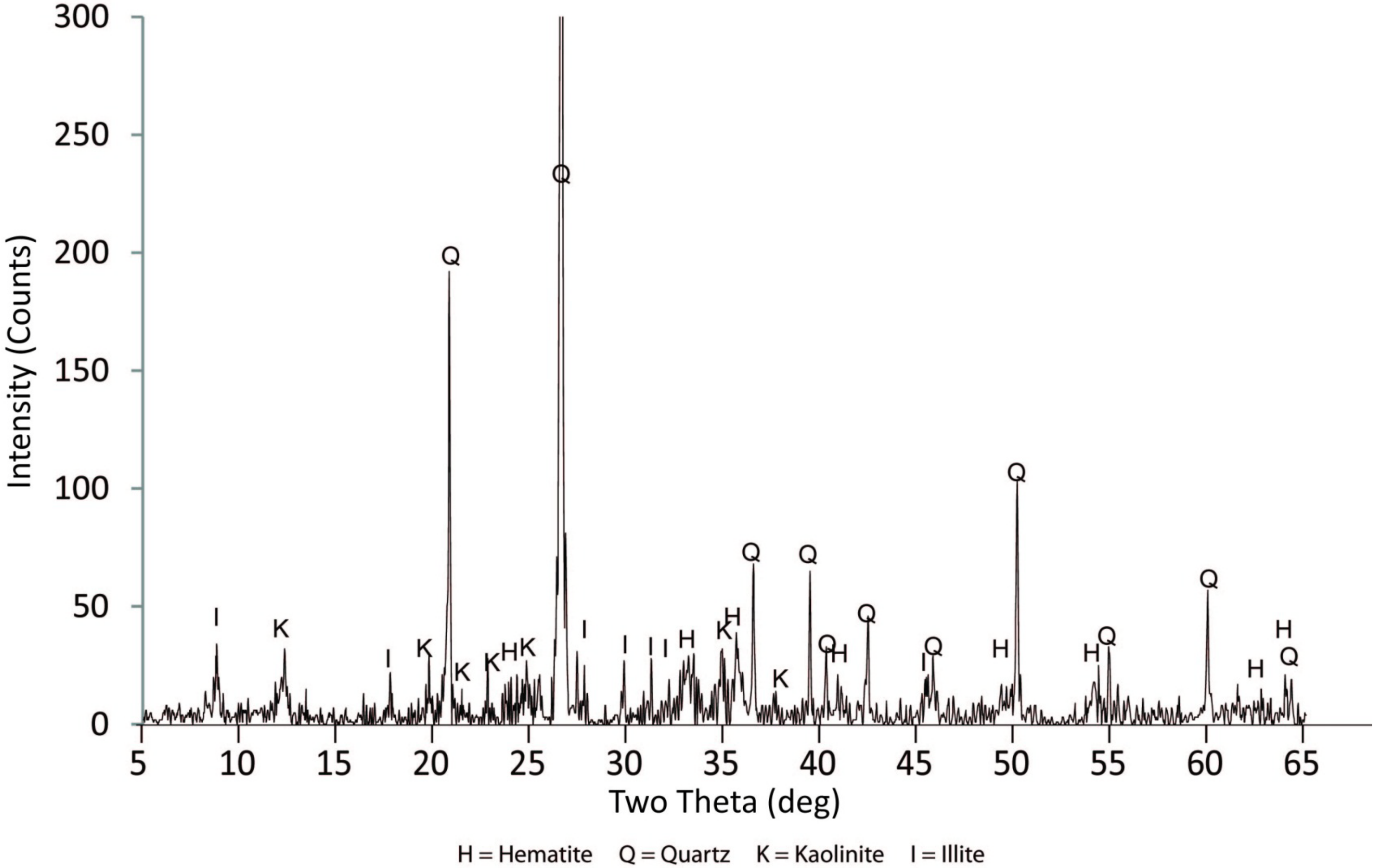

Fig. C.61. LBSR 257433

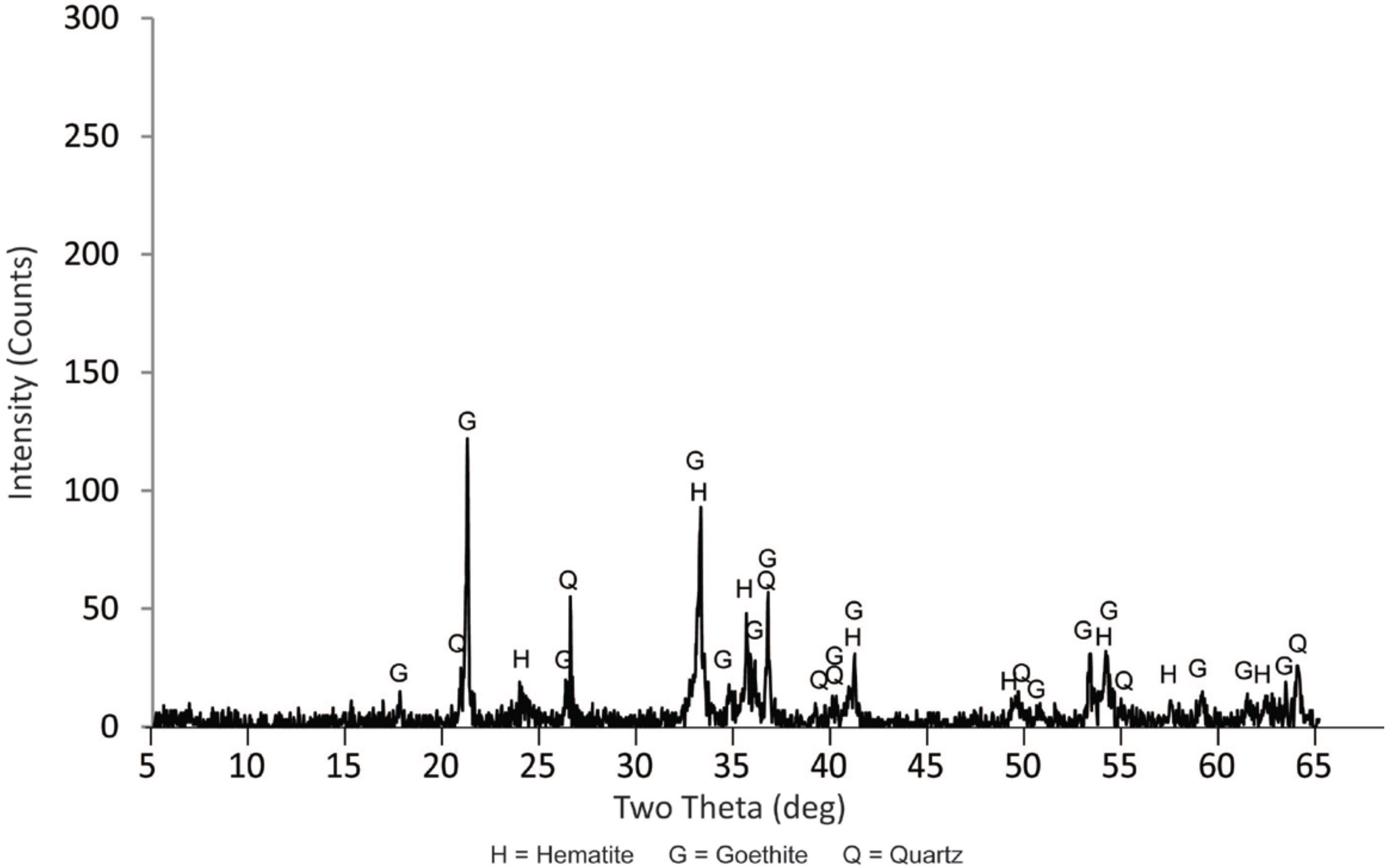

Fig. C.62. LBSR 257449