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8

HANDPRINTS OF THE WESTERN CAPE: RECORDING, MEASURING, IDENTIFYING

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1.

INTRODUCTION

The handprints of the western Cape of South Africa are a common phenomenon, yet remain one of the most unexplored and intriguing features within the rock art of this country.

Known to occur mainly in the western Cape of South Africa, they represent a different style, class, and hence meaning, of rock art.

This dissertation is an approach to answer questions concerning the emergence and meaning of handprint-making in the western Cape. Through experiments, statistical analysis and hypotheses testing in the field on the original handprints, a different approach towards recording rock art, and in particular handprints, was investigated.

One of the main aims is to examine whether we can distinguish between individual handprints and therefore individual people, and between groups of people and clusters of handprints of the same person. This examination will hopefully provide us with the opportunity to answer questions concerning the authorship of the handprints, as well as questions concerning the relationship between archaeological deposits and the rock art of the same sites. We might see whether the conceptions of previous researchers in the interpretation of their data were correct, and what remains indeterminable.

To achieve this goal and truly understand the meaning and the reasons behind the making of the handprints, a methodology and technique needed to be established which allowed for highly accurate recording and later assessment of the measurements of archaeological handprints. For this reason, I chose to digitally obtain the data with close-range photogrammetry. This technique offered a fast and efficient way of creating sets of measurable data for further analysis.

To better understand what role the handprints play within the rock art of South Africa, two

archaeologically well-known sites, Elands Bay Cave and Diepkloof Shelter (later referred to as EBC and DK), were examined. The sites contain a combined total of approximately 950 printed hands, and display not only a wide variety of different "styles" of handprints, but also encompass other paintings and a rich archaeological background.

Comparative material of schoolchildren's handprints was collected, which allowed me to put the original archaeological handprints into a larger framework. With the new photogrammetrical recording system, the handprints of the western Cape can be documented. This system helps to discover the people and the reasons behind this feature of rock art, and therefore advances the investigation of the worldwide phenomenon of handprint-making. The fact that handprints are very common in other parts of the world, such as Australia, South and North Americas, Asia and Europe (see Grant 1983, Sieveking 1979, Walsh 1988, Baffier and Feruglio 1998, Freers 2001), makes the investigation even more promising, as it provides material for further research.

I will now briefly outline the structure of the thesis to provide a broad scope for understanding the individual objectives of each chapter.

In RESEARCH DESIGN (CHAPTER 2), I will explain my motivation and intentions, as well as the problems I encountered and the questions which I tried to answer with this dissertation. Subsequently, in the LITERATURE REVIEW (CHAPTER 3), I will briefly describe what other researchers have discovered so far, the different approaches they took, and the conclusions they drew. At the same time, I will address mistakes they made and investigate ideas which were useful for my approach. As the reader will need information about the surroundings of the sites and the material I examined, the following chapter BACKGROUND (CHAPTER 4) is dedicated to the archaeological, geological and environmental background of the sites. This will incorporate a description of the distinctive rock art categories, their dating, meaning and distribution, as well as an brief introduction of the occupational history of the western Cape and the different theories associated with it. Once this

is clear, I will begin to characterize the methodology and techniques, such as photogrammetric recording and classification, which I used to achieve my aims in the next chapter, METHODOLOGY AND TECHNIQUES (CHAPTER 5). Thereafter in RESULTS (CHAPTER 6), some of the statistical evaluations will be presented, followed by a discussion about their meaning and reliability, and which approaches "worked" and which did not. In DISCUSSION (CHAPTER 7) problems which have occurred during the analysis will be considered. The CONCLUSION (CHAPTER 8) will list my interpretations of the data and results, and will furthermore show to which degree they influence existing theories and established knowledge about the handprints of the western Cape. I will conclude the thesis with a summary of the outcome and give recommendation as to what other researchers interested in the topic of handprints should consider. These are issues which I encountered during the process of my investigation which exceeded the scope of this thesis, yet remain pertinent in the larger context of handprint or rock art research.

2.

RESEARCH DESIGN

2.1. Motivation and objectives

Little is known about the handprints of the western Cape (but see Willcox 1959; Maggs 1967; and Manhire 1998, 2003 in prep.). Researchers argue about who the artists were, why the prints were done and when these events happened. More questions arise if we scrutinize other details. How many people were involved in any one event of handprint-making, and what were the rules applied to the process? Of course, some of these and of the following questions are difficult to answer and will remain elusive simply because we are dealing with human beings and the arbitrariness of the human mind. It should be considered that we work with a substantial depth of time. Factors such as erosion of the wall surface and the paint, the fading of the colours and damage from visitors to the cave-sites over the years can change the images and influence the results. In addition to this, we have only a few indicators of when and how the authors of the handprints created their "artwork". However, there is the possibility of obtaining useful observations for an in-depth analysis, and with that, answers to some of the questions raised. The possibility lies in the work of previous researchers and potential projects which could result from their ideas. Henneberg and Mathers' work (1994), whose technique and resulting formulas derived from the handprint measurements of children in the western Cape, was used by Manhire (1998) to calculate the age and height of the archaeological handprint makers and provided the initial idea for this research project.

2.2. Problems and solutions

2.2.1. Methods of observing through time

The previous methods of observing and gathering the images and subsequent measurements used require explanation. D. Bleek (1940) started to gather information by simply looking at the handprints and estimating their relation to other paintings. Willcox (1959) "measured" them, but gave no indication, how and with which methodology. I assume that he used a calliper directly on sites where he found handprints and measured from "...end of the longest finger to 'heel' of hand" (Willcox 1959:296). His measurements were to the nearest quarter inch, while Maggs (1967) in his investigation of handprints in the western Cape measured "...to the nearest .1mm by means of Vernier scale..." (Maggs 1967:103). Manhire (1998) also utilized a calliper (pers. obs.) to obtain the measurements in the field, where he measured "...only prints with the fingertips and 'heel' of the palm clearly visible". (Manhire 1998:102). Other less subjective and more comprehensible techniques of obtaining measurements of handprints in the field, such as those proposed by Freers (2001) or such as I propose, have not been tried so far in South Africa. It will become clear that some methods are unsuitable for our purposes.

2.2.2. Technique and methodology

In my research two factors hindered data collection. The observations cannot simply be obtained by going to the caves and measuring every handprint on the cave walls. This is a very time-consuming task, would have taken weeks and could have possibly damaged the paintings considerably. Secondly, the handprints inevitably would have been recorded subjectively, as I would have been the only person measuring the imprints. There would also have been a substantial measuring error due to the inaccuracy of the manual measuring equip-

ment and the rock curvature. In order to solve these problems an alternative technique had to be developed which would enable me to work with the images without always being at the handprint site. Taking the handprints 'out of the cave' would additionally allow for other researchers to verify or critique the measurements. Moreover, a convenient and efficient technique of recording the images of the handprints had to be developed. Tracing each handprint singularly was one of the possibilities from which to choose. Through tracing, nevertheless, another level of inaccuracy will be introduced. Only those parts of the obtained images which are perceived, or thought to be perceived by the researcher will be recorded, thus the records become subjective (see Asmus 2003 for a detailed discussion).

Moreover, these tracings would not have been as easily accessible to many other researchers in the world, rather merely representing a single project. In addition, tracing paintings is a time consuming task. I also considered taking pictures of the prints; however this would also create inconveniences. In addition to taking the pictures, they would need to be scanned afterwards. Furthermore, photography by itself does not allow for good accuracy as the dimension of the picture will be distorted unless the lens is calibrated (see for more information in chapter 5). Furthermore, Photography would also have been an expensive task as films would have to have been bought and developed.

New technological advances offered a very easy solution for these problems. Each handprint could be photographed with a digital camera and a scale, so that all the measuring work could be done on the computer without touching the paintings. As it turned out, these photographs were not accurate enough, because the lens distorted the measurements of the pictures to the sides depending upon the angle at which the camera was held. This is a problem that would have occurred with analog photography as well. I wanted, however, an accuracy of about 1mm or less, as opposed to the imprecision of about 5mm when using normal cameras without a photogrammetrical framework.

Furthermore, I wanted to extrapolate height and age of the ancient handprint-makers, since

Henneberg and Mathers (1994) developed a method for calculating the aforementioned parameters of a person by the size of his hand. The issue arises of whether individual people are identifiable from the images of their handprints to a reasonable degree of certainty.

Questions to be considered were: How many people were involved in the process? Did one person make only one, a pair, or even more prints? Are there certain patterns or clusters within the arrangement of handprints? On a broader scope I wanted to consider the possible explanations for why people made handprints on their living sites, and if they actually were living sites at the time the prints were made.

A method to potentially distinguish individuals had to be developed, one which could perform the identification process based on the techniques of image-processing and stereo-photogrammetry. The effectiveness of such a method would need to be tested to see where its limitations are. I have to admit that it is impossible to prove that identical-looking handprints represent the same person. It is conceivable that people with exactly the same hand size (or within the variation of one hand repeatedly printed) made their handprints on the same site. The handprints can then appear to have had the same maker.

In addition I wanted to test if there were rules in applying prints to the surface based on their patterning and distribution. Are there specific groups, such as lines or clusters of handprints, and could the handprints be made over other paintings or vice versa? This may be important as it would make significant changes to the dating, which is mainly based on superpositioning. For example, it is often thought that handprints are younger than fine-line paintings, because they have never been found below these paintings. This should not be assumed from the superpositioning, for perhaps the handprints were not allowed to be painted over. Apart from this, the ratio between right and left-handedness can be an indicator of specific rules. Schick and Toth (1993:140) write that

"...[i]n modern human populations, approximately 90 percent of people are dominantly right-handed (dextral) and about 10 percent are dominantly left-handed (sin-

istral). This is a very unusual pattern, as it is unique to humans. In the rest of the animal world, including non-human primates, the breakdown of handedness (or pawedness) tends to be about 50 percent left-handed and 50 percent right-handed. "

I would therefore expect a ratio of 9:1 or close to that on the cave-walls of Diepkloof and Elands Bay Cave, or I must otherwise assume that certain rules existed which influenced the proportion. These rules, implied by the society and thus the cultural background, might still resonate presently in the rituals of the hunter-gatherer societies of the Kalahari.

As already mentioned, many of these questions are not easily answered, though some research has been carried out on the topic, and different hypotheses have been offered. In the next chapter, I present the theories of various researchers who scrutinized the subject of handprints.

3.

LITERATURE REVIEW

3.1. Handprint research

In this chapter I will briefly describe the literary sources, and the authors who have covered this topic in their work, be it in a purely descriptive way or in the form of a thesis. I will begin this section by outlining the history of research to the present, thus enabling the reader to comprehend and engage in this discussion about the handprints of the western Cape. The review starts with the earliest sources and ideas and ends with the most current research.

There are no oral sources, such as stories or written documents from the handprint authors themselves, as they were preliterate hunter-gatherers or pastoralists. In addition there are no sources from foreign people who witnessed this particular phenomenon. The only sources are ethnographic comparisons in which people have been reported to have decorated themselves with ochre as a kind of body decoration, sunblock or in a ritualistic manner (Rudner 1982). This lack of information forced most researchers to focus on creating a plausible explanation for the handprints in the caves and shelters of the western Cape.

3.1.1. Recording handprints - the beginning

The first person to record hand imprints as rock art was Dorothea Bleek (1940). The prints were noted as "being perhaps the latest addition" to the rock art because of their superposition. No real analysis of the rock art was attempted in her study.

The first researcher to study them closely and offer a detailed hypothesis about their author-

ship was A. R. Willcox (1959). In his article he tried to show the occurrence of handprints using the painting-group areas previously defined by van Riet Lowe (1952). He wrote that "...[i]t may be thought possible that the hand imprints were made by people other than those who made the paintings. This is so highly improbable that the notion can safely be rejected." (Willcox 1959:293) This referred to his own observations, in which he had found "...clear cases of superpositions including hand imprints..." (Willcox 1959:293). He protested against Bleek's statement that "...the hands occur over and under the ordinary paintings" (Bleek, D. in Willcox 1959:293). By placing hands on an ink pad, printing on paper, and finally outlining the hand, Willcox determined that the ratio of hand length to length of hand imprint was 1.112. A different ratio of 1.0383 for hand length to handprint length was obtained by Freers (2001), who observed "...63 mixed race high school children..." (Freers 2001: 323). These differences can be explained by the choice of people, technique of measuring, instructions of how to print or varying pressure whilst printing. Nevertheless, the ratio obtained by Freers (2001) for hand width to handprint width is 1.1278 remains uncontested.

3.1.2. Anthropometric approaches

Willcox measured the original handprints of the western Cape originating from van Riet Lowe's (1952) zones 3a and 3b. He compared his observations with measurements he had obtained from Bushmen groups on several expeditions to the former Bechuanaland, the Kalahari and the Ghansi district, as well as with Schultze's (1928) measurements of handprints from a Hottentot group. Willcox concluded that by applying the "Student's" t-test to these measurements, the hand imprints were with a probability of one to a million not Hottentot ($t=6.3517$), and must therefore be associated with the Bushmen ($t=0.6653$) Willcox 1959:297). Willcox also suggested a ratio between hand length and height. To obtain the latter, he calculated that the hand size should be multiplied by a factor of 9.61.

In his paper, he made the dangerous assumption that only one of the two groups, Hottentots and Bushmen, were responsible for creating the imprints. His measurements included handprints from caves and shelters which were distributed all over the western Cape. However, they could have been the product of many groups and individuals created over a great length of time. Even though he never explicitly said so, Willcox's observations suggest that he accepted only adults as the primary makers of the handprints. The average length of handprints of his sample from the western Cape had the same value as those measurements from his Bushmen sample, but with a higher standard deviation. On average, the hands of Schultze's (1928) Hottentot individuals were longer. However, if children had been included, the results could have dramatically changed, so that the average lengths, depending on the age of the individuals, would have been shorter than those of Willcox's (1959) Bushmen. Moreover, statistical tests showed no significant difference between his two samples, as p equals 0.8. "Mean and standard deviation for the three samples overlap considerably and the three samples can be seen as a series of a continuous range" (van Rijssen 1985 :148). Whether or not his ratio between handprint size and body length of 9.61 is true remains uninvestigated. A final point of critique is directed at the choice of the sample material. It contained only male individuals, even though it is not clear which gender is responsible for making the imprints. Cooke (1965a) referred to handprints from Zimbabwe, well beyond the extent of the western Cape, but I will mention them as they are similar in style and also situated in southern Africa. He briefly described the different types, but did not make any statements about why they were made or who created them. He described hand imprints from five shelters, one of which was particularly interesting as it contained over 150 prints. The other sites exhibited no more than three or four examples, a phenomenon which can also be observed elsewhere in the western Cape (Manhire 1998). This peculiarity in sample size has triggered some authors to hypothesize a travelling route from modern Zimbabwe to the western Cape using the occurrence of rock art. (Wilton-Smithfield C rock painters - in Willcox 1956).

In 1967, Maggs (1967) published an article in which he proposed a quantitative analysis of the rock art of the western Cape. He was primarily considering the "...main components, humans, animals and handprints" (Maggs 1967: 100) of 46 rock art sites. Maggs analysed handprints with regard to their size, like Willcox (1959), and to their quantity per site. He concluded that "...making handprints was not just another aspect of the art but represents a somewhat separate cultural trait. It seems that certain rock shelters tended to be set aside for this purpose" (Maggs 1967:103). The similarity of his measurements with those of Willcox is perhaps a result of his sampling material, which came from the same area. Maggs also concluded that the authors of the handprints of the western Cape were of Bushmen stature, albeit somewhat smaller than average. He accepted, however, the possibility of children being the makers of the handprints. He also understood that if this was the case with the handprints in the caves, then these would not be comparable with the sampling material Willcox had used, which was derived from adult individuals.

Apart from this, Maggs made the arguably dangerous decision of putting handprints from different rock art sites into one data category. The sites where he recorded dimensions of the handprints of the western Cape are widely distributed, and no reference exists which allows for accurate placement of hand imprints in time. In addition a hiatus between the making of the prints in different caves must have existed, as the same group could not have been in the same location at the same time. We also do not know how long this gap was. Even within one cave it is impossible to determine whether all the handprints were made as a singular event, or if the authors returned several times. Secondly, there is no indication as to whether all the handprints were made for the same purpose by one group or several groups of a people, such as Khoe or San. It is also possible that the handprints were made by both peoples or various groups of the latter.

3.1.3. Hunters or herders?

Manhire et al. (1983) argued that one could try to understand rock art on a larger scale considering the distribution of rock art sites and their contents. For one such component, the handprints, they suggested "...that most handprints post-date the local appearance of the pastoralists and probably reflect an as yet poorly understood coastal plain response to that incursion" (Manhire et al. 1983: 32). They also noted the total absence of hand imprints in the Drakensberg.

Following these thoughts, van Rijssen (1984, 1985 and 1994) offered another hypothesis. He stressed that the occurrence of handprints and sematographs, which are

"...abstract or non realistic paintings, excluding trance and trance-related scenes"

(van Rijssen 1985: 146),

are found in the areas which pastoralists would have occupied due to the need for adequate pasture and water for their livestock, and

"...are not merely an indication of the deterioration of a more elaborate early form of painting." [...] "Since the representational paintings, however they are interpreted, are more widespread throughout southern Africa, most can be attributed with confidence to the widely distributed hunter-gatherers. This leads to the conclusion that sematographs and handprints must be the work of the herder / pastoralists..." (van

Rijssen 1985: 152).

In his paper van Rijssen did not agree with Willcox's (1984: 245-247) suggestion that the handprints were "art for art's sake". His argument was not very clear in this respect, as Manhire et al. (1983) had already suggested that the incursion of the pastoralists could have been a reason for the hunter-gatherers to start making handprints and sematographs. One would only find these in areas where hunter-gatherers were in contact with herders - areas with adequate pasture and water for their livestock. This would also explain the occurrence of hand

imprints in the mountainous regions.

Parkington et al. (1986) emphasized the importance of the intrusion of the herders into the life of the hunter-gatherers. They suggested that the increased stress on the life of the hunter-gatherers caused by the pastoralists and their livestock "...stimulated both ecological and social responses, two of the latter being an intensification of ritual and an increase in painting" (Parkington et al. 1986).

Willcox (1984) dedicated one chapter in *"The rock art of Africa"* to handprints, noting the worldwide phenomenon of making handprints and also trying to explain the rationale of this practice. Discarding the theory that the handprints are merely signatures, he offered several other hypotheses for the meaning of a handprint ranging from "...a symbol of power to create, destroy, protect or heal..." (Willcox 1984: 246) to giving the owner power over the painted beast next to the handprint, or to simply representing art for art's sake.

Lewis-Williams and Dowson (1999) offered another hypothesis whereby they explained the making of handprints with neuropsychology. In fact, Lewis-Williams and others (Lewis-Williams 1982, 1983a; Lewis-Williams and Loubser 1986) argued earlier that some of the rock art of southern Africa was closely connected with the rituals and the mythology of the Bushmen, which were mostly related to the experience of trance, and therefore essentially shamanistic. Bushmen shamans cured with their hands and also experienced a tingling sensation in their hands when in trance. Earlier, Lewis-Williams and Dowson (1989) inferred that potency might have been associated or somehow linked to the making of handprints.

"Feelings experienced in trance are an important element in Bushman shamanism and rock art. It thus seems probable that making handprints in a rock shelter was, at least in some ways, akin to painting eland. Both fixed potency on the walls..." (Lewis-Williams and Dowson 1989: 108).

Shamans are also known to experience entoptic phenomena, which are shapes such as spi-

als, zigzags and honeycombs. Nested U-shapes on handprints or U-shaped honeycomb paintings may reflect these episodes.

Later Lewis-Williams (2002) disavowed and revised his statement that all southern African rock art is trance-related.

However, as others have already mentioned, the purely shamanistic approach does not appear to explain this phenomenon (Anderson 1997). If it did, we should be able to find handprints all over southern Africa and not only in the western Cape and a few in Zimbabwe. In these regions a handprint could have been used variably as a symbol (Anderson 1997; Parkinson pers. comm.).

In his article Anderson (1997) questions if the handprints are related to the sensation of trance and therefore a pan-San cognitive system. As San also populated the mountainous region of the Drakensberg, we should also expect to find handprints here. However, there are no handprints in the Drakensberg. He continued with a discussion of the Khoe female's menstruation and menarche rites as well as taboos. According to Anderson, the "...finger paintings and handprints relate to Khoi female menarche rites" (Anderson 1997: 43), as these involve seclusion (possibly in a shelter) and the use of red ochre. Using Willcox's sample he further argued that the handprints in the caves were also the same size as those of Khoe females. So as to conform the usage 'Khoikhoi', 'Hottentots' or 'Khoi' are called 'Khoe', have been herders and at some point in time pastoralists.

Anderson (1997) did not consider the possibility that there may be different groups involved in the process of making the hand imprints. There are some handprints which are too small to be from Khoe females who have had their menarche (Manhire 1998), and others which are too big to be female Khoe handprints at all.

Lewis-Williams and Blundell (1998: 40) explained the hand imprinting as "...remains of rituals during which shamans encountered the spirit world" and put aside the theory of the handprints as an indicator of 'I was here'. "Touching the rock with a supernaturally power-

ful substance [such as blood of an eland, used as a binder] was probably tantamount to entering the spirit world" (Lewis-Williams and Blundell 1998: 40).

Again, the critique against this explanation would be that the distribution of handprint sites in southern Africa speaks against this approach. Nevertheless, this explanation is not insufficient if we combine Lewis-Williams and Dowson/Blundell (1998, 1999) and Anderson's (1997) explanatory attempts. The former claimed that Bushmen shamans fixed potency to the wall (Yates and Manhire 1991) while the latter expressed that the Bushmen countered or balanced increasing stress with social creativity (Anderson 1997: 27) such as through painting or the making of handprints. Thus, a combined hypothesis of these different theories might be more conceivable.

One very interesting point regarding the appearance of handprints was reported by Freers (2001) and others (Smith and Turner, 1975). It referenced the occurrence of "Stylized Impression Hand Prints" (Freers 2001: 327), as well as stylized palm impressions (Montleone 1998: 23-24) in the North American Southwest. These prints exhibit patterns such as nested U-curves almost identical to those decorated hand and palm prints with nested U-curves of the western Cape. Patterned handprints which display U-curves and other similar patterns were also reported to have occurred in central Australia (Gunn 1998). A connection with shamanism is existent in all three cultures, and given the distance between the three continents, the explanation of the nested U-curves as an entoptic phenomenon (potency fixed on the wall) is not implausible.

Manhire (2003) again scrutinized the subject of handprinting however more elaborately, by comprising a large database of samples collected from caves and shelters of the western Cape. He attempted to determine the age and height of the handprint makers, two "biologically"-related characteristics. Manhire compared four different sets of data with his sampled data of handprint measurements: 1. Dart's (1937) Auni-Khomani Bushmen measurements; 2. Schultze's (1928) Khoikhoi population, which is probably best under-

stood as genetically hybridised (see Wilson 1986: 17); 3. handprints he collected from a group of Bushmen living at the Kagga Kamma Reserve; and, 4. skeletons whose stature he determined by converting their femur length (Lundy and Feldesman 1989).

With the measurements of the handprints from those individuals Manhire calculated their respective age and height by referring to Henneberg and Mathers (1994) ratio, which estimates age and height from handprint length.

Manhire concluded that primarily sub-adults were responsible for the production of handprints. Furthermore, he suggested that this fact considered together with the choice of large shelters with few other paintings imply "...a special event or occasion focusing on a particular age group" (Manhire 1998: 106). He stated that the hand imprints represent a "...conceptual and technical departure from the drawn images of humans and animals, which characterize much of the earlier art... (Manhire 1998: 106/107) [and] ...involve the replication of the same image again and again" (Manhire 1998: 98). He further asserted that several individuals were involved in the process at different sites, which "...strongly suggests that handprinting was a group activity rather than a solitary endeavour" (Manhire 1998: 107). Finally, he proposed that the replacement of finely drawn images was not "...a degradation of the artistic standards but rather... [] ...a change in the role of the painters and painting" (Manhire 1998: 107). This assertion followed Anderson's (1997) line of thought on the changing roles of San men within a society, due to increased social pressure induced by the incoming herders.

Regarding authorship, he suggested that it is unlikely that pastoralist Khoe were living in the Cederberg mountains, as the area was unsuitable due to lack of water and pasturage. It would therefore be improbable that they were responsible for the handprints in this region. As for the prints in the caves and shelters of the coastal plain (Sandveld), he considered both Khoe and Bushmen eligible.

Although this approach is still by far the most informative, complete and explicit, some

facts remain misleading or not completely utilized. Making the same mistake as Willcox (1959) and Maggs (1967), Manhire assumed that only one group was responsible for the production of the handprints. He considered the handprint measurements from different sites as only one dataset. Therefore, it is impossible to know if one or both groups, Bushmen or Khoe are responsible for making the prints at any particular cave. The problem could have been addressed by simply examining each site separately and then combining the different datasets together. Moreover his datasets have limited statistical value, as they are very small.

3.1.4. Handprints - a worldwide phenomenon

As the making of handprints is a global phenomenon, I would like to mention a few examples from other parts of the world. This 'global phenomenon' of handprint-making is relevant to the questions I hope to answer in this paper. By understanding the process and magnitude of hand- printing in other parts of the world, we might achieve a better comprehension of the potential reasons for the rock art and especially handprints in the Western Cape.

The simplicity of making handprints certainly implies that they belong to the oldest elements of rock art. The most renown sites are in the Franco-Cantabrian region of southern France and northern Spain. Sites such as Castillo, Les Trois Frères, Pêche Merle, Castillo, Altamira and Gargas all include handprints, albeit often negatives. The last site mentioned, stands out with over 150 negatives of hands. These negatives have probably been created by spraying paint with a tube or the mouth as an outline around the hand (Lorblanchet 1988). Handprints are also abundant in the rock art of Australia (Walsh 1988). Few handprints are known from India and are probably of medieval age, although some are used decoratively on hut walls today (Brooks and Wakankar, 1976). Mainly negative hand imprints are report-

ed to exist in northern Africa - in sites like Tassilli-n-Ajjer (Algeria) and Wadi Sora (Egypt/Libya). Moreover, handprinting was common from North America down to Patagonia and includes positive and negative prints. (Grant 1967, 1983). Furthermore, sites in Sudan, Tanzania, Zambia, Malawi and Mozambique, as well as the afore mentioned sites in Zimbabwe, represent the diffusion of this custom, activity or rite within Africa.

A recent study in the South-west of North America was exemplary as the investigator (Freers 2001) assessed the problem in a similar way to Manhire's (1998) approach. Freers scrutinized handprints metrically and then examined the relationship of handprint size and height, considering the possibility of distinguishing between males and females. He applied a regression formula derived from 166 adult males and females from Egypt (Abdel-Malek et al. 1990) to calculate height using handprints of native American Indians. Furthermore, he examined the relationship between the second and fourth digits in determining sex using the relationship described by Manning et al. (1998) and applied by Williams et al. (2000). Freers (2001) addressed the problem of the lack of a methodology for recording handprints. He developed a methodology but like other researchers lacked a precise technical recording system. No description of how the prints were measured was given. One is left to assume that a calliper was applied to measure the dimensions of the handprints.

An explanation of the theories behind the making of the prints and their authors of these different sites exceeds the scope of this thesis. Thus I only mention them and give no further explanation.

The purpose of this literature survey is to raise several points, which will be important in the later discussion. The first noteworthy concept is that of superpositioning as it puts the handprints in a certain time frame as well as in a context to other paintings. Secondly, handprints clearly break away from all other rock art categories within southern Africa due to their uneven distribution. As they are hardly found anywhere else other than in the western Cape, we must raise the question of why that is so. Furthermore, we must realize the sim-

plicity of their creation and their repetitiveness when compared against elaborate drawings such as those of elands or human figures. Each imprint represents an individual in a group, and equally distinguishes the handprints as a whole from other rock art through its uniformity. Apart from this each author expresses his/her ego and individuality, possibly individualising them further through decoration. Handprints are biological and therefore size is predetermined. At the same time they are an artistical impression even though their creation does not require a lot of skill. While other paintings can be biological, they have a different connotation, as elaborate expression of the artist. This is expressed by the size of the animals and human paintings, which are not life-sized images, but rather scaled representations, possibly stories or beliefs.

In this thesis I try to answer the aforementioned questions as completely as possible. Furthermore I seek to avoid various mistakes of earlier researchers and to consider new ways of looking at the interpretation of handprints.

My first point of critique is that during data collection many researchers (Willcox 1959, Maggs 1967, Manhire 1998, 2003 in prep.) did not distinguish between one or many sites and therefore compiled one dataset from several different sites. In my approach I examine two sites, Elands Bay Cave and Diepkloof, both individually containing a substantial amount of 500 or more handprints. Both sites have been compared in this study and exhibited different patterns and results in variability and similarity.

Secondly the technique of obtaining and measuring the handprints is neither accurate, nor is it a methodological system. The prints are a piece of cultural heritage which should not be touched, as they can deteriorate if in contact with sharp objects. In all previous attempts, if a researcher measured the imprints he did so with callipers or comparable measuring equipment, failing to avoid contact with the rock surface and art. The technique I use incorporates the application of photogrammetry, which will be explained in a later chapter. Basically it exhibits that the rock art does not need to be touched to be accurately measured.

Furthermore, all images are processed and measured systematically.

As other researchers measured the handprint with a calliper, a measurement error was added with each measurement. A calliper measures two dimensions, a distance from point A to point B. The rock surface on which the handprints are located has three dimensions and can therefore be curved. The curvature of the rock surface will "shorten" the actual length of each measurement taken. The system I used calculates the curve and estimates the "real" length, or the length the print had when it was put on the bent rock surface.

Through the additional datasets obtained from schoolchildren in Calitzdorp, Clanwilliam and my own prints, I will try to show how many different people were involved in making the handprints. Whether statements about age and height of authors can be given, or in how far those claims of other authors are true, will be shown by statistical analysis.

4.

CONTEXTUAL BACKGROUND FOR STUDYING HANDPRINTS

Before discussing a detailed description of the handprints and the facts associated with them, I will briefly characterize the environment and the surroundings in which they occur. These setting will serve as a backdrop throughout the thesis. Furthermore the archaeological framework of the handprints, as well as the introduction of pastoralism and its impact on the western Cape will be illustrated.

4.1. ENVIRONMENT

Handprints are, as previously mentioned, a world-wide phenomenon. Nonetheless, in southern Africa they only occur in the regions of the western Cape of South Africa, particularly the Cederberg, a mountainous region and part of the Cape Fold Belt, and in five sites in Zimbabwe (Cooke 1965a). Handprints also represent a major component of the rock art in the coastal region adjacent to the Cederberg (Manhire 1998). Elands Bay Cave and Diepkloof are situated in the Sandveld on a coastal lake, the Verlorenvlei. These two sites contain a number of handprints and are the focus of this research paper. I will concentrate the description of the geology, fauna and flora on the region surrounding Lake Verlorenvlei (for a summary thereof see Miller 1987).

4.1.1. Topography, terrain and landscape

Geologically, the Sandveld is an expanse of lowland coastal plain where Tertiary and Quaternary white to slightly red sands cap a corrugated landscape.



Figure 1: Map of the western Cape

Outcrops and mountains of white to reddish-brown, conglomeratic, medium to coarse-grained sandstone (Sinclair et al. 1986) attributed to the Table Mountain group and therefore to the Cape Supergroup (Viljoen and Reimold 1999: 66; Truswell 1977: 114-130) overlay red thinly bedded siltstones, shales and sandstones belonging to the Klapheuwel formation. "...[T]he Cape Supergroup build the north-south trending mountain ranges belonging to the western branch of the Cape Fold Belt" (Viljoen and Reimold 1999: 66) and form the eastern boundary to the Sandveld. The outcrops, which stretch along the southern coast of Lake Verlorenvlei, sloping towards St. Helena Bay, are discontinuously connected and often con-

tain painted caves and rockshelters.

The Verlorenvlei is also a seasonal river, flowing northwest across the coastal plain of the western Cape about 180 km north of Cape Town.

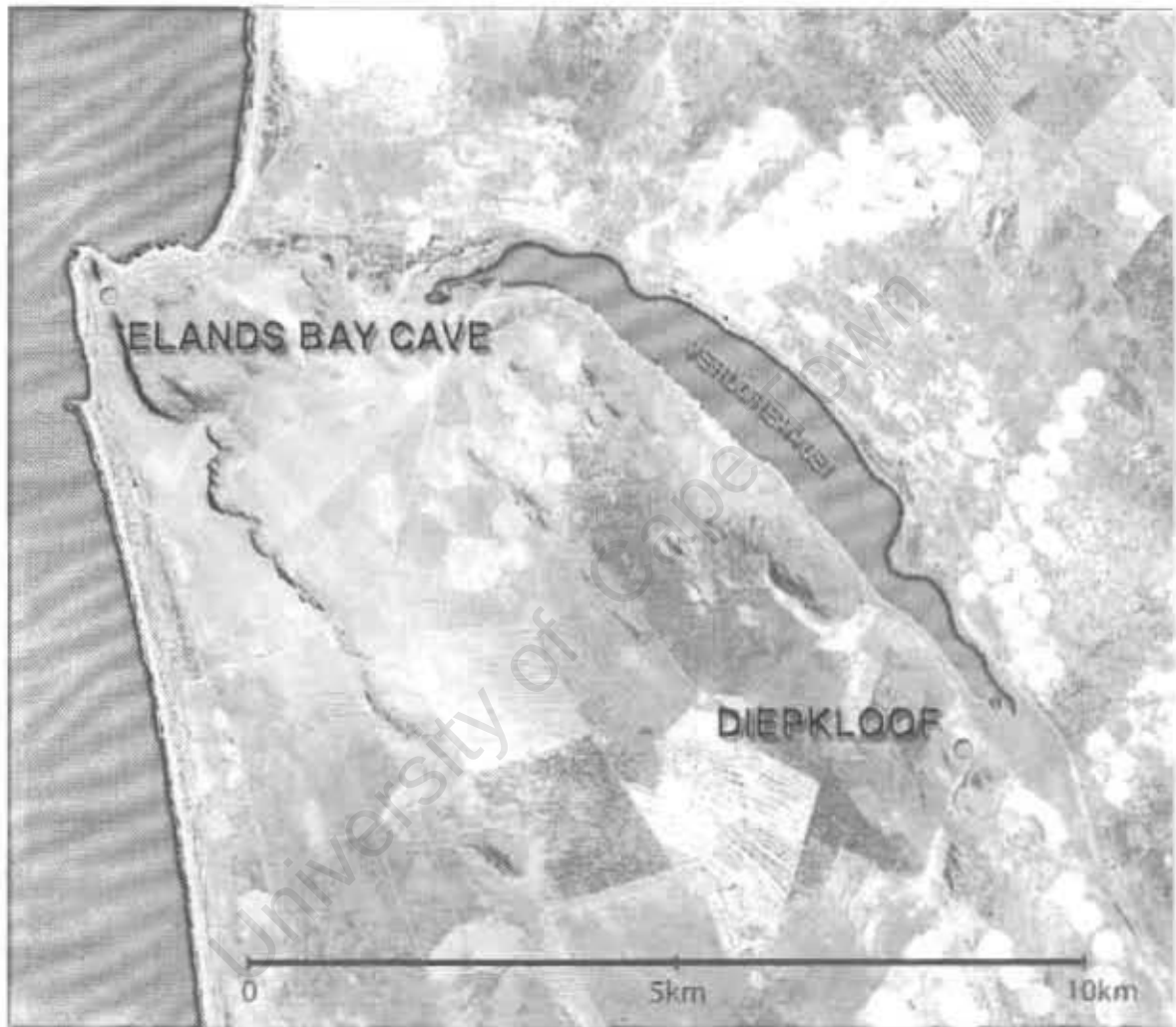


Figure 2: Map of the Verlorenvlei area

The river flows into the Atlantic, which forms the western boundary of the Sandveld, only when there is sufficient winter rainfall in the catchment area. Most of the time, however, the water does not cross a sandbar across the mouth. Therefore sea- and freshwater do not interchange so as to render the system fully estuarine. In fact, the estuary consists largely of freshwater, with the salinity increasing towards its mouth (Parkington 1977). This freshwater lake fills a partly silted basin from 4 km to 20 km upstream with a depth of up to 5m

(Grindley and Grindley 1987). This varies heavily in accordance with rainfall, 80% of which "...occurs during the months April to September. During dry summer months high temperatures undoubtedly contribute to large evaporative losses from the Verlorenvlei system" (Meadows et al. 1996: 82). The lake of the Vlei stretches longitudinally about 13,5 from southeast to northwest with a maximum width of 1,4 km, covering about 10 km². It acts as a drainage and storage basin for a 87 km long catchment area, receiving between 150 and 250 mm of rain in the Sandveld annually. The catchment originates in the Piketberg and Olifants River Mountains and covers an area of 1890 km² (Meadows et al. 1996).

4.1.2. Fauna

One of the many variables which evidently remained constant through time was the availability of food resources which sustained hunter-gatherer groups:

"In the Vlei itself there are pelicans, flamingos, many other bird species, many marine and estuary fish and, in the past, though not seen historically, hippopotamus. The surrounding Sandveld plains and rocky hills support a range of small bovids, large communities of hyrax (known locally as dassies), small carnivores and tortoises, and historically there are reports of larger game such as eland, hartebeest and elephant (Skead 1980)" (Parkington et al. 1988: 24).

An important source of nutrition was seafood (see Buchanan 1987) which is signified by large shellfish accumulations in the archaeological deposits of Elands Bay Cave, Diepkloof, Tortoise Cave, Steenbokfontein Cave and other archaeological sites in the area of the Sandveld (Jerardino 1996: 151). Colonies of limpets and mussel beds are easily accessible today. It is conceivable that in earlier times, when the level of the ocean was higher than today, this was also the case. Fish, crayfish, sea-birds, seals and whales add to the resources from the sea that can be taken advantage of.

4.1.3. Flora

Sinclair et al. (1986) mapped a number of various vegetational types: The littoral dunes and sandy plains cover the Strandveld and contain "...hardy shrubs, geophytes and grasses and, succulents such as Euphorbiaceae and Mesembryanthemaceae..." (Meadows et al. 1996: 82-83). The Lowland fynbos has adapted to deep and sandy soils and shows mostly Restionaceae, Proteaceae and other drought-resisting sclerophyllous fynbos shrubs, like Iridaceae and Gramineae. "...[T]he term fynbos derives from early settlers descriptions of the fine leaves or slender growth (Boucher 1987) of the Cape vegetation" (Parkington (ed.) 2003 in prep.). Other fynbos vegetation such as the Karroid fynbos or the scrub forest elements can be found on the shale of the lower slopes or sheltered, fire-protected gullies, respectively. As the Verlorenvlei is an estuary it also offers a diversity of marsh vegetation which depends on the salinity and is more or less salt-tolerant (Meadows et al. 1996). Many of these reeds grow abundantly in dense stands in the eastern part of the Vlei.

4.1.4. Location of Diepkloof and Elands Bay Cave

Diepkloof is situated on the southern bank of Lake Verlorenvlei in one of the rocky outcrops, approximately 500 m upslope from the reed-covered shore and about 18 km from the mouth. It comprises two shelters, one facing north-east, the other in an easterly direction. At a freestanding sandstone kopje the occupants would have had a fair view of the surrounding landscape, such as the lake and the undulating, shrub-covered lowland. Large blocks of quartzite have fallen from the roof and partly shelter the north-eastern cavity, with about 200m² of living space available (Parkington and Poggenpoel 1987), whilst the eastern shelter offers about 150m² of occupiable space.



Figure 3: Diepkloof Shelter - View from the north-west



Figure 4: Occupational space and handprint panels in Diepkloof

Both are up to 15m high and should be regarded as shelters rather than caves due to their wide entrance (Figure 4 on page 27). The shelters are known as DK1 and DK2, respectively (Mguni 1997) and will both be examined, as each contains measurable handprints.

Elands Bay Cave consists of a single cavity up to 5 m high (8 m when empty - Parkington 2003 in prep.), 11-13 m wide and from dripline to back 7-8 m deep. It was cut into the formation of the orthoquartzitic Table Mountain Supergroup to the south of the Vlei. Furthermore it is located approximately 300 m south of Baboon point, which forms the tip of Cape Deseada. This is the location where the Verlorenvlei now empties into the sea. The cave has a westerly to northwesterly aspect, lying about 40 m above and 200 m upslope from the intertidal rock, thereby offering a good view of the seashore. The roof covers an area of about 80-100m², protecting this space for occupation. In the following chapters Elands Bay Cave will be referred to as EBC.



Figure 5: Elands Bay Cave - View from the west

4.1.5. Other environmental factors

The caves and overhangs provide shade and shelter. The availability of freshwater from the river and lake was certainly a major attraction for the prehistoric groups and the game these people hunted. Nonetheless, we find large occupational gaps in the archaeological sequence which need explanation. Meadows et al. (1996) offer a theory as to why the caves in the area were not occupied at all times and have been abandoned for several hundred years or even millennia. Palynological studies have shown that a depositional gap in the archaeological record of sites in the region of the Verlorenvlei probably resulted from a very dry period at the beginning of the Holocene (Meadows et al. 1996). Furthermore, it seems that the rise of the sea level at the beginning of the Holocene correlates with the occupational hiatus in Elands Bay Cave and other archaeological sites in the vicinity.

"...[T]he Verlorenvlei flooded back about 8000 years ago with rising sea-level, maintained a broad open mouth for several millennia and experienced a closing of the mouth with gradually lowering of sea-level after the mid Holocene high..." (Meadows et al. 1996: 94).

The resulting lack of water would then have prevented people from occupying and populating the area.

We must ask why these shelters and caves around the Verlorenvlei and its mouth were so attractive to prehistoric communities for occupation. We must understand that "...whereas EBC [and DK] has remained a fixed point in the landscape through the millennia it has not remained the same place, understood as the set of opportunities it offers to potential occupants" (Parkington 2003 in prep.). This is demonstrated by the facts that archaeological sites such as EBC and DK are known to have been abandoned for long times. The occupants of the sites probably came episodically and did not stay for a long time. The seasonal occupation of the archaeological sites in the area and its implications are very complex and I deal with these topics in section 4.2.

4.2. Archaeology

In this section I will briefly explain the archaeology of EBC and DK, more specifically the depositional remains. This is necessary to understand the connection between the archaeological remains, the handprints and the other paintings found in the shelters. Another important factor that I will discuss in this section is the relative chronology of the painting categories which is linked to the question of authorship.

4.2.1. Occupation and people

If we postulate a relationship between the archaeological deposits and the paintings in rock art sites, particularly EBC and DK, we can assume that the authors lived in the LSA. Radiocarbon dating of DK samples from the LSA deposits shows that occupation occurred between about 300 and 1600 years ago (390 $\pm$ 30BP (Pta 1055), 1050 $\pm$ 85BP (GaK 4597) and 1590 $\pm$ 85 BP (GaK 4595)(Parkington and Poggenpoel 1987: 271-274)), whilst the dates for earlier MSA are between 25000 and 45000 (24400 B.P. (GaK 4596) and 29400 $\pm$ 675 BP (Pta 1051) to >45270 years BP (Pta 1054) (Parkington and Poggenpoel 1987: 271-274). These dates are probably an underestimation, as they exceed the range of modern day C-14 dating methods. In EBC we encounter a similar situation; Parkington (2003 ed. in prep.) describes the sequences (or "event stack", as he terms it later) as "heavily pulsed", in which "...superimposed occupations reflect very different kinds of use". Gaps or periods of non-use can be observed by the lack of archaeological accumulation (as in occupational deposits) "...between 17800 and 13600 years ago, between 7900 and 4300 years ago and between 3200 and 2100 years ago..." (Parkington 2003). They coincide with the non-use of other sites in the vicinity, such as Tortoise Cave (Robey 1987) and the already mentioned Diepkloof shelter (Parkington and Poggenpoel 1987). Occupation was short termed and is therefore poorly understood. Assumptions about the occupants can only be made with the help of a larger scale when evi-

dence of settlement in the western Cape coincides, Yates et al. (1994) argue that evidence from changing bead-size, bead aperture size, formal stone artefacts as well as the emergence of pottery and sheep bones in the Cederberg and the adjacent coastal region of the Sandveld "...reflects the markedly uneven disruption of existing cultural practices" (Yates et al. 1994: 47) between 2000 and 1600 years ago. This does not necessarily mean that there were intruding groups of pastoralists who settled there at once, but rather a slow trickling of herders or their way of life into the western Cape. This then progressively changed and influenced hunter-gatherer communities already living there. Furthermore, Yates et al. (1994) argue that this change comes about gradually primarily in the coastal regions which were more suitable for pastoralist herding than the mountainous region of the Cederberg. In the case of EBC we do not know who lived there from 2000 B.P. on, but indications from beads and other artefacts (Yates et al. 1994, Yates 1998) suggest that the people who occupied the cave were at least influenced by the pastoralists way of living (see Sadr 2003 in prep.). If I make the same assumption as Parkington and Poggenpoel (1987) did for DK, the inhabitants are most likely to be hunter-gatherers. This is because they "...were reputed to prefer caves and mountainous areas..." (Parkington and Poggenpoel 1987: 288). Before these times of changing cultural practices, artefacts and subsistence strategies clearly show evidence of hunter-gatherer communities or individuals of the LSA (Parkington and Yates in Parkington (ed.) 2003 in prep.).

Few, if any, researchers think that the people of the MSA were advanced enough to create an artwork as elaborated as the fine line painting, notwithstanding the fact that there are indications of artwork of the MSA, with the decorated ochre from Blombos (Henshilwood et al. 2002) and the recent discovery of Middle Stone age decorated ostrich eggshell in Diepkloof (Poggenpoel pers. comm.). The oldest known rock art in Africa is about 27500 and 25500 years old and was discovered on fallen slabs of wall in the deposits of the Apollo 11 Cave in Namibia (Wendt 1976). These were covered and therefore protected for a substantial period of time. The radiocarbon dates from deposits of clearly demonstrated a large occupa-

tional and depositional hiatus of at least 30000 years between the orange/black complex of the MSA and the ash/grass series at the surface (Parkington and Poggenpoel 1987), while in EBC few MSA deposits with virtually no organic material to estimate an age from have been uncovered (Parkington and Yates in Parkington (ed.) in prep.). To belong to the MSA the paintings in DK or EBC would have had to be at least 30000 years old. There are no indications that they were covered by deposits at any stage. It is doubtful that paintings made during the MSA in DK (or EBC where the situation is similar) would have survived the climatic processes due to natural forces, such erosion, sun, wind and humidity, to which the art of both shelter (DK) and cave (EBC) is still exposed today.

4.2.2. Painting traditions

Other researchers debated the authorship and attribution of the different painting categories to certain groups (van Rijssen 1984; Anderson 1997; Manhire 1998). The high frequency of sheep bones in the LSA deposits at DK indicates that the occupants of the cave had some access to domestic stock during this time (Parkington and Poggenpoel 1987:279). To understand the LSA occupation of these sites, it is necessary to understand the nature of the evidence at the end of the stone age. Two distinct groups, hunter-gatherers and herders, may have inhabited the region of the Sandveld, either alone or at the same time. As Parkington and Poggenpoel (1987) put it, San, (or Soaqua in the western Cape), are unproblematically seen as hunters, and Khoe as herders. Parkington (1984b in Parkington and Poggenpoel 1987: 288) however, warns that "...the term 'San', or even Soaqua is not [a] synonym for hunter-gatherer...", as they could acquire stock and live as herders and the Khoe could, vice versa, loose their cattle and start hunting. In the study case of DK, the uppermost deposits seem to derive from one or several occupations of Soaqua, as these "...were reputed to prefer caves and mountainous areas..." (Parkington and Poggenpoel 1987: 288) in contrast to the Khoe, who preferred "...to camp out on the plains, where they could erect their beehive-shaped mat

huts..." (Parkington and Poggenpoel 1987: 288). The bedding and ash complexes observed at DK and other sites conform to the Soaqua pattern (Parkington 1984b). After the appearance of the pastoralist groups, caves and rock shelters were more regularly sought out as domestic sites by Soaqua than they were earlier in the Holocene. Therefore we should expect a high density of occupational layers (with Soaqua pattern) in the caves after the appearance of pastoralists, and a low density, if any in pre-pastoralists times. This perhaps partly explains the large occupational hiatus of 30000 years between MSA and LSA.

Nonetheless, we must be careful to establish affiliations of one or the other group to the paintings using habitation of the sites, as creation of the parietal art and occupation might not coincide. It is possible to see the creation as brief flashes of painting events during times of non-occupation, or as a constant addition to the parietal art, whilst occupation lasted. A combination of the two scenarios is also imaginable. We lack knowledge about the time-frame for the creation of paintings within sites, which originates from too few points of reference to establish a direct chronology. Clustering and superpositioning of paintings are indicators of events or sequences and certainly help to understand the relative chronology, but hold no proof for any of the hypotheses postulated. We must therefore refer to the context presented in the art to find answers regarding the authorship of certain painting categories.

4.2.3. Categories of rock art:

Generally speaking, the rock art of South Africa can be grouped in three distinct categories, fine-line paintings (which might be referred to as representational art with a conceptual component which cannot be omitted (Lewis-Williams 1981)), handprints and the colonial/historical period paintings. The fine-line paintings (or tradition) are also referred to by other researchers as detailed representational paintings (Yates et al. 1993), finely detailed paint-

ings and fine-line imagery (Manhire 1998) as well as fine painting or representational painting (Yates et al. 1994). I am going to use the expression fine-line paintings, but may also refer to them in the same way Yates and colleagues (1993; 1994) or Manhire (1998) did, when I cite these authors. The fine-line paintings were created by using a thin instrument, possibly a stick or a brush, to apply the paint to elaborate fairly naturalistic drawings of animals, humans, as well as objects of everyday use, such as bows, quivers, bags, nets and sticks (Yates et al. 1994, own observations). These could be drawn in various colours, such as different shades of red, maroon, yellow, white or black, with red occurring predominantly. The paintings, especially humans and various animals such as eland, elephant, hartebeest and more are often painted in a bichrome and polychrome manner. (Asmus 2003, Asmus and Meister 2001, Yates et al. 1993).

Lewis-Williams and others (Lewis-Williams 1981, 1982, 1983, Lewis-Williams and Loubser 1986, Lewis-Williams and Dowson 1989) point out that these depictions bear a resemblance to some of the trance rituals of the Bushmen. Moreover, the ethnographic parallels might suggest similarities with living 'Bushman', as stories, customs and rites (Bleek and Lloyd 1911, 1923) seem to be depicted in the rock art. These elaborated paintings do not have the dimensions of life-size objects, differing not only in this aspect from the handprints. Drawing instead of printing necessitates some sort of artistic skill. Handprints in contrast were simply made by pressing the palm to a wall and could therefore be easily repeated and copied. To amplify the subject of difference it is important to mention that fine-line paintings are distributed over the whole of southern Africa, occurring almost wherever suitable rock surfaces to paint on can be found, while the handprints are predominantly found in the western Cape.

In contrast to the detailed representational paintings are the crude finger painted colonial applications, differing not only in quality but also in subject matter. Including graffiti, the majority of these images are depictions of horses, cattle and other unidentifiable animals,

humans with typical attributes of the European settlers such as brimmed hats, high-heeled shoes and guns, as well as images of ships, wagons and crude grid symbols (Yates et al. 1993). Colours used are predominantly shades of red, maroon and black from charcoal drawings. The crudeness of the finger applied artistic expressions corresponds with the printing of hands rather than with the fine-lined drawings of the traditional images. It is possible, though, to find crude finger-painted signs, symbols or depictions of animals that are not necessarily attributed to the colonial style or context. "The distribution of colonial period rock art in southern Africa as a whole is not particularly well documented. It is apparently widespread, both as engravings and paintings..." (in Yates et al. 1993: 59).

4.2.4. Appearance of the handprints:

At this time, I would like to describe the appearance of the subject matter of this thesis, the handprints. Moreover, differences from the above mentioned categories will be clarified to show the delimitation of hand imprints as a rock art class of its own.

In the case of handprints, we are dealing with a very specific element of rock art because they are not drawn but printed, as the name suggests. Made by smearing the palm and digits with ochreous paint and placing the hand on a wall, they differ from stencils, negative images of the hand, "...which are the rule in many localities outside of southern Africa" (Manhire 1998: 99). There are, nevertheless, two contrasting results from different ways of making handprints: plain and decorated ones. Made by scraping a pattern, usually nested curves or U-shapes, from the already paint-smearred palm and fingers, before placing the hand for an imprint on the wall, the decorated prints seem to be a variety particularly met in the coastal area of the Sandveld and the northern part of the Cederberg. (Manhire 1998: 99). There are, nonetheless, two varieties within the decorated prints, in that either the whole hand or only the palms were decorated with the nested curves. It is impossible to tell

if in the case of palm prints, the fingers were not smeared with paint, or if the artists deliberately tried not to print with them. Apart from this there is the possibility that the fingers were missing, due to mutilation (Drennan 1937) or loss in another way. These finger would consequently not be visible. However, this scenario is doubtful, as there is no indication of single missing digits or fingers. Aside from that, palm prints are certainly not a product of the amputation of all fingers. Fingers that cannot be measured or seen are probably the result of poor preservation, as some colour traces are visible in many cases, but very smeared or faded. The technique of applying the previously decorated hands onto the wall in order to generate the decorated prints was suggested, because whorls from the palm and finger can be recognized within the prints on the rock in many instances. It seems very likely that the above described method is correct (Manhire 1998).



Figure 6: Different appearances of handprints

Colours are an important distinguishing factor, differentiating between handprints and other rock art categories. Handprints are known to occur only in monochromatic shades of colour such as the already mentioned maroon, red, orange and occasionally yellow. For that reason I considered using the Munsell colour charts to distinguish between the different shades of maroon, red and orange, but felt dubious about it, as colours change with the different daylight shed on them. Moreover I do not know if the colours I see are the original ones or faded and consequently just shades or stains (see Mirmehdi and Chalmers 2001 for experiments of colour degradation). The fine-lined paintings are not only drawn in other colours, such as white and black, but also occur in variations of two or more colours. Handprints and the colonial paintings are typically painted in one colour, usually red.

Another distinguishing feature between handprints and fine-line or historical paintings is the repetitiveness of the actual image. Contrary to drawings of humans and animals, handprints always resemble the original size of a hand, as they are prints and the authors seemingly never intended to make a painted copy. Paintings of humans on the other hand are not known to occur in life-size paintings. Life sized animal drawings were only found occasionally.



Figure 7: Line of handprints from Diepkloof; note the left-right pattern in the long upper row (red = left, blue = right, black = not determinable print)

Handprints are often grouped in clusters or displayed in lines and seem to be secluded from other images. There are very few sites where many handprints and fine-lined paintings can be found simultaneously. I found several examples in DK, where handprints superimpose fine-lined paintings, but not vice versa (Figure 8 on page 38).

"There is little evidence that superpositioning was an imperative of handprinting; many sites with both types of images [fine line imagery and handprints] are marked by an absence of superpositioning. Vast arrays of handprints occur, within which only some of the detailed representations present are overprinted" (Yates et al. 1993: 61).

Noticeable is a very large eland in Elands Bay Cave which is totally covered by numerous decorated palm prints, while no attention seems to have been paid as to where the palms have been pressed (Figure 9 on page 39).



Figure 8: Handprints superimposing fine-line paintings in Diepkloof (marked with blue circle)

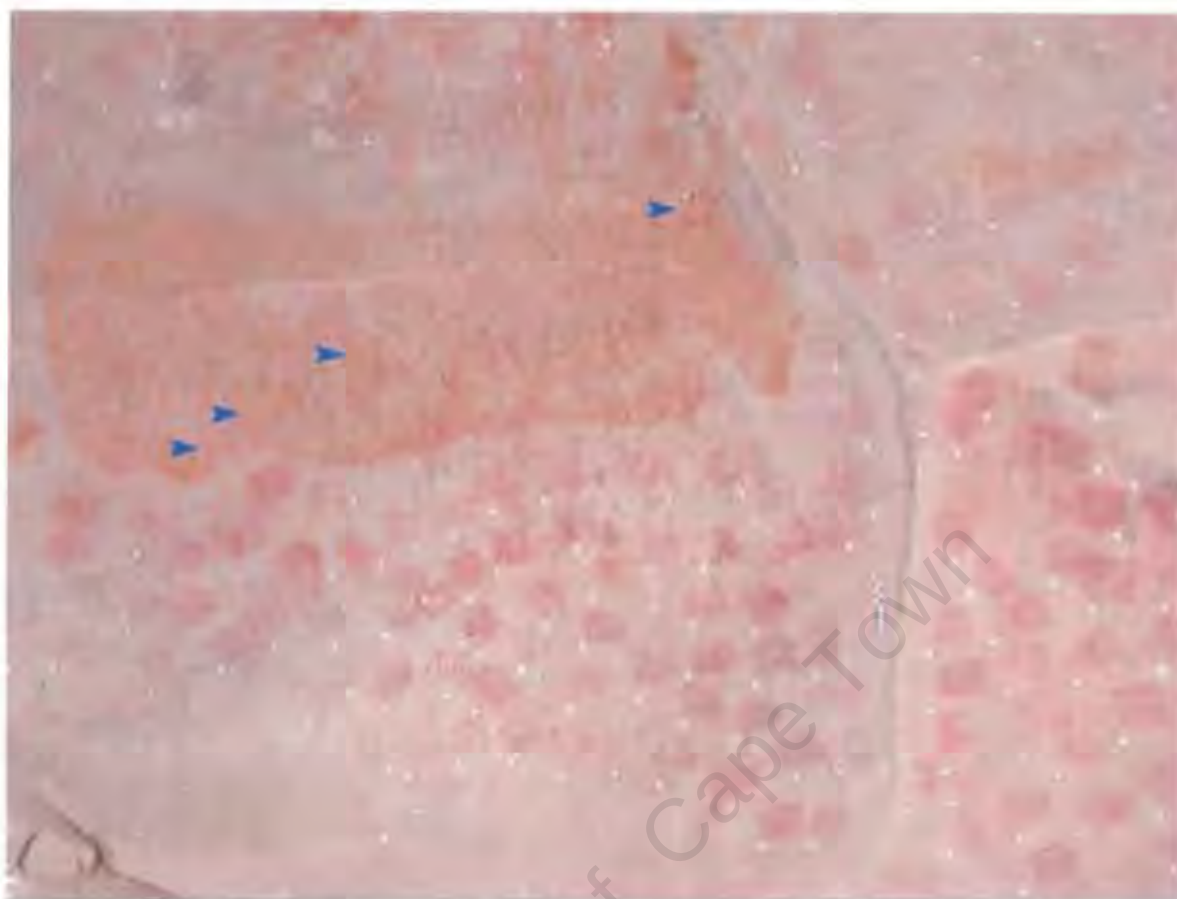


Figure 9: Handprints or rather palm-prints superimposing eland torso in EBC

There are no examples of fine line paintings known to superimpose handprints. (Yates et al. 1993: 61). However, handprints sometimes superimpose each other.

Two possibilities may explain the composition of the painted sequence. The chronology (Yates et al. 1994. Figure 10 on page 44) established, assumes that there is a sequence from fine-line paintings to handprints ending with the colonial imagery. If we believe the chronology, we presume that a direct relationship between handprints and fine-line or colonial imagery does not exist. The fine-lined tradition was long given up and the colonial imagery was still to be painted when handprints were made. Otherwise the handprint maker must deliberately have avoided making a print on the colonial images and painters of fine line images must have avoided putting paint on handprints. We would then assume a contemporaneousness within the different categories. Further variations between these scenarios are also imaginable.

The reason for this discussion is to make clear that handprints should be classified as a different category of rock paintings which clearly breaks from the earlier fine-lined tradition in style and manner of making, just as it breaks from the later colonial imagery in different aspects. This will be important later since, for these reasons, the interpretation of meaning must be different. This assumption leads other researchers to make interpretations about the authorship of the handprints (Willcox 1959; van Rijssen 1984; Anderson 1997).

4.2.5. Meaning of the rock art:

The meaning of the rock art has been a much discussed issue and many different opinions about the interpretation of the paintings exist. Many authors tend to conclude that there is only one possible solution in interpreting or understanding the paintings.

One hypothesis which approaches the interpretation of rock art is suggested by Lewis-Williams (1981, 1982, 1983, 1998, 1999). He is convinced that most, if not all the rock art of southern Africa is somehow related to the trance experience of hunter-gatherers such as the Bushmen, described by ethnographers Lee (1968), Lee and DeVore (1976) and Katz (1982). Lewis-Williams justifies his hypothesis with a comparison of depictions in the rock art of humans having nasal haemorrhage, and entoptic signs (symbols experienced or seen whilst being in an altered state), with the experiences and rituals performed by various Bushmen groups. These have been observed by the various ethnographers in the 1960's, 70's and 80's in the Kalahari. This is definitely a very important observation by Lewis-Williams and becomes more understandable once we consider the stories of the /Xam, collected by W. Bleek and L. Lloyd in the late 19th century (Bleek and Lloyd 1911). With Lewis-Williams explanations is it possible to see a connection between the Bushmen living today in the Kalahari or in the 19th century in the northern Cape and the people of the past, the artists who created the paintings. Many paintings closely resemble figures in these stories, or show people pos-

sibly experiencing trance, dancing and clapping hands. These are activities which the Bushmen in the Kalahari are known to engage in when they perform ritual or social gatherings (Lee 1968). Lewis-Williams and Dowson (1988) also show that the signs, like zig-zags and other entoptic phenomena (such as spirals), we so often encounter in the rock art, are part of what people experience when they fall into the state or condition of trance. This is suggested as an indication that the rock art of southern Africa was, for the most part, created by people experiencing trance and painting either afterwards or while they were in a trance state. I disagree, as does Lewis-Williams in his later work (Lewis-Williams 2002), that all Southern African rock art is only trance related, because there are figures, paintings and even whole sites that are best explained by a combination of different notions. One of these is the gender approach, brought forward by Solomon (1989, 1994) who uses "...a 'fertility hypothesis', derived from a reading of the ethnographies in order to explain various elements of Southern African rock art..." (Solomon 1989: abstract). Thereby she points out the importance of gender and its depiction in the art and proposes an approach of seeing the art " 'as ideology' in which gender 'as ideology' is central" (Solomon 1989: 105). Parkington et al. (1986) show the importance of the rock art as a tool of hunter-gatherer communities to compensate social stress, inflicted by the incoming herder communities. The paintings, therefore, can also be put into another context. The context might be trance related, although this explanation does not account for all the paintings, especially as the background of the different groups and single artists will be specific to each case. We must consequently account for the individuality and reasoning of the different persons painting with varying context, depending on the situation as well as the social and environmental background of the painter. Solomon (1989: 157-158) points out that "...meaning is dependent to a large extent on the interpreter, and is variable according to his/her positioning in space, time and within particular societies". She thereby does not deny the importance of trance as a major influence in the creation of the rock art.

A painting might be 100 percent correlated to the trance experience, or have some importance for a gendered view of the art; it may be a statement, or a mere depiction of something seen by the artists, as well as a fusion of some or all of these. Nevertheless, some meaning might be more closely attributed to one or the other hypothesis, some might remain enigmatic, but as we do not know any of the artists and have no oral or written reports left by them, we are forced to interpret the rock art with the sources available. Some of these I have already mentioned, like the ethnographic comparisons (Lee 1968, Lee and DeVore 1976, Katz 1982), the stories of the Bushmen of the Northern Cape, documented by Bleek and Lloyd (1911, 1923) and finally the reports from travellers (Orpen 1874) in times when people (not only Bushmen) still painted.

Most ideologies attributed to South African rock art mostly refer to the fine-lined imagery. Handprints resemble images with no distinction between the individuals. Their repetitiveness separates them from fine-lined imagery, where single images might look similar but will never exhibit the same repetitions. Therefore, the individuality of fine-lined paintings might infer a separate meaning from the meaning of handprints. This distinction also becomes clear once we consider the relative chronology.

4.2.6. Dating, age and chronology

The next sections will exclusively deal with the dates and dating of rock art, in particular with that of handprints. Thackeray (1983) has provided an overview; though quite old, useful, because the methods and techniques used have not changed much. The introduction of AMS-Radiocarbon dating is the only major change, allowing for relatively precise dates, using only small amounts of sampling material, which in the case of rock art is precious as one has to partly destroy the rock painting which is to be dated. As this dating method works on the basis of carbon containing materials, and South African rock art is mostly made of ochre-

ous paint, which in many cases has deteriorated or been drawn into the rock (own observations), AMS-dating is less important. Moreover does the use of direct dating of organic material in paint "...still seem to be problematic in Australian and European contexts (Lorblanchet et al. 1990; McDonald et al. 1990)" (in Yates et al. 1994)). A few radiocarbon dates have been attained so far in South Africa (Van der Merwe et al. 1987, Mazel and Watchman 1997, Yates and Jerardino 1996, Jerardino and Swanepoel 1999) with ages of 300, 500 and 3000 years for some charcoal drawings and a slab deriving from the sediments of Fallen Rock Shelter and Steenbokfontein, respectively.

The chronology established originates from the assumed correlation of rock art and archaeological deposits in sites, which is difficult to assess systematically. Furthermore, the superpositioning of the different rock art categories suggests the idea of the relative ages. The proposition of something like categories is dangerous especially as we impose our knowledge and cultural background, as well as our perception of art onto the rock art. According to Yates et al. (1994:30), is it "...a temptation to generalize across space and to impose uniformity on different regions," hereby referring to chronology and to the existence of the various categories and classes of rock art. We therefore must be careful not to "...obscure the marked differences at regional or even sub regional scales" (Yates et al. 1994: 30), if we accept that we are the creators of entities such as regions and sub regions. Nevertheless we have a need for categories and classes as well as a chronological framework for rock art to understand the contexts, i.e. why and by whom the art was created. The time frame I am describing is that of the western Cape. It has to be mentioned that situation, dates and context are oftentimes different once we look further east (Drakensberg and Eastern Cape) or north (Brandberg).

As mentioned in a previous chapter, the rock art of the western Cape is conventionally subdivided into three categories, fine-line imagery, handprints and historical subject matter depictions. Figure 10 on page 44 describes the relative chronology using the archaeological

information known so far. It deals with the introduction of domestic stock and shows the importance of this process and its possible influence on the painting style.

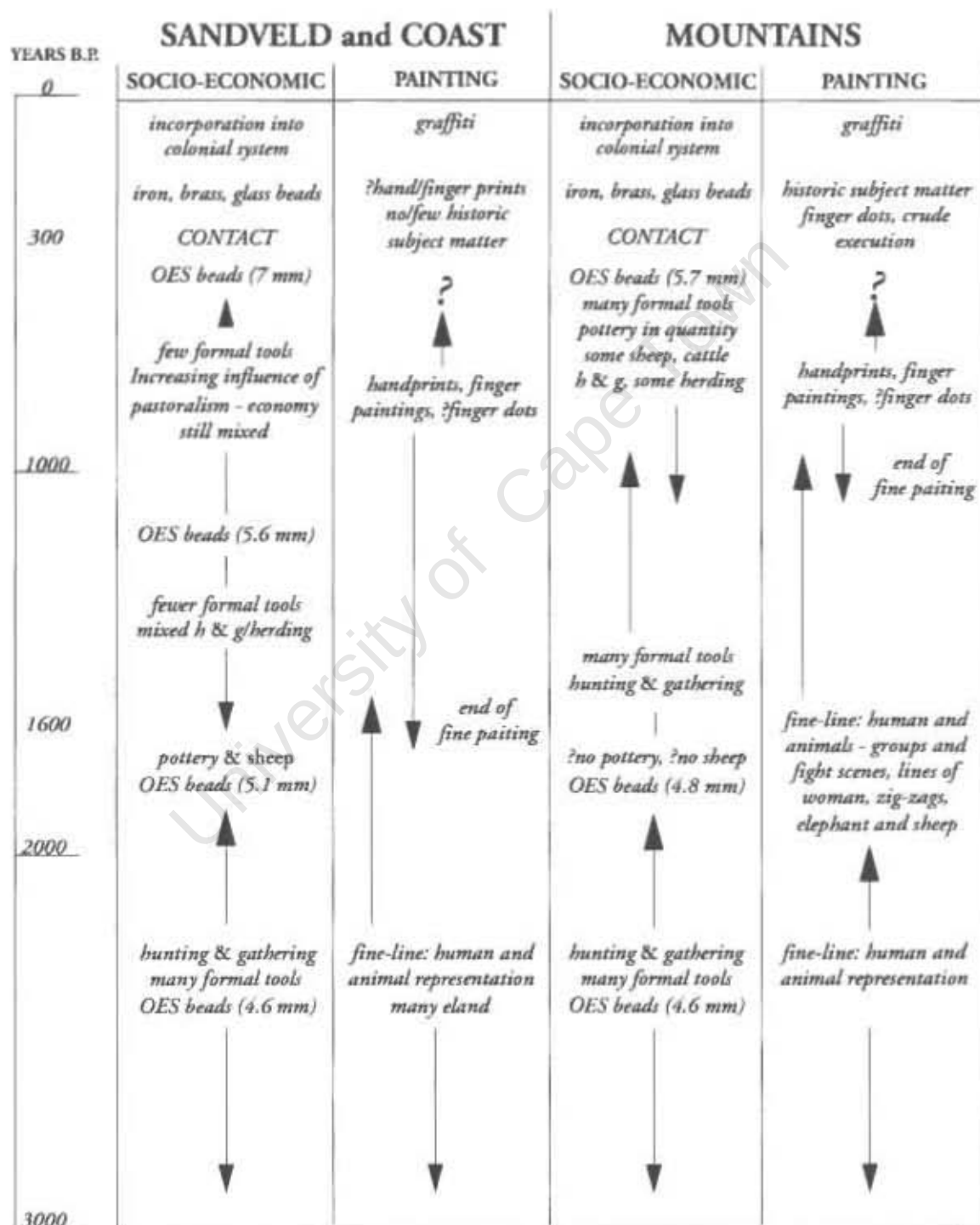


Figure 10: Relative chronology of rock paintings and relations to the archaeology (Yates et al. 1994: 56)

Neither cattle nor sheep have wild progenitors in southern Africa. Fat-tailed sheep were introduced to the western Cape around 1900 - 1600 B.P. (Henshilwood 1996, Smith 1998, Sadr 1998) and can still be found nowadays. These sheep are the fat-tailed variety and can be easily identified in the paintings with their characteristic ears and tails. Only a few sheep have been painted in the fine line tradition, with few examples of their depictions in the Cederberg (Yates et al. 1994: 58 - table 8, Jerardino 1999) and almost none in the coastal areas (van Rijssen 1980). Yates et al. (1994:53) therefore conclude that "...the finely detailed tradition survived in the mountains until at least the early second millennium BP, apparently ending before that time near the coast...". Moreover cattle are not depicted as finely drawn subject matter in the western Cape, but exist in the Drakenberg, so we must conclude, that in former region the tradition of fine-lined painting was given up before or with the introduction of domesticated cows. This introduction occurred in the western Cape about 1000 years after sheep bones can be traced in the archaeological record. Very few cattle bones from these times are traceable despite the substantial numbers of cattle encountered by early seafarers and colonists (Raven-Hart 1971). It is surmised that sheep may have entered (diffused) the Cape in small numbers and some hunter-gatherers adopted small stock herding (Sadr 1998: 123-124, Sadr 2003 in press.). Cattle did not appear until the end of the first or beginning of the second millennium A.D., the emergence of pastoralist groups. Some cattle bones "...have been positively identified...[] ...in deposits postdating 1300 years ago" in Kasteelberg (Klein and Cruz-Uribe 1989:85). European sailors (1488 A.D.) and settlers (1652), who arrived some hundred years later observed large herds of cattle in the area (Thom 1952: Raven-Hart 1967: 62, 124).

Younger paintings must inevitably be on top of older ones, because the laws of stratigraphy require that a younger layer must be on top/above an older (Lyell 1867, Harris 1989). This can be used to create a relative sequence of dates. If we assume that the tradition of handprint making is later in sequence than fine-lined painting, handprints have to be younger than 1000 years, as they never superimpose fine-line paintings. Yates et al. (1994: 37) note

that handprints and the related imagery, such as finger dots and finger paintings, must be later in sequence than the finely painted imagery, since they are on top of them and are never to be found below (van Rijssen 1984; Yates et al. 1994; Mguni 1997; own observations). Furthermore, there is no evidence of other images overlaying handprints, except other handprints or colonial imagery (Yates et al. 1994; Manhire 2003 in prep.). In addition to this Manhire et al. (1983: 32) state that "...handprints are found in very large numbers in near coastal sites, often associated with shell middens and potsherds, and must therefore be considered late in the painting sequence". As there are no paintings which both depict colonial events and topics and lie underneath handprints, is it reasonable to argue that the tradition of making prints ceased before or about the time the first European settlers arrived at the Cape. We can, therefore, conclude that they must be at least 350 - 400 years old, because this is the time when the first explorers, like van Riebeeck, went northwards from the coast into the western Cape (Raven-Hart 1971).

Yates et al. (1994: 55) think that "...the colonial images found in the south-western Cape are simply too circumscribed in distribution to represent a widespread tradition". They are best described as responses to "...local historical circumstances..." (Yates et al. 1994:55) and therefore incomparable to other rock art categories. Depiction of wagon and horses rather than oxen indicate a late historical context of the eighteenth or early nineteenth century. These items and animals were seldom used in the seventeenth century.

The parallelism of the temporal contrasts in the rock art and the archaeological deposits affirms this chronological frame (Yates et al. 1994, Figure 10 on page 44). The occurrence of sheep, pottery and larger ostrich eggshell beads, relics of a herder society, probably falls into the time when fine line painting was abandoned, a tradition associated with the hunter-gatherers. Nevertheless, most of these conclusions are debatable and partly based on enigmatic evidence and we cannot make stronger statements unless a method is found which allows for direct dating of the paintings.

4.3. HUNTERS AND HERDERS

4.3.1. *The authorship of hand printing in the western Cape:*

In this section I cite the different points of view regarding the topic of the authorship of handprints of the western Cape. Furthermore, I offer a deeper insight (or rather literature survey) how the introduction of livestock and pastoralism into the area might have happened. This is necessary, as previous researchers have discussed, to clarify the issue of whether Bushmen or Khoe were responsible for making handprints in the western Cape (Willcox 1959, van Rijssen 1984, Anderson 1997, Manhire 1998).

In the literature survey, I cited Willcox (1959) as being the first to comment on the origin of the handprints of the western Cape. He concluded a Bushmen origin, justifying this with comparative measurements of prints he took from Bushmen. For a comparative analysis he had obtained handprints of Hottentot individuals (presumably with pastoralist origin) in the western Cape. Maggs (1967) agreed with Willcox' opinion that handprinting related to the Bushmen. Manhire et al. (1983) believed that the making of handprints arose as a reaction on the intrusion of the pastoralists around 2000 B.P.. It "...probably reflects an as yet poorly understood coastal plain response to that incursion" (Manhire et al. 1983: 32) by the San Bushmen, who are prevalently believed to be the authors of the fine line rock art. Manhire et al. (1983: 29) are also convinced that the San hunter-gatherer societies "...were put under more stress by the appearance of pastoralists who competed for their land, and whose lifestyle meant that domestic stock replaced part of the wild animal biomass". Later van Rijssen (1984, 1985, 1994) picked up the topic, protesting against Willcox' (1959) and Maggs' (1967) arguments. Because of certain relationships between handprints and sematographs (explained in chapter 3 on page 13), the late position in the painting sequence and "...the dis-

tribution of these non-realistic images... [these areas]...seasonally, have been attractive to the Khoi herders who needed adequate pasturage and water for their livestock" (van Rijssen 1984: 128). He concluded that the prints therefore must be the work of the Khoe herders. Parkington and colleagues (1986) made the argument that the hunter-gatherers were put under stress by the pastoralists and released this through social activities such as painting. Anderson (1997) opted for a pastoralist authorship, substantiating his theory with ethnographical reports of the use of ochre by Khoe women and the small size of the handprints on the cave walls. The last to contribute to the discussion is Manhire (1998), arguing for an authorship of the Bushmen in the mountainous regions, which were unsuitable for pastoralist stock keeping. He furthermore suggests that both, pastoralists and hunter-gatherers might have been responsible for making handprints in the coastal area of the Sandveld.

All researchers assume a co-existence of pastoralist groups and hunter-gatherers in the western Cape during the time period in which the handprints were made. The archaeological record it is not clear, whether pastoralists came into the western Cape around 2000 B.P. (see Sealy and Yates 1994, Henshilwood 1996, Sadr 1998, Bousman 1998, Smith 1998 for dates), or whether this incursion happened about 500 years before European settlers arrived (Sadr 1998; Sadr 2003 in prep.). Furthermore we do not know if these pastoralist groups brought livestock such as fat-tailed sheep with them, or if these were, through diffusion, already in the Cape when they arrived. This implies that Bushmen had to abandon their 'traditional' way of life and with that the sharing ethos, and had to start to keeping livestock themselves (Parkington 1984, Sadr 2003 in press). Some researchers now agree with Sadr (2003 in press) that the appearance of sheep did not coincide with the arrival of cattle pastoralists. Sadr (2003 in prep.) as cited, opts for a late arrival of cattle around the end of the first millennium.

4.3.2. The introduction of pastoralism into the western Cape

Until the end of the last century many researchers generally assumed that the origins of the Cape khoe-speaking herders either lie in eastern Africa (Stow, 1905: 267-268; Schapera, 1930: 43; Cooke 1965a; Tlou and Campbell, 1984: 20), in northern Africa (Meinhof, 1910; 1912) or as far north as Egypt (Theal, 1910: 80-82).

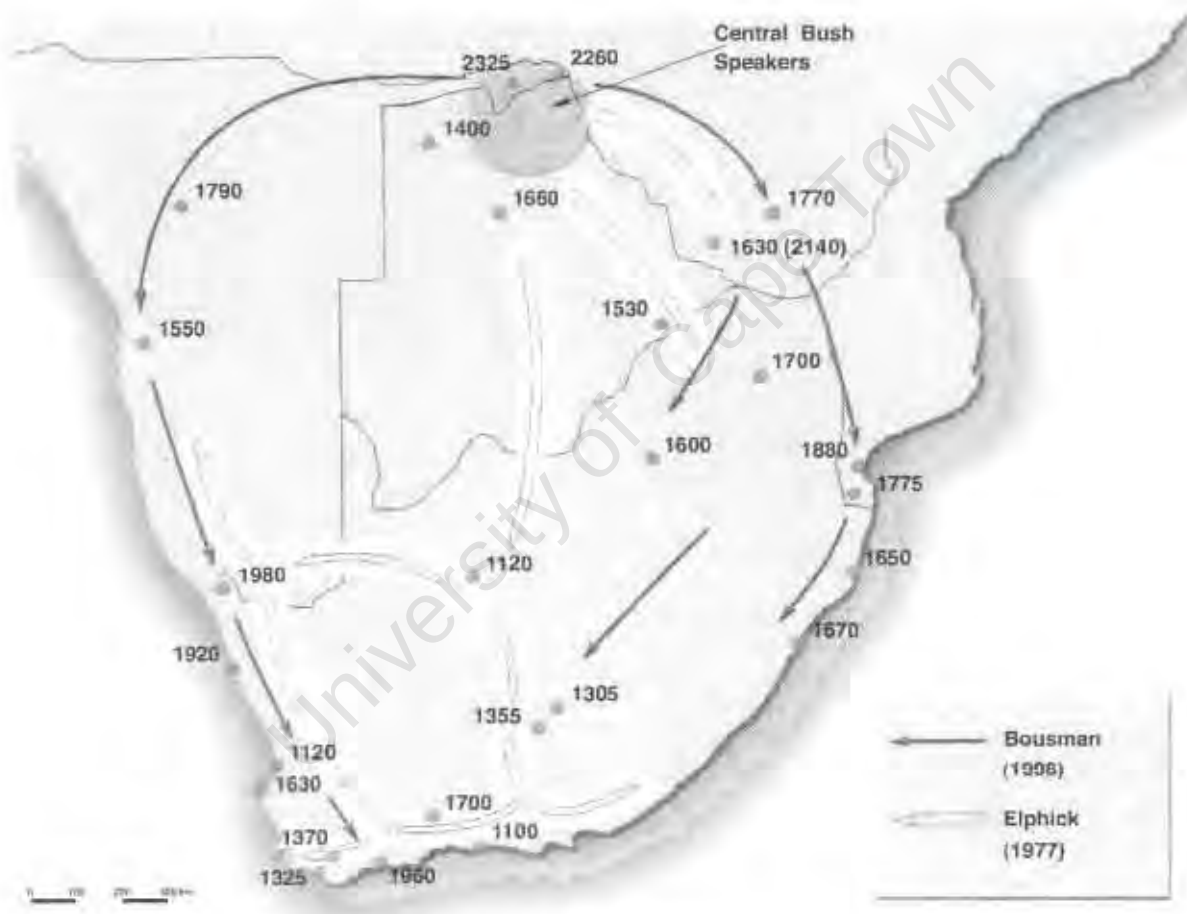


Figure 11: The introduction of pastoralism after Stow (1905) and Cooke (1965a); dates after Bousman (1998)

Stow (1905) and Cooke (1965b) both suggested a route through Angola, whereby these herders migrated either from Zambia or Zimbabwe into the western Cape competing there with the indigenous Bushmen for the scarce water and food resources. This theory was based on oral traditions and the suitability of the environment for grazing. The distribution of rock-

paintings of sheep seems to follow this route too (Figure 11 on page 49).

Opposing this, linguistic researchers such as Westphal (1963) argued for another area of origin and therefore another route of migration. He suggested,

"...that the Cape Khoi language diverged from Central Bushmen in northern Botswana... Influenced by Westphal, the historian Elphick (1977, pp 11-12; see also Inskeep 1969, p. 24; Smith 1990, p. 65) proposed that ancestral Khoi-speakers acquired live-stock in northern Botswana from their Bantu-speaking, Iron-Age neighbours...[.]...[b]locked to the east and north they wandered south and west, eventually reaching the Cape of Good Hope".

Elphick also proposed (1977: 11-13) that "...the Cape Hottentots, or the Khoekhoe as they are now known, had originally migrated from northern Botswana shortly before the Europeans reached the Cape..." (Figure 12 on page 51). Later Elphick (1985) revised his statement and pushed the migration back to about 2000 B.P. .

This theory of Khoe migration is generally accepted by most researchers (Parkington 1984: 122-123; Parkington et al. 1986: 317; Smith 1992: 93-94; Boonzaier et al. 1996: 25-27). However, others (Deacon, J. 1984: 275; Klein 1986: 9; Kinahan 1995: 218) proposed a diffusion of live-stock within the hunter-gatherer groups to the south, slowly reaching the Cape.

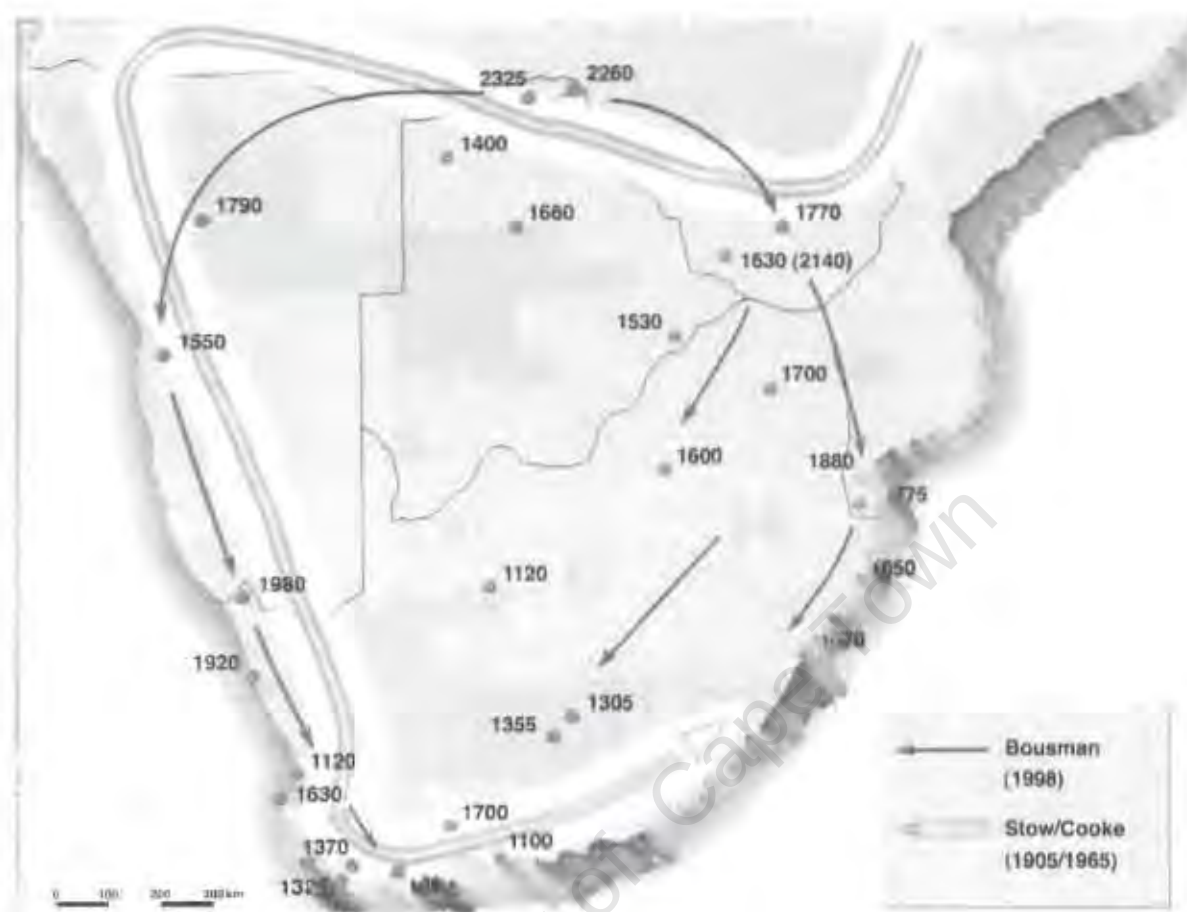


Figure 12: The introduction of pastoralism after Elphick (1977) and dates after Bousman (1998)

Contrary to many to many previous assumptions, recent research showed (Sadr 1998, 2003 in press.) that there is a possibility that the pastoralists could have immigrated only around the end of the first millennium A.D.. Sadr (1998) suggested that the sparse data of sheep in the archaeological layers of sites in the western Cape, dated to 2000 B.P., was not a product of the general poor preservation of the bones, but rather showed that sheep were not herded in great numbers and kept as livestock, suggesting a pastoral way of life. Moreover he argued that hunter-gatherer groups could have obtained small numbers of livestock, bartered in the northern or north-western regions (e.g. Botswana, Namibia) from pastoralist groups. This proposition that the livestock reached the Cape partly by diffusion around 2000 B.P. is possibly shown by the data of dated sheep bones in archaeological deposits of that time

(Yates and Sealy 1994, Henshilwood 1996, Bousman 1998). Hunter-gatherers might have kept small numbers of live-stock, were not depended on them.

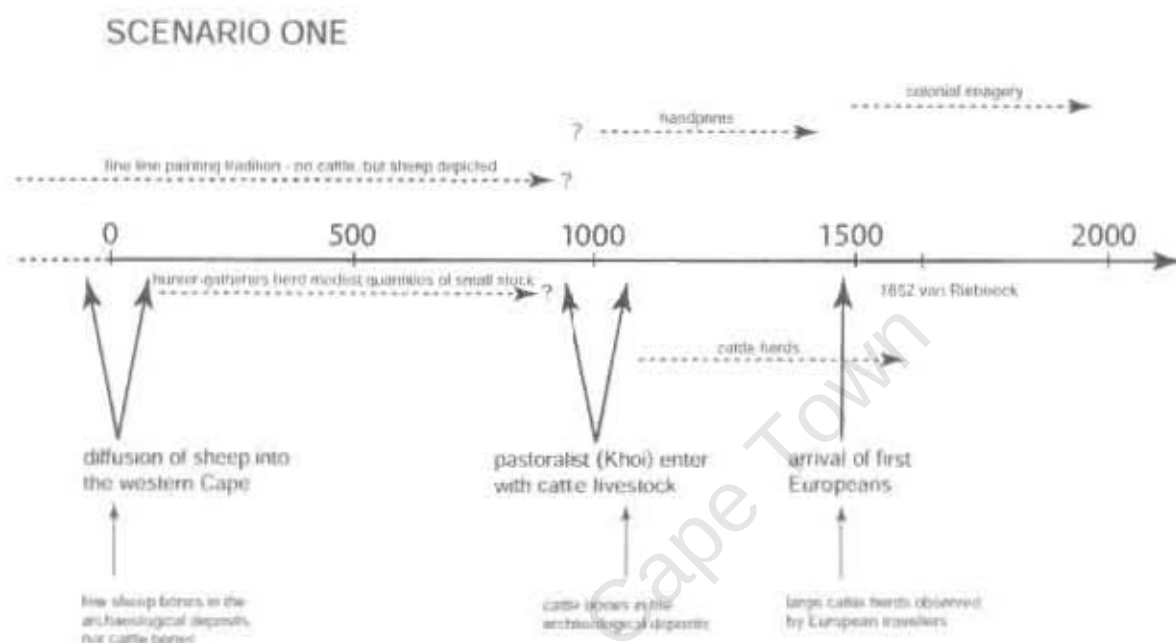


Figure 13: Introduction of livestock into the western Cape as suggested by Sadr (2003 in press.)

A late arrival of the Khoe herders in the Cape a few centuries before the appearance of the Europeans, as proposed by Sadr (2003 in prep) and earlier by Elphick (1977) (Figure 13 on page 52) does in fact agree with the dating-frame for the handprints, postulated by Yates et al. (1994). A late appearance of the herders coincides with the dates, when the fine-lined tradition was abandoned and hand printing might have started.

Ethnographic accounts of large herds owned by cattle pastoralists are reported just some centuries later. They were described by early European travellers (Raven-Hart 1967). It cannot be ruled out that the pastoralists came into the Cape around 2000. B.P. in small groups with little livestock and slowly built up larger herds before the end of the first millennium A.D. .

SCENARIO TWO

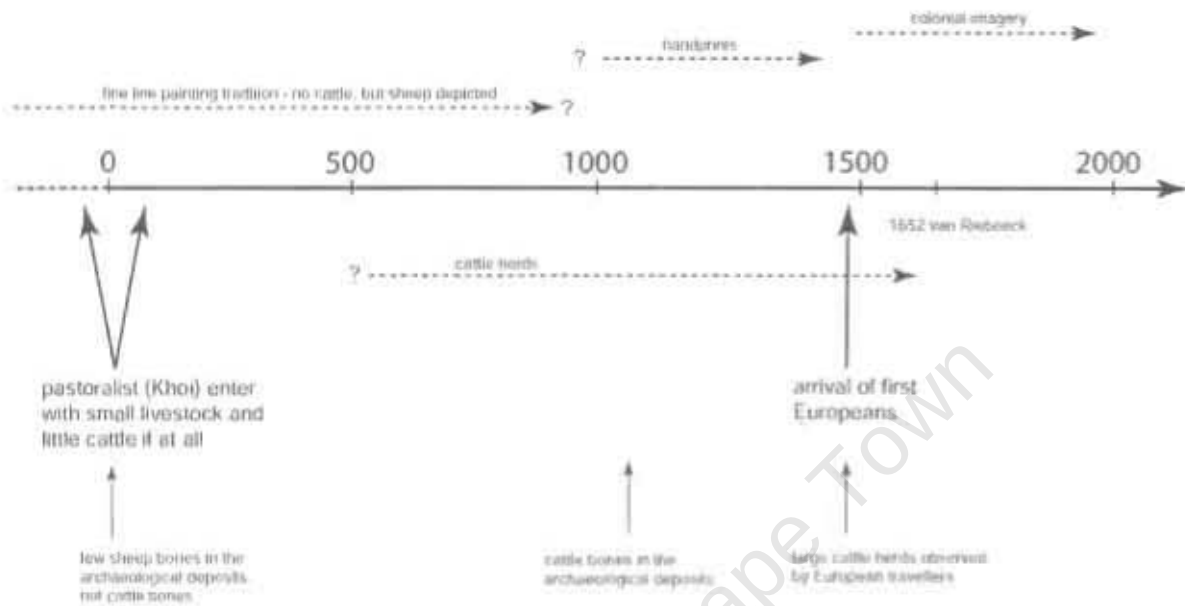


Figure 14: Introduction of livestock into the western Cape as suggested by Smith (1998)

It should be taken into consideration that the livestock had to adjust to the new environment (Gifford-Gonzalez 2000). A similar event can be observed in the archaeological data of southern Kenya, where domesticated stock probably needed time to adapt to the new environment, as fatal diseases, such as Bovine Malignant Catarrhal and East Coast Fevers and others transmitted from wild animals decimated the livestock population (and human population). There the newly arriving Bagro-pastoralists had to get used to the new conditions of the landscape for some centuries, before they could finally manage to establish a stable way of life and avoid the infected areas. After that period of learning, an explosion in the dimension of the herds and living sites can be observed. A comparable scenario in the western Cape is imaginable, even if the kind of malignant diseases are not as common in this area. If we believe the dates, sheep spread relatively quickly from the northern to the southern Cape (Bousman 1998). This section shows the complexity of settlement history in the

western Cape and demonstrates that we are far from getting a neat and clear answer. We therefore must be careful with assumptions and postulations made about the authorship of artefacts in archaeological deposits or rock art on the cave walls, especially as we are not dealing with static objects, but with a network of people, which are classified with our understanding of society.

An approach to get closer to answers concerning the authorship of handprints was offered by Manhire (1998), when he argued that hand printing was a group effort and the authors were sub-adults. An intra-site examination of the distribution might help to identify repetitive authors and answer the question whether groups were responsible for making prints. Additionally the clarification of the sex would be helpful to confirm or refute Anderson's (1997) statement of (Khoen) women being the artists. Furthermore it would be interesting to see if the age and height proposition made by several authors (Willcox 1959; Maggs 1967, Manhire 1998) must be revised.

4.4. DISTRIBUTION

In this section I describe the distribution of sites with handprints in the western Cape, as mapped by different researchers. Manhire (1981; 1998) examined about 1600 rock art sites in the western Cape, gathering a substantial amount of recordings including site by site frequencies of handprints and other rock art categories. Using this dataset he argued for the existence of two principal areas within the region of the western Cape where sites with handprints primarily occur. These are the Sandveld and the mountainous range of the Cedarberg. Moreover, it is necessary to differentiate between the general distribution and frequencies of handprints across the landscape as well as the intra-site distributions and frequencies, because these can be very different.

Manhire (1981, 1998, 2003 Parkington (ed.) in prep.) showed that 15,5% of sites with hand-

prints occur in the coastal plains and mountains (Table 1 on page 55), and sites with decorated prints are more common in the coastal Sandveld (6,8% in the Sandveld: 1,8% in the mountains - Table 1 on page 55). The overall percentage of handprints and images of humans and animals (representational images) differs substantially in the Sandveld from the percentage obtained in the mountains. Almost every third painting in the Sandveld is a handprint, but only every thirtieth image in the Cederberg mountains is represented by the latter (Table 2 on page 56). Additionally, representational paintings far outnumber handprints in the mountains (8.8 : 1; 21.7 : 1; 35 : 1), while there are less than half as many handprints (1 : 1.8) as there are detailed images on the coast (Table 3 on page 56). Consequently, we would expect handprints to outnumber representational images at sites in the Sandveld. In the Cederberg mountains handprints are less common, but can still be found in many sites. This leads to the assumption that they are often found in small numbers in sites with representational paintings, such as humans and animals. These dissimilarities between the two areas, Sandveld and Cederberg mountains, need to be explained and are possibly an indication of the incursion of the pastoralists, if not their doing, as the herders would have preferred the Sandveld for keeping their stock (van Rijssen 1984)

	Sandveld	Mountains
Total rock art sites	517	1074
Sites with handprints	79 (15,3%)	168 (15,6%)
Sites with plain handprints	76 (14,7%)	164 (15,3%)
Sites with decorated handprints	35 (6,8%)	19 (1,8%)

Table 1: Comparison of sites with handprints in the Sandveld and the mountains (Cederberg). Figures in brackets show the number of handprint sites as a percentage of total number of rock art sites in the area (Manhire 1998).

Area	Reference	Handprint (%)
Coast / Sandveld	Manhire (1981)	31,9
Mountains	van Rijssen (1980)	2,7
	Golson (1984)	2,6

Table 2: Percentage of handprints in the Sandveld / Coastal region compared to the mountains (Cederberg). Percentages are calculated against the total number of images (Yates et al. 1994).

Area	Reference	Ratio of handprints to humans and animals
Sandveld (coast)	Manhire (1981)	1 : 1,8
Olifants River (mountains)	van Rijssen (1980)	1 : 21,7
Booentjieskloof (mountains)	Golson (1984)	1 : 35
Putslaagte (mountains)	Halkett (1981)	1 : 8,8

Table 3: Ratio of hand prints to human and animal images in the Sandveld and in the mountains (Manhire 2003 in prep.)

If we compare the frequency of handprints to other images in the Sandveld two interpretations can be hypothesised: One explanation is that the number of prints at a site simply exceeds the number of other paintings because of the greater number of individuals coming there during one brief event. On the other hand it could indicate that these sites were set aside as places to which people would repeatedly come for a special ritual and the purpose of making handprints.

Until now, no attempt has been made to map the intra-site distribution and frequencies of handprints, be it in general or as a distinction between decorated and undecorated handprints. Handprints often show patterning in the sites, clusters and lines are frequently apparent (Mguni 1997, own observations - Figure 7 on page 37) and can be interpreted in many ways. This is where an intra-site analysis must start. With methodology and technology har-

monized, it should be possible to make statements on a small scale, starting the analysis at the level of the individual handprint in a single cave. Preferably, these sites should display large numbers of handprints to make results of a statistical analyses credible. If the analysis on this level shows valuable results, it might be possible to comment on the distribution of handprints and their meaning, as well as authorship on a larger scale. This thesis approaches this intra-site analysis with a precise measuring system, a large number of experimental handprint-sets and a statistical analysis constructed to find patterns and distinguish between individuals and groups.

University of Cape Town

5

METHODOLOGY AND TECHNIQUES

5.1. Sets of observations (Recording)

5.1.1. Introduction

This chapter contains the description of the techniques applied to collect and process images of the handprints, as well as a clarification of the sets of measurements utilized. I collected different sets of handprints from five different locations, two derived from the above mentioned caves of the western Cape, EBC and DK, two sets obtained from pupils of schools within the western Cape and one set made by the author of this thesis. The aim of this thesis is to provide more information about the handprints in the western Cape. I therefore chose two exemplary caves in this area, EBC and DK, both with a large number of prints. I have previously explained the background of the handprints of the western Cape in general, but deem it necessary to further illustrate the prints in the two caves as they provide the central handprint sets for this study. I will begin by describing the datasets from EBC and DK, which are composed of handprints left by the earlier inhabitants of the western Cape. Secondly, an experiment performed by the author in Cape Town to establish handprint dimensions and measurements is explained. This explanation is followed by a description of the experiments conducted by the author to obtain comparative datasets and measurements of handprints from schoolchildren. These latter observations were made because there is evidence that the ancestors of these schoolchildren were Bushmen or Khoe and the comparative material derives therefore from the people most closely related to the "original" printmakers in the caves (Manhire 1998). A comparison of different sets of handprints, experimental and archaeological, could help to recognize authorship through resemblance

of age and height. Height- and age-dimensions from handprint makers of the experiment can be compared with those computed from the archaeological handprints. Moreover, this chapter contains an introduction to the relevance of photogrammetry, the technique used to record the different datasets of handprints, as well as a portrayal of the other techniques applied previously to realize the recording and measurement of the images. Whilst assessing my observations I discovered significant errors resulting from the techniques used to record the handprints. The techniques utilized and the differences between them therefore need to be explained. Finally, this chapter concludes with a description of the measurements obtained from the "original" and "experimental" handprints.

5.1.2. Handprints in EBC and DK

The handprints of EBC are distributed in a seemingly non-systematic manner. In two different recording sessions 494 and 555 handprints were obtained, respectively. The discrepancy can be explained due to different techniques of recording and enhancement of the images, both described below. The datasets are composed of normal and decorated handprints as well as palmar prints, which can also be decorated with nested U-shapes. Prints have been made on top of other images, such as some big eland torsos (Figure 9 on page 39), as well as on top of each other, as if little care was taken concerning their position on the rockface.



Figure 15: Overview of an array of handprints around an eland torso in EBC

Nevertheless, it is interesting to note that most of the palmprints are spread on top and around a large eland torso and hardly occur anywhere else, whereas the other normal and decorated full prints do not superimpose paintings other than other prints. It could be argued that the palmprints were purposely made in connection with the eland. An investigation of the superpositional sequence of EBC would be very interesting and promising in this respect, especially as a comparable account on the superpositions of DK already exists (see Mguni 1997).

DK is in some respects even more unusual than other caves or overhangs, as it consists of two shelters, with different distributions of handprints. It looks as if in the north-westerly facing shelter the distribution of handprints is non-systematic, as in EBC. In contrast to this stands the easterly facing cavity, which contains apparently organized long lines of 163,

mostly decorated, handprints (Figure 7 on page 37). If the prints of the two shelters are counted together, the different techniques result in counts of 382 or 374 handprints, respectively. For the most part the handprints are preserved in a better state than those of EBC. Only two examples of palmar prints in DK could be recorded. There are more decorated full prints present than normal ones. The results and a detailed list of these ratios will be presented in Chapter 6. In the superpositional sequence handprints seem to be above fine-lined imagery and below smears, crayon-lines and historical images (Mguni 1997).

SETS G and SET H are EBC and DK handprints, respectively, and are generally described in "Appearance of the handprints" in Chapter 4.2.: ARCHAEOLOGY (page 35). Ratios and numbers are listed in Chapter 6.

5.1.3. Experimenting with handprints

Other researcher such as Willcox (1959), Maggs (1967) and Manhire (1998) obtained measurements of handprints from caves of the western Cape in order to comment on their authorship. As stated earlier the initial idea for this research project derives from Henneberg and Mathers' work (1994). Their formula to calculate the age and height from handprint-measurements, was used by Manhire (1998) on the archaeological observation of handprints in the western Cape. I saw potential in the method, but was not sure about the techniques; could the formula be trusted on other sets of observations (a fact they pointed out in their article (Henneberg and Mathers 1994: 496)), and did the techniques utilized to obtain the images of the handprints have the level of accuracy and precision needed to interpret the paintings. I had various reasons to make the handprint-experiments by myself rather than to test the existing measurements mentioned above. For one, the images Henneberg and Mathers collected were obtained from an age group of people between 5 and 20 years old. I wanted to test if another set of handprints made by a group with a much smaller variation in age

would still be attributable to the individual makers. This is worth knowing, since Manhire (1998) associated the makers of the handprints in the caves of the western Cape with sub-adults, with high concentrations of handprints in certain age groups, such as boys between 12 to 14 years of age or girls between 14 to 16 years of age.

5.1.4. Aims and reasons behind the experiments

I wanted to understand whether prints show unique and distinguishable features of individuals. Is a set of several handprints from one person distinguishable from a set of handprints made by several people? To add to this, the variation between left and right hands could potentially bear interesting results, considering that a similarity of left and right handsizes has previously been assumed (Henneberg and Mather 1994). Furthermore, I wanted to examine the variability within the measurements of one observer and compare these with sets of measurements of the same prints examined by another observer. Apart from this, I needed to understand how different techniques of measuring the images altered the information. Another objective of the experimental sets of measurements was to assess variability in measured handprints in the caves against variability in the different experiments.

In order to answer the different questions, I had to obtain different sets of handprints from known sources. I investigated all sets of prints, as will be described below, by measuring them in different ways. Initially I measured handprints using a calliper, the technique utilized by Henneberg and Mathers (1994) and Manhire (1998), and secondly by photogrammetry, the technique I later also used to record the handprints in the caves. Although prints as parts of my sets of observations were obtained in different locations and by different persons, the techniques applied were the same. Two sets of experimental handprints were collected by myself, while a third set was assembled by M. Henneberg and K. Mathers made available to me.

From visits to Elands Bay Cave and Diepkloof, as well as from extensive survey in the Cedarberg, I was able to carefully examine a large number of prints in order to make my own experimental prints in a similar way. I concluded that most of them were made, by putting the fingers together or slightly apart from each other, whilst stretching the thumb outwards. Because fingerprints can often be seen, it is clear that the hands had to be pressed against the rock. Other researchers suggested "...outlining it with a brush, then filling in the outline" (Willcox 1959:292) as one possibility. There are no indications of an enhanced or in another colour delineated outline around the handprints. Experiments with palmprints were not conducted, because the original palmprints were for the most part decorated and no applicable points of measurements could be observed. Palmprints in this sense are prints with colour missing at those points, where marks from finger should normally be present. In many cases I was not even sure which was the distal and which the proximal side of the hand. I concentrated therefore on making complete prints in the experimental sets.

5.2. Description of experimental sets

SET	origin	short	count and hand side	measurer
A1	Cape Town	CPT	person A 50 rights	person X
A2	Cape Town	CPT	person A 50 lefts	person X
MPA1*	Cape Town	CPT	person A 50 rights	person Y
MPA2*	Cape Town	CPT	person A 50 lefts	person Y
MPA1#	Cape Town	CPT	person A 1 hand 50 x repeatedly measured	person X
B	Cape Town	CPT	person B 50 right hands	person X
C	Cape Town	CPT	person C 50 right hands	person X
D	Clanwilliam	CLW	100 persons right hands	person X
E	Clanwilliam	CLW	100 persons left hands	person X
F	Calitzdorp	CZD	104 persons left and right hands	person X
G	Elands Bay Cave	EBC	494/555 archaeological prints, depending on technique used	person X
H	Diepkloof	DK	382/374 archaeological prints, depending on technique used	person X

Table 4: Description and labelling of experimental sets

5.2.1. Experiment A - Cape Town (CPT)

The first set consists of 200 handprints from three persons. All persons had the same height of 1.80m and were over 23, an age in which an adult assumedly has reached the maximum of his/her growth two men and one woman participated.

One male and the female person made 50 prints of their right hand, while the other male individual provided in addition to his 50 right hand prints, 50 left ones. From now on I refer to the last mentioned sets as SET A1 (left hand prints) and SET A2 (right hand prints) and to the former two as SET B and SET C, respectively. To produce the handprints I used a water-soluble paint, which was applied, as a rich film, to the whole of the palm and fingers with a soft sponge.



example of SET A1



example of SET A2



example of SET B



example of SET C

Figure 16: Examples of handprints-SETS A1, A2, B and C, made in Cape Town

The use of ochreous material was not considered, as it would have been too time consuming to gather and grind a sufficient amount of ochre as would have been needed. Moreover there are still arguments as to what other ingredients such as which binders were utilized (for a discussion/comparison about pigments and paints see Rudner 1982).

In my experiment the hands were pressed against a paper, which lay flat on a table below the printer's hip. It is arguable if it would have been better to press the hands against a wall parallel to the persons major axis, to simulate conditions met in the cave. Handprints in the cave, however, do not always appear on a wall perpendicular to the floor. Many are underneath ledges or in heights, which can only be reached by crouching or stretching. To simulate the conditions in the cave I would have to determine the differences between handprints made in different body postures which exceeds the scope and time-frame of this thesis. I therefore assume that the difference in the results is smaller than the variability in the measurements. In any case, as all three persons made them in the same manner, SETS A(1-2), B and C can be compared with each other. Each print was furthermore executed in almost the same way, regarding the position of the fingers, as has been observed on the original handprints in the western Cape (personal observation.).

From the evaluation of these prints I hoped to gain several results: First, I wanted to learn if different measurers obtain statistically different results, using the same basic dataset. For that purpose DATASET A(1-2) was measured by a second person, resulting in different observations which will be referred to as MPA1* and MPA2* (measured prints DATASET A1; * stands for different measurer) for right and left handprints, respectively. Furthermore I tested how much left and right prints of one person differed from each other. Moreover, I hoped to get an indication, what the variation within one individual's handprints is, when repeatedly generated. For this reason one handprint of DATASET A1 was measured 50 times by one observer. These observations will be cited in future as MPA1# (measured prints DATASET A1, # stand for repeated measurement of the same hand).

5.2.2. Experiment B - Clanwilliam (CLW)

As already mentioned in Chapters 1 and 2, I wanted to know, what a set of prints made by a large group of people looked like compared to a set made by a single person (SET A, B, C), as described above. I therefore conducted another experiment, involving 100 children, 41 boys and 59 girls, from a school in Clanwilliam, in the Cederberg mountains. The above described technique to obtain SETS A(1-2), B and C was used again, differing only in the manner in which the paper on which the hands were pressed, was held. In this experiment the paper was held to a wall parallel to the persons major axis. Each individual made two prints one of the right and one of the left hand, respectively so that 200 prints of this group were collected in overall.

To simplify, I will refer to them as SET D (right hands) and SET E (left hands). Furthermore the height of each individual was obtained with an anthropometer, measuring to the nearest centimetre. The group, which helped so kindly, consisted of pupils from the 2001 matric classes of the Clanwilliam Highschool, with an age range between 16 to 20, with a few "outliers" of 15, 21 and 22. This experiment comprises a group with a small variation in age, which also offers material for a comparison between left and right handprints. I knew the heights, sex and ages of these printmakers, and wished to test if the measurements of their handprints could be used to successfully predict either height, age or sex on prints of unknown authorship. Henneberg and Mathers (1994) computed a formula from which height and age of an individual could be calculated by knowing the handprint length. It is risky to apply the Henneberg and Mathers (1994) regression-formula to SETS A, B, C, D and E, especially as it derives from a group of people between 5 and 20 and therefore exhibits a far greater variation in age and height, as well as size of handprint.



Figure 17: Example of Clanwilliam handprints

5.2.3. Experiment C - Calitzdorp (CZD)

Parts of the third set of experimental handprints from schools close to Calitzdorp (Towerkop Primary, Ladismith Senior Secondary and Dysselsdorp Primary), were kindly provided by M. Henneberg. This dataset, SET F, consisted of 104 handprints, from 68 girls and 36 boys, made with their preferred, probably but not necessarily dominant, hand. This SET F, with age ranging from 5 to 20, was acquired to give me an indication of what the variation is, if a group of people with a strong divergence of age, height and bodily dimension made handprints.

5.3. Techniques to acquire measurements:

To acquire measurements from the prints of SETS A-H I used three different techniques, one of which will be referred to as "manual", a second as "digital" and a third as "photogrammetrical". These three techniques are derived from different approaches towards recording the handprints in the caves and the experimental prints. The choice of measures will be explained later, in paragraph 5.3.11..

5.3.1. Technique A - recording manually

Initially, I obtained comparative SETS A-F and measured them manually. The manual technique is very simple, as all prints were present as red images on a white sheet of paper, and the measurements were recorded with a standard calliper to the nearest 0.5 mm. All sheets were numbered and had the names of the creators of the prints noted alongside the height.

5.3.2. Technique B - recording digitally

The "digital" documenting of the handprints in the caves of EBC and DK followed afterwards. The choice of the word digital is not optimal, as the photogrammetrically obtained prints are also digitally recorded. Lacking a better description I, nonetheless use it to describe this technique.

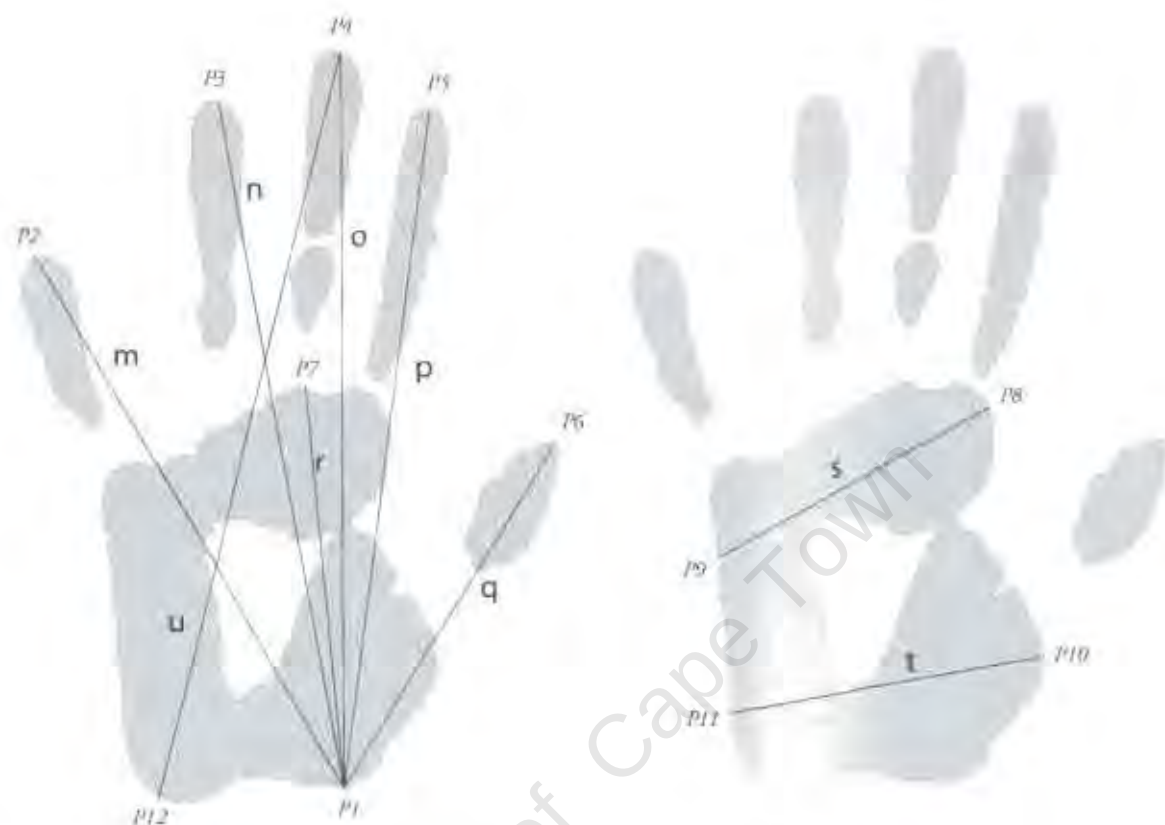


Figure 18: Length -and width-measurements obtained from the handprints

point 1 to	point2	distance-name	short
P1	P2	little finger	m
P1	P3	ring finger	n
P1	P4	middle finger	o
P1	P5	fore finger	p
P1	P6	thumb	q
P1	P7	palm-length	r
P8	P9	subdigital width	s
P10	P11	lower width	t
P12	P4	total length	u

Table 5: Description of length -and width measurements of handprints

I numbered all prints on the cave wall with buttons and a non-residual, oil-free adhesive, avoiding contact with any painted part of the wall. Each print was digitally recorded with a NIKON® 990 digital camera, with an maximum resolution of 3.4 megapixels, and a 10cm scale next to the handprint, not obscuring or touching it. The pictures were transferred to a computer to rescale them using the ADOBE PHOTOSHOP 6.0® and the scale. Rescaling in this sense means to remodel the image-size to the scale defaulted by the scale in the picture. As the images were digital, an enhancement, especially of the red particles of the pictures and therefore the handprints with ADOBE PHOTOSHOP 6.0® was possible. The application furthermore allows for precise measurement of images and dimensions within. Unfortunately, but significantly I discovered by looking at the same handprint in different pictures that length-measurements varied by more than 5mm, where I had expected a variation of 1mm or less. This inaccuracy can be explained by the following factors:

5.3.2.1. Inclination of the picture

Because the result of photography is a 2-dimensional projection of the three dimensions of space, the actual proportions of an image are distorted (example camera 1 in Figure 19 on page 72). This distortion depends on the angle of the camera towards the surface and the surface undulation, in my case the rock surface with the handprints. Minimum distortion without photogrammetrical support can be achieved by holding the camera parallel to the surface (example camera 2 in Figure 19 on page 72). Even then, distortions occur, because the rock surface is undulating and the centre and edges of the object have different distances to the camera.

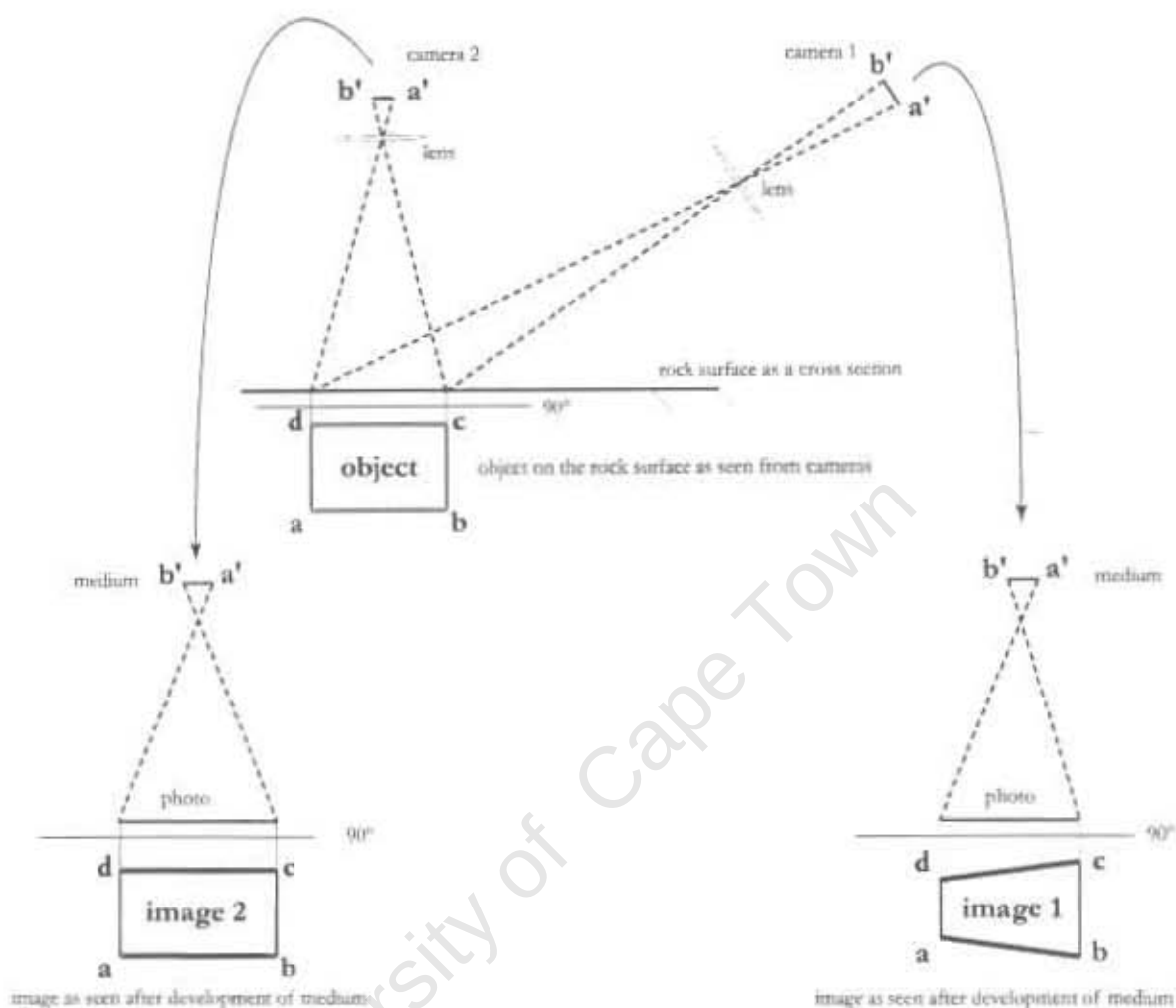


Figure 19: Distortion of images through inclination of camera towards the surface

5.3.2.2. Surface undulation

In a similar way as the above described inclination, dissimilar object-image distances resulting from undulations of the wall, lead to different image scales for objects at different distances.

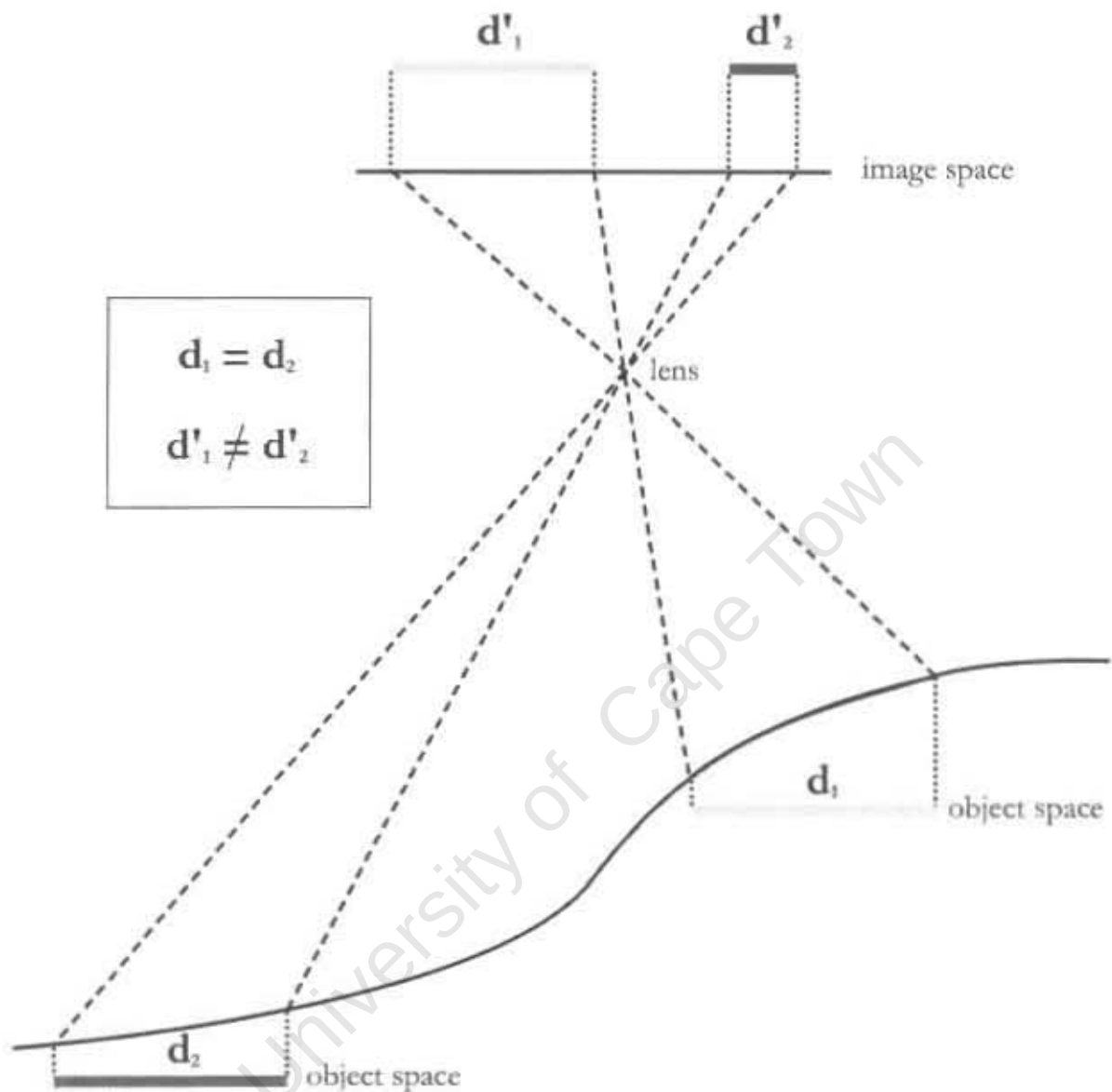


Figure 20: Scale differences in the image as a result of surface undulations

5.3.2.3. Lens distortions:

"The principal source of errors on 35mm [or analog amateur] cameras is lens distortion, and, in particular, radial distortion. If a stereo pair is taken of a flat surface and the radial distortion is left uncorrected, one will notice a "hump" in the middle of the stereo model instead of the flat area photographed (Fryer, 1992:596). In other words, the one-to-one correspondence between the object and its image is disrupted. It is pos-

sible to perform a relatively simple in-house calibration which will determine the amount of distortion. These [calibrations] could then be fed to the softcopy system or analytical plotter to apply the correction to each photo processed. This method has proved to yield accuracies of 1 to 4000 units (Fryer and Fraser, 1986: 75)." (in Gisiger et al. 1996: 17)

The calibration of an 28mm lens, used for this project, exhibited/displayed a deviation of 0.12mm on the edge of the picture. This equals an error of 4mm for the scale of images used to measure the dimensions of the handprints (pers. comm. H. Rüther).

5.3.3. Technique C - recording photogrammetrically

Applying photogrammetric principles to standard photography makes it possible to shift the recording and measurement of objects in images from mere estimation to precise and accurate determination of dimensions. Photogrammetry has been applied in the past century to survey and measure topography as well as objects. Besides the traditional relevance in producing maps, close-range photogrammetry has been applied to other domains such as medicine (Veress 1989; Robertson et al. 1989), archaeology (Mendonça 1992, Benz-Zauner et al. 1995, Bezoari et al. 1998), architecture (Carbonnell 1989) and zoology (Panwar, Paranjpe, Parson 1992, Sell 1996). Photogrammetry is based on the principles of stereoscopy which can be demonstrated briefly with the following illustration (Figure 21 on page 75). For a detailed explanation of the theory of close-range photogrammetry, the reader is referred to Gisiger et al. 1996.

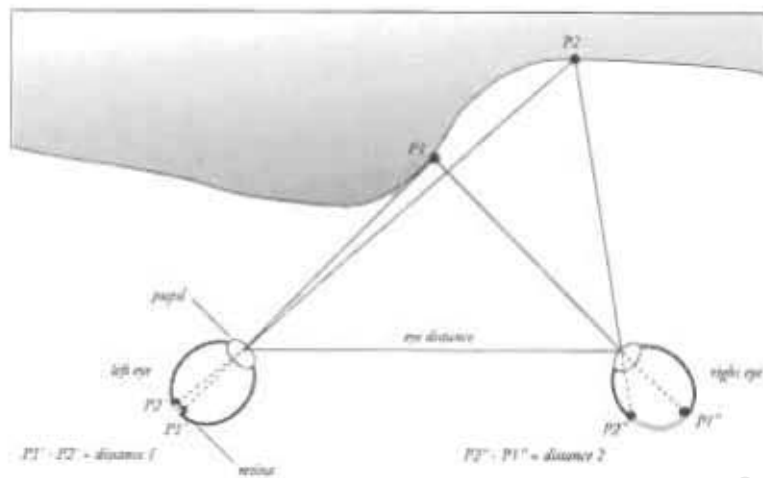


Figure 21: Principle of stereoscopy

It is based on the same principles as our eyes. Points and objects are recognized as reflections on the retina. The eyes measure difference in distance between two points P1 and P2 for each eye respectively ((P1' - P2') - (P2'' - P1'')). Our brain converts the differences in distance between observed points, the so called parallax, into 3-dimensional perception (Figure 21 on page 75).

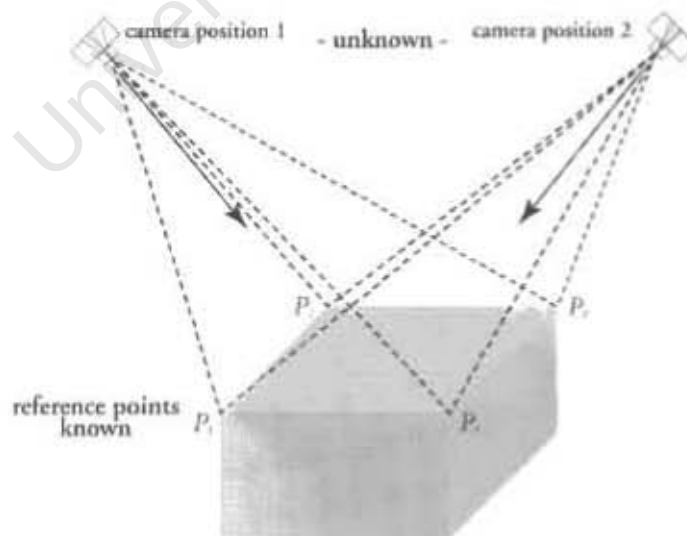


Figure 22: Photogrammetric measurement - part one - determination of camera position and orientation (spatial resection)

To measure the object of interest, images need to be taken from at least two spatially dis-

placed camera stations with one or more calibrated cameras. Furthermore, the object has to be surrounded by control points with known x -, y - and z -values. In a first step of evaluation the positions and orientations of the different cameras have to be acquired by using the x -, y -, and z -coordinates of control points (a definition of control points will follow below), captured in the images. The observations gathered in this step are the measurements of image-coordinates of control points. The mathematical model utilized here it is known as the spatial resection or absolute orientation (Figure 22 on page 75), which results in the calculation of the x -, y -, and z -coordinates, the optical centre of the lens, as well as the rotation angles of the optical axis of the camera, which represents the deviation of the camera axes against the three object space coordinate axes.

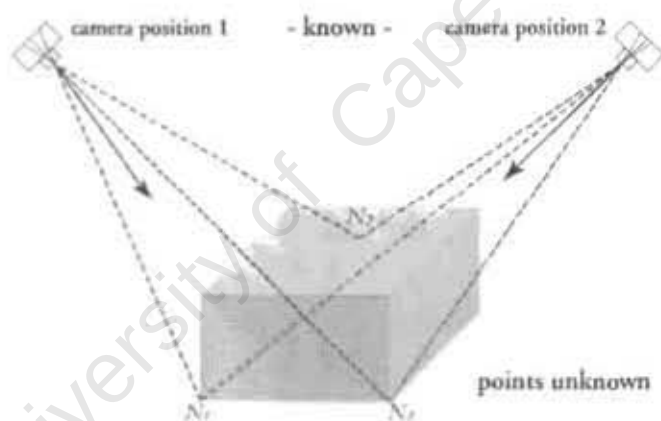


Figure 23: Photogrammetric measurement - part two - determination of point positions by means of known camera parameters (spatial intersection)

Once the parameters of the camera are known, coordinates of any point within the picture can be obtained, provided the point of interest is captured in more than one image. Spatial coordinates of these new points are using the photogrammetric process of the spatial intersection (Figure 23 on page 76). Both steps can also be exercised in one step, by applying another mathematical model, which was introduced as bundle adjustment to photogrammetry (Brown 1959).

"To obtain reliable three-dimensional measurements, artifacts being studied must

first be related to a known three-dimensional reference system or control field. This allows any points within the image to be mapped to a unique set of coordinates with respect to a single origin. The accuracy of the control field is extremely important and is directly related to that of the measurements which can be retrieved from a stereo pair" (Gisiger et al. 1996: 23).

The following steps are prompted for the calculation of dimension of the handprints.

5.3.4. Determination of coordinates for the control points of the frame

A frame with control points is absolutely necessary to calculate positions and orientations of the camera (spatial resection), which in turn are needed to determine the desired coordinates of the object (spatial intersection). For the purpose of measuring the handprints a frame of aluminium (25 x 25cm) was equipped with 37 circular aiming spots of 3mm diameter. These spots consist of disks with a retroreflective plastic surface, which is normally used for traffic signs.

The 3D-coordinates of these frame control points were obtained photogrammetrically, using the reference matrix of points in the Department of Geomatics at the University of Cape Town. Alternatively, the coordinates of the frame may be determined by the means of a theodolite.

5.3.5. Calibration of the digital camera

Photogrammetric point acquisition demands a calibrated camera. The parameters which therefore have to be established are camera constant (focal length), picture principal point (centre of picture), values of distortion of the lens (typically three radial contortions and at least two more to model further distortions). The camera calibration was undertaken in a pho-

togrammetry laboratory at the Department of Geomatics of the University of Cape Town.

5.3.6. Photography of the handprints

To accomplish the task of recording and therefore put theory into practice, I needed a camera with a fixed, pre-calibrated focal length and a calibrated frame, which had to be both easily transportable, and large enough to encircle one or more handprints on the wall. The frame was, as already mentioned, fitted out with 37 regularly distributed retroreflective controlpoints. Control points in the photogrammetrical sense are points with x -, y -, and z - coordinates, which are known to be highly accurate within a local matrix. A high accuracy is defined as following: The average error of the control point determination must be ten times more accurate than the desired accuracy of the result, in this case the dimensions of the handprints.

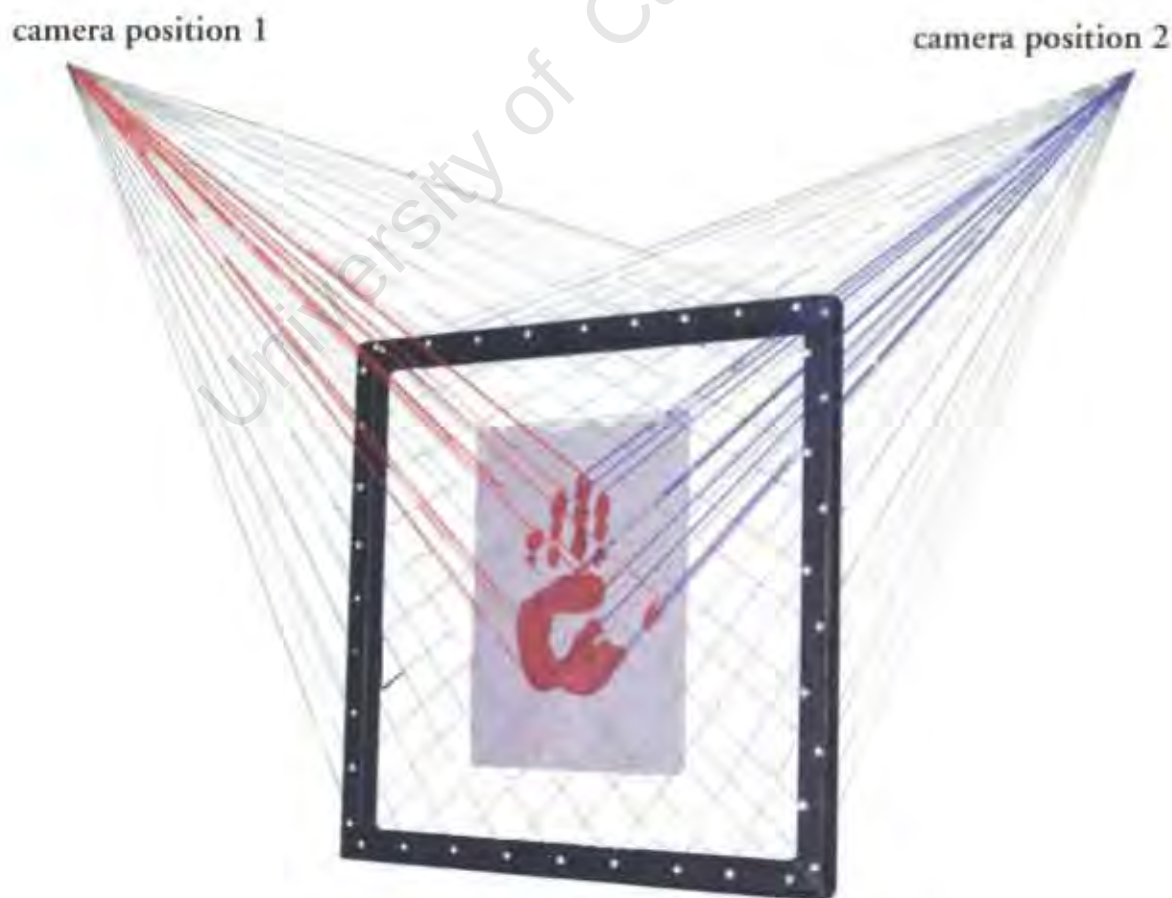


Figure 24: Frame and rays (bundles) to measure one handprint (rays to obtain handprint parameters are red and blue)

For recording purposes, the frame was held over one or several handprints and two pictures from different positions were obtained, while attention was paid strictly that the frame remained at the same location. In total 398 photographs were recorded.

5.3.7. Determination of camera position and orientation

The photogrammetric evaluation was conducted with the help of the digital close-range photogrammetry system AUSTRALIS® (Fraser and Edmundson, 2000). In the first step, all records had to be orientated, calculating the spatial resection determining six parameters of orientation for each camera position (x , y , z and three angles of orientation). The station of the camera in relation to each image is calculated respectively, using 'rays' which go from the centre of the lens to the points on the frame (Figure 24 on page 78). To procure three-dimensionality, one set consists of two pictures. With this methodology I obtained measurements, which guaranteed accurate calculations of the object points on the handprints.

5.3.8. Determination of handprint dimensions

After successfully realising the step of orientation, points on the extreme ends of the handprints could be measured (Figure 18 on page 70 and Table 5 on page 70), using the AUSTRALIS® application to determine x -, y - z values of the latter points of interest. Selected spatial distances between these points could be directly calculated thereafter.

5.3.8.1. Test for applicability of the photogrammetric technique

Before going to the field to record the handprints in the caves, I wanted to make sure that the photogrammetric technique proved useful to record with the promised accuracy. I therefore tested the technique on 3 handprints printed by myself onto a sheet of paper. The resulting measurements were compared with manual measurements obtained on the same

prints. These measurements deviated by less than 0.2mm. One print was measured three times on different occasions. These measurements did not vary more than 0.1mm.

5.3.9. Techniques to acquire the prints of EBC (SET G) and DK (SET H)

The equipment, such as the calibrated digital camera and the hand-held calibrated frame were provided by the Department of Geomatics at the University of Cape Town to record the handprints a second time (first time was the application of technique B). I used the same numbering system as described above (see technique B). The lack of a distributional map of the handprints in the caves made it difficult to assign the same numbers to the same handprints previously recorded with technique B. Only SET H (DK) was comparable on a print to print basis. I obtained overview pictures of DK, which were detailed enough to trace back the old numbering system. The overviews of EBC could, unfortunately, not be used, as the cavity was too dark and the small flash of the camera was unable to illuminate these overviews to an extent that the numbers were clearly visible. Overviews in this sense can be described as pictures taken from various points of the cave to documents the general appearance of the cave as well as the numbering system, recording about 50 handprints at a time in one picture. The overviews were not made for measuring purposes and are therefore not recorded photogrammetrically.

5.3.10. Techniques to acquire sets Cape Town (SET A), Clanwilliam (SET D, E) and Calitzdorp (SET F)

The above described technique of photogrammetrically recording the handprints in the field also was applied on the comparative prints of SETS A, D, E and F. This was done to

guarantee comparability to the SETS G and H from the caves. Each sheet of paper with an experimental print on was laid out flat on the ground and enclosed in the control point frame I used for obtaining the handprints at DK and EBC. Two pictures were taken from different positions with the same pre-calibrated camera, as the one in the field. Following this, spatial resection and intersection could be conducted to then obtained points of interest in the image (Figure 24 on page 78). The portrayal of the latter will follow now.

5.3.11. Characterization of measurements

All prints from the different datasets (SETS A-H) were examined and measured. The lengths of each of the five fingers (m-q) was taken, from tip to the point where the heel of the palm has its largest extension towards the distal end of the hand (Figure 18 on page 70, Table 5 on page 70). The hand length measurement (u) was obtained from the tip of the middle-finger to the proximal end of the hand on the little fingers side (Figure 18 on page 70, Table 5 on page 70) agreeing with the standard proposed method for measuring the hand-length.

"...With the bar of the sliding calliper held parallel to the longitudinal axis of the hand, the fixed arm of the calliper is aligned with the most distal palpable point of the styloid process of the radius. The sliding arm of the calliper is placed so that it makes light contact with the fleshy tip of the third (middle) digit..." (Lohman et al. 1988: 23-24). (Figure 25 on page 82)

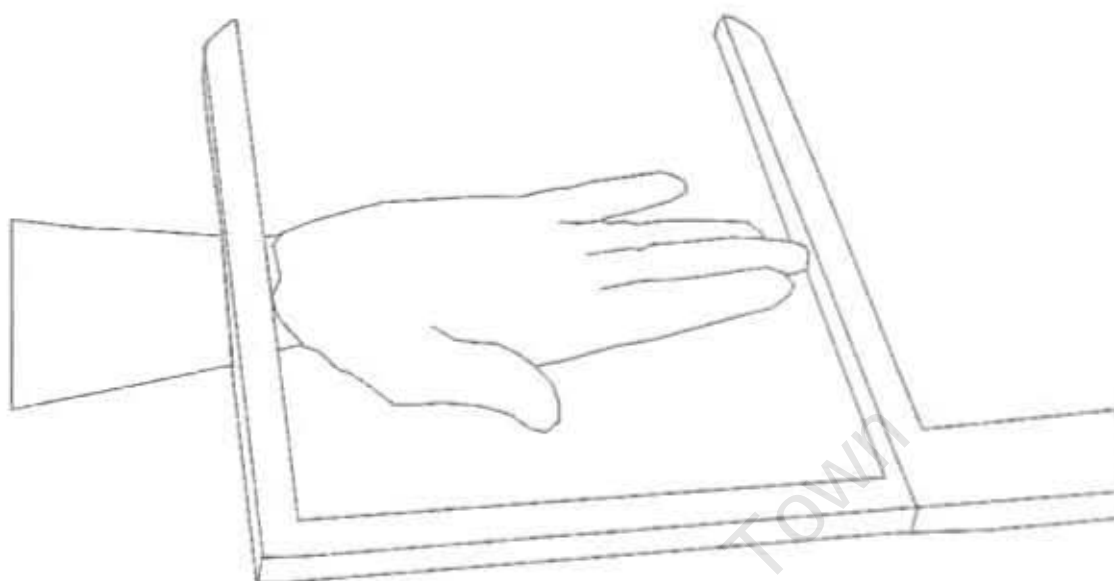


Figure 25: Scheme illustrating proposed method for measuring hand-length

Furthermore two measurement of the width of the hand were acquired, the sub-digital width of the palm (s), extending from flexion crease of the base of the forefinger to the flexion crease on the other side of the hand, which is easily obtainable in any handprint. The second measurement was of the lower width of the hand (t), which reaches from the base of the thumb parallel to the line of the subdigital width. The last measurement obtained is the length of the palm (r), a line from the base of the middle-finger, and therefore the flexion-crease, to the proximal ending arch of the hand on the thumbs side, which is the distal palpable point of the ulna (Figure 18 on page 70). Measurements, which were unclear or incomplete prints were not used for the examination.

To check the results of my different datasets with the formula Henneberg and Mathers (1994) had computed, my measurements needed to be referred to the same points. They obtained three measurements for their experiments: 1. total length, 2. subdigital width and 3. palm length. "...[T]otal length was measured from the edge of the tip of the middle finger to the

distal flexion crease on the wrist or the estimated position of this crease in cases of incomplete prints" (Henneberg and Mathers 1994: 493). "...The length of the palm was taken from the flexion crease at the base of the middle finger to the proximal crease on the wrist along the same line as the total length" (Henneberg and Mathers 1994: 493-494). In my experiments, it was frequently difficult to locate the distal flexion crease of the hand, as this varied with the pressure exerted by the print maker. I used the other side of the distal end of the hand instead (Figure 18 on page 70), which I considered, a more stable and reliable point.

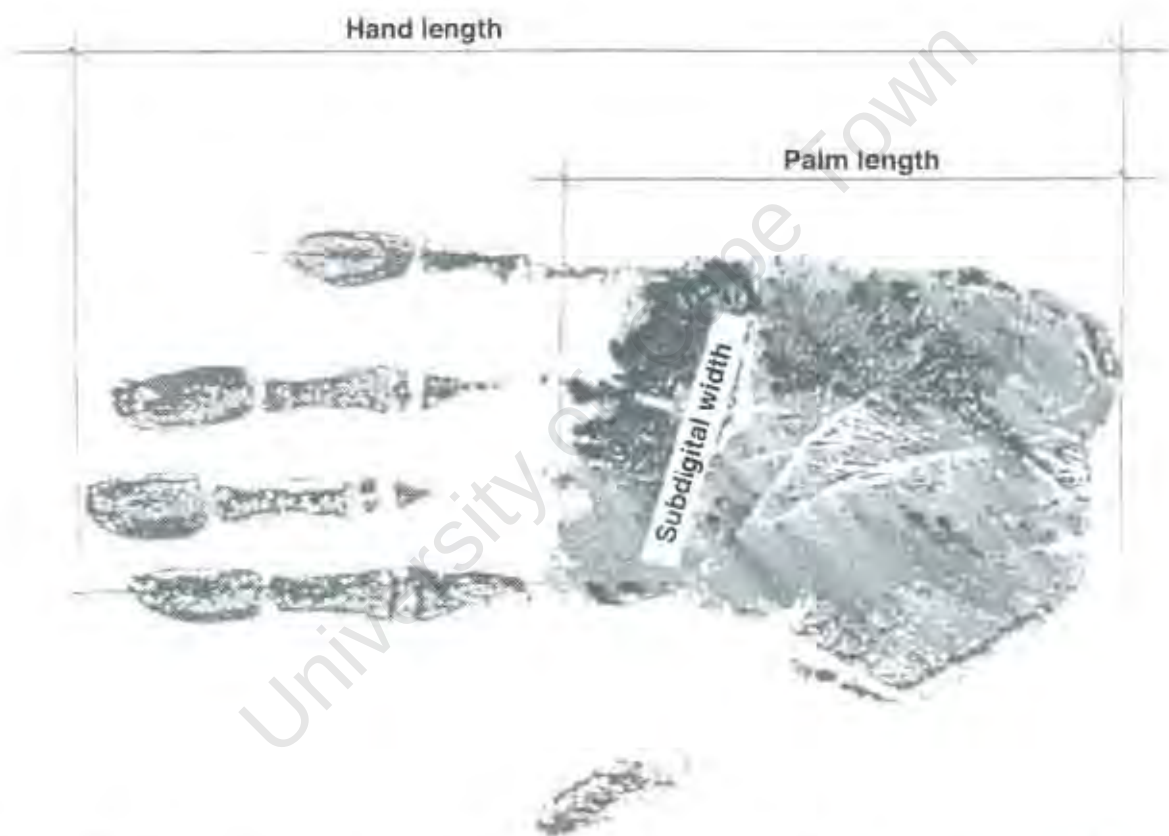


Figure 26: Proposed acquisition of handprints dimension after Henneberg and Mathers (1994) (note that this is their approach of assessing the measures and not mine)

"...The subdigital width of the hand was measured from the centre of the second metacarpophelangeal joint to the centre of the fifth metacarpophelangeal joint. The position of these points were estimated by drawing axes through index finger and the little finger and then by drawing a line perpendicular to them at a short distance below the

flexion creases at the base of the fingers" (Henneberg and Mather 1994: 494).

The measurements are not satisfactory for my purposes as they vary, depending on how much the hand is spread and where the perpendicular line is drawn. The subdigital width measurement, as I suggest it, should rely on the outline of the hand, which is determined by the hand size and not the position of the fingers.

Collecting several similar measurements, such as those of the length of the fingers, has various advantages. A hypothesized relation between length measurements of the different fingers, allows for a stronger statistical statement, as a multivariate analysis can conduct. Moreover, if some measurements cannot be obtained, due to missing fingers, smearing or damage of the archaeological prints, a connection between the finger lengths could help to identify individuals or groups in the caves.

To measure the prints I wanted to enhance them further and make, if possible, not immediately visible parts apparent. To do so, I chose an application capable of classifying pixels belonging to the handprint and to the rock surface, respectively. A portrayal of the application and the techniques utilized to enhance the pictures will follow in the next section.

5.4. IMAGE ENHANCEMENT

This section provides the reader with information regarding the further visual enhancement of the images of SETS A, D, E, F, G and H. The techniques and applications used to enhance will be characterized below. In a previous section of this chapter I mentioned the undulation of the rock on which the "original" handprints have been printed. Other researchers disregarded or simply overlooked this fact.

As I had the possibility to measure the parameters in three dimensions with the technique provided by the photogrammetric approach, I was able to evaluate to which extend the rock

on which the handprints are printed curves. The technique and calculations to rectify the error induced by the rock curvature to the measurements will be explained in this chapter.

5.4.1. Enhancement

An image generally consists of layers or spectra of different colours. Satellite images, for example, have at least 12 layers including hyperspectral ones, such as infrared and ultra-violet. In normal photography not as many layers are needed, as the eye is not able to perceive them. The basic layers of a picture are red, green and blue (RGB), each pixel of an image being made up of a combination of various intensities of these three colour components. To enhance information in one layer of a picture necessitates overpowering information in the other remaining layers. In the images with the handprints, red needs to be enhanced, implying that blue and green parts of each pixel will be subdued to a certain degree in favour of the red, leaving the latter intensity to emerge more clearly. The more red there is in a pixel, the more red it will appear on the screen if the other layers are reduced. Because the handprints are red or contain a substantial amount of red pigments, the blue and green parts of the image can be subdued to make the red particles (or red pixels of the image) and therefore the handprint clearly visible. The amount of the adjustment of the colours is different in each picture, which makes batch processing difficult. Batch-processing combines several steps of work and applies them to a stack of files (in this case images). The user creates a "batch-file", which contains the information of working-steps to be applied to the images and the order thereof. To simplify this I will give an example: The colour-mode of 500 pictures has to be converted from colour to greyscale and to be saved afterwards. It will take longer to open each picture, convert and then save it, individually than to use batchprocessing. Batch-files help shorten the process, by programming the computer to repeat the desired tasks a given number of times.

Images which were not clearly visible now needed to be enhanced. This process is called segmentation. For this reason I applied the image processing application ERDAS IMAGINE 8®, which is mainly utilized for classification of satellite images, but also offers a variety of other GIS related services, which I will not discuss here. With this software it was possible to classify pixels which belong to hand-prints and differentiate these from those pixels which belong to the background wall. Using the different levels of colour of each pixel, I enhanced the images by applying a supervised classification, which is normally employed to manipulate satellite images. A supervised classification generates classes of pixels, the parameters of which are defined by the user of the application. An unsupervised classification defines and creates in opposition to this its own classes with only the number of these preset by the user.

In a first step I had to establish a signature layer, defining parts of the image that resemble handprints and other part that reflect wall, algae or frame. I assigned different colours to each of the classes to distinguish them later. The application was then able to assign the pixels of the image to different classes. In the end a picture is created, in which all pixels are classified to one or another class, depending on their similarity to either of these.

This affiliation is determined by their spectral Euclidean distance (or relative resemblance of their pixel-composition - for a definition see page 105 in Chapter 6) to any of the user-assigned classes. A pixel containing a lot of red parts is therefore expected to be in the "hand-print" class, a pixel with black in the "frame" or "algae" class (Figure 28 on page 88).

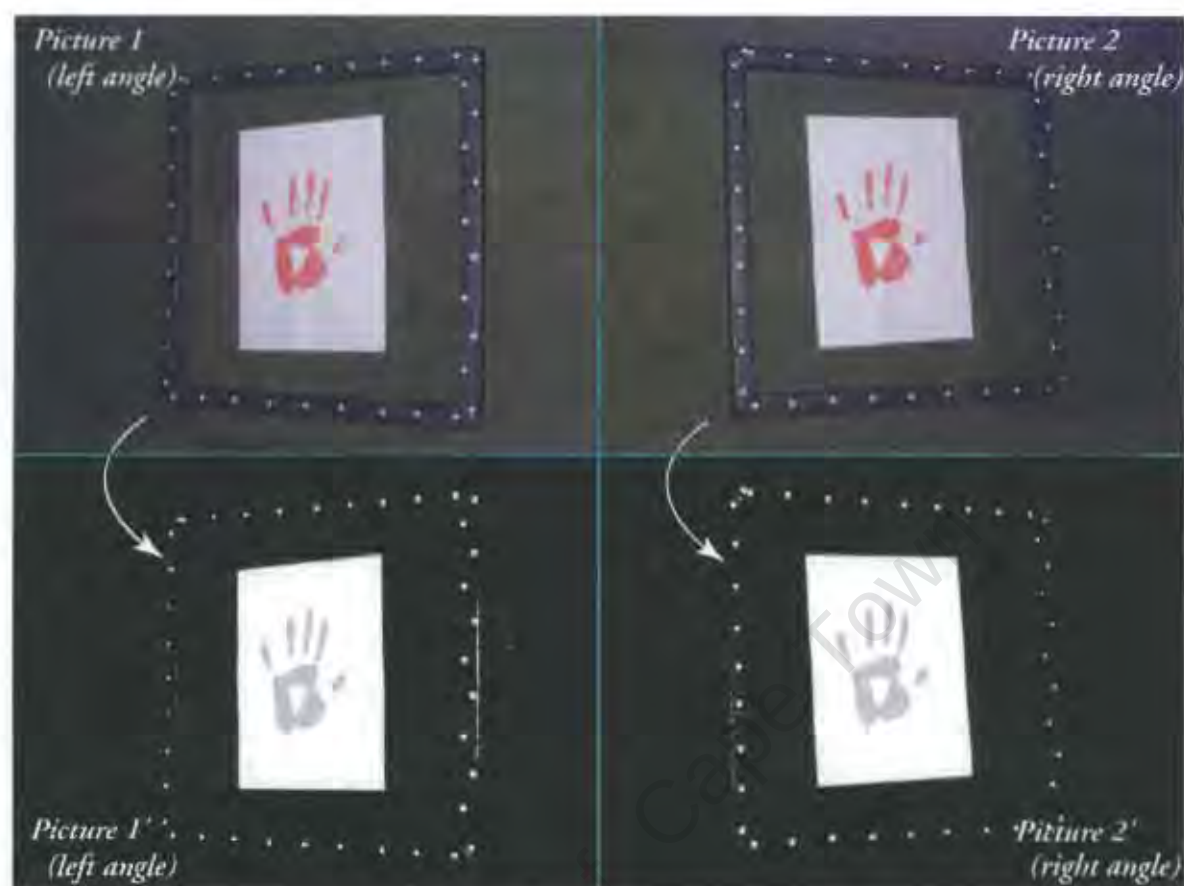


Figure 27: RGB-images (pictures 1+2) classified to greyscale-images (pictures 1' + 2')

5.4.2. Batch-Processing (ERDAS IMAGINE 8®)

To classify the large number of images, I had to rely on batch-processing. As the pictures are slightly different, depending on the underground, daylight, position as well as the flashlight they were exposed to, the colour information of the pixels must vary too. Thus, batch-processing proved difficult, but not impossible, as I created not one but thirty different batch-files in ERDAS IMAGINE 8®, to classify the different digital photographs (over 1000 pictures x 30 for each batch file). Only clear images were selected for further processing. The classified images of the comparative datasets (SETS A-F) were easily chosen, as the handprints clearly broke away from the background of the white sheet of paper they were printed on. Admittedly this selection is subjective, as the "best" picture chosen, was the one that corresponded best with

the original, although these classified pictures resemble each other closely.

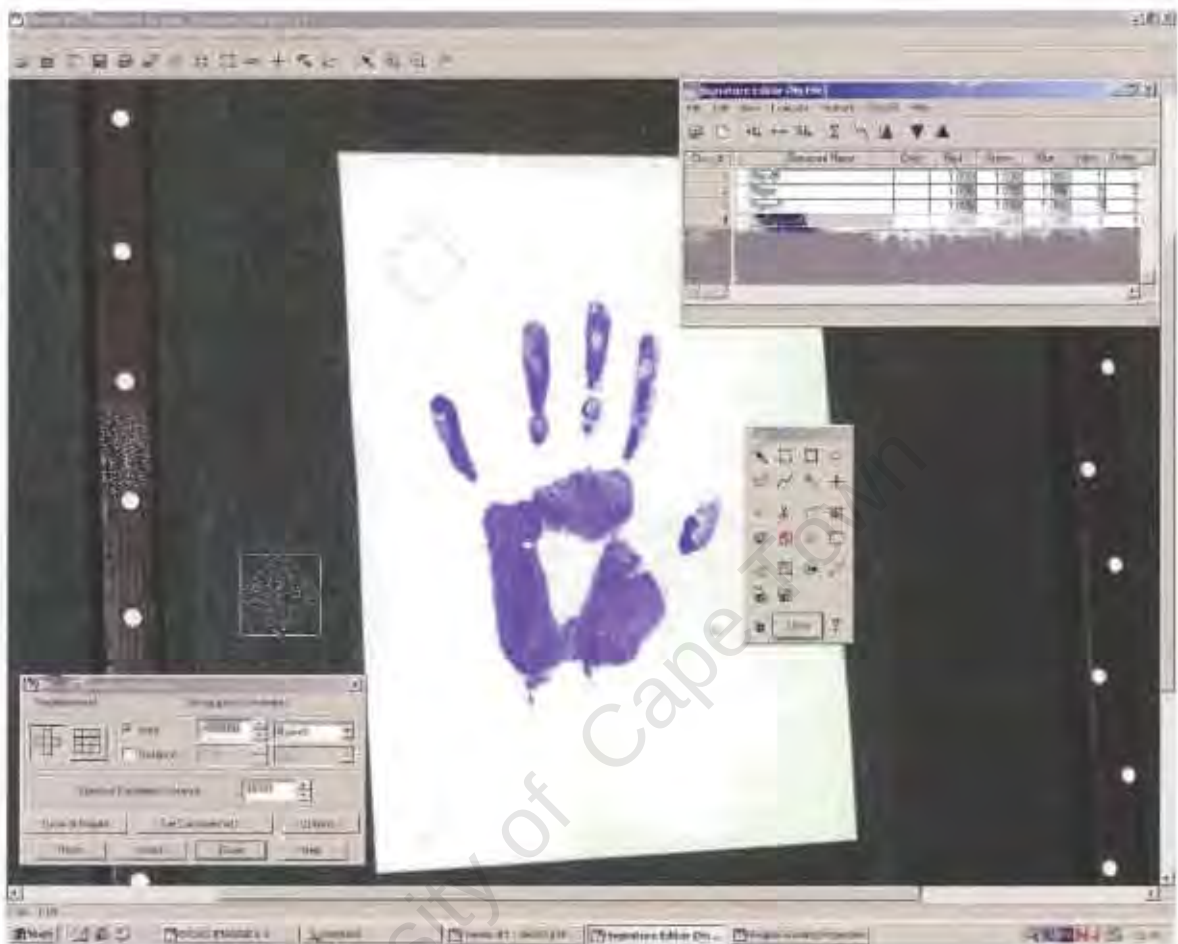
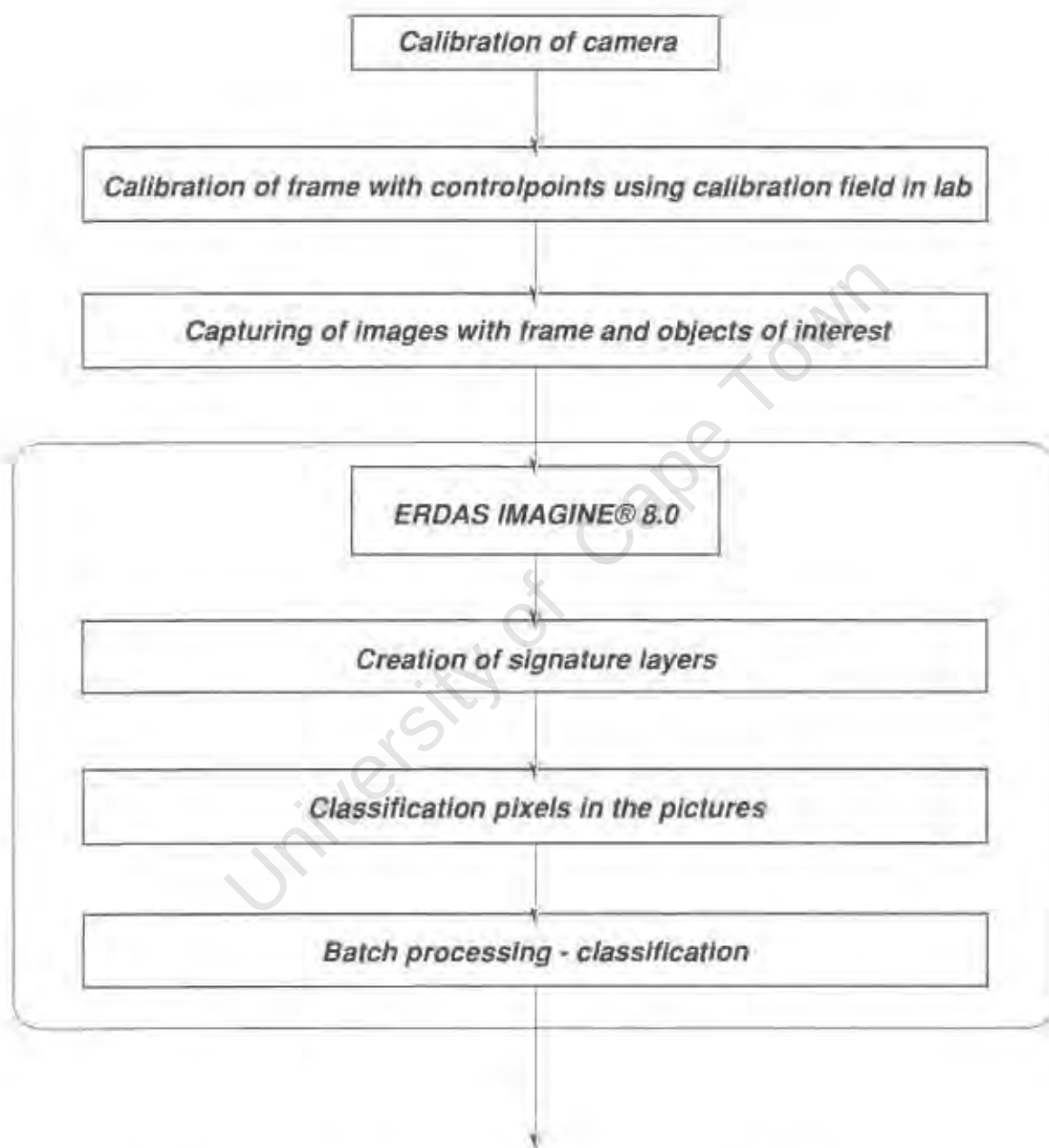


Figure 28: Image-processing in ERDAS IMAGINE 8 ®

However, as measuring dimensions of the handprints under permanently varying conditions in the caves must inevitably lead to errors, I am convinced that it is better to do a selection on the computer. I can compensate for most of these errors on the computer (e.g. different lighting due to different sun and flash exposure) and can also choose between images and points to measure without time pressure, which I would have in the cave. For each original picture I now had a classified duplicate in ERDAS IMAGINE 8®, ready to be measured.

Recording and processing



Enhanced, classified, segmented images

Figure 29: Scheme for supervised classification in ERDAS IMAGINE 8®

5.4.3. Greyscaling

Before I was able to measure the handprints in the images, their colour-mode had to be changed from RGB-colour to greyscale, as the AUSTRALIS® software can only work with greyscale images. The change from colour to greyscale had to be made, because the pixels of pictures contained colour information, which needed to be converted. This step was conducted again using batch-processing in the ADOBE PHOTOSHOP 6.0® application. The process of grey scaling adds the colour information of the RGB-layers together. Colours, which were different before (as they appeared red, blue or green), might now be represented by the same grey shade. The application regulated the conversion of the colour-information in all images, utilizing the process obtained from the batch-example.

5.5. MEASURING

This section portrays the step of measuring the dimension of handprints. It illustrates the adaptation of the photogrammetric techniques to an archaeological topic, in particular rock art. The working steps, which led to assemblage of measurements will be outlined.

5.5.1. Resection and intersection

First, camera positions and orientation of the two images were acquired using the control points of the frame in the AUSTRALIS® application (spatial resection - Figure 24 on page 78). Two images are then established as one entity. Subsequently, the points of interest can be obtained using spatial intersection. These points have to be marked and labelled the same way in both images (Figure 30 on page 91).

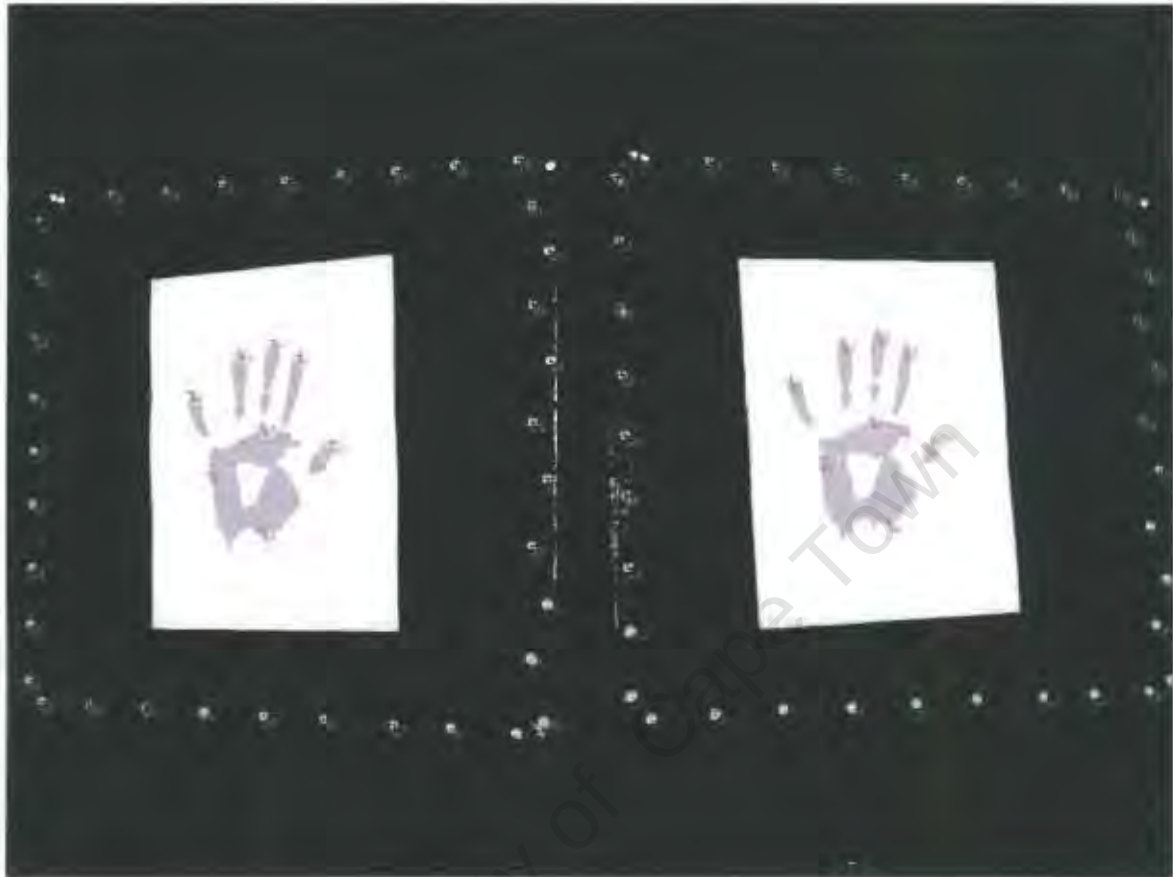


Figure 30: White dots with green label on the frame represent control points; the points of interest are labelled red

The x-, y- and z-coordinates of the desired points were stored in a text-file created by AUSTRALIS®. The distances between the points of interest are still unknown, as I only obtained the coordinates for them. The calculation of the latter will be explained in chapter 5.5.

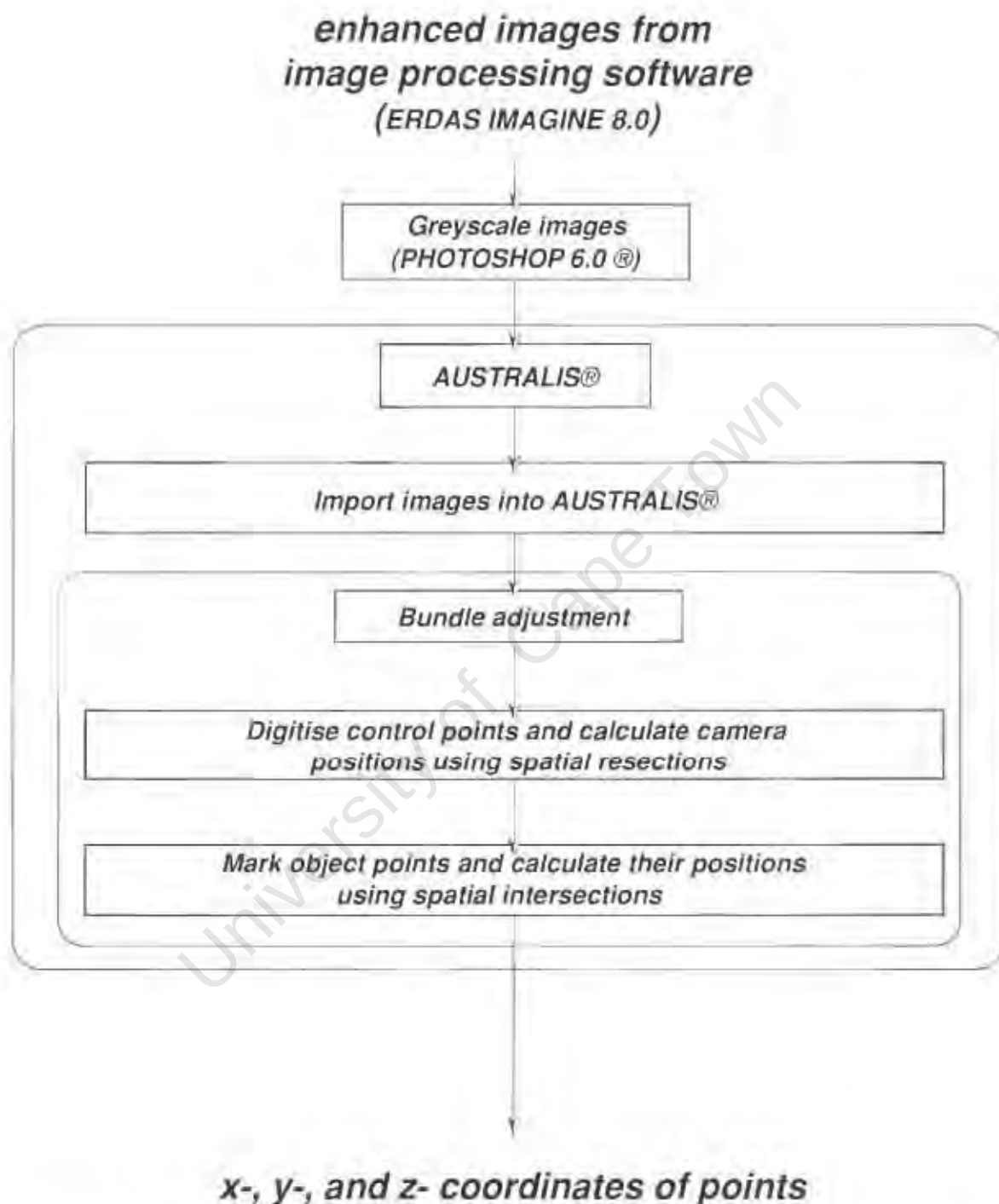


Figure 31: Scheme for the acquisition of x-, y-, and z- coordinates of the points of interest in AUSTRALIS®

5.6. DIMENSIONS

An application was programmed for the purpose of converting the information of the AUSTRALIS® text-files to distances between points of interest. The basics of the application were created with MICROSOFT VISUAL BASIC 6.0®. It computes straight distances between x-, y-, and z-coordinates of points obtained with AUSTRALIS®.

5.6.1. Curvature

These distances are very precise, but lack a calculation of the curvature. As mentioned the rock on which the handprints are made can bend slightly (Figure 32 on page 93). This can lead to a shortening of the actual hand length, as the hand bends around the rock surface when printing on it.

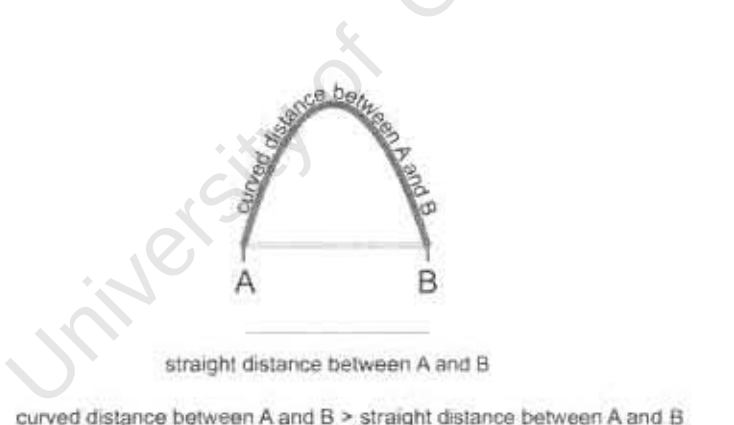


Figure 32: Rock surface undulation and implication for distances between points

Straight measurement from point to point will ignore this bend. To avoid this problem I tried to calculate or at least estimate this curvature. This was possible as my method of measuring includes three dimension. I had two different attempts to solve the problem.

In the equations utilised, it must be hypothesized that the curvature of the rock is constant. By calculating the curvature (Bogenlänge=B) of the straight distance, the "real" length of the

hand can be estimated.

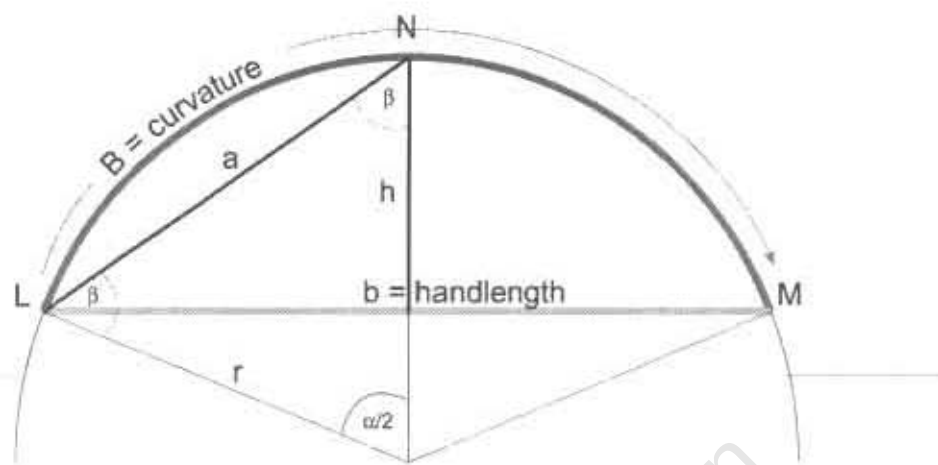


Figure 33: Calculation of curvature in a two dimensional space

If we further hypothesize the distance between points L and M is to be our hand length b and N as the top point of the arch in the middle of the hand (Figure 33 on page 94), we can calculate the curvature (B) using the formula:

$$B = a \times r$$

where r is the radius of a circle created by the rock curvature and alpha (α) the angle created from the centre of the circle to points L and M (Figure 33 on page 94). As N can be measured, the distance (a) of the line between L and N is known.

$$a = \sqrt{(x_N - x_L)^2 + (y_N - y_L)^2 + (z_N - z_L)^2}$$

Beta (β) can be calculated by:

$$\frac{b/2}{a} = \sin \beta$$

The radius (r) is computed by:

$$r = \frac{\alpha/2}{\cos \beta}$$

while alpha (α) is:

$$\alpha = 180 - 2\beta$$

This model assumes that N is exactly in the middle between N and M.

5.6.2. Vector calculation

I was not entirely satisfied with the calculation, because it is calculated in a two dimensional space. To have a similar result in three dimensional space, I have to refer to vector calculation.

A level is defined by a point and two vectors, three points in all. In case of the handprints we have the points for level 1, P1, P3 and P4 (for distances P1-P3 and P1-P4), points for level 2, P1, P3 and P5 (for distance P1-P3 and P1-P5), points for level 3, P1, P4 and P5 (for distances P1-P4 and P1-P5) and points for level 4, P1, P4 and P12 (for distance P4-P1 and P4-P12). Point P7 in all cases has to be plumbed down to the levels, respectively. If no point P7 is available no calculation of curvature is possible, which will be denoted in the file.

The cross product of two vectors leads to a vector which is perpendicular to both single vectors and therefore to the level. $\vec{X}_1 \times \vec{X}_2 = N$ (normal vector):

$$\begin{bmatrix} i & x1 & x2 \\ j & y1 & y2 \\ k & z1 & z2 \end{bmatrix}$$

$$\begin{bmatrix} nx \\ ny \\ nz \end{bmatrix} = \begin{bmatrix} i \cdot y1 \cdot z2 - i \cdot y2 \cdot z1 \\ j \cdot z1 \cdot x2 - j \cdot x1 \cdot z2 \\ k \cdot x1 \cdot y2 - k \cdot y1 \cdot x2 \end{bmatrix}$$

N has to be nominated, as it can be arbitrarily long. This means that it has to be divided by its own length to bring it to a length of 1 (Einheitsvektor). Another way of showing this equation:

$$0 = \begin{bmatrix} n_x \\ n_y \\ n_z \end{bmatrix} \times \begin{bmatrix} x \\ y \\ z \end{bmatrix} + d$$

distance (d) to zero-point of the level is calculated by putting the coordinates of a point into the equation.

In the example this is point P7. The distance of point P7 from the level is then known and can be corrected. As all point are now in a straight line, the model can referred to as two-dimensional and thus distance can be computed,

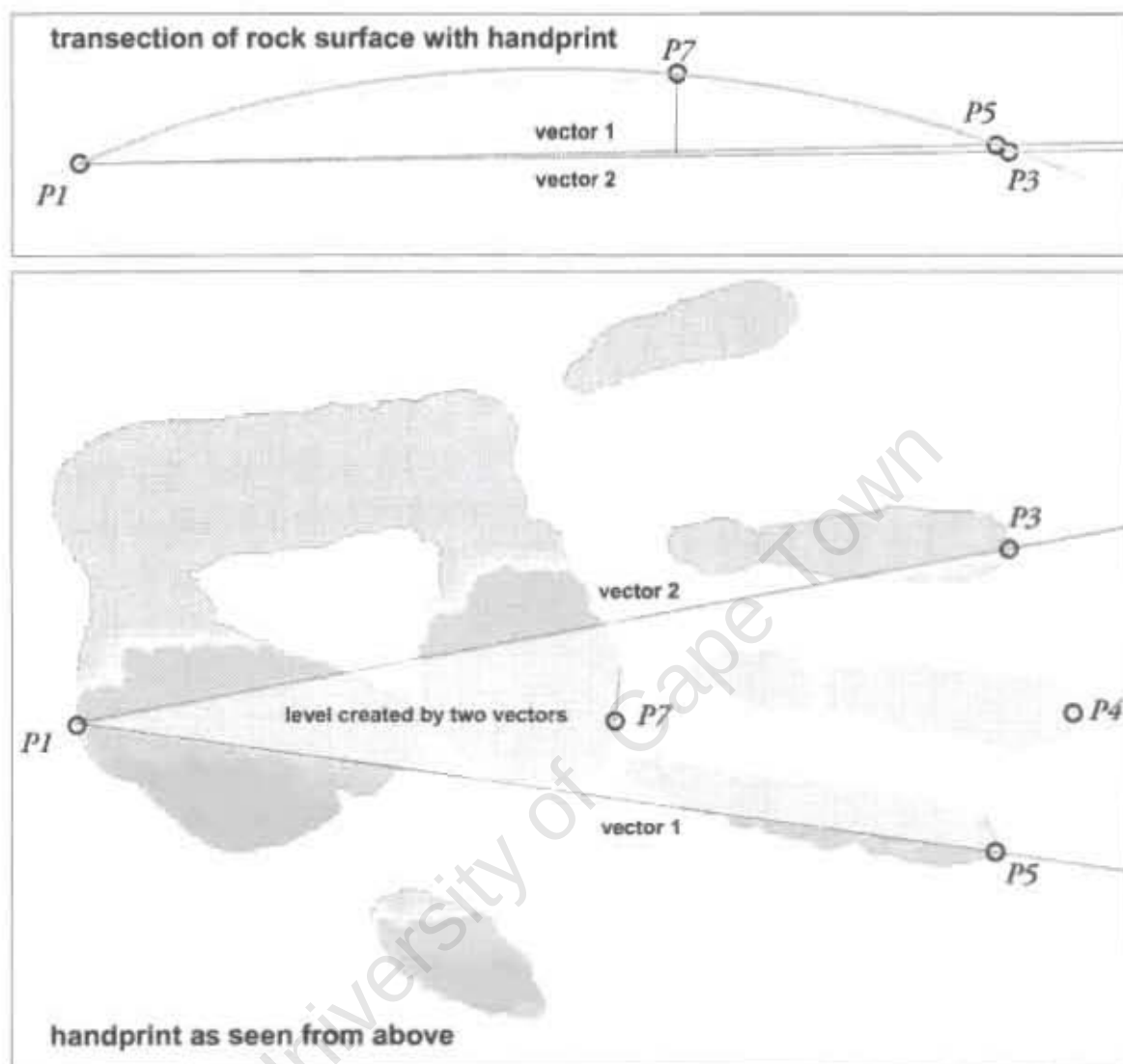


Figure 34: Scheme to explain calculation of distances (in this example P1-P3 and P1-P5) by means of vector calculation; P7 is plumbed to the level to ensure 2-dimensionality

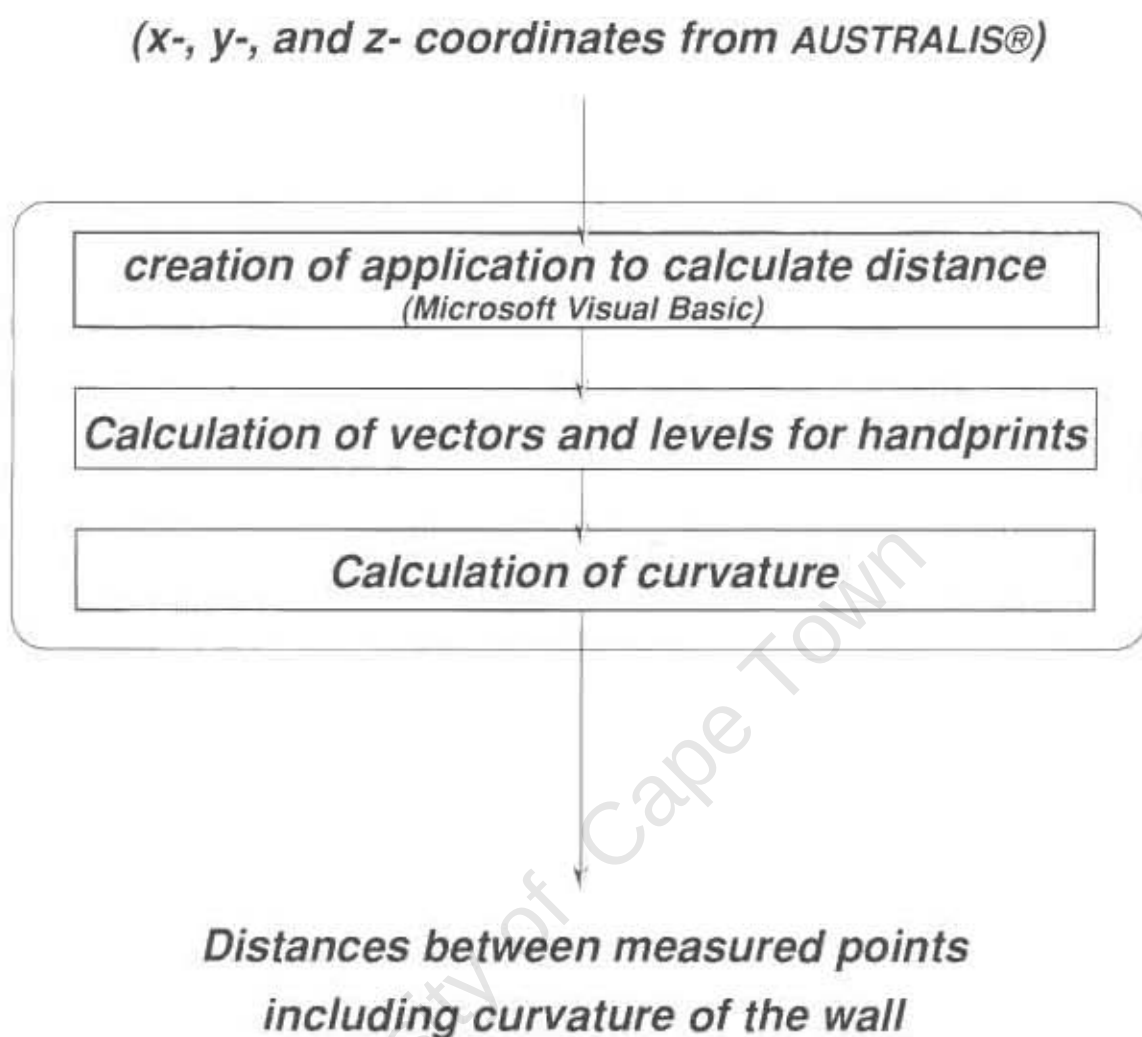


Figure 35: Scheme of measurement extraction from MICROSOFT Visual Basic®

6.

RESULTS

6.1. Aims of the results chapter

The main aim of this dissertation is to estimate the number of contributors (MNC) of printmakers in DK and EBC and make some inferences about their height and age from series of extant cave hand prints in a single cave. MNC refers to the minimum number of individuals (MNI), a term used in archaeozoology to estimate the minimum number of animals at a site by assuming that identical bones (e.g. two right ulnae. These bones must account for a MNI of two.) and overlapping parts of identical bones cannot derive from the same animal. Would the handprint measurements collected in DK and EBC resemble one or even a combination of two or more experimental sets in size or composition?

A methodology had to be established in which a common hand source for a set of prints (9 measurements or variables) could be identified.

The following circumstances, which the methodology must account for, should be taken into consideration:

- a). all 9 measurements exist and coincide exactly
- b). all 9 measurements exist and coincide sufficiently
- c). only some measurements exist but coincide exactly
- d). only some measurements exist but coincide sufficiently.

Moreover prints were classified as having distinct authorship when they were:

- e). sufficiently different on all variables
- f). sufficiently different on some.

The examination mainly concentrates on the experimental sets from Clanwilliam (CLW - SETS D + E), Calitzdorp (CZD - SET F) and Cape Town (CPT - SETS A1, A2, MPA1*, MPA2*, MPA1#, B + C), as they represent controlled observations. Testing whether different methods and techniques affect results in the experimental sets will indicate if the results obtained from the archaeological sets are reliable. Moreover, the experimental sets will allow a classification of the archaeological observations and relate the results by numerical comparison. The controlled experiments were examined, as to whether they would exhibit appropriate similarities and differences of handprints, when the personal information for these sets has been dropped.

At this point it must be clear that the tests were conducted and analysed in a specific order. It was crucial to investigate which errors were to be expected and how these would influence the analysis of the archaeological sets. Errors, such as measuring error, error of different observers assessing the same measurements, error of the measuring technique and left-right handprint difference (which might result in an error if size indifference is assumed but not existent), can be introduced in many ways. It was important to have these errors computed as they determine the degree of accuracy and therefore the degree of contrast between individuals.

Furthermore it is important to know that interpretations could be made on different levels. An examination of left-right handedness and its distribution across a site as well as an overall analysis of distribution of handprints on a site, as in clustering or alignment of handprints, is possible. This subject is difficult to assess, as I am lacking the coordinates for spatial distribution of handprints in the two archaeological sites. The statements I can make are all based on my personal observation and therefore subjective. This problem can only be solved in the future by recording the spatial location and its relation to the others for each print at a site. Spatial patterning definitely occurs (Figure 7 on page 37) and studying it in combination with the measurements of handprints could yield interesting results. An in-

vestigation of "individuals"-level is elusive, because statements are based on assumption made in the "set"-level. Errors introduced by various factors are likely and may distort the individual results to an extent where no predictions are possible.

6.2. Statistics

Some statistical formulas and methods applied in the analysis have to be explained beforehand, as the illustrations and the implications cannot be understood without these. For one method is the Hotelling's multivariate analysis and the other are the single, complete and Ward's Method cluster analysis with accompanying explanation for Euclidean distance.

6.2.1. HOTELLING'S T^2

"A measure that takes into account the multivariate covariance structure was proposed by Harold Hotelling in 1947 and is called Hotelling's T^2 . It may be thought of as the multivariate counterpart of the Student's t. The T^2 distance is a constant multiplied times a quadratic form" (<http://www.itl.nist.gov/div898/handbook/pmc/section5/pmc543.htm>).

The formula for the Hotelling's T^2 is:

$$T^2 = nQ = n(\bar{X} - m)'S^{-1}(\bar{X} - m)$$

with n being the constant for the size of the sample from which the covariance matrix is estimated. $\bar{X} = (x_1, \dots, x_p)$ is a mean of n individual vector measurements. The vector of population means (targets) is m ($m_1, \dots, m_p$) and S the unbiased covariance with its inverse S^{-1} . S

is computed by:

$$S_{jh} = \frac{1}{n-1} \sum_{i=1}^n (x_{ij} - \bar{x}_j)(x_{jh} - \bar{x}_{jh})$$

(www.itl.nist.gov/div898/handbook/pmc/section5/pmc543.thm - with corrected notations)

6.2.2. Clustering methods:

I applied different methods of statistical analysis and also used various graphs to demonstrate the results of the following analyses.

1. Cluster analysis and the use of hierarchical agglomerative methods to distinguish between different sets of handprints:

"Hierarchical agglomerative methods start with all the items under consideration separate and then build up groups from these, starting by grouping the most similar items together, then grouping the groups at increasingly low levels of similarity"
(Shennan 1988: 197).

Three methods have been applied which are generally speaking hierarchical agglomerative methods, but begin with different parameters in their analysis.

6.2.2.1. Single linkage clustering

Single linkage clustering, described by Sneath (1957), tends to maximize the "connectedness" of two clusters through the parts of the clusters. "...[S]imilarities or distances between individuals and groups, or between groups and other groups, are defined as those between their nearest neighbours" (Shennan 1988: 213). "Connections are thus based solely upon single links between cases and clusters" (Aldenderfer and Blashfield 1984: 38). This kind of

analysis will produce more accumulated and fewer distinct clusters.

6.2.2.2. Complete linkage clustering

Complete linkage clustering in contrast to this tries to minimize intra-cluster distance with each case, tending to create smaller, but more compact clusters, growing parallel in the tree structure.

"...[F]or two groups to join, the two individuals, one from each group, which are most dissimilar from one another must have a specified degree of similarity. Once again then we are looking for the highest similarity values in the succession of matrices, but defined on the basis of furthest rather than nearest neighbour" (Shennan 1988: 215).

6.2.2.3. Ward's Method

As clusters should be as homogeneous as possible, Ward's Method defines homogeneity

"...in terms of the distance of each member of a cluster from the mean of that cluster. In Ward's Method the distance is the error sum of squares (ESS): the total sum of squared deviations or distances of all points from the means of the clusters to which they belong. The aim of the method is to join individuals and groups successively in such a way that at each step in the fusion process the error sum of squares is the minimum possible..." (Shennan 1988: 217).

Ward (1963) suggests the use of sum of squared deviations of every point from the mean of the cluster to which it belongs. This measure stands for the loss of information resulting from the grouping of individuals. All clusters are considered for fusion for each analytical step and the clusters whose unification results in the lowest increase in the error sum of squares are combined.

"The error sum of squares (ESS) is given by

$$ESS = \sum_{i=1}^n x_i^2 - \frac{1}{n} \left(\sum x_i \right)^2$$

where x_i is the score of the i th individual" (Everitt 1974: 15).

Shennan (1988: 228) warns that a cluster analysis method may impose its own patterning on the data. At the same time he states that

"[A] way of trying to ensure the validity of clustering results on a particular data set is to analyse it by a variety of different methods. If they all give very similar answers in terms of strongly overlapping cluster membership then it suggests that the patterning is genuine..." (Shennan 1988: 229)

For this reason I am using single, complete linkage and Ward's Method clustering. If all methods show similar results, it will be more likely that a "genuine" patterning exists. Furthermore my analysis is better grounded than "...those situations where we know very little about the structure of our data, while the theoretical foundation of many methods is itself uncertain" (Shennan 1988: 228). This is, because a general frame and knowledge about the data is already provided with the results gained from the experimental sets of Cape Town, Clanwilliam and Calitzdorp. The experimental sets represent sets of which authors and measurements are known and which can therefore be utilized as comparative material to the archaeological data.

6.2.3. Euclidean distance

All distances are in Euclidean distances, which is the geometric distance in multidimensional space. The coefficient d_{ij} is given by:

$$d_{ij} = \left(\sum_{k=1}^p (x_{ik} - x_{jk})^2 \right)^{\frac{1}{2}}$$

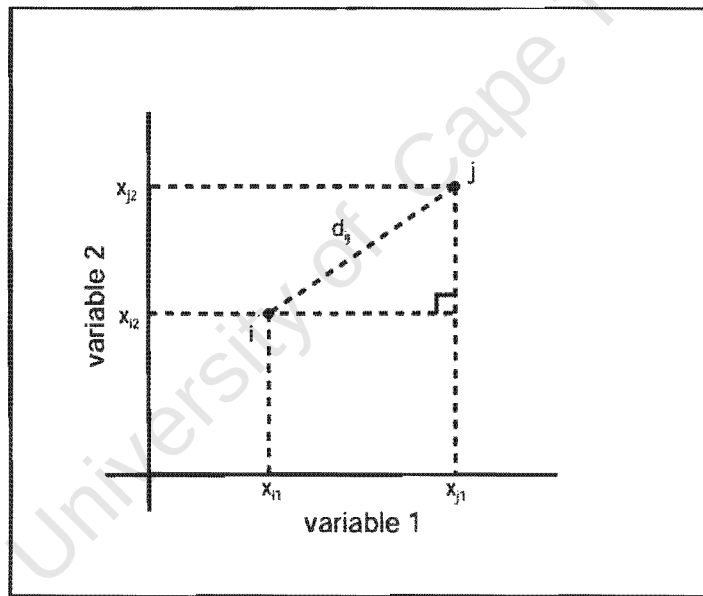


Figure 36: Euclidean distance coefficient (d_{ij}) illustrated on two points (for $p=2$)

"This is simply the straight-line distance between two points and what its calculation involves, of course, is Pythagoras' theorem" (Shennan 1988: 199).

6.3. SET-Level

6.3.1. First experiment - origin of variation and errors within a set

This experiment tests multiple prints which are all known to derive from one single hand and helps to explore the within-hand between-print variation.

A single complete flat print is measured repeatedly and exhibits variation of the measurer. The extent of the variation does not account for the variability between handprints.

The next step is to analyse the contrast between two distinct observers. The results depend on measurements used and method of analysis applied. The difference between the two observers is not accountable for the variability of measurements. Length variables correlate well. Nevertheless, width measurements do not correlate and make multivariate analysis difficult. Apart from this, width measurement differences between two observers are negligibly low.

Furthermore the dissonance between photogrammetrically and manually obtained handprint measures is investigated, probing both techniques for their reliability.

It was questioned whether measurements of the same print exhibit exact equivalence. A difference of zero between the techniques demonstrates no biases. Moreover it is interesting to know whether measurements of the same print exhibit linear equivalence. A correlation of one reveals a linear equivalence. Linear adjustments for biases may be possible.

Variation in technique shows similar patterns as variation of two observers. Length measurements are sufficiently accurate, while width measurements are inadequately correlating with the techniques. Additionally, the manual technique proves unreliable as it is inaccurate.

6.3.1.1. Variability of measurer evaluating common distances in different handprints

The first set of experimental handprints deals with the variation introduced by the measurer. This is the error created by the measurer due to imprecise measuring of the same point on different handprints. To confirm reliability of measurements in a set, the variation (MS) of repeatedly determined measurements of one case in a set (in this case one handprint) must be significantly smaller than the variation of this measurement (SS) within all cases of the same set (all handprints of the set). Repeatability thereby is the proportion of the total variation in individual differences rather than measurement error (Ackermann 1998, Cheverud 1995).

To test this, the 9 different variables (measurements) of 30 handprints from different individuals were measured five times (SET A1).

$$var(x) = MS(x) - MS \frac{(error)}{(\text{number of repetitions})}$$

$$k = var \frac{(x)}{var(error) + var(x)}$$

For the 9 measurements (Table 6 on page 108) variation of measurement within the sample is not important enough to influence the variation which is reflected by k-ratios. The ANOVA statistics test was applied to compute these results.

variable	SS	df	MS	F	var(x)	k
little finger	19963.3	29.00	688.39	1746.45	137.5994	0.997144
error	47.30	120.00	0.39			
ringfinger	23188.0	29.00	799.59	739.22	159.7009	0.993272
error	129.80	120.00	1.08			
middlefinger	23654.0	29.00	815.66	2286.89	163.0599	0.997817
error	42.80	120.00	0.36			
forefinger	18007.2	29.00	620.94	463.10	123.9192	0.989296
error	160.90	120.00	1.34			
thumb	9404.43	29.00	324.29	397.50	64.69503	0.987547
error	97.90	120.00	0.82			
palmlength	6003.07	29.00	207.00	981.83	41.35843	0.994928
error	25.30	120.00	0.21			
upper width	4378.65	29.00	150.99	474.31	30.13393	0.989546
error	38.20	120.00	0.32			
lower width	7122.61	29.00	245.61	229.18	48.90707	0.978558
error	128.60	120.00	1.07			
total length	26331.2	29.00	907.97	1433.64	181.4679	0.996522
error	76.00	120.00	0.63			

Table 6: ANOVA statistics for repeated measures of 30 handprints

The next step of this experiment was to measure a randomly chosen print of a person A repeatedly 50 times (SET MPA1#) to investigate, how much one measurers assessments varied within one print (Table 7 on page 108). As the handprint is the same, inaccuracy can only be introduced by the measurer X. In this scenario we expect that the least number of deviations should occur. The values for the standard deviations are so small that they are negligible, being at most 5/100 of a millimetre.

variable	mean in mm	standard deviation in mm
total length	181,010	0,047
palm length	94,726	0,028
upper width	91,323	0,043
lower width	97,286	0,030

Table 7: One print of person A measured repeatedly 50 times by measurer

variable	mean in mm	standard deviation in mm
little finger	146,661	0,029
ringfinger	170,248	0,036
middle finger	176,818	0,044
forefinger	164,966	0,038
thumb	108,281	0,038

Table 7: One print of person A measured repeatedly 50 times by measurer

This investigation shows that the errors made by the measurer are so minor that they have no influence on the results.

6.3.1.2. Variability within two measurers

This experiment dealt with the variability of two or more persons (SETS MP1A* and MPA2*) measuring the same variable (determining two points) in different ways. It was conducted to examine how precisely an observer could measure distances, referred to her/him by a description of what to measure. Some measurements are more difficult to assess than others, because they are hard to recognize, as when one of the points needed to determine distance of a measurement is dubious or the rendition of information of what to measure is unclear. This error is often neglected in the recording and discussion of archaeological data, as it seems to be covered by the measuring error of one measurer. However, it is not an error which necessarily derives from measuring inaccurately or imprecisely, but from transmission of what and how to measure. I think that there is always a level of interpretation for each observer to decide where and how to measure her/his data (unless it is done by a machine). If a scientist wants to make statements which go beyond her/his own data, this possible error has to be investigated and considered.

It is possible to approach the problem differently, using either one (Figure 43 on page 172, Figure 44 on page 173 for correlation of middle finger) or more variables at a time to examine whether the same sets measured by different people correlate and to what extent they actually vary. Correlation measures the degree of associated variation between variables. In this

case, it informs me about the relationship of a set of variables to another set, but not how close a single measurement in one set resembles its counterpart in the second set (Table 8 on page 110, value of 1.000 = 100% correlation). A way of showing the resemblance is to calculate the average difference between each single variable of the two sets. Summing the values of difference between each matching case of a set, whilst ignoring sign, and dividing this sum by the count of matches will reflect the resemblance of the two sets. Small numbers predict good resemblance. Table 8 on page 110 shows similar averages but poor association between some of the individual measurements (subdigital width and lower width). The other variables have similar averages and good association. This means that either width measurements, such as subdigital width and lower width, are difficult to assess or information of how and where to measure was not precisely transmitted from one observer to another.

variable	mean of observer (X) mm	mean of observer (Y) mm	correlation coefficient r between observer (X) and (Y)	p	average difference in mm
little finger	148.06	148.04	0.978	0.00	0.34
ring finger	171.13	171.15	0.989	0.00	0.17
middlefinger	178.62	178.70	0.997	0.00	0.17
forefinger	165.68	165.76	0.981	0.00	0.24
thumb	105.69	105.52	0.698	0.00	0.95
palm	97.65	98.03	0.987	0.00	0.40
subdigital width	91.47	91.06	-0.180	0.859	2.50
lower width	100.59	99.97	0.647	0.00	1.11
total length	181.06	180.97	0.993	0.00	0.18

Table 8: Correlation and errors between two measurers using photogrammetric single measurements

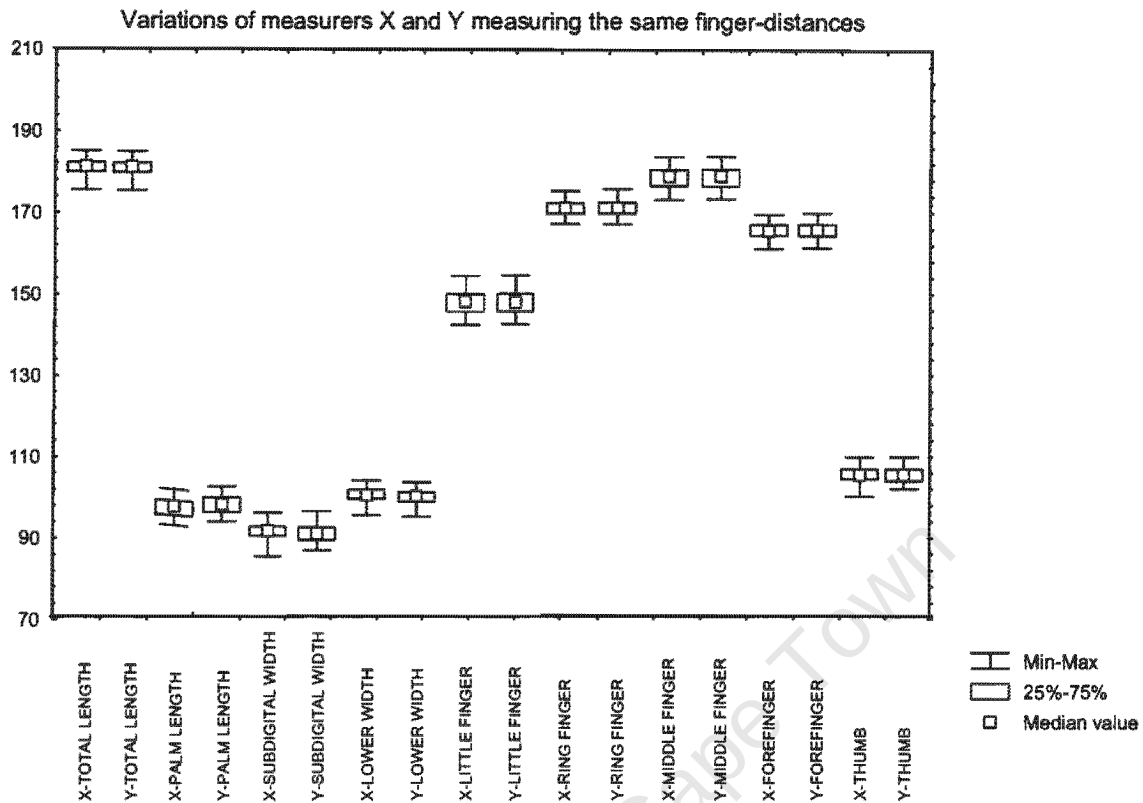


Figure 37: Box and whisker plot showing inter-quartile, means and distribution of photogrammetric single measurements of both measurers

A second test included all nine measurements, calculating the co-variances between the first (SET MPA1*) and second measurers (SET MPA2*) results. I used the Hotelling's statistic formula, which can be applied to distinguish between different sets using multiple variables.

In this experiment the Hotelling's T^2 showed that results from the 1st (SET MPA1*) and 2nd (SET MPA2*) observers measurements of the same sets of prints were significantly different, with a p-value of 0.01. This difference can be understood in several ways: The Hotelling's formula considers all variables in a set, and therefore includes errors of each single variable. I have mentioned above that if one or more variables has a substantial error introduced by the measurer, it will affect the formula and blur the unit's result as a whole entity. Furthermore it must be clear that the strength of relationship will decrease with an increasing number of variables or cases, as individual errors sum. The measurements for lower width, upper width and thumb correlate badly or not at all and have a substantial variation

in the mean differences (Table 8 on page 110, Figure 37 on page 111).

	Hotelling's T^2	F	p-value
measurer X vs. Y person A left prints	255.52	23.76	0.00
measurer X vs. Y person A right prints	388.76	31.37	0.00

Table 9: Hotelling's T^2 for comparison of matched pairs of prints assessed by measurers X (SET MPA1*) and Y (SET MPA2*) for nine measurements

The results in Table 8 on page 110 depict how "safe" particular variables are, as in the level of interpretation of where to measure them. The results in Table 9 on page 112 indicate which measured variables are useful for a multivariate co-variance test (Hotelling's T^2). Not correlating variables obscure the results of the covariance for two sets in a multivariate analysis. The covariance is a measure of association. This means that results (for correlation) obtained by applying multiple variables to an analysis might not reflect true non-correlation. One or more variables in the sets, which are compared, might not correlate and are therefore misleading.

6.3.1.3. Variation in measuring techniques

Inaccuracy can be introduced by various means, for example by applying different measuring techniques. To show this, the same set of 50 handprints of person A (SET A1) was measured manually with a calliper, as well as photogrammetrically using the "AUSTRALIS®" application. We must keep in mind that these measurements already include errors made by the measurer, such as the variation of the measurements and the variation within different measurers which will be mentioned below. I therefore expect the error within different techniques of measuring handprint-dimensions to be larger than the error between different observers. I estimated whether each variable of these two sets correlates on a single variable (measurement)-level (Figure 45 on page 173). Furthermore it was tested whether the correlations were directional, suggesting that measurer X assessed distances (lengths and

widths) differently with different measuring techniques (photogrammetric or manual).

variable	means of manually assessed prints in mm	means of photogrammetrically assessed prints in mm	correlation coefficient r between manual and photogrammetrical prints	p	average difference in mm
little finger	148.46	148.06	0.898	0.00	0.61
ringfinger	171.58	171.13	0.841	0.00	0.51
middlefinger	178.05	178.62	0.815	0.00	0.52
forefinger	165.38	165.68	0.850	0.00	0.79
thumb	105.71	105.69	0.540	0.00	1.67
palm	98.12	97.65	0.787	0.00	0.57
subdigital width	90.93	91.47	0.635	0.00	1.19
lower width	102.66	100.59	0.414	0.03	2.08
total length	180.56	181.06	0.381	0.06	1.42

Table 10: Correlation and errors between photogrammetrically and manually assessed handprints of person A

Furthermore, the multivariate Hotelling T^2 distance analysis was applied. I expected the covariance between manual and photogrammetric measurements of a set of handprints from one person to be poorer than the covariance between different measurers evaluating the same hand repeatedly printed, as the Hotelling's T^2 did not show significant resemblance between these. In fact, I observed no significant resemblance between all sets measured with both techniques with a p-value lower than 0.01 (person A right (SET A1), person A left (SET A2), CLW right (SET D), CLW left (SET E) and CZD (SET F)). Notwithstanding these results, a correlation is apparent on the single measurement level. The mean differences are in most of the cases below 1 mm. (Table 10 on page 113). Subdigital width, lower width, thumb and total length show differences which are over 1 mm and can affect the analysis. They also correlate badly, but are still significant.

The discrepancy confirms that the width measurements are difficult to evaluate. The change between the techniques might result from the difficulty of assessing the two points accu-

rately, rather than from the inaccuracy of either technique. Nonetheless, this implies that the use of multiple variables for analysis is risky as errors derived from technique and assessment of points can influence the results. Even single variable analysis of some variables will be affected and might result in incorrect results and interpretations.

For reasons of uniformity and comparability Figure 46 on page 174 and Figure 47 on page 174 are placed in this section, although the sets they represent were not made by one person. Scatter plots Figure 46 on page 174 and Figure 47 on page 174 depict the correlation between manually and photogrammetrically assessed middle finger measurements of Clanwilliam (SET D+E) and Calitzdorp (SET F). The correlations at 96.6 and 99 percent respectively, are highly significant and differences of measure are at 1.2 and 1.4 mm negligible (Table 11 on page 114, Table 12 on page 115). As this analysis was conducted on sets of several persons, the differences should be higher than those of person A, because the shape of prints and the points of measurements vary more. Again the highest differences can be observed in total length, thumb and lower width. These measurements must therefore be considered unreliable, even if differences are below a 3mm maximum error. These results might alter the results of the analysis substantially.

variable	means of manually assessed prints in mm	means of photogrammetrically assessed prints in mm	correlation coefficient r between manual and photogrammetrical prints	p	average difference in mm
little finger	145.27	143.96	0.988	0.00	1.65
ring finger	161.10	160.12	0.981	0.00	1.29
middle finger	165.60	164.87	0.978	0.00	1.17
fore-finger	150.76	149.99	0.973	0.00	1.37
thumb	95.67	95.53	0.906	0.00	2.51
palm	87.76	86.90	0.915	0.00	1.60

Table 11: Correlation and errors between photogrammetrically and manually assessed handprints of Clanwilliam (n=200 - left and right)

variable	means of manually assessed prints in mm	means of photogrammetrically assessed prints in mm	correlation coefficient r between manual and photogrammetrical prints	p	average difference in mm
subdigital width	72.35	72.91	0.954	0.00	1.38
lower width	80.02	81.05	0.877	0.00	2.17
total length	168.62	165.73	0.949	0.00	3.19

Table 11: Correlation and errors between photogrammetrically and manually assessed handprints of Clanwilliam (n=200 - left and right)

As the photogrammetric technique is proven to give accurate results, it must be assumed that the error is induced by manually determining the measurements of the handprints.

This technique should therefore not be used, as substantial errors can be introduced.

variable	means of manually assessed prints in mm	means of photogrammetrically assessed prints in mm	correlation coefficient r between manual and photogrammetrical prints	p	average difference in mm
little finger	120.31	119.28	0.987	0.00	1.27
ring finger	138.01	136.59	0.997	0.00	0.97
middle finger	144.11	142.56	0.995	0.00	1.42
fore finger	132.55	129.77	0.984	0.00	2.04
thumb	86.71	84.69	0.909	0.00	2.77
palm	79.21	78.04	0.984	0.00	2.05
subdigital width	65.03	64.96	0.972	0.00	1.15
low. width	69.39	70.05	0.922	0.00	1.62
total length	145.86	142.31	0.978	0.00	2.73

Table 12: Correlation and errors between photogrammetrically and manually assessed handprints of Calitzdorp (n=104)

6.3.2. Second experiment - differences between left and right handprints

The second experiment was conducted with multiple prints known to come from a single hand of a specified number of persons of a similar age. It was examined whether the prints seem to cluster into groups, whether left and right prints contrast on an individual and on a multiple print (set)-level. Furthermore I investigated the possibility of knowing which left and right belonged to the same person.

It was previously assumed that differences between a left and a right handprint of one person would be negligible so that either handprint could be used for analytical purposes (Henneberg and Mathers 1994). I tested the issue on a set of 50 left and 50 right prints of person A (SET A1 and A2) and on a set of 1 left and 1 right print from 100 persons (SET D and E), respectively. Correlation and directionality of the single measurements were compared. The covariance was also calculated with the multivariate Hotelling's T^2 to scrutinize the relation of the sets.

The results demonstrate that it is dangerous to assume left and right handprints are the same, notwithstanding that analysis depends on the measurements applied. Left and right sets of one person can differ substantially. Prints of different sets cluster in distinct groups with left and right prints of the same set clustering next to one another. Nevertheless a distinction between two persons left and right handprints on a set-level basis is not possible. Moreover, correlation between one persons left and right sets of prints cannot be observed.

6.3.2.1. In detail analysis:

This series of graphs (Figure 71 to Figure 82 on pages 195 to 205) shows the importance of using multiple variables for the analysis of handprints to distinguish between sets of individuals. It also depicts the significant influence of some single variables onto the analysis.

Three sets, consisting of 50 right handprints from persons A, B and C (SETS A1, B and C) plus an additional set of 50 left handprints from person A (SET A2) were examined with single - and multi-variable cluster analysis as well as Ward's Method. The purpose was to establish, whether handprints of the same set (left or right of person A and right of person B and C -

SETS A1, A2, B, C) resembled one another when grouped together. In the graphs (Figure 48 on page 175, Figure 49 on page 176, Figure 50 on page 177) which take all nine measurements (described earlier in Chapter 5) into account, it is apparent that all prints within one person's set align with a print of the same set. The distance to a print of another person's set is by far (at least double) greater than the greatest distance within one set of the same prints. Left prints link with left prints and right prints with right prints of the same person. All three different analytical methods show the same results. The most obvious is Ward's Method, where intra-cluster distance is very small compared to inter-cluster distance. The results depict four small clusters, one for the right prints of each person's set and one cluster for the left print set of person A. Left and right prints of person A (SETS A1 and A2) do not cluster next to one another. This means that left and right prints of one person can be so different from each other that they might resemble handprints from another person more closely than their own counterpart. The single linkage cluster analysis emphasizes the results Ward's Method exhibited. Even if linkage distance between single cases is maximized, four clusters can be identified by the sharp rises of linkage distance at the end of each known cluster of person A left and rights, B and C, respectively. The complete linkage cluster analysis also distinguishes between the cases and sorts them in distinctive clusters. As this method establishes many small clusters, it is hard to interpret these graphs with datasets for which the designation of individual hands is unknown.

The boundaries of the "real" clusters cannot be known beforehand (as is the case with the experimental sets) and comparative graphs are not very useful, because the clustering-scale is relative. Nevertheless, this method could be useful in cases where experimental and unknown ("real") data-sets are intermingled. Experimental sets with known age or height will work as indicators. If unknown prints arrange with experimental prints of a known age group, we might assume a relation between them. Furthermore, it is perceivable that different experimental sets will arrange in certain ways, if combined (for example SET D/E - CLW (15 to 21) and SET A1/A2 - person A - Figure 149 to Figure 157 on pages 259 to 267). Sets of

combined experimental and "real" data that look similar to the combined experimental sets, might reflect resembling sets.

The problem with the analysis of nine variables is that in reality, there are rarely as many measurements for a print in the caves, as there are for the experimental sets. Eliminating some of the measurements in the experimental sets is therefore necessary, because this reduction can increase the number of usable cave-prints for comparison. It is more common to have two or three measurements of a cave handprint than nine, as preservation, smearing and fading have made some measurements unobtainable.

The graphs of Figure 51 on page 178, Figure 52 on page 179 and Figure 53 on page 180 exhibit 5 of the original 9 measurements. These are lengths for middle-finger, thumb and palm as well as upper and lower width. These measurements were applied, because they appear best to represent the different dimensions of a hand (two length-, two width measurements and the thumb as an in-between measurement). The dissimilarities in the grouping of the handprints are not different from the nine variable cluster analysis. Cases cluster within their own set, before joining with a print of another set. Ward's Method (Figure 53 on page 180) portrays smaller clusters than before, but still has four large cluster indicating the presence of four different persons. The single linkage cluster analysis (Figure 51 on page 178) also distinguishes between the four sets (except three outliers of left and rights of the same person). The complete linkage cluster analysis (Figure 52 on page 179) is difficult to interpret because of the formation of many small clusters.

In these illustrations (Figure 54 on page 181, Figure 55 on page 182, Figure 56 on page 183) two more measurements were deleted with no change in the joining structure visible. The three measurements used, are middle-finger, upper and lower width. It seems that these three are sufficient measurements within three dimensions to distinguish between the sets, as the appearance has not changed. With the following graphs (Figure 57 on page 184, Figure 58 on page 185, Figure 59 on page 186) it will become clear that different variables

show dissimilar results. The choice of measures such as middle-finger, little finger and fore-finger renders the prints of the three persons group indistinguishable. This contrast shows that the width-measurements are important for the purpose of distinguishing between sets of hands of different people, even if they are difficult to measure and exhibit a lot of variation. Further reduction of the measurements to two (middle finger and subdigital width - Figure 60 on page 187, Figure 61 on page 188, Figure 62 on page 189) (middle finger and little finger - Figure 63 on page 190, Figure 64 on page 191, Figure 65 on page 192) indicates greater difficulty in distinguishing between clusters.

The sequence of analysis suggests that the more measurements are available, the better the results for distinguishing between sets of hands of different people are. A single variable analysis can in this scenario lead to unreliable conclusions. With cluster analysis it is impossible to do linking with one variable.

The analysis of the clustering of many prints from the same persons shows that it is possible to distinguish between groups of hands from different persons, as prints of one specific person align with one another. With fewer variables involved, separation becomes difficult, and depending on the variables applied to analysis, even impossible. Some variables (such as the width measurements) might have a greater variation and are more difficult to assess, but are important for distinguishing between different persons' handprints.

Figure 66 on page 193 and Figure 67 on page 193 exhibit the inter-quartile ranges and means for the four sets of person A, B and C (SETS A - C) for the middle-finger and subdigital width, respectively. These graphs depict that a differentiation between the hands. It is not possible to use single measurements because inter quartile ranges overlap substantially. This means that this one measurement is so similar in different person's hands that cases (handprints) of the different sets will link indiscriminately with prints of their own and other person's cases (handprints). The middle finger and subdigital width (as with other measurements) alone are not suitable for distinguishing between different people or left and

right hands of the same person.

Depending on the selection of one or more measurements, the sets of handprints as a whole, vary in their linkage, structures and distances. If I utilize for example the middle finger length, a cluster analysis will show, that person A's left handprints (SET A2) as a set can be more similar to person B's (SET B) and C's (SET C) than to their own right-hand counterparts (SET A1) (Figure 68 on page 194, Figure 69 on page 194, Figure 70 on page 195). If in contrast, I utilize nine measurements, the cluster analysis arranges left and right prints of one person together (Figure 71 on page 195, Figure 72 on page 196, Figure 73 on page 196). This difference demonstrates the unreliability of a single measurement in distinguishing between different people and even between left and right handprints of the same person.

The graphs of Figure 74 on page 197 to Figure 82 on page 205 depict the differentiation between left and right handprints of one person using single and complete linkage clustering as well as Ward's Method. The nine measurement Ward's Method cluster analysis clearly showed the best results in distinguishing left from right (Figure 76 on page 199). Complete linkage clustering (Figure 75 on page 198) yields similar results, whilst single linkage clustering (Figure 74 on page 197) cannot distinguish between left and right of the same person.

In my case study some variables are more likely to influence the outcome of the analysis than others. I used a two measurement complete cluster analysis with middle-finger and subdigital width and, as a second exploratory method, with middle-finger and little finger to demonstrate how more variables lead to better results. While the second test clearly differentiates between left and right with Ward's Method (Figure 82 on page 205) and complete linkage clustering (Figure 81 on page 204), intermingling can be observed (though only for two cases) (Figure 78 on page 201 and Figure 79 on page 202). This demonstrates that the little finger is a better differentiator for left and right than upper width in this analysis given the middle finger measurements. Nonetheless, it is advisable to be careful with the results obtained, as this analysis was conducted on a single person. Other persons may have a dif-

ferent measurement pattern or different variables (measurements) which are better or worse at differentiating between left and right. The single linkage clustering (Figure 77 on page 200) depicts similar results.

Interpretation: All of the above mentioned figures (Figure 71 on page 195 to Figure 82 on page 205) indicate that it is dangerous to assume that left and right handprints from the same person are identical or even close to being so, based on one measurement.

6.3.3. Third experiment:

From a third experiment multiple prints known to come from a single hand of a specified number of persons of a similar age have been analysed to see, whether these prints cluster into distinctive groups. This test resulted in no observable grouping of handprints.

Furthermore, multiple prints known to come from both hands of a specified number of persons of a similar age have been examined.

Here I questioned whether the prints cluster into pairs, whether these pairs are the correct pairs and if the prints seem to cluster into groups of sizes other than two. Pairing is not evident, while grouping of matching (correct) pairs is only observable in a few cases.

6.3.3.1. In detail analysis:

Single left and right handprints of 100 people (Clanwilliam - SETS D+E) were examined to explore if these would align with each other rather than with prints from other persons.

Pairs of left and right prints have the corresponding numbers. Identical numbers next or closely linked with one another indicate similarity of prints of the same person. None of the methods showed a stronger resemblance of single left and right prints of the same person towards other matching prints. Using the nine measurements for the examination, a few left and right handprints of the same person link with each other (10/11/13 pairs (or matches) -

for single/complete/Ward's cluster analysis), but the majority does not (Figure 83 on page 206 to Figure 85 on page 208).

linkage type	9 variable-pairing (percentage of analysed pairs)	2 variable (1) pairing (percentage of analysed pairs)
single	10 (20%)	2 (4%)
complete	11 (22%)	2 (4%)
Ward's Method	13 (26%)	3 (6%)
linkage type	9 variable-pairing (percentage of analysed pairs)	2 variable (1) pairing (percentage of analysed pairs)

Table 13: Number (and percentages) of linked pairs of CLW-cluster analysis indicating similarity of left and right handprints from 100 individuals (50 pairs)

A lesser congruence can be observed if only two measurements - middle finger and subdigital width (Figure 86 on page 209 to Figure 88 on page 211) or middle finger and little finger (Figure 89 on page 212 to Figure 91 on page 214), respectively are used (2/2/3 pairs and 3/2/6 pairs - for single/complete/Ward's cluster analysis, respectively).

The results of the multivariate Hotelling's method for the prints from Clanwilliam (CLW - SETS D+E) confirms the non-equivalence between left and right prints. This statistic and the percentages can be interpreted as implying that a left handprint of one person is as likely to match the right print of another individual just as frequently as the print of the same individual. Interestingly, the number of pairs increases with the number of variables used in the analysis.

	Hotelling's T^2	F
manually assessed lefts vs. rights prints	73.76	7.28
photogrammetrically assessed lefts vs. rights prints	81.31	8.12

Table 14: Hotelling's T^2 for comparison between matched pairs of left - right prints of Clanwilliam (CLW) pupils with nine variables

6.3.4. Fourth experiment - similarity between archaeological and experimental sets:

In this section archaeological observation are compared with the known experiments, made under controlled conditions. First, I wanted to examine which of the experimental sets the archaeological sets resemble in their variation and spread of measurements around the mean. Apart from this, several issues have been examined, such as what patterns emerge for complete data (all 9 measures); what patterns emanate from incomplete data, and do these equal patterns in the experimental set. Furthermore I have questioned what other difficulties appear when collecting and analysing the archaeological handprints, what issues seem still undecided on this evidence, and whether there is a good argument for collecting and using such data.

What emerges from the results is that the variation in the DK-set (SET H) resembles CLW (SET D+E) in spread, but the size of the handprints is smaller. Furthermore, most individual prints in the DK-set match those of the CZD (SET F) 10 to 14-set in size and variation. Most of the prints in DK could not have been made by either 5 to 9 nor 15 to 20 year olds, as a comparison with the similar CZD-set suggests. It is impossible that the DK print could have been made by one author in one session, because of spread and non-compatibility of the DK-set with the set of person A (SET A1+A2).

It was difficult to obtain enough measurements to make a multi-variate analysis. The use of one variable can be misleading as it leads to indistinguishability of individuals.

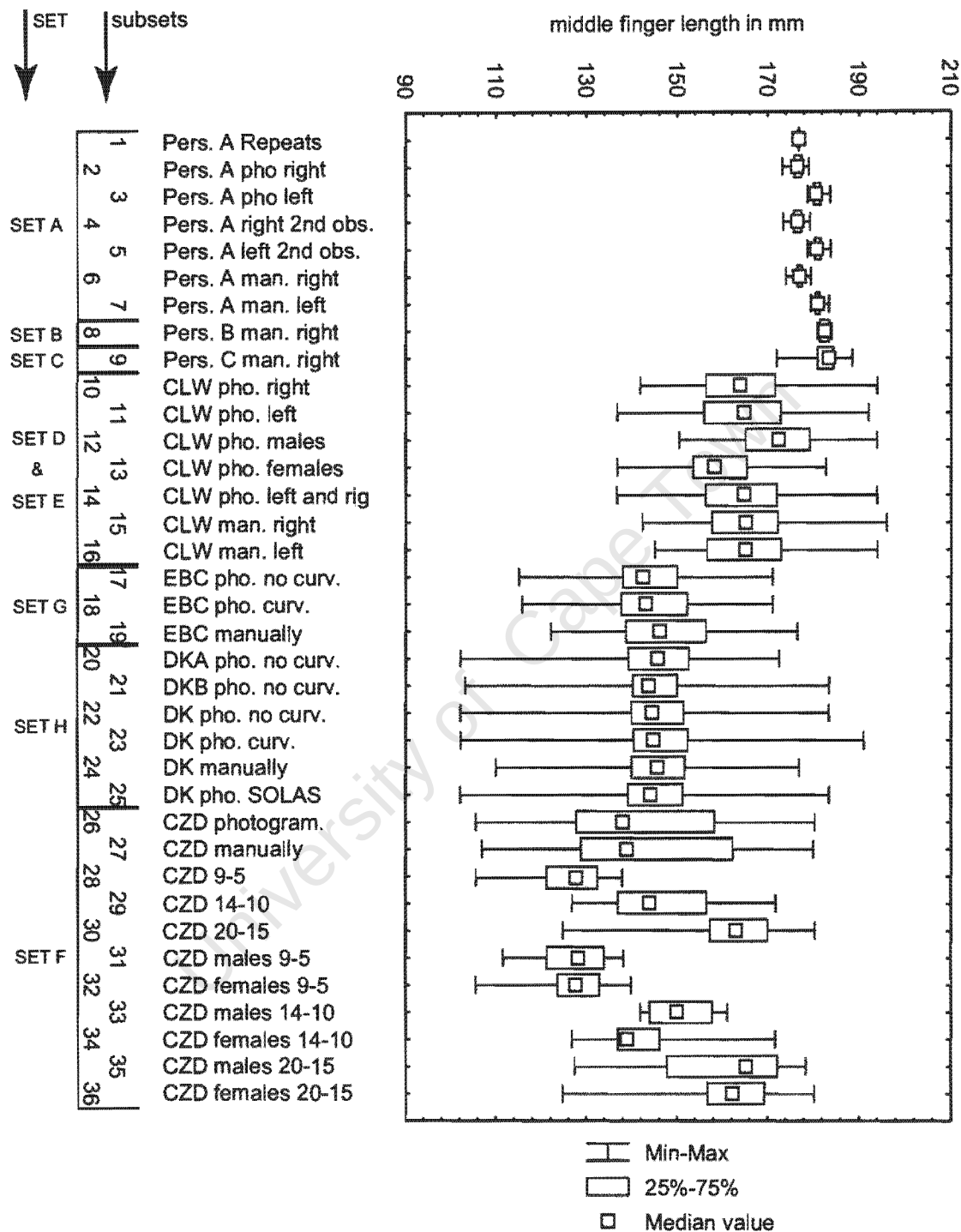


Figure 38: Box and whisker plot of variation in middle finger measurements of all sets

6.3.4.1. In detail analysis:

The plot (Figure 38 on page 124) depicts the variation in the middle-finger of each set measured. The first nine sets from the left clearly do not show much variation within the SET A as these are the handprint sets made by one person. I can distinguish between subset 1, which represents one handprint of a person A (SETS A1+A2) repeatedly measured, followed by subsets 2-5 of 50 handprints from this person A, photogrammetrically evaluated by two different measurers. Boxes 6 and 7 represent subsets of person A, this time measured manually with a calliper. Subsets 8 and 9 refer to 50 manually measured handprints of person B and C (SETS B+C), respectively, and demonstrate that the variation within one person can be different. A few outliers in subset 9 extend the whiskers, but the inter-quartile ranges of the measurements above and around the median are minimally affected.

The definition for the inter-quartile ranges are as follows:

"...The first quartile has 25 per cent of the observations below it and 75 per cent above it, while conversely the third quartile is that value which has 75 per cent of observations below it and 25 per cent above it. The difference between the value of the first and third quartile, the middle fifty percent of the distribution, is known as inter-quartile range...". (Shennan 1988: 41)

It is very useful to depict the main part of the data against the preceding sets. To follow the line of description, the experimental data subsets 10-16 are the sets made by matric (15 to 21 years) pupils from the Clanwilliam school (SETS D+E). Left and rights hands, photogrammetrically and manually measured are depicted. A few outliers are noticeable, but these cases do not affect the inter-quartile ranges.

Subsets 17-19 represent the Elands Bay Cave handprints (SET G). Subset 17 is made up of the photogrammetrically measured prints with no attention paid to the curvature of the rock, whilst in subset 18 this curvature was estimated. These two subsets are virtually the same and are different from subset 19, which exhibits the manually measured handprints

from Elands Bay Cave. This subset has a larger variation than the photogrammetrically measured sets and handprints appears to be larger. Notable is the span of variation of the subset, including small and large prints, but no extreme cases. It is possible to observe the same variation as in the Clanwilliam (SETS D+E) samples (subsets 10-16), with the difference that the handprints in the EBC-sets (SET G) are smaller.

In Diepkloof (SET H) I divided the photogrammetrically measured sets in two, as there are two shelters DKA and DKB (subsets 20 and 25). Subsets 22 and 23 depict variations of all DK-prints without and with calculated curvature. There is not much difference in variation within either subsets 20 to 23, nor within 24 to 25, whereas 24 are the manually measured handprints and 25 are the values calculated by the SOLAS application. This means that most of the prints of the subsets are very similar and the subsets are not different from each other. All the sets from DK were obtained by different measuring techniques and length-calculations. It can therefore be expected that they look similar. Although there are a few outliers in both directions, large and small, the variation of the inter-quartile ranges is very small.

Finally I plotted the Calitzdorp sample (SET F) at the end of the graphic to make it easier to compare it with the DK (SET H) -and EBC (SET G)-sets. The first two subsets, 26 and 27 represent the handprints of all 104 persons, measured manually and photogrammetrically. I already observed in EBC (SET G) that manually measured handprints are larger than photogrammetrical measured ones. This effect also occurs in Calitzdorp (SET F) and indicates that one of the techniques creates an error. In the analysis I will test if this error is a constant effect or just a result of the "usual" variation within the measuring techniques. As these two samples include handprints from individuals with ages ranging from 5 to 20 years, it is not surprising that there is a lot of variation, also evidenced by the inter-quartile ranges.

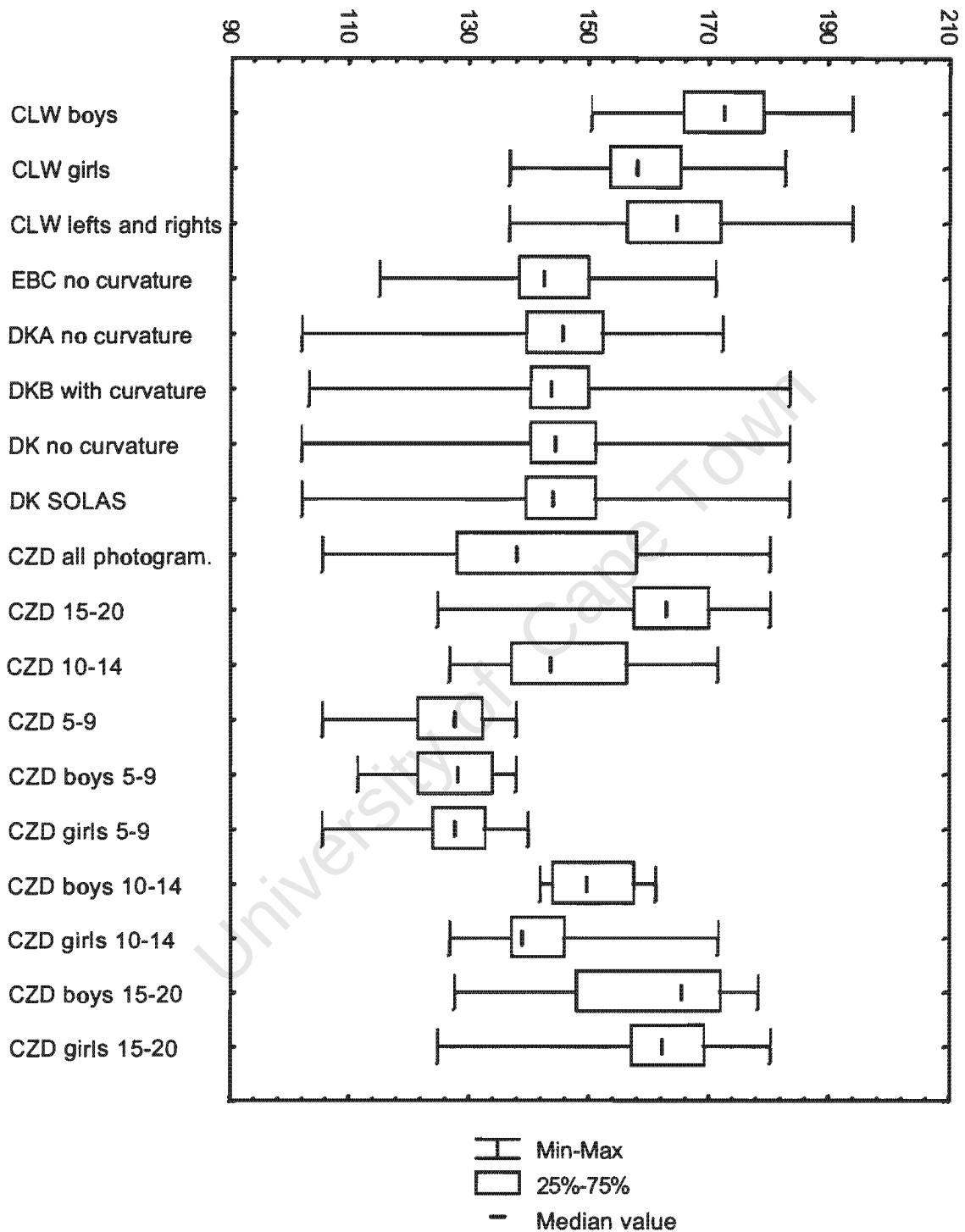


Figure 39: Experimental sets divided by sex, compared with DK- and EBC-sets

Consequently subset 26 (SET F) was subdivided into age groups from 15 to 20 years (subset 28) (as a comparable sample from Clanwilliam already exists), 10 to 14 years (subset 29) and

5 to 9 years (subset 30). As expected, variation in the 15 to 20 years subset falls persuasively into the range of the Clanwilliam (SETS D+E) sets (subsets 10-16). Following this, all samples from EBC (SET G) and Diepkloof (SET H) fall in the variation of the age group of 10 to 14 years old individuals from Calitzdorp subset 26. Combined split age and sex distribution of the variation are depicted in subsets 31-36. As there are only 105 prints in all, these partitioned groups represent only a few individuals, which can be problematic, as one outlier can seriously distort the plot.

The sets of DK (SET H), EBC (SET G), Clanwilliam (SETS D+E) and Calitzdorp (SET F) are displayed in Figure 39 on page 127 and illustrate all sets and subsets from 10 to 36 of CLW and CZD in Figure 38 on page 124 but separated by age and sex. Once the CZD set is divided into the different sexes it becomes apparent that the 10 to 14 year old people are more variable than any of the other age group sets. Unfortunately, the number of individuals in these sets is too small to make more generalized statements. DK and EBC sets appear dissimilar to the CLW sets and therefore not likely to include the age group of 15 to 21 year olds.

The variation within the rock art sets (subsets 14-21) is too great to associate the authorship with one person (subsets 1-9) and appears best explained by the CLW set (subsets 10-13).

Nevertheless, the size of the Clanwilliam prints is too large but allows one to suggest that the people who made the prints are older than people from DK and EBC. It seems clear that the majority of the archaeological handprints were made by people between 10 to 14 years of age (as their variation mirrors the variation of DK and EBC). There are a few outliers in the EBC and DK sets and these can be interpreted in two ways. The outliers may represent people, who were older or younger than 10 to 14 years. A second possibility and perhaps more plausible, is that these outliers are the same kind of outliers we can observe in the CLW sets (subsets 10-13), in which middle finger sizes vary from just above 135mm to almost 200mm. Other scenarios are imaginable, for example the possibility that the handprint makers were of a mixed age and sex, varying from 5 to 20 years old. Manhire (1998) pointed

out that growth in boys and girls differs with age, especially during the growth-spurt during the puberty. The growth-spurt during puberty also varies from individual to individual. Participation of younger individuals therefore cannot be ruled out.

The more factors, such as age and sex, are analysed, the more difficult it is to make statements supporting the interpretations.

The most striking result is the resemblance in the variation-spreads of the EBC (SET G) and DK sets ((SET H) subsets 17-25) to the CLW set ((SETS D+E) subsets 10-16) and the size resemblance to the CZD ((SET F) subset 29) 10 to 14 year old set. From the spread of the variation it seems to be clear that the archaeological sets can not have been made by only one person (subsets 1-7) nor persons from 5 to 9 or 15 to 21 years old exclusively (subsets 10-16, 28).

6.3.4.2. Interpretation of variation in sets

Which set of controlled observations or combination of sets do the archaeological sets resemble? To answer this question, I constructed a matrix showing variations of the middle finger length of all sets of experimental data I have. On one axis, different sets are listed by increasing variation within the sets, on the other axis sets are allocated by increasing variation in a sets by means of different techniques (Figure 92 on page 215 to Figure 94 on page 217).

From the matrix of a single measurement (Figure 92 on page 215 to Figure 94 on page 217) variable is middle finger, as proposed by Henneberg and Mathers (1994), it becomes clear that the variation of the DK (SET H) measurements is almost equivalent to that of the Clanwilliam sample (SET D+E), a set representing a small agegroup. However, the size of archaeological prints is smaller than the size of the Clanwilliam (SET D+E) matric pupils, thus suggesting that we are dealing with people smaller in stature, as handprint-size and height are related. This view in turn means that either the handprint-makers from Diepkloof and Elands Bay Cave had different proportions from people today, or they were young-

er than the Clanwilliam matric pupils (with an age between 15 and 21). It seemed likely that the Calitzdorp (CZD - SET F) 10 to 14 year olds set resembles the DK (SET H) and EBC (SET G) sets. (Figure 38 on page 124 subsets 29-33, 34). This matrix involves different levels of accuracy. The more error sources are introduced, the more the results get indistinguishable and unclear. It is still evident that one person could not be responsible for all the DK and EBC handprints. The fact that people of all ages were responsible for making the prints can be rejected. The error levels suggest that different observers and different techniques do not cause a significant differences in the measurements. Nonetheless, a combination of several errors, including combined left/right prints can negatively influence the results.

6.3.4.3. Absence of variables to measure

Unfortunately there are few cave-prints from which all nine variables of the handprints in the archaeological sets could be measured. To increase the number of DK (archaeological)-cases, I have to decrease the number of variables for evaluation. I have already pointed out that this strategy in turn leads to indistinguishability between prints. Therefore it is difficult to make assumptions, as either the number of analysable handprints is too small or the results are unreliable. Nevertheless I analysed the graphs, but kept these complications in mind. The measurements used for the three variable-analysis were middle finger, subdigital width and lower width (3 variables (1)) and middle finger, little finger and forefinger (3 variables (2)), respectively. The middle finger was used in both, because it is the most common measurement and exhibits little variation within hands.

Figure 95 to Figure 103 on pages 218 to 226 show cluster analysis plots with joining cases of the CLW prints (SET D+E) (ages 15 to 21) and the Diepkloof sample (SET H). In all graphs some clustering of the Diepkloof cases is recognizable, but no jumps of linkage are observable. Furthermore there is no distinguishable DK-set, but rather smaller subsets, intermingling with CLW prints.

This summary means that many of the Diepkloof handprints (SET H) are in their linkage

distance in general closer to each other, but are on a set level not uniform enough to appear as one grouping. The same statement can be made in the comparison of Diepkloof (SET H) and Calitzdorp (SET F) in Figure 104 to Figure 112 on pages 227 to 235. Most of the DK handprints join with some other DK handprint, but then divide into unrelated subsets, indistinguishable from the Calitzdorp handprints. One observation can be made on the difference between DK - CLW and DK - CZD cluster analysis. Within the CZD prints (SET F) the DK handprints (SET H) are more dilated than within the CLW prints (SETS D+E). This increased dilation means that the DK prints must be more closely related to some of CZD prints than to the CLW prints. This relationship is confirmed by the single linkage clustering where, in the DK-CZD graphs (Figure 104 on page 227, Figure 107 on page 230, Figure 110 on page 233) prints of both sets intermingle, whilst in the DK-CLW graphs (Figure 95 on page 218, Figure 98 on page 221, Figure 101 on page 224) many DK-handprints are either at one or the other end of the cluster, demonstrating high linkage distance from the CLW-prints.

The Calitzdorp sample (SET F) was subdivided into the three age groups 5 to 9, 10 to 14 and 15 to 21 years (Figure 113 on page 236 to Figure 121 on page 244) to examine which of these groups would link with the DK prints and therefore be most similar to them. From this analysis I can suggest that most handprints from Diepkloof (SET H) are more closely associated with the CZD (SET F) 10 to 14 year olds than with the other two groups. I would also expect that handprints of different age groups within the CZD sample are linked with handprints of their group. Dividing CZD into three age-groups (5 to 9, 10 to 14, 15 to 20) and making a cluster analysis together with the DK-set showed that most of the DK-cases connected either with each other or with the 10 to 14 year olds. A few single prints are connected with the 5 to 9 or 15 to 20 cases (which can be seen as outliers). Furthermore handprints of the age-groups 5 to 9 and 15 to 20 would be expected to link with the 10 to 14 group rather than with handprints of the other two groups. The DK prints join among themselves, or if not, then more frequently with the 10 to 14 years olds than with handprints of another group. This

pattern confirms my assumption previously made using box and whisker plots (Figure 38 on page 124).

In all evaluations (Figure 122 on page 245 to Figure 130 on page 249) of the DK-set and the CZD (SET F) 15 to 20 set together, it is clear that the prints of these sets are not related and form two distinguishable sets within the cluster analysis. A few prints mix and represent an area of overlap. This overlap is not noticeable, once DK and CZD 10 to 14 are clustered together (Figure 131 on page 249 to Figure 139 on page 253). Unfortunately there are only a few 10 to 14 year olds, but the existing CZD prints are distributed among the DK handprints. This pattern implies that DK and CZD 10 to 14 prints are so similar to each other that they cannot be clearly differentiated by a cluster analysis and therefore represent similar sets. The DK and CZD 5 to 9 years old prints (Figure 140 on page 254 to Figure 148 on page 258) cluster rather like those of the DK and CZD 15 to 20. Except for a few outliers all DK-handprints link with each other and the set of 5 to 9 years old prints also appear to link only with each other as one set.

6.3.4.4. One author of the handprints?

From the Figure 149 on page 259 to Figure 157 on page 267 it will become apparent that it is highly unlikely that the DK handprints were made by only one person. These graphs contrast the level of similarity between person A's repeated prints and those of a set of people known to be of about the same age. If the archaeological DK prints were made by one individual, the linkages of DK cases with the CLW-set (Figure 95 on page 218 to Figure 103 on page 226) should look similar in distance as those of person A and the CLW-set (SETS D+E). All DK prints should have been next to each other and the distance between each case should be substantially smaller than the distance among the CLW- cases. As this feature does not emerge with either nine (Figure 95 on page 218 to Figure 97 on page 220) or three measurements (Figure 98 on page 221 to Figure 103 on page 226) we can clearly reject the hypothesis of one printmaker in Diepkloof. Using complete cluster linkage or Ward's Method,

person A's prints (SET A1 + A2) break away from CLW (SET D+E) as one set, whilst the DK prints (SET H) break away in subsets, which indicate heterogeneity within their own set.

6.3.5. Fifth experiment - regression formulas to estimate height and age:

I will show that it may be better to use a regression-formula derived from a restricted and appropriate age group to estimate height and age rather than using a formula which is derived from the whole population. This improvement is important, as Henneberg and Mathers (1994) calculated such a whole sample regression and Manhire (1998) used it thereafter to estimate height and age of the handprint makers of caves in the western Cape.

I wanted to examine whether regression formulas derived from (sub)populations (or subset e.g. CLW 15 to 21 - SET D+E) applied to a similar sub-population (as in CZD 15 to 20 - SET F) estimate age and height better or worse than formulas derived from the whole population (SET CZD applied to CLW 15 to 21). Furthermore it was interesting to learn whether formulas of dissimilar (sub)populations (subsets - e.g. CLW 15 to 21 on CZD 5 to 9) but of the same variation (spread) estimate age and height better or worse than formulas derived from the whole population.

It can be demonstrated that formulas derived from whole populations estimate age and height less accurately than regression formulas from parts (subsets) of a population that fits. Nevertheless regression formulas of dissimilar (sub)populations estimate age and height inadequately.

6.3.5.1. In detail analysis:

As the formula calculated by Henneberg and Mathers (1994) (n=196)

$$height[mm] = 8,86mm/unit \times handlength[mm] + 52,73(\pm 4,08)$$

$$r = 0,94$$

$$age[years] = 0,19years/unit \times handlength[mm] - 16,12(\pm 0,14)$$

$$r = 0,85$$

takes all age-groups into account to estimate height and age, it is better to represent the regression-formula calculated from the CLW (SET D+E) or a restricted CZD (SET F) sets of photogrammetrically and manually recorded handprints (lefts and rights together). I separated these age groups and used a regression formula which originates from an age group that appears similar to the one I want to examine. As shown earlier, using several variables, it is more likely that the handprint makers of DK and EBC were in an age group between 10 to 14 years. The discrepancy of computed and actual height derived from the formula for height in an unrestricted age-group, like the whole sample of CZD, is larger than the discrepancy of computed and actual height of a tight, restricted age group such as the 10 to 14 year olds from the same sample. If I apply the Henneberg and Mathers (H and M) formula for estimation of height and age (1994), derived from their sample of schoolchildren (Figure 158 on page 268 and Figure 159 on page 268 for height, Figure 168 on page 273 and Figure 169 on page 273 for age, manually and photogrammetrically assessed), to the 10 to 14 years olds of Calitzdorp-sample (SET F), the formula estimates the individuals heights with a mean difference of ± 4.78 cm and calculates the age by ± 1.29 years on average (Figure 40 on

page 135). Using the regression formula derived from Calitzdorp 10 to 14 year old persons (Figure 166 on page 272, Figure 170 on page 274), the mean difference between real and calculated height of this age group is only ± 3.29 cm and the age difference is ± 0.83 years (Figure 40 on page 135). A 100 percent correlation between handprint length and height/age would result in ± 0.00 cm/ ± 0 years difference. The correlation for CZD 10 to 14 is ~72 percent. Furthermore, the application of a regression formula to a non-fitting age group (e.g. CLW 15 to 21 on CZD 10 to 14) leads to substantial variation (± 15.13 cm and ± 6.07 years see Figure 40 on page 135). Regression formulas generated from similar agegroups generally work better than those obtained from the whole sample. This claim can be demonstrated further with a comparison of the 5 to 9 and 15 to 20 years age groups. The application of the Henneberg and Mathers regression formula again shows increased variation around the mean from the original heights than those calculated from the similar age groups (see Figure 178 on page 278 and Figure 179 on page 279 for further results).

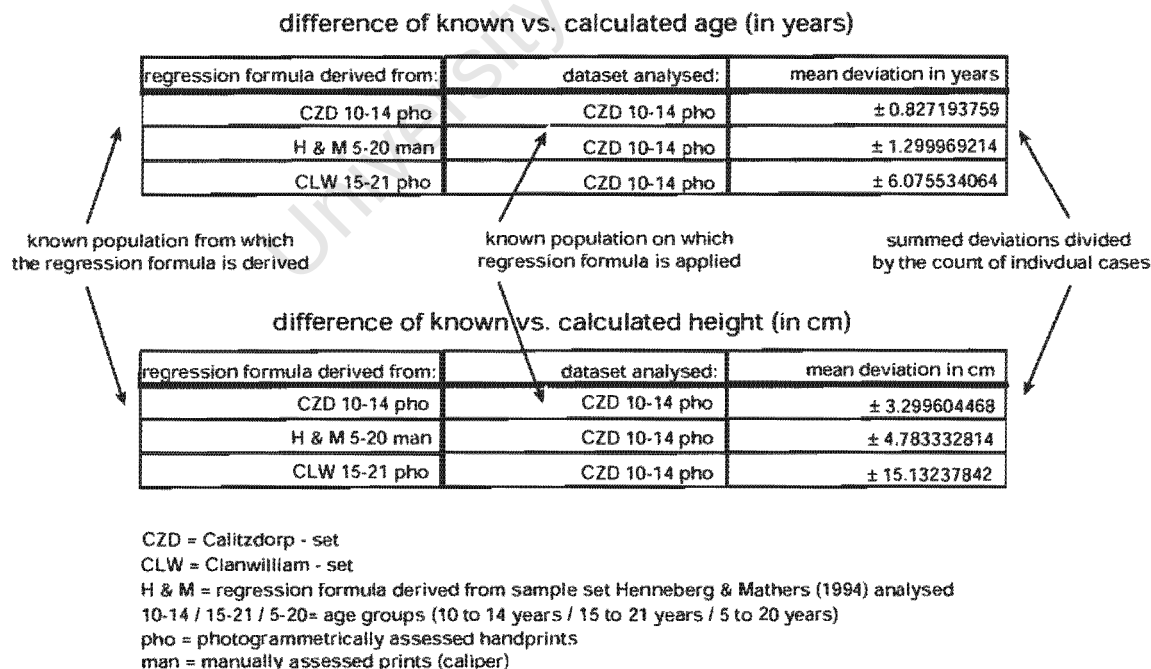


Figure 40: Deviation from the mean using various regression formulas to estimate height and age of experimental set CZD (SET F) 10 to 14 years

Significance in regressions from Henneberg and Mathers (1994) may be higher, but the difference to the newly calculated variations is negligible.

To estimate the height of people who made the prints in DK and EBC, a regression formula derived from people with an age of 10 to 14 years is probably best. I therefore used the regression formula derived from the sample of 10 to 14 year old individuals of Calitzdorp to estimate height and age for the makers of the Diepkloof and Elands Bay Cave prints. The sample size from which this formula derives is very small. However, until a larger set of prints from 10 to 14 year old individuals can be evaluated, it represents the best basis for comparison.

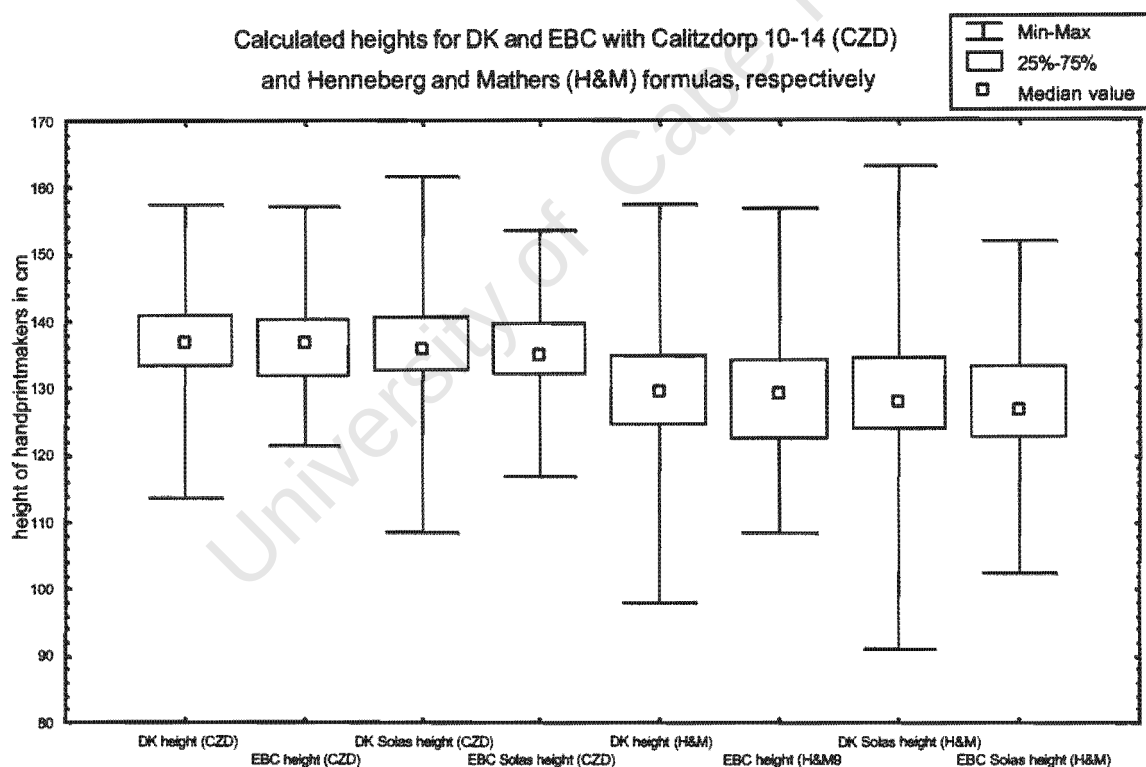


Figure 41: Difference of means of predicted height obtained by applying Henneberg and Mather's (1994) and CZD 10 to 14 formulas to sets of DK (SET H) and EBC(SET G)

For further research about the height and age of the handprint makers in the western Cape, I suggest the application of a regression formula derived from a larger sample of people with the same age of 10 to 14 years.

The graphs (Figure 41 on page 136 and Figure 42 on page 137) show results derived from the application of the regression formula from the CZD (SET F) 10 to 14 year old individuals and those derived from the application of Henneberg and Mather's regression formula(1994 - H & M) to the DK (SET H) and EBC (SET G) sets.

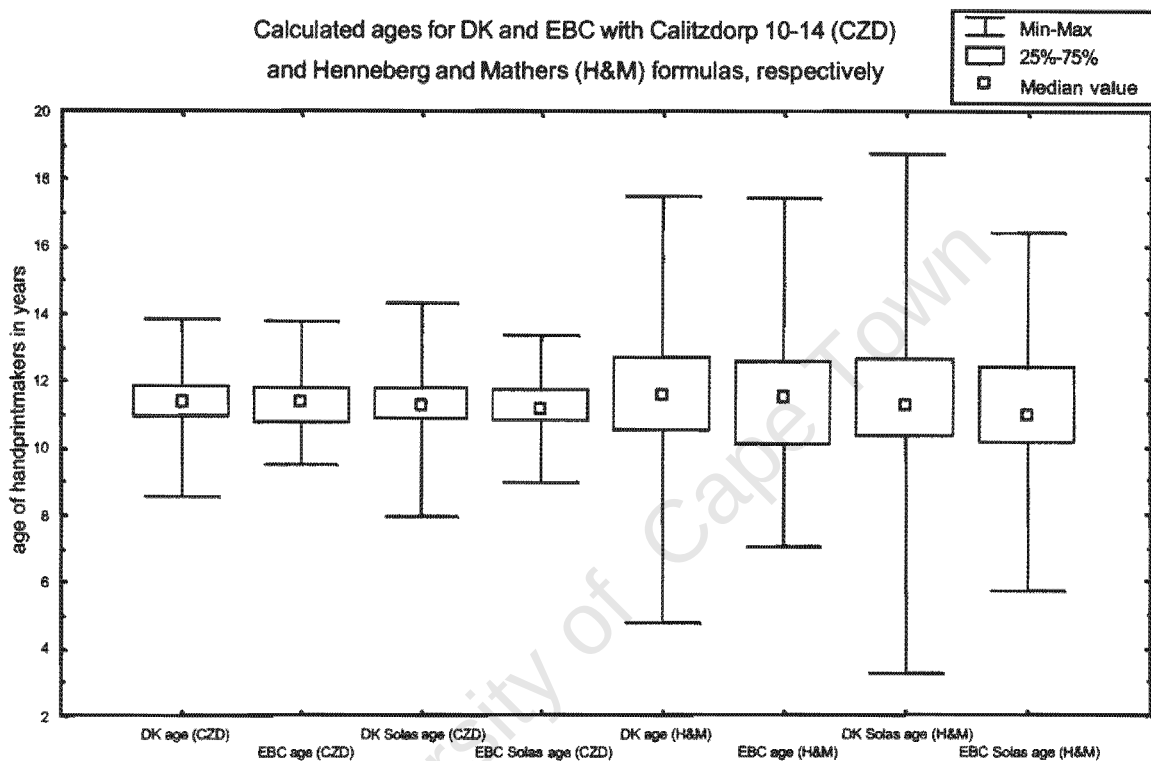


Figure 42: Difference of means of predicted age using the formula derived from Clanwilliam matrix for CZD, CLW, DK and EBC

Height means differs about 8 cm, with the CZD (10 to 14) formula calculating higher values. Age in both plots is similar, differing only in the variation around the mean. As the CZD (10 to 14) regression derives from 10 to 14 year old individuals, we can expect an age range between 10 and 14 years. The mean and inter quartile ranges are at around 11 to 12 years, while outliers go as far as 8 and 14 years. If this conclusion is correct, I can reasonably infer people of an age of 11 to 12 years to be the authors. The H & M regression shows about the same variation around the mean in height as the CZD (10 to 14) regression. Nevertheless, age varies substantially with a mean around 11 to 12 years, but an inter quartile range of 10 to 13 years and outliers between 3 and 19 years of age. This wide range means that small children

and adults could have been responsible for making the handprints, but most of the prints were made by sub-adults.

6.4. ORGANISATIONAL-Level

6.4.1. Sixth experiment - organisation of handprints in the archaeological sites:

The question arose, as to whether the left prints in one row are similar to one another making it likely that they were made by the same person, or more whether they are more variable, suggesting some kind of ritual, where only the left hand was used. The question whether the alternating left and rights could stem from the same person arose. Alternatively the pattern of left-right prints could have been important, and not the order of persons doing the handprints. As no surveyed localities of the handprints in the cave were available, I can only refer to my personal observations of which print is next to which. As a point in a line can only have one left and one right neighbour, this identification was only difficult in a few cases, where two lines met and intermingled.

Prints next to each other do not link with one another. This divergence could derive from the various combined errors or from a non-association. Nonetheless it is notable that handprints in Diepkloof are arranged in one long and several short horizontal rows either alternating from left to right or in rows of left prints with no observable rows of right prints (Figure 7 on page 37).

6.4.1.1. In detail analysis:

Figure 180 on page 280 to Figure 193 on page 293 depict the handprints of DKA linked using single, multiple linkage and Ward's Method cluster analyses. Because prints in DKA are

distributed in lines, adjacent print numbers reflect spatial proximity. If there is a relation between handprint-dimensions and their spatial location, this analysis should expose it. I utilized multiple variables (three and two measurements) for which the results vary with variables used, as their reliability is different. Unfortunately it is not possible to use all nine measurements. Five measurements at a time is also difficult, as there are only a few handprints from DK and EBC which meet the requirements. To obtain sets with a larger number of data cases, three and two variables were used (middle finger, subdigital width and lower width (3 (1)); middle finger, forefinger and little finger (3 (2)); middle finger and subdigital width (2 (1)); middle finger and little finger (2 (2))). Additionally, I plotted the length and number (position) of a single variable: middle finger and subdigital width.

The analysis was difficult, as I have already shown that left and right hands of one person can be as different from each other, as prints from different people. Because an analysis using two measurements has limited analytical weight, results obtained will also have little archaeological significance. To circumvent the lack of data, I used the application SOLAS (www.statsol.ie/solas/solas.htm), which computes missing data from the best known part of the same data-set. For example, it uses the known middle finger values and their relation to known forefingers values to generate data for missing forefinger values. The application continues computing other variables by using multiple variables to compute the missing parts - for example middle finger and already computed forefinger to estimate the matching ringfinger length. This procedure was applied to the Diepkloof sample in order to create a pseudo-data set with more complete cases of 9 variables. At this point I must warn that using this method can introduce errors into the analysis. This exercise is an attempt to get more insight, but such results will need to be viewed with these uncertainties in mind.

The analysis of the spatial distribution of similar sized prints did not yield meaningful results as no patterns could be detected. Some prints which are spatially related, group in related links or clusters, but the main bulk of prints seems to demonstrate that prints from

different locations across the site are more similar to each other than prints which are spatially close. The cluster analysis of the spatial DKA-Solas (Figure 194 on page 294 to Figure 210 on page 310) data does not demonstrate better results than the normal DKA datasets. The availability of more prints does not help in obtaining more matches of prints that look the same. The absence of similar handprints next to each other could be due to the small sample of handprints or the unreliability of the Solas data. The indistinctiveness of the handprints also plays a major part, but patterns will be difficult to pick up with several levels of errors included such as measuring error and condition of handprints on the wall and left-right difference for an individual.

If the results are interpreted without ignoring the influence of the errors, it can be argued that prints from the same person were not made next to each other, possibly indicating that one person did one print at a time.

6.4.2. Seventh experiment - spatial distribution of handprints in a site

General patterns of spatial distribution of handprints seem to appear in the caves. Decoration, left-right distribution, palm prints and complete prints may indicate that caves are unique. Different patterns could have implications towards the interpretation of the phenomenon of hand printing as a universal tradition.

The investigation shows that more left than right prints exist in EBC and more right than left handprints in DK. Both ratios disagree with the proposed 9:1 ratio of right- to left-handed people in human population (Schick and Toth 1993). Different decorated – non-decorated prints and palm prints - complete prints ratios exist in the different caves and even within parts of the same cave (DK) and demonstrate the contrast of handprint making between single caves. Decorated palm prints represent something special in EBC as none oc-

cur in DK. For all these reasons it is difficult to put handprints of different caves together and analyse data of different caves together.

6.4.2.1. In detail analysis:

The relative frequencies of left and right prints differ at the two archaeological sites EBC and DK. However, only 34% of the prints in EBC are identifiable and therefore the graph might not reflect the true ratio (Figure 211 on page 311 and Figure 212 on page 311 for a ratio without unknown prints). There is a difference in the ratio of decorated to non-decorated prints from the two caves. While at EBC decorated prints (70%) by far outnumber plain prints (19%), the ratio at DK between the two categories is almost equal (40.1% to 41.1% - Figure 213 on page 312 and Figure 214 on page 312 for a ratio without unknown prints).

When analysing DKA and DKB separately, it becomes clear that two different ratios exist. There are twice as many left as right prints in DKA. In DKB the numbers are almost equal (45.6% rights 37.9% lefts - Figure 211 on page 311). This difference between the cave locations is strengthened by the ratio of decorated (nested U-curves) to non-decorated prints (plain) (Figure 213 on page 312). Whilst in DKA about 17% are plain and 74% are decorated, DKB has almost the reverse percentages with 57% plain and 17% decorated handprints. EBC and DKA have almost identical percentages, whilst DKB and EBC strongly contrast one another.

In the modern human population about 80-90% of people are right-handed (Schick and Toth, 1993; Annett and Kilshaw, 1983). Nevertheless, DK and EBC exhibit differing, if not contrasting ratios. Especially DKA is different with 60% of the prints being left prints. There are three possibilities to explain this phenomenon. First, the handedness of the population from which the printmakers came could have been different from most of the current world's population. I cannot exclude this possibility, but deem it unlikely, as the human brain functions in a similar way all over the world. I therefore would reject the possibility of the handprint makers at DKA being mostly left-handed, using their dominant hand.

Secondly is it possible that people were mostly right-handed, but used their favoured hand (right, whereas I define handedness with using the favoured hand, even though it might not be the better skilled one) to paint on the print-hand (left). If the printers painted their hands themselves, they could have needed some skill to paint the nested U-curves. This would not explain the contrary ratio of left to right prints in DKB (45.6% right vs. 37.9% left).

The third possibility is that certain rules of some tradition or ritual are imposed on the making of prints. This could mean that some people were only allowed to make prints with either left or right hand. This tradition or rule can be explained by different events or scenarios, such as gendering or status.

Another factor that must be examined is the occurrence of palm prints. In the whole of DK there are only 2 palm prints among the 411 prints (0,5%), whereas in EBC 37.8% of the handprints are missing the imprints of fingers on the wall (Figure 215 on page 313 and Figure 216 on page 313 for a ratio without unknown prints) This also explains the low number of left-right identifiable prints in EBC.

The occurrence of palm prints in EBC and the absence in DK (only two prints) might mean that making palm prints was a special event or tradition in EBC. They might represent handprints but have been made in a different style, but could also be interpreted completely different. Most palm prints as well as most of DKB handprints are decorated. It is more likely that palm prints simply represent another variation of handprints.

The results obtained for the spatial distribution of the handprints definitely show that caves and the ratios of handprints for decoration, left/right handedness and palm/full handprints are different from one another. Considering the depth of time that the accumulations of handprints in different caves (and even of the same caves) might resemble, they should not be analysed as one dataset, unless it is clear that these handprints origin from the same authors and/or the same event. If this cannot be proven, statements made, have to be carefully reflected.

6.5. INDIVIDUALS-Level

6.5.1. Eighth experiment - distinguishing individuals

Results and statements about this level are preliminary, as the variation within the handprints is very high and distinguishing between single individuals becomes difficult. Cluster analysis cannot help because it relies on the Euclidean distance, which is a relative measure. This is the final level of analysis and one of the crucial points I wanted to examine, is whether the number of individuals could provide information about the reasons behind handprint making.

This analysis confirms the result that handprints were made by more than one person. Furthermore it becomes clear that in the case of DK a group of people of a certain age must have been responsible for making them.

6.5.1.1. In detail analysis:

One approach was made to obtain the minimum number of individuals (MNI) of printmakers in DK and EBC. As the variation of one persons left and right print together is known (SET A1+A2), it is possible to relate the percent variation to the archaeological prints. As a working hypothesis it is assumed that each print of DK and EBC has a value that varies around the mean, equivalent to a value that 50 left and 50 right prints of person A (SET A1+A2) vary around the mean. The standard deviation acts as an indicator of how closely individuals resemble one another.

If it is furthermore assumed that prints whose variations do not overlap are different, then it is possible to estimate the minimum number of individuals (MNI).

A test on the original set of person A (SET A1+A2 n=100) should show that few or only one person was responsible for all of these handprints. A test on the CLW set (SET D+E n = 196)

should show that a few people were responsible for doing these prints. I expect this, because these people are all between 15 and 21 years of age and some handprints from different persons will resemble each other. A third test on the CZD set (SET F n=104) should reveal a greater number of individuals as this set consists of people with ages between 5 to 20 years. These individual prints should not be as similar to one another as an age-related set, such as CLW.

In the previous analysis it was suggested that the handprints from DK (SET H n=142) and EBC (SET G n=44) resemble an age group of people between 10 and 14 years. It would therefore be expected that they show a ratio (percentage) of distinguishable individuals to all individuals, which resembles the ratio (percentage) of the CLW (SET D+E).

The first test with person A's prints showed the expected low numbers and percentage of identifiable individuals to all individuals with 2 (2%) and 1 (1%) definite individuals out of 100 identifiable individuals to 66% and 95% certainty, respectively. The CLW sample demonstrated, as expected, a low percentage with 7 (3.6%) and 4 (2%) definite individuals out of 196 possible individuals (to 66% and 95% certainty). Moreover, the analysis distinguished 11 (11.1%) and 5 (5.1%) definite individuals out of a possible 99 individuals in the CZD set. Therefore, the proposition that more individuals can be identified from samples that have a bigger agespread is demonstrated.

The test on the DK set showed similar percentages to those of the CLW set. In Diepkloof there were at least 9 (6,3%) or 5 (3.5%) individuals with a certainty of 66% and 95%, respectively. This also confirms that more than one person had to be responsible for the making of the handprints.

Surprisingly the Elands Bay Cave set exhibited different results. At least 7 (15,9%) or 4 (9,1%) individuals had to be responsible for the prints in EBC (to 66% and 95% certainty). The percentages are higher than in CZD, which means that these handprints varied markedly in size. The proposition that EBC represents a group of a small age group can therefore

not be verified. Nevertheless it is possible that this result is a reflection of the relatively small sample size (Table 15 on page 145).

SET	66 % certainty			95 % certainty		
	number	number of individuals	(%)	number	number of individuals	(%)
person A	2	100	2	1	100	1
CLW	7	196	3.6	4	196	2
CZD	11	99	11.1	5	99	5.1
DK	9	142	6.3	5	142	3.5
EBC	7	44	15.9	4	44	9.1

Table 15: Minimum number of contributors of person A, CLW, CZD, DK and EBC, calculated from person A's standard deviations for left and right prints around the mean

If only left or only right prints are analysed the number of determinable individuals increases as the variation of person A's left or right print is, taken independently, much lower than their combined variation around the mean.

In Diepkloof 14 (19.2%) or 10 (14.5%) of the 73 individuals who made all the right handprints were identified, agreeing again with the percentages of CLW. EBC, on the contrary, shows very high percentages and almost every print is so different from the next that it could be another individual. A surprisingly high percentage can be observed in DK with 22 (31.9%) or 14 (20.3%) individuals making all the left handprints, resembling CZD in percentage (Table 16 on page 146 and Table 17 on page 146). This would mean that in Diepkloof people of a tight age group made right prints, while left prints were made by individuals of a wide range in age.

SET	66 % certainty			95 % certainty		
	number	number of individuals	(%)	number	number of individuals	(%)
person A	3	50	6	2	50	4
CLW	19	97	19.6	10	97	10.3
CZD	24	70	34.3	16	70	22.9
DK	22	69	31.9	14	69	20.3
EBC	15	32	46.9	9	32	28.2

Table 16: Minimum number of individual of person A, CLW, CZD, DK and EBC, calculated from person A's standard deviations for left prints around the mean

SET	66 % certainty			95 % certainty		
	number	number of individuals	(%)	number	number of individuals	(%)
person A	3	50	6	2	50	4
CLW	20	99	20.2	13	99	13.1
CZD	18	29	62.1	12	29	41.4
DK	14	73	19.2	10	73	13.7
EBC	10	12	83.3	8	12	66.7

Table 17: Minimum number of individual of person A, CLW, CZD, DK and EBC, calculated from person A's standard deviations for right prints around the mean



DISCUSSION

Handprints represent a different style, class and hence meaning of rock art. They are different from other rock art categories, such as the fine line paintings, as they are repetitive and represent the individuals who made them. Furthermore their size is different from other paintings, because it reflects the size of the original and not, as in the case of animals and human in rock art, a diminution. Furthermore handprint making presumes copying the same thing over, as they are not painted but printed, while fine line paintings are individually painted images, none looking exactly the same.

However, the analysis confirmed my reservations towards a generalized approach of evaluating handprints. I am therefore convinced that each cave and the handprints in it have their own meaning and background, and may represent different people and times. A bigger picture can only be created when the differences between each single locality are known to demonstrate only local variations of a widespread tradition. Apart from this, I agree that the making of handprints is probably subject to some tradition, scheme or institution on a larger scale into which we have up to now had little insight.

Handprinting might not have been a group activity. It is possible that single persons did one, two or several prints at a time, after or before some kind of event (menarche, first eland kill, first hunt, marriage). The existence of such an event or tradition can be suggested, as it was shown that, judging by the sizes of the handprints (see also Manhire 1998), sub adults were for the most part responsible for print making.

Differences of ratios of decoration as well as left-right and palm-full hand use in different caves might derive from certain rules of a tradition or ritual imposed on making the handprints. Possibly only certain people were allowed to make prints with either left or right

hand. This scenario is not inconceivable as other researchers have stated that Bushmen societies have, for example, classifications such as right-male and left-female (Solomon: 1989). The gendering of left and right seems to be common among African, e.g. San groups (Wieschhoff 1973). Drennan (1937) observed this with regards to the amputation of digits from the hand. Men had digits amputated from their right hand, whilst women were missing a left hand digit. Apart from this, campsite organisation indicates this "gendering of orientation" (Solomon 1989). Wadley (1986) uses observations of spatial distribution in !Kung camps (Marshall 1959) to explain phenomenon such as the occurrence of ostrich eggshell beads on the left side of a cave in an archaeological site.

A factor that has to be considered is the point of view from which left and right are observed. Solomon (1989: 66) suggests that "feminine space is probably to the left of the corresponding male relatives's". The distinction of left and right hand can still be difficult, as it may vary with perspective, but as the right "male" arm is the one with which they [the bushmen] shoot (Bleek and Lloyd 1911: 328), right in this sense must be the physical dextral side of a person.

Apart from this, any large number of animals or objects in one group is classified as feminine (Solomon, 1989: 67). The accumulations of handprints in EBC and DK therefore might point to some female activity. Girls who have their menstruation are secluded in a hut (or shelter) (Bieseke 1993: 197). Bieseke furthermore states that " 'to make themselves beautiful', Ju/'hoan girls say, they imitate the stripes of the zebra on their thighs and on their cheekbones, 'because the zebra is the most beautiful animal'. Thus women are likened to the zebra..." (Bieseke 1993: 123). Many handprints display stripes or as I called it, are decorated. This further validates the suggestion of females making the prints, but as percentages of left to right prints vary from cave to cave, a generalisation about the authors is dangerous and not justifiable.

The left to right hand distributional differences add to the tendency to different appearanc-

es in different caves and leads therefore to a further non-justifiableness of generalisation of statements about the caves, the handprint makers and handprint making as a tradition.

Other possibilities for reasons behind handprint making are imaginable. Given the fact that one's handprint is unique, making it, is a way of expressing yourself, such as saying "I was here", or even the better known "Kilroy was here" (van Rijssen 1984). It also is a way of self-identification, in which one represents him/herself as a single person, but also can identify with a group. Everybody did his/her part and with placing ones own handprint, one will be part of it. Maybe this means entering the society, by being part of a ritual - being allowed to do, what everybody was allowed to do before. Here I'm referring to initiation and entering the society of the adults. This is not necessarily accomplished by placing a paint-smearred hand on the wall. It is possibly a way of showing your new status. People also could have just thrown a stone in the river, and by doing so, they show that they were part of their group, because everybody in the group followed the same ritual, by being allowed to throw their stone in the river. The repetition of the same thing the same way makes the individual part of the group.

It also somehow expresses one's group's identity. Your clan or family throws their stone only in this river and only that way. A certain tribe makes their handprints only in a certain cave and only a certain way. The substantial amount of "decorated" handprints in both Diepkloof Shelter and Elands Bay Cave and the existence of palm prints only in Elands Bay Cave might indicate such group identities. By placing the hand on the Elands Bay Cave wall, the person may have expressed that he/she belonged to this specific tribe.

Apart from this, it is interesting to know that the decorated handprints not only occur in the western Cape of South Africa, but also in North America (Smith and Turner 1975, Freers 2001) and Australia (Gunn 1998). All these societies are known to perform rituals and incorporate shamanism a parts of their belief system. A shamanistic explanation for the making of handprints is therefore also imaginable, despite the fact that the numbers of individuals

making the handprints holds against this scenario.

Another question asked earlier is the attribution of authorship - Khoe (herder) or Bushmen (hunter-gatherers). Unless we have some observations or written source it will be difficult to assign handprint making to either of these two groups, as subadults were responsible for making the prints. Because the makers of the prints were not grown up, older Bushmen- and younger Khoe- sub-adults could have been responsible for printing. Dissimilar groups or individuals (possibly even divided by sex) might have printed in different parts of the caves.

However, it was discussed earlier that the making of handprints could have either arisen as a reaction to the intruding pastoralists around 2000 B.P., most likely as part of a self-realization of the San who are believed to be the authors of the most of the rock art in the western Cape (Yates et al. 1994), or as a statement of the pastoralists Khoe articulating their identity as van Rijssen (1984) suggests.

As the question, whether hunter-gatherers or herders were responsible for making the handprints is at the moment impossible to answer, it is difficult to include my findings into the greater framework of the society and its organisation in the western Cape. This question of authorship of handprints (and other rock art imagery) can only be answered with a better chronological framework for the events in the western Cape. An accurate dating-method for rock art would also go a long way to answering this point. I would not go so far to re-evaluate earlier work, as I am sure that different caves (sites) have different backgrounds and would not necessarily exclude possibilities stated by other authors (Anderson 1997, van Rijssen 1994, Manhire 1998, Lewis-Williams 1999). I stated earlier that it might be possible that several ideas work together (Chapter 3 on page 16).

One question left unanswered, is how to print. Have any instructions been given to the handprint makers or were authors bound to any rules? This question first appeared when I made my experiments. It is impossible to answer as we simply don't have any sources which

give any indications of how and under which circumstances the handprints have been made. Even if we knew about the background and making of some handprints, we would not know if these instructions or rules were obeyed in every cave and to any time. I have decided to make the experimental handprints an equal manner so that at least all of those were comparable with each other.

University of Cape Town



CONCLUSION

This thesis has approached the problem of identifying individuals from their handprint dimensions, taking advantage of the results observed in experimental datasets in comparison. The focus was to apply the knowledge obtained from the experimental handprint sets onto the handprints of Diepkloof and Elands Bay Cave, caves in the western Cape, known to display a large number of 950 handprints.

A photogrammetrical recording system was utilized to measure experimental and archaeological handprints with an accuracy of less than 1 mm deviation. Analytical studies were predominantly conducted with single and multiple variable cluster analysis, exploring different eventualities to find answers to the questions asked.

8.1. RESULTS

8.1.1. Variation in measurement and its impact on the analysis

Four experiments with handprint datasets of people with known age and height showed that most of the variation within a dataset derives from the variability within the set as a difference between the prints and instead of from the measurer(s) nor the technique applied. Therefore handprints must be, at least to a certain level, distinguishable from one another. Further, it was demonstrated that the photogrammetrical approach of recording prints resulted in a higher accuracy than the manual recording technique. The use of various different measurements, combinations of these and different statistical methods demonstrated

that results will vary depending on methods and measurements applied. Length measurements generally correlate better than width measurements. This is important, as in a multivariate analysis one wrong variable or measurement can distort the results considerably. Nevertheless, width measurements are important to distinguish between individuals in a multivariate analysis.

Moreover, it was discovered that left and right prints of the same individual differ substantially. In the experimental sets, a left print of one person was more likely to be associated with a right print of another person than with its own match.

8.1.2. A comparison of archaeological and experimental handprints

The handprint sets of Diepkloof and Elands Bay Cave best resemble the experimental set of 10 to 14 year old individuals from Calitzdorp in handprint size and variation. The experiments showed that most of the prints in the caves could neither have been made by 5 to 9 nor by 15 to 20 year old people exclusively. However, it is conceivable that all archaeological prints could have been made by one person during different stages of adolescence. The variation of the sample cannot otherwise be explained. For further research, I suggest measuring a large population of 10 to 14 year old individuals to obtain a large comparative set of hand-prints, as this is the assumed age of the handprint makers in DK and EBC. The project showed that there are differences between handprint sizes of boys and girls, with older girls aged 14 to 16 having a similar handprint size to boys aged 10 to 12. Moreover, it was suggested that handprint making might have some connection to a gendered ritual, possibly with a feminine context. With a larger sample it could be possible to investigate, whether sets of boys or sets of girls handprints of the mentioned age groups correspond better with the archaeological prints.

8.1.3. Estimation of age and height

Regression formulas from restricted, matching age groups estimate height and age better than formulas derived from the whole population, including all age groups. Regression formulas derived from restricted age groups applied to sets of handprints from a dissimilar age group compute age and height inadequately.

8.1.4. Spatial organisation

Pairing of archaeological left and right prints cannot be observed. Especially adjacent handprints in the caves are, in a statistical sense, not significantly matching. Furthermore, utilizing one variable for this analysis can be misleading as results change with variables used (length and width measurements).

8.1.5. Spatial distribution

Ratios of left to right handprints differ from cave to cave and even in different locations within a cave. As 80-90% of the human population of the world are right-handed, it is surprising that the ratios in both caves and parts thereof do not mirror these ratios, as if people used their dominant hand. Ratios of left to right prints in both Diepkloof Shelter (DKB) or Elands Bay Cave (EBC) are almost equal, with a slight prevalence of right prints. Of particular interest is the ratio of left to right prints in Diepkloof Kraal (DKA), where the handprint makers dominantly used their left hand (60%) for printing hands on the rock surface.

In addition, ratios of decorated to plain, and palm to full prints also vary between and within the caves. In the beginning of this thesis, I questioned the generalized analysis of the handprints of the western Cape by other researchers (Willcox 1959, Maggs 1967, van Rijssen

1984, 1985, 1994, Manhire 1998), who examined ratios of handprints to other rock art categories from different caves as one entity. A generalised analysis, however, should be avoided until intra-site contexts and numbers of the single caves are understood, as numbers, ratios of handprints to other rock art categories and handprint styles in different caves vary.

8.1.6. Identifying individuals - minimum number of individuals

With a certainty of at least 95%, 14 individuals must have contributed to make left prints in Diepkloof and at least 10 to make right prints. With a single standard deviation or 66% certainty, 24 individual made left and 14 individuals made right prints. Numbers representing 66% certainty will hereafter be displayed in brackets.

The ratio of determinable contributors compared to existing prints in an experimental print set suggests that right prints have been made by people from a restricted age group because handprint length varies little within the sample. On the contrary, the ratio of determinable contributors set against existing left handprints shows that these vary as much as a whole population of people with mixed ages. If left and right prints are analysed as one set, 5 [9] individuals with 95% [66%] certainty were accountable for print making in DK, which displays a ratio of determinable individuals to existing prints that conforms with the ratio of a restricted age group.

EBC exhibits very different results. This might be due to the small sample size, as many EBC prints are blurred, incomplete or palm prints and are therefore not measurable. Eight [10] individuals were responsible for making left and 9 [15] for right handprints. In both cases the percentages are very high and almost every identifiable handprint represents an individual. At least 10 [14] persons were responsible for all the prints in EBC. The ratio of determinable contributors compared to existing prints is even higher than the ratio of a whole

population making prints.

The photogrammetrical recording of the handprints proved very successful, as it allowed the specified measurements to be obtained accurately. These measurements, however, could not entirely distinguish between each single handprint or allocate them precisely to an individual. Two scenarios are conceivable; the choice of handprint measurement does not enable one to differentiate between individuals, or handprints of different individuals may appear equal, because they actually exhibit equal dimensions. In my detailed analysis of experimental handprint data sets I have shown that the likelihood of identification of individuals increases with the number of measurements utilized. For future research I therefore suggest a technique which incorporates more than the suggested nine measurements, and perhaps area size of palms and fingers.

8.1.7. The application of the photogrammetrical method to other rock art imagery

I am sure that the methodology used here to measure and evaluate the handprints of the western Cape can be utilized for other rock art imagery as well (see Benz-Zauner et al. 1995, for paintings in Altamira) I am not convinced, though, that it will be of much use for further research in the western Cape at this point. This is because handprints are mostly uniform and have a predetermined size and shape, contrary to other rock art imagery. Other paintings such as images of humans and animals vary in these aspects considerably, depending on the place, painter and age. Some of these aspects remain for the researcher indeterminate and/or indefinite. I have shown that even with a relatively uniform and predetermined shape (the human hand) many parameters exist which may change the results of the analysis to a considerable degree.

For further research I would suggest the technique of digital stereophotogrammetry as a tool to measure handprints. The use must not be restricted to southern african rock art, as handprints as a worldwide phenomenon with the same shape. The same is true for the application of the statistical method of cluster analysis. The results of the analyses will be interesting, especially as there are handprints with almost identical patterns in Africa (Manhire 1998), Australia (Gunn 1998) and North-America (Freers 2001).

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University of Cape Town

HANDPRINTS OF THE WESTERN CAPE: RECORDING, MEASURING, IDENTIFYING

Part II - Appendix

Conny Meister

*Submitted to the Faculty of Science, University of Cape Town, in fulfilment
of the requirements for the degree of Master of Science in Archaeology*

2003

10.

APPENDIX

Note that the number at the very end of each subtitle of cluster analysis figure indicates:

1 - single linkage cluster analysis

2 - multiple linkage cluster analysis

3 - Ward's method cluster analysis.

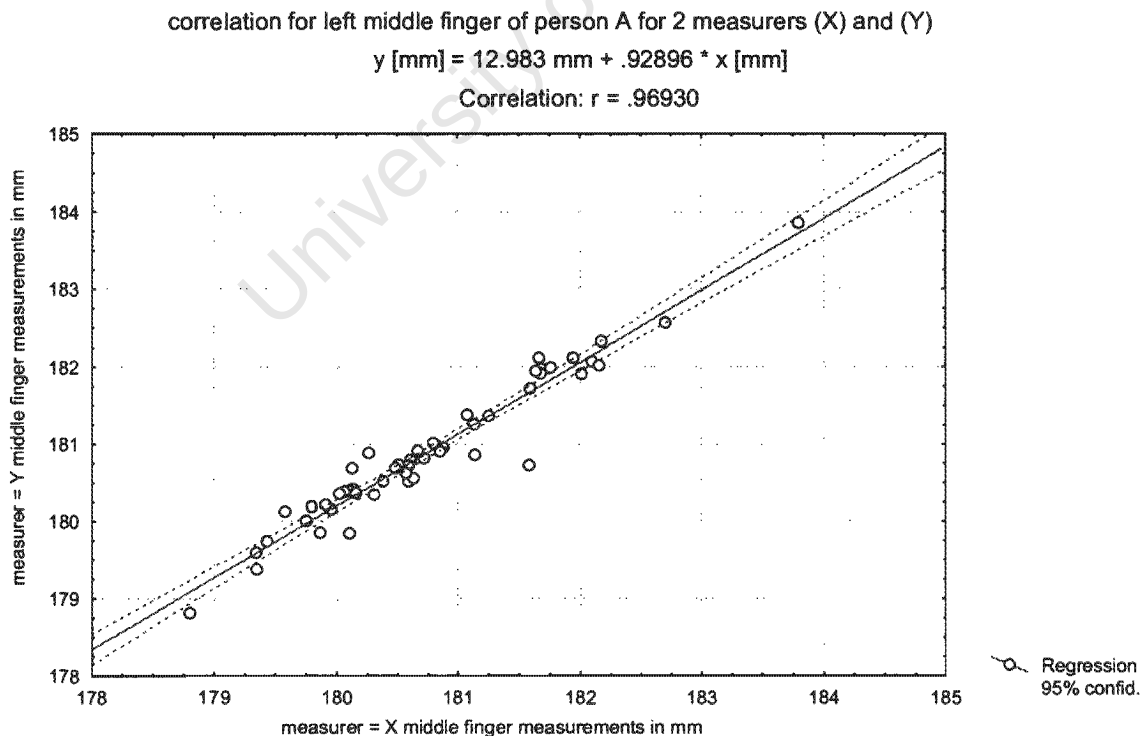


Figure 43: Regression formula for two observers measuring a repeatedly made left handprint

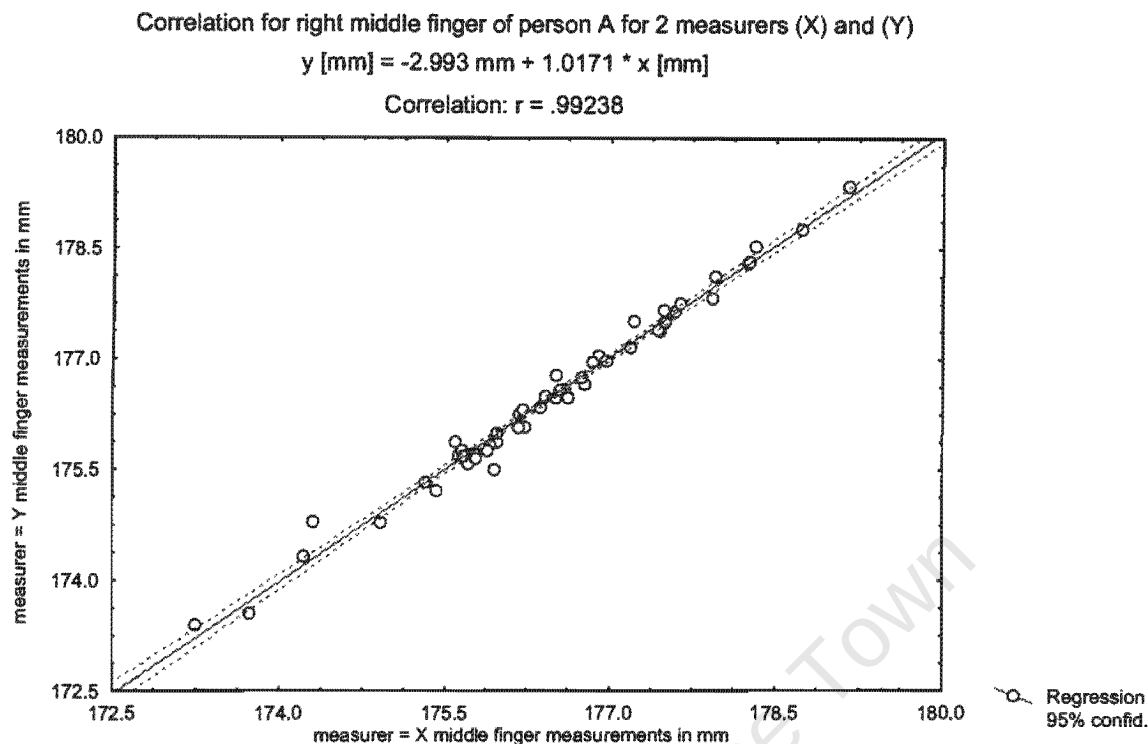


Figure 44: Regression formula for two observers measuring a repeatedly made right handprint

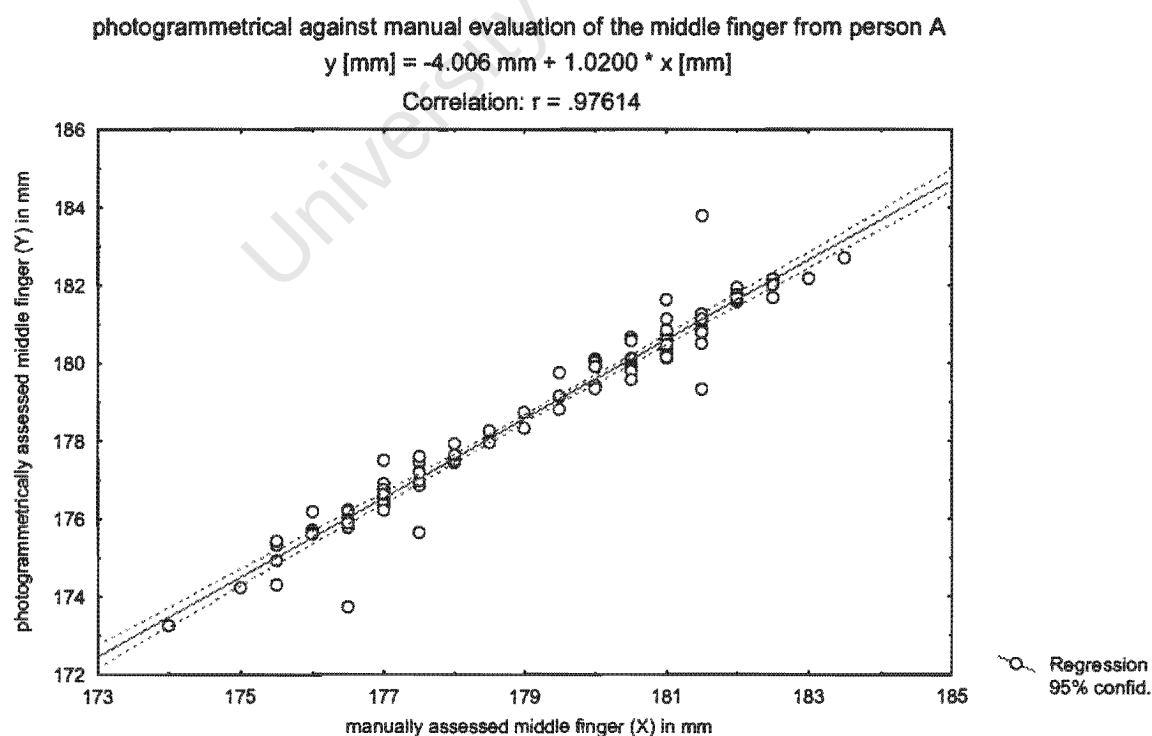


Figure 45: Regression formula for manually and photogrammetrically assessed handprints of one person (A)

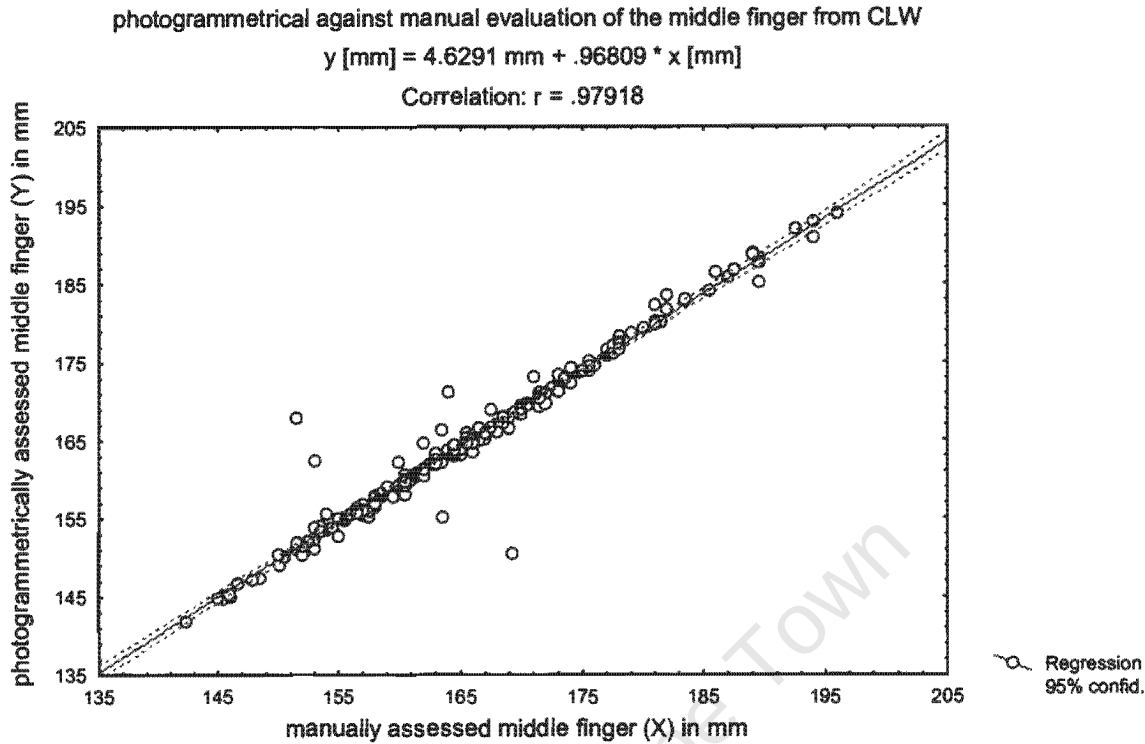


Figure 46: Regression formula for manually and photogrammetrically assessed prints of the CLW matric pupils

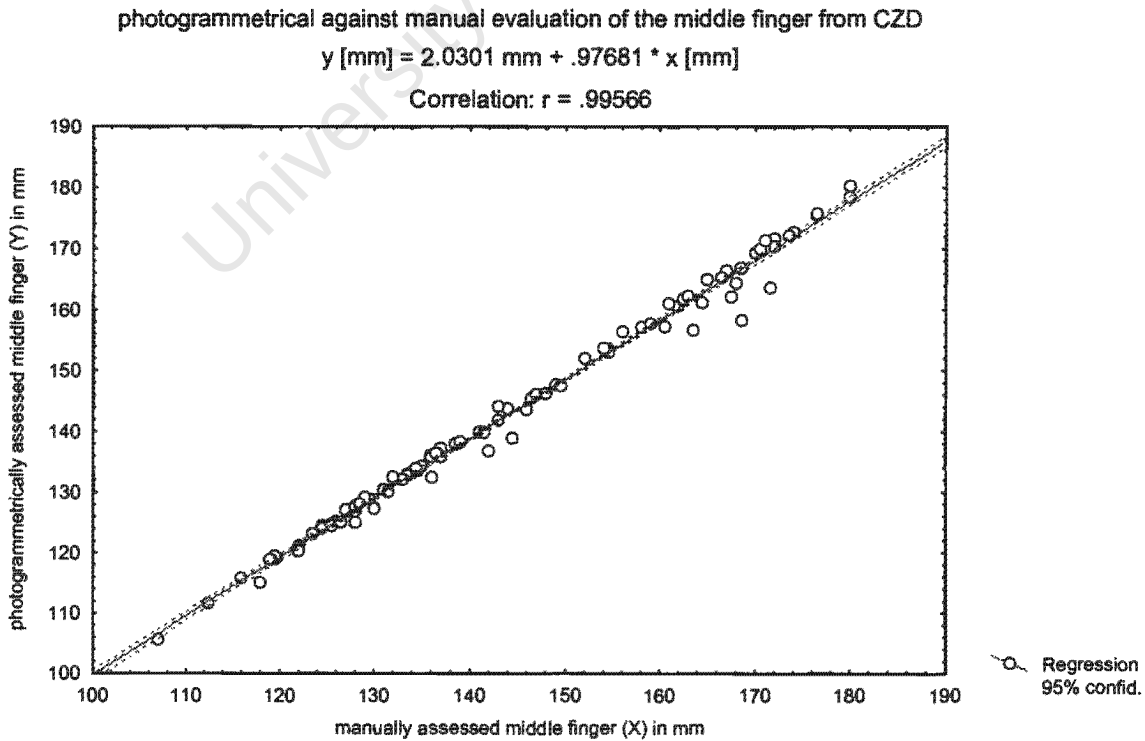


Figure 47: Regression formula for manually and photogrammetrically assessed prints of the CZD school pupils

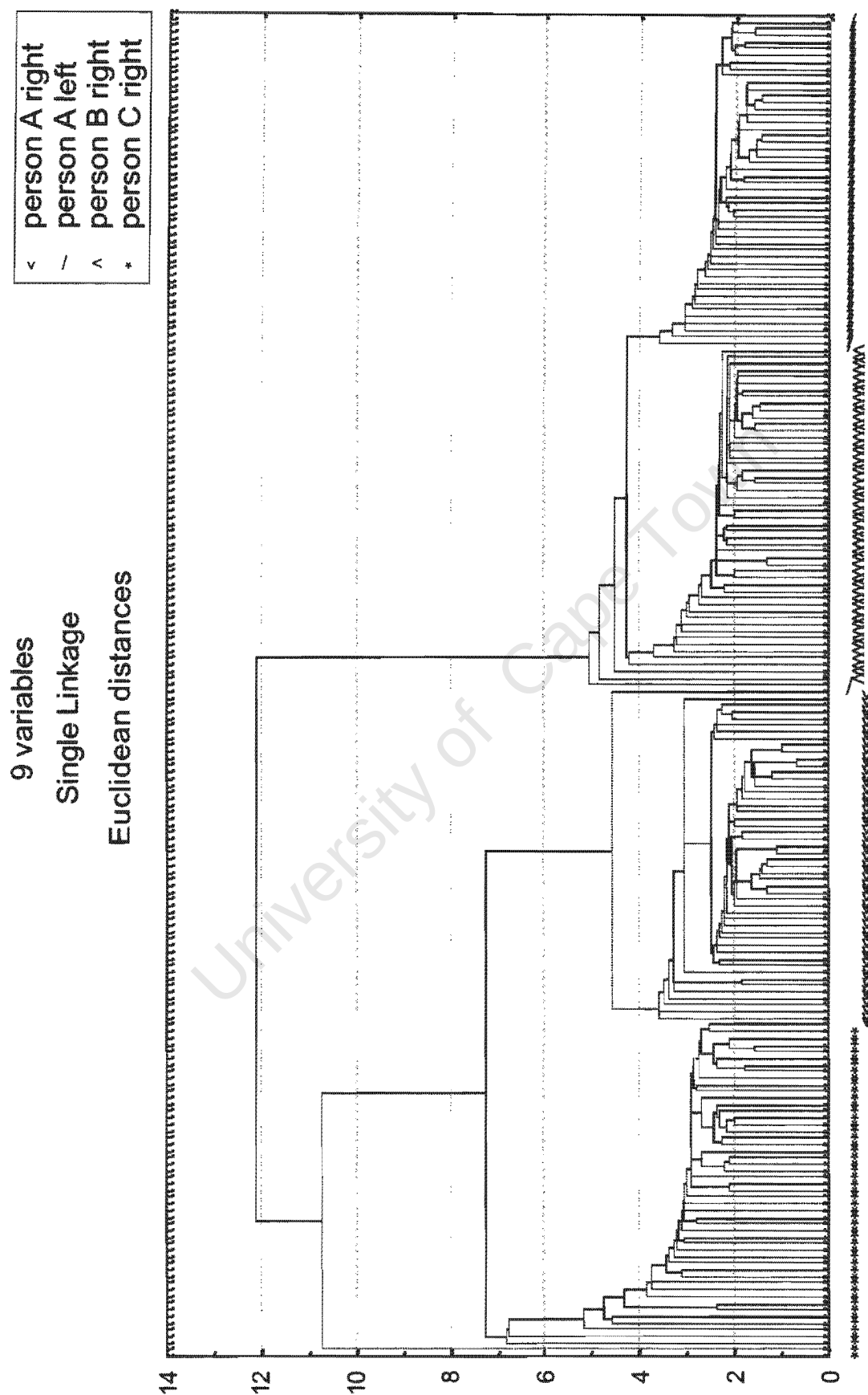


Figure 48: Cluster analysis of 9 handprint-variables to distinguish between 3 persons - SETS A1, A2, B, C (1)

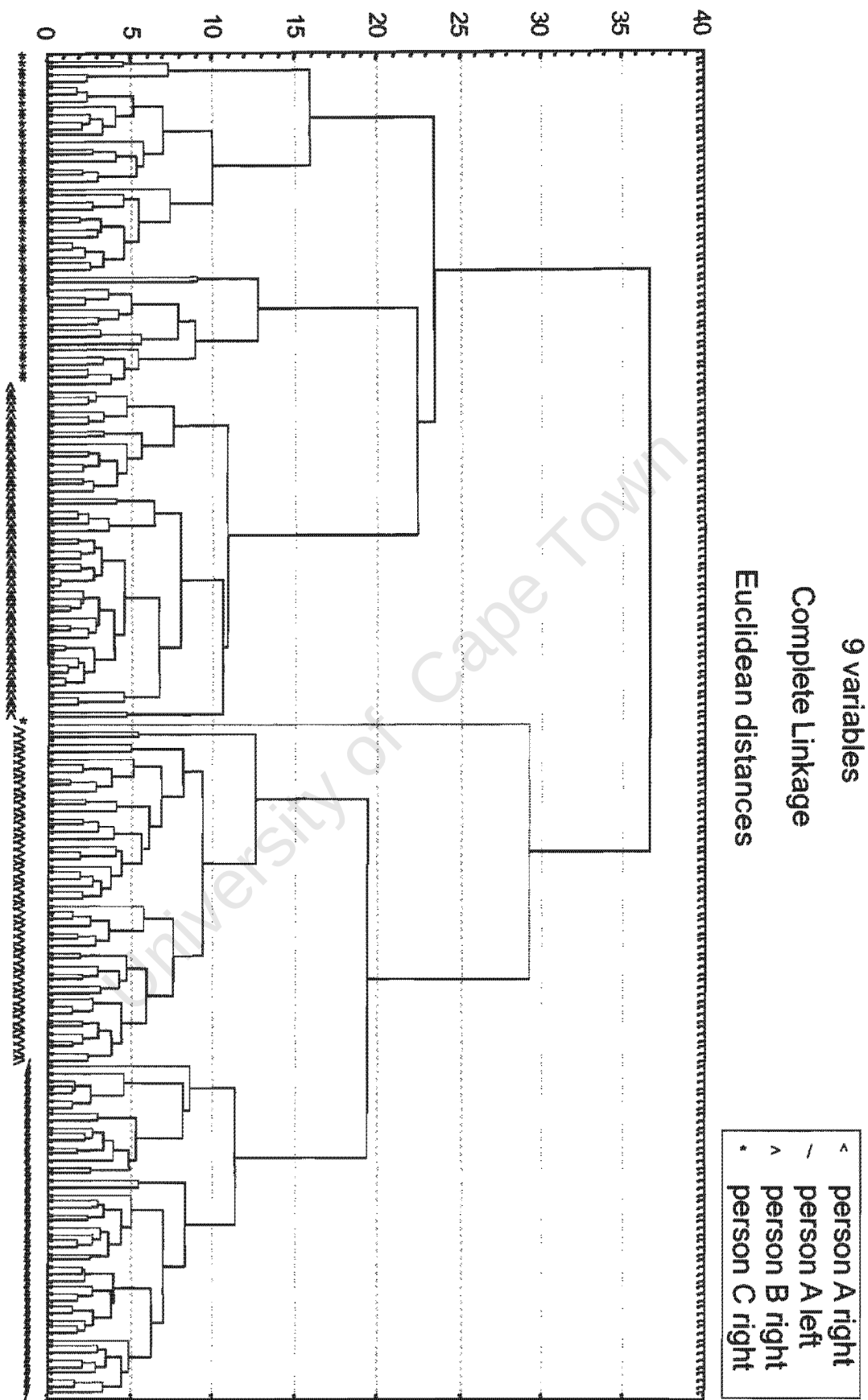


Figure 49: Cluster analysis of 9 handprint-variables to distinguish between 3 persons - SETS A1, A2, B, C (2)

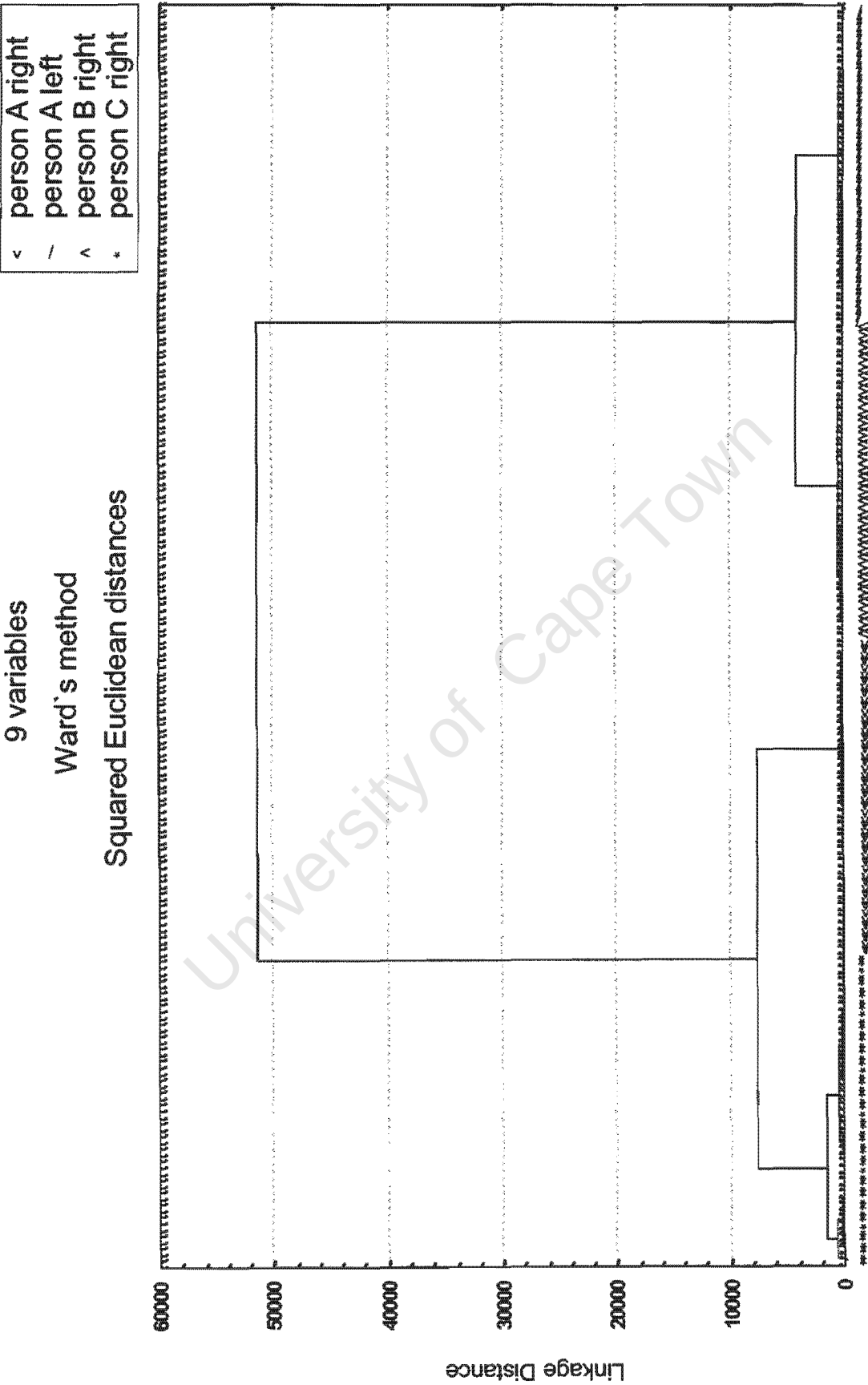


Figure 50: Cluster analysis of 9 handprint-variables to distinguish between 3 persons - SETS A1, A2, B, C (3)

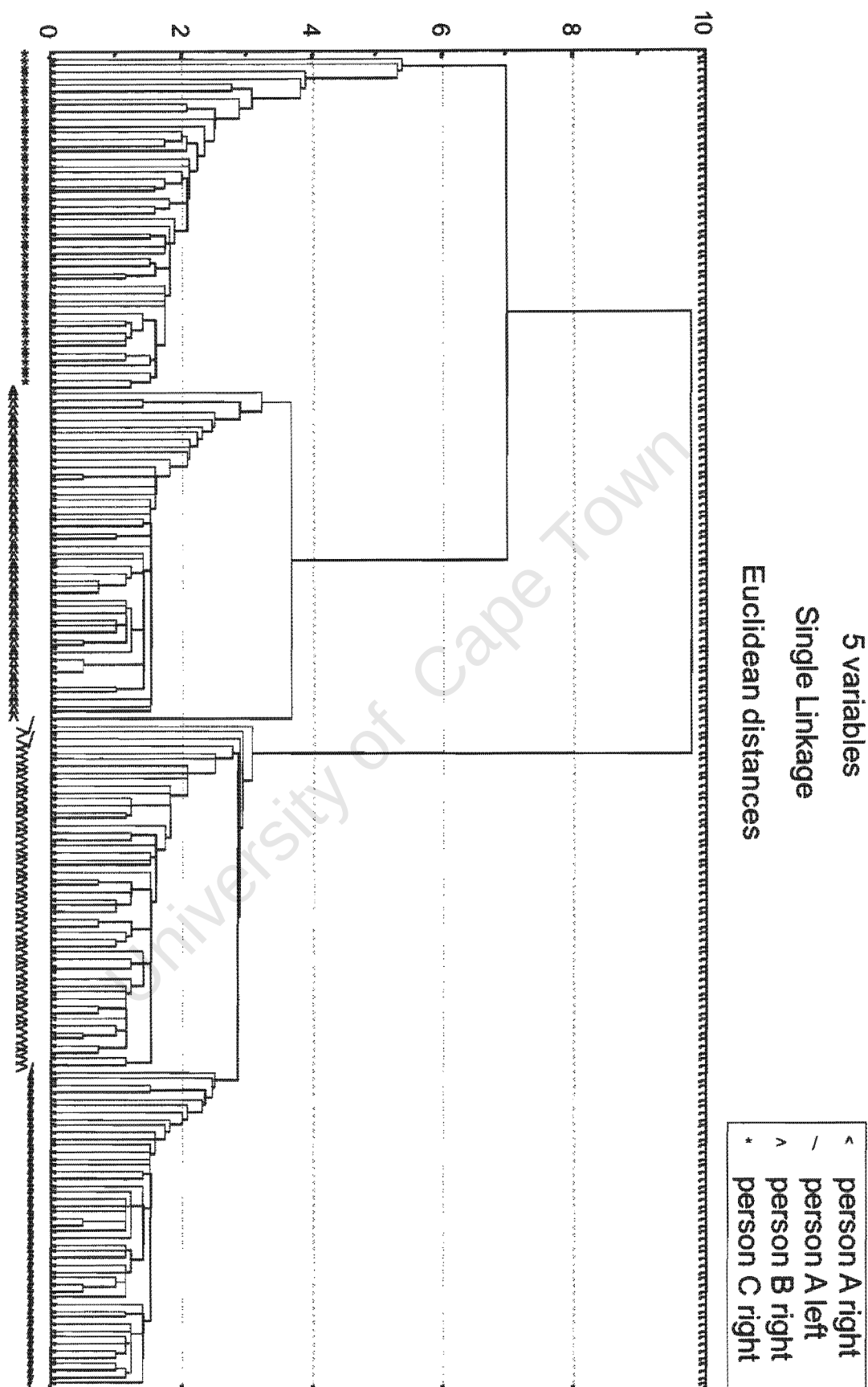


Figure 51: Cluster analysis of 5 handprint-variables to distinguish between 3 persons - SETS A1, A2, B, C (1)

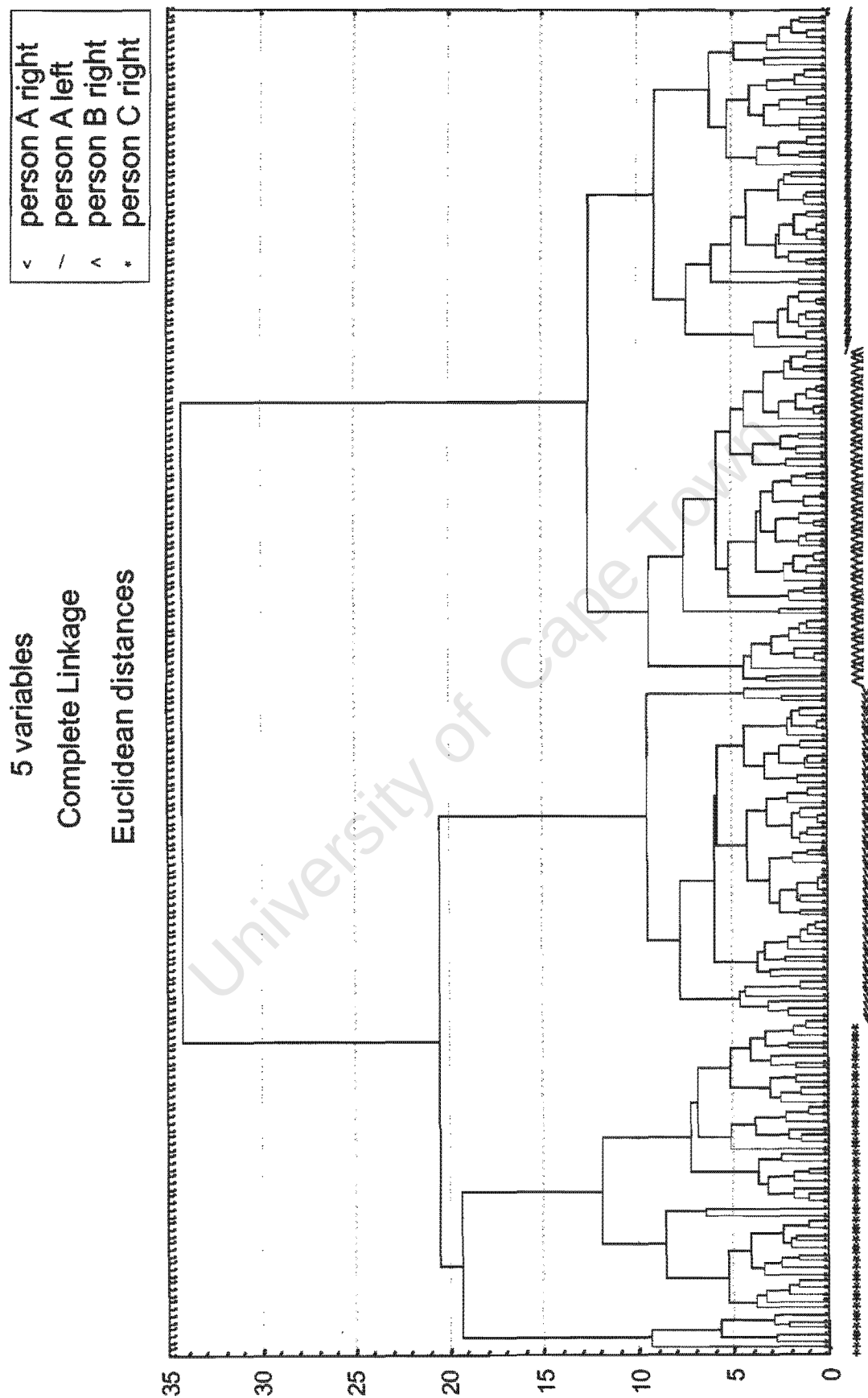


Figure 52: Cluster analysis of 5 handprint-variables to distinguish between 3 persons - SETS A1, A2, B, C (2)

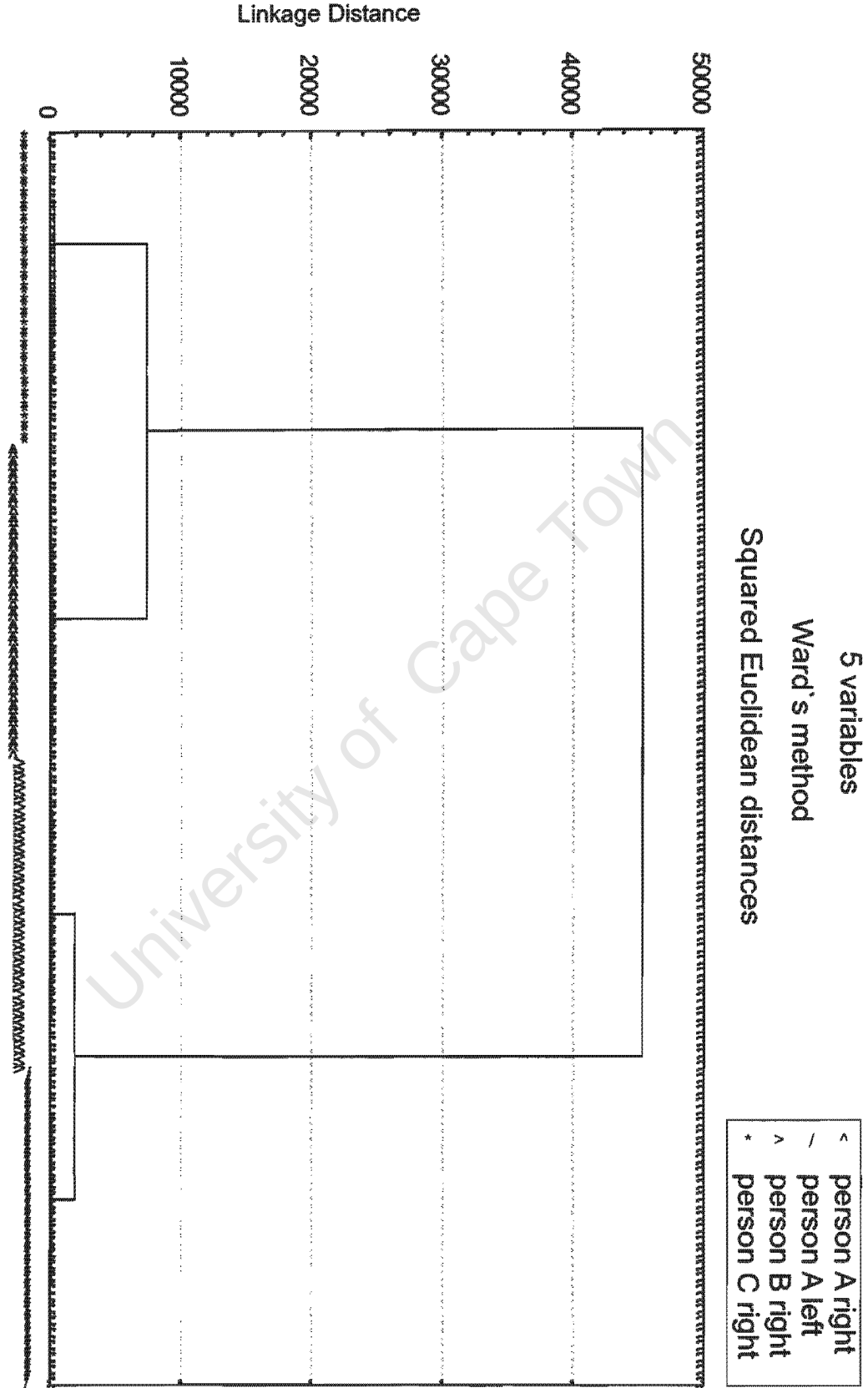


Figure 53: Cluster analysis of 5 handprint-variables to distinguish between 3 persons - SETS A1, A2, B, C (3)

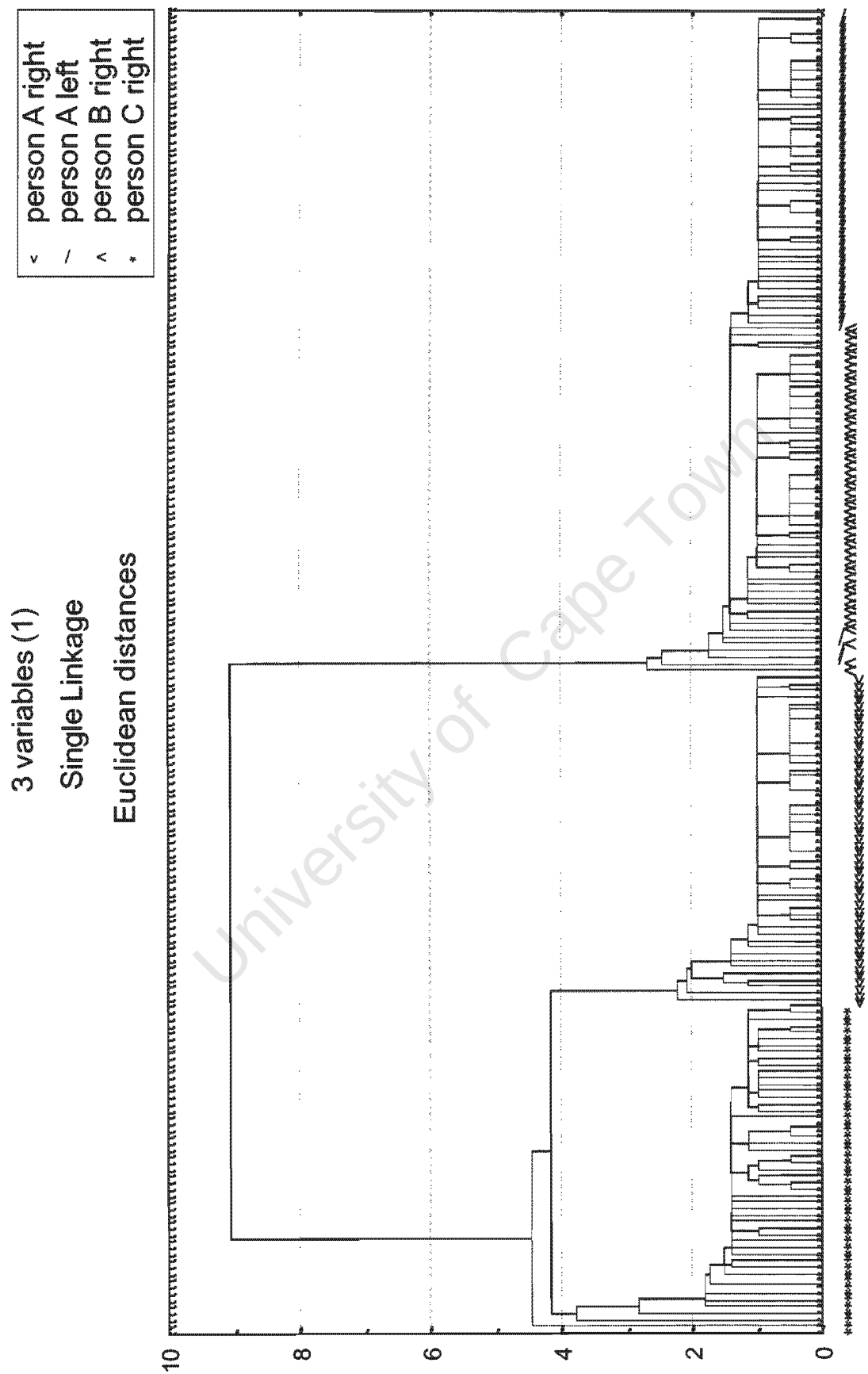


Figure 54: Cluster analysis of 3 handprint-variables (1) to distinguish between 3 persons - SETS A1, A2, B, C (1)

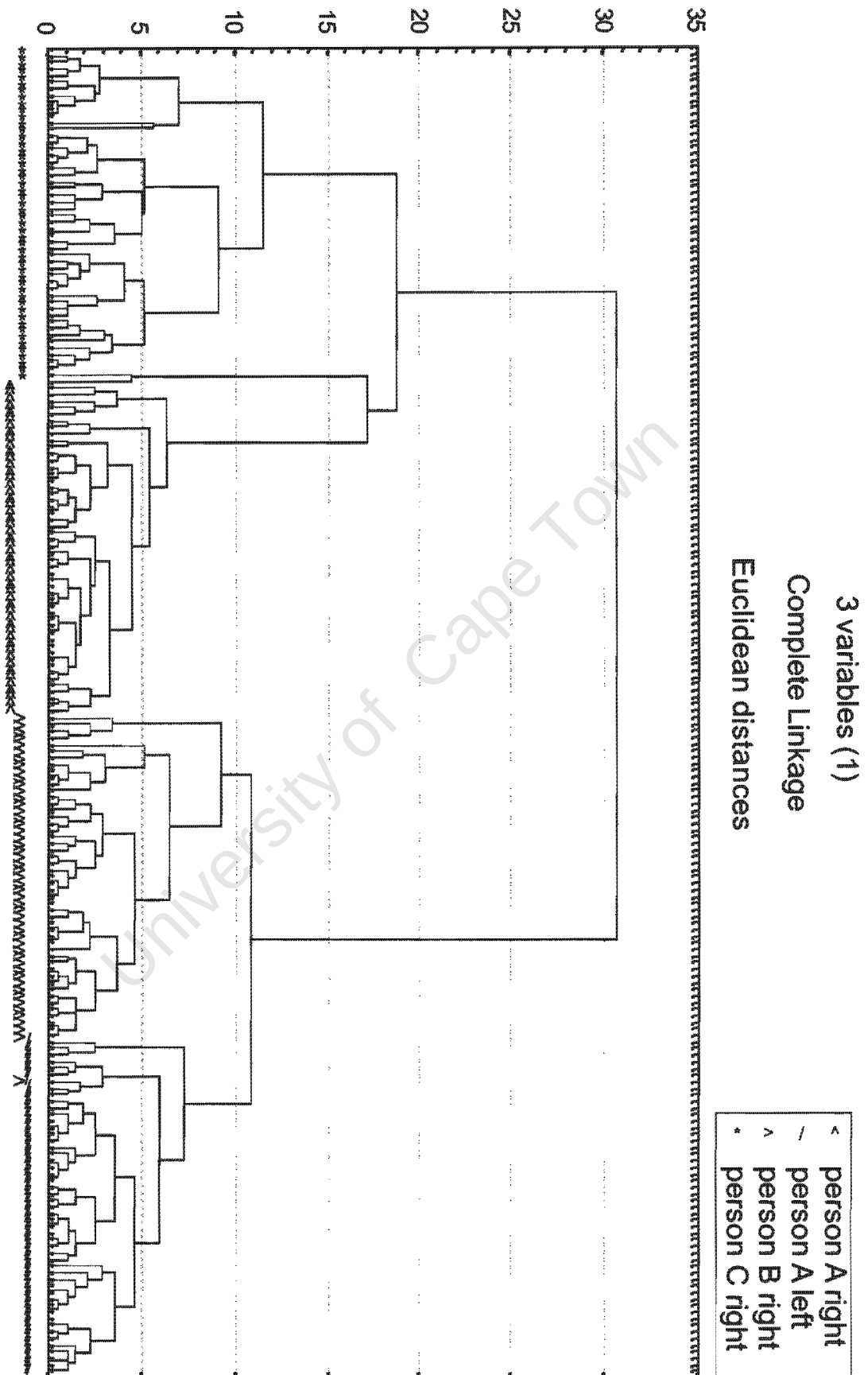


Figure 55: Cluster analysis of 3 handprint-variables (1) to distinguish between 3 persons - SETS A1, A2, B, C (2)

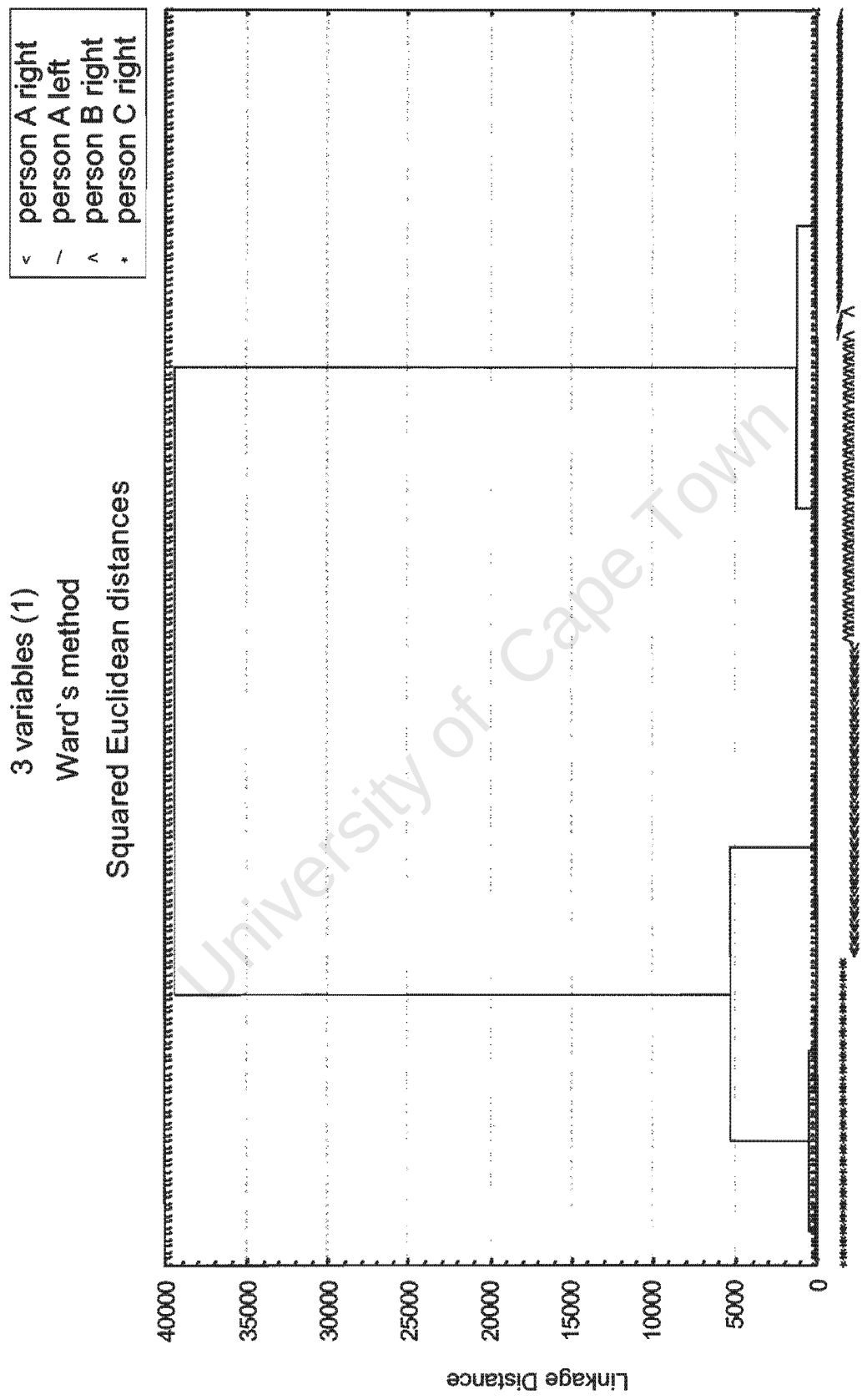


Figure 56: Cluster analysis of 3 handprint-variables (1) to distinguish between 3 persons - SETS A1, A2, B, C (3)

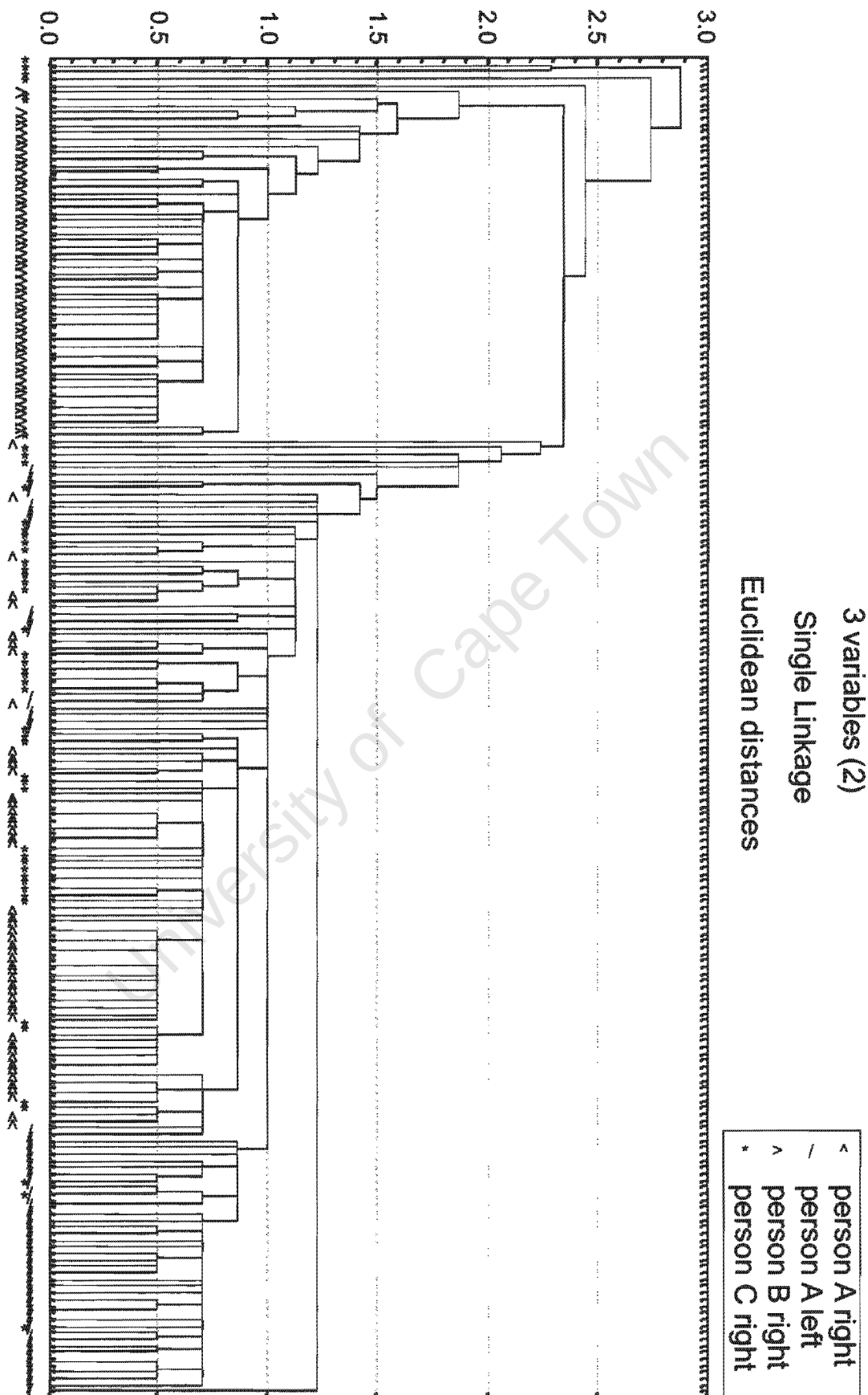


Figure 57: Cluster analysis of 3 handprint-variables (2) to distinguish between 3 persons - SETS A1, A2, B, C (1)

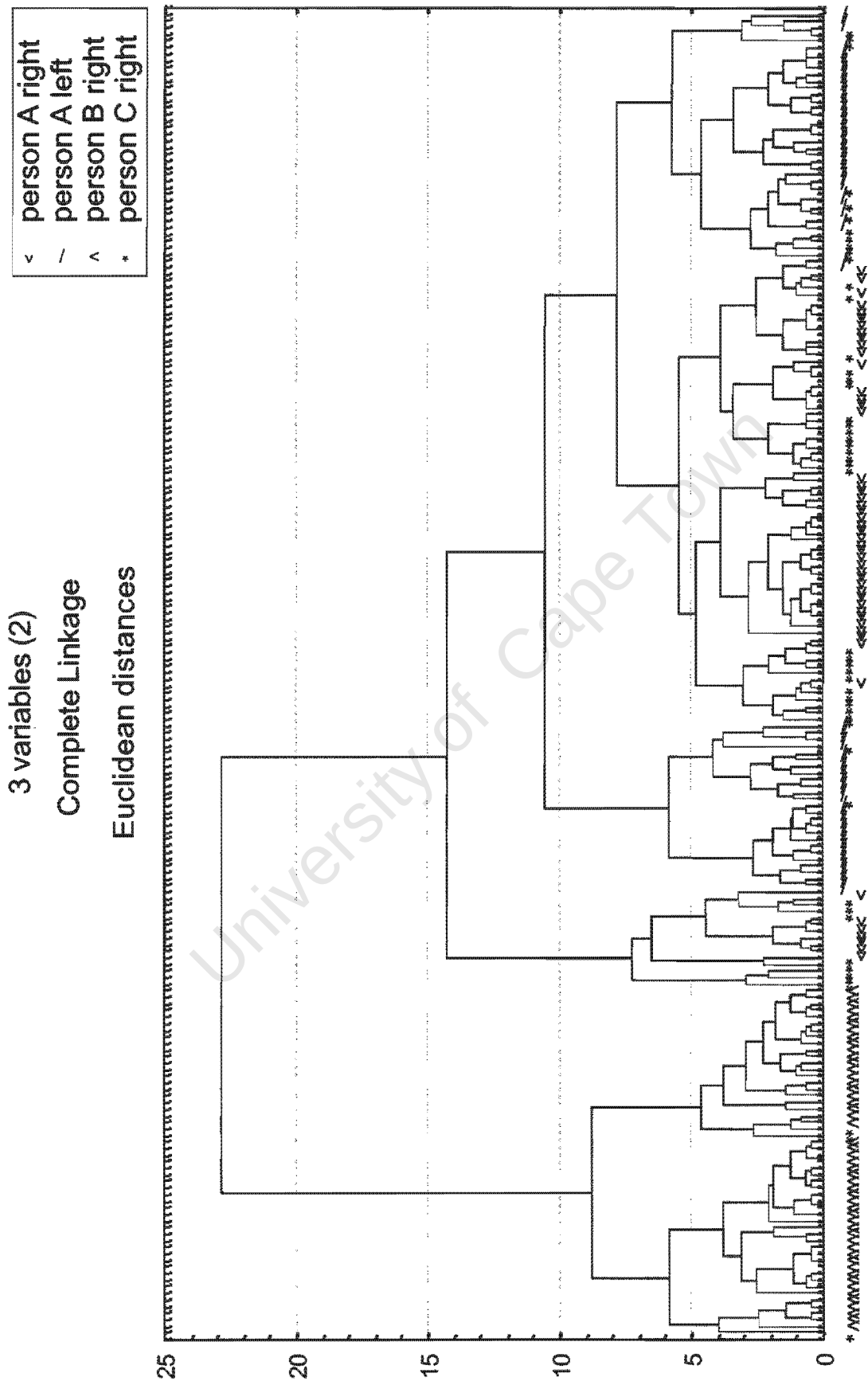


Figure 58: Cluster analysis of 3 handprint-variables (2) to distinguish between 3 persons - SETS A1, A2, B, C (2)

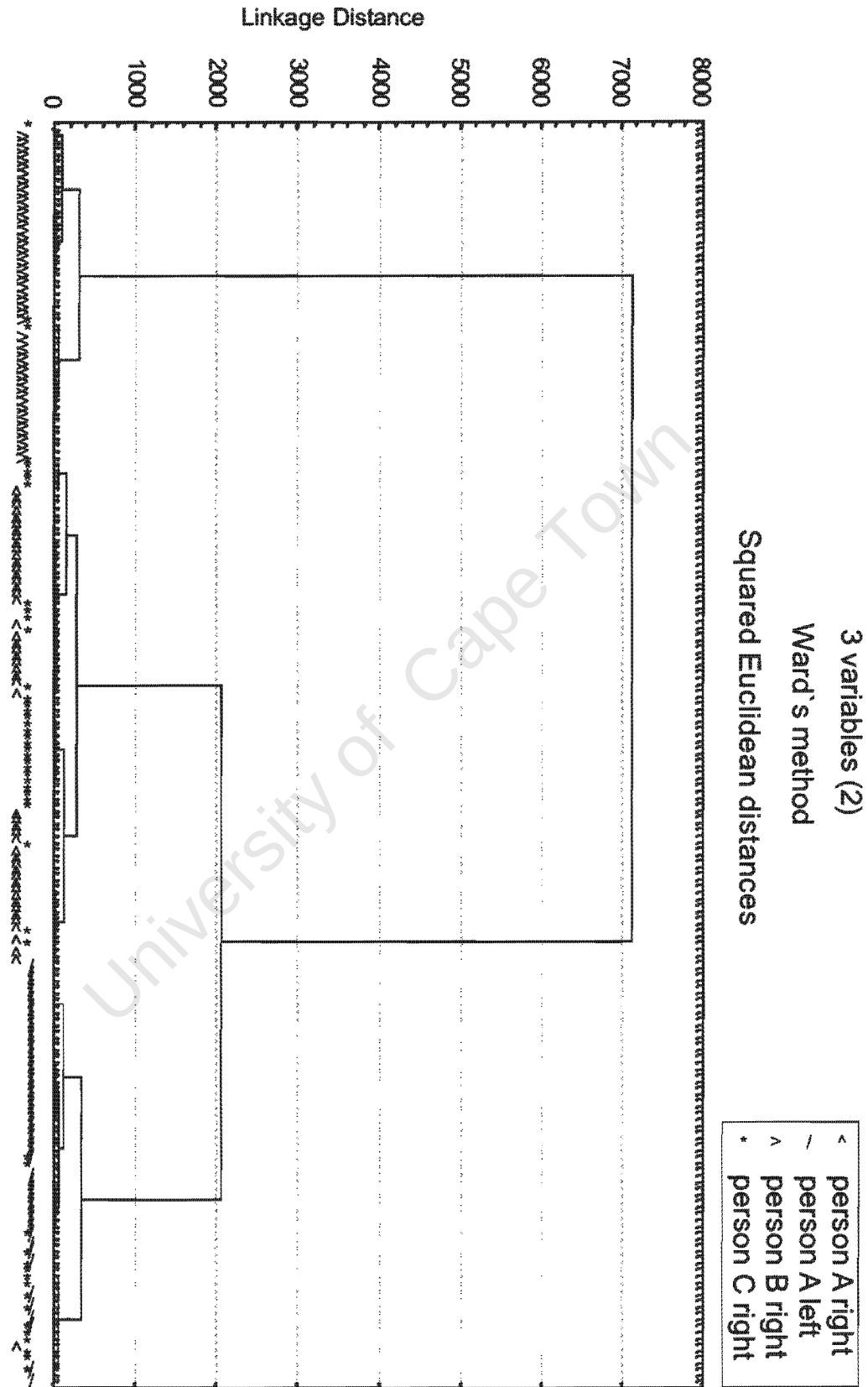


Figure 59: Cluster analysis of 3 handprint-variables (2) to distinguish between 3 persons - SETS A1, A2, B, C (3)

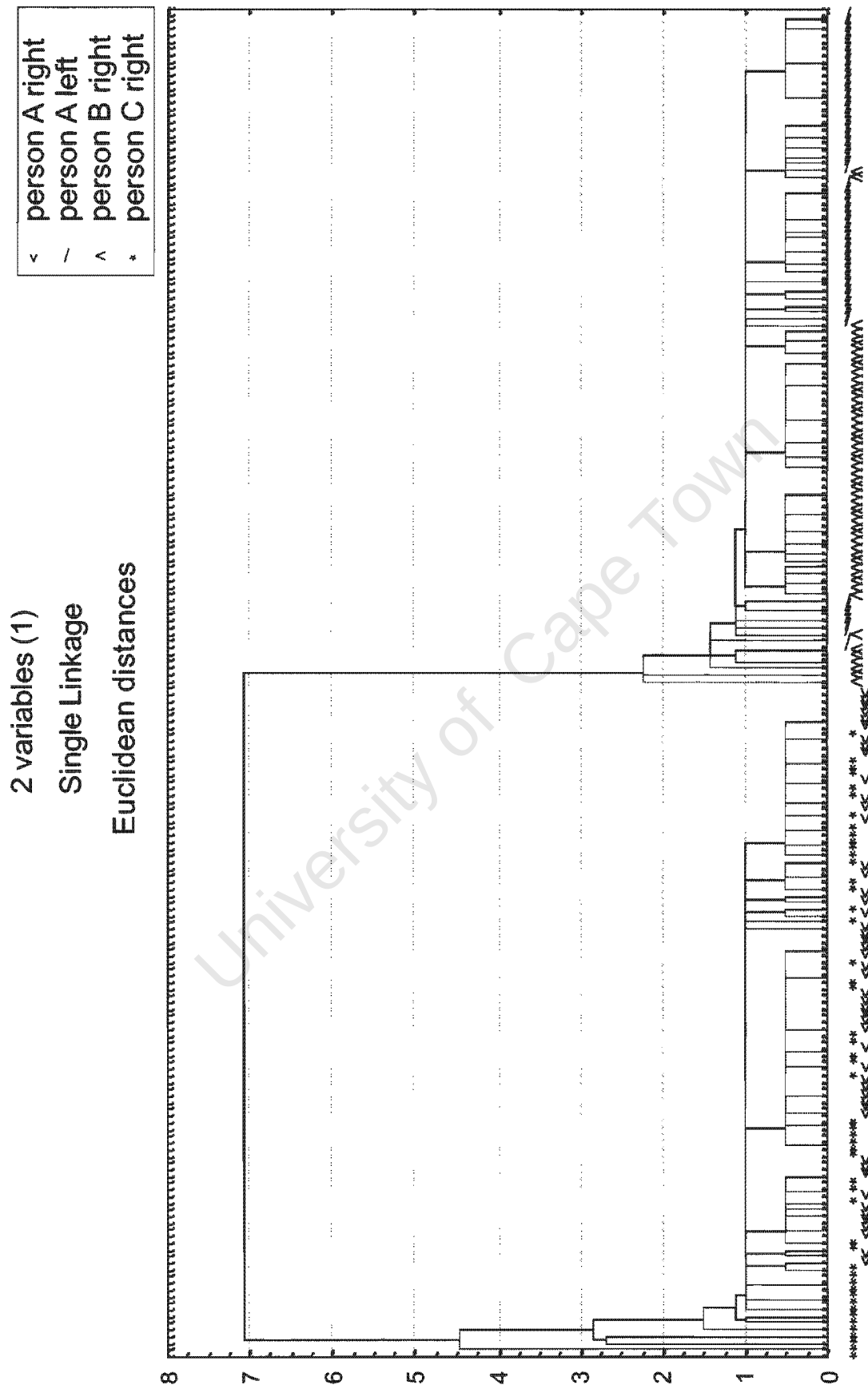


Figure 60: Cluster analysis of 2 handprint-variables (1) to distinguish between 3 persons - SETS A1, A2, B, C (1)

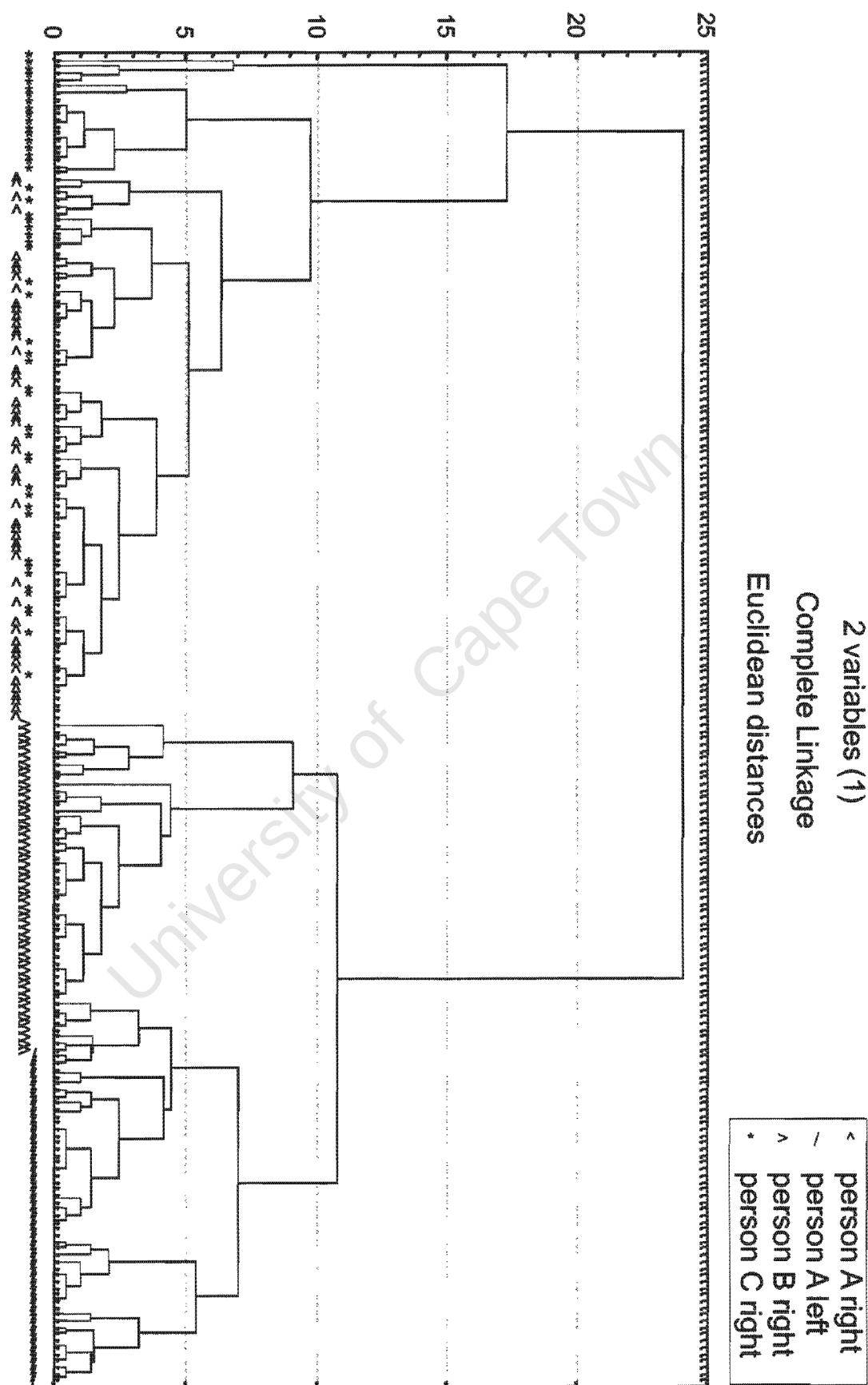


Figure 61: Cluster analysis of 2 handprint-variables (1) to distinguish between 3 persons - SETS A1, A2, B, C (2)

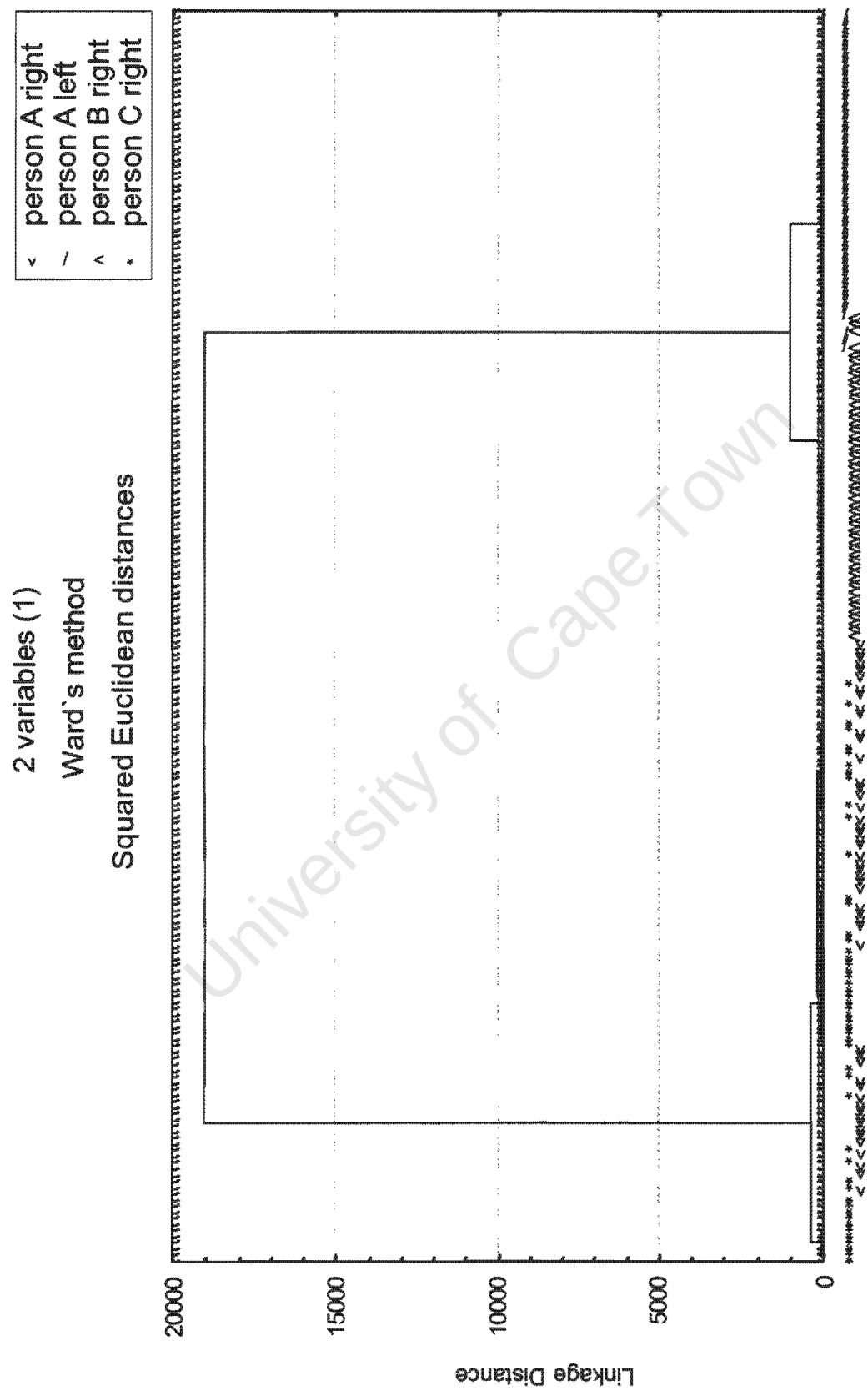


Figure 62: Cluster analysis of 2 handprint-variables (1) to distinguish between 3 persons - SETS A1, A2, B, C (3)

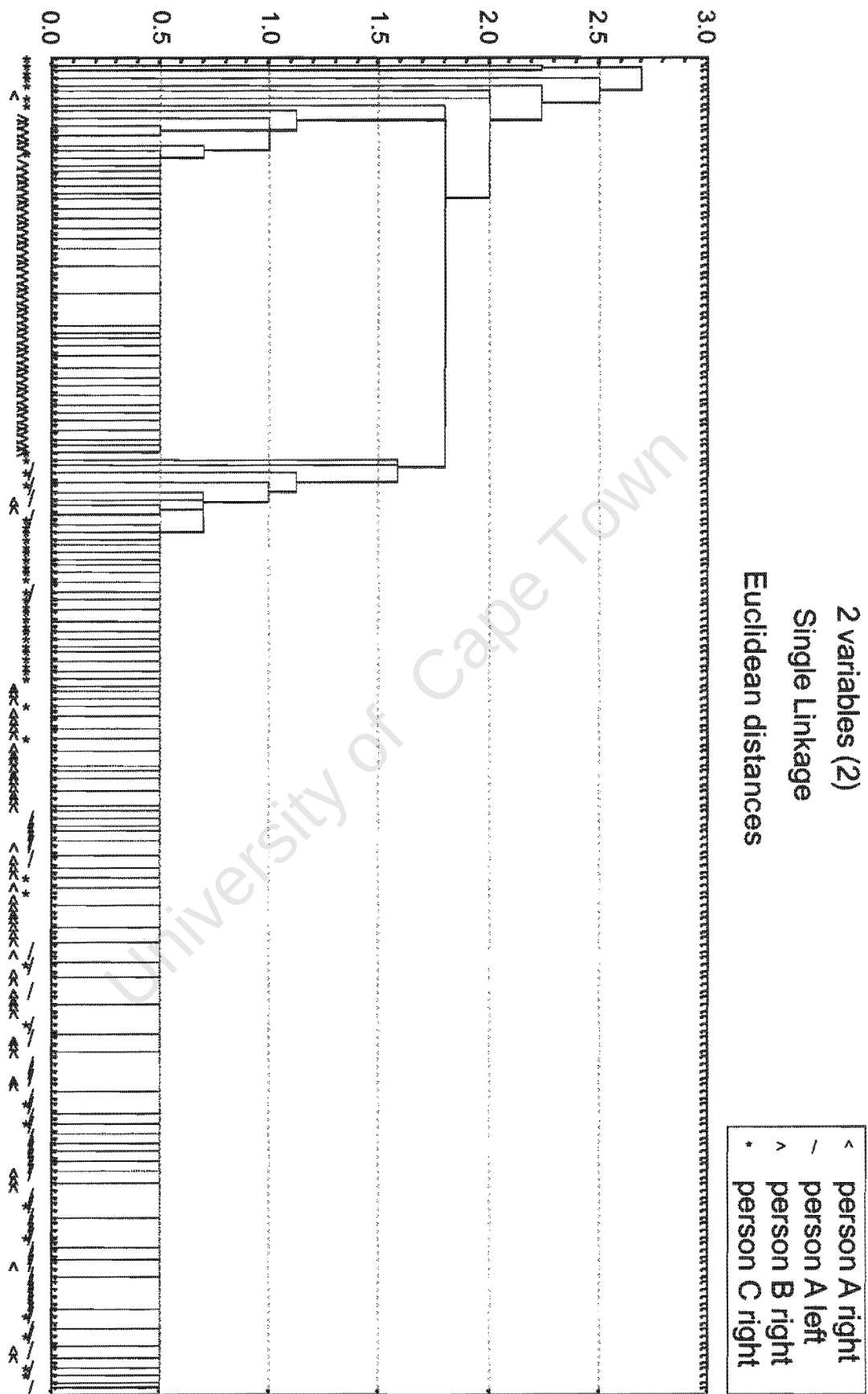


Figure 63: Cluster analysis of 2 handprint-variables (2) to distinguish between 3 persons - SETS A1, A2, B, C (1)

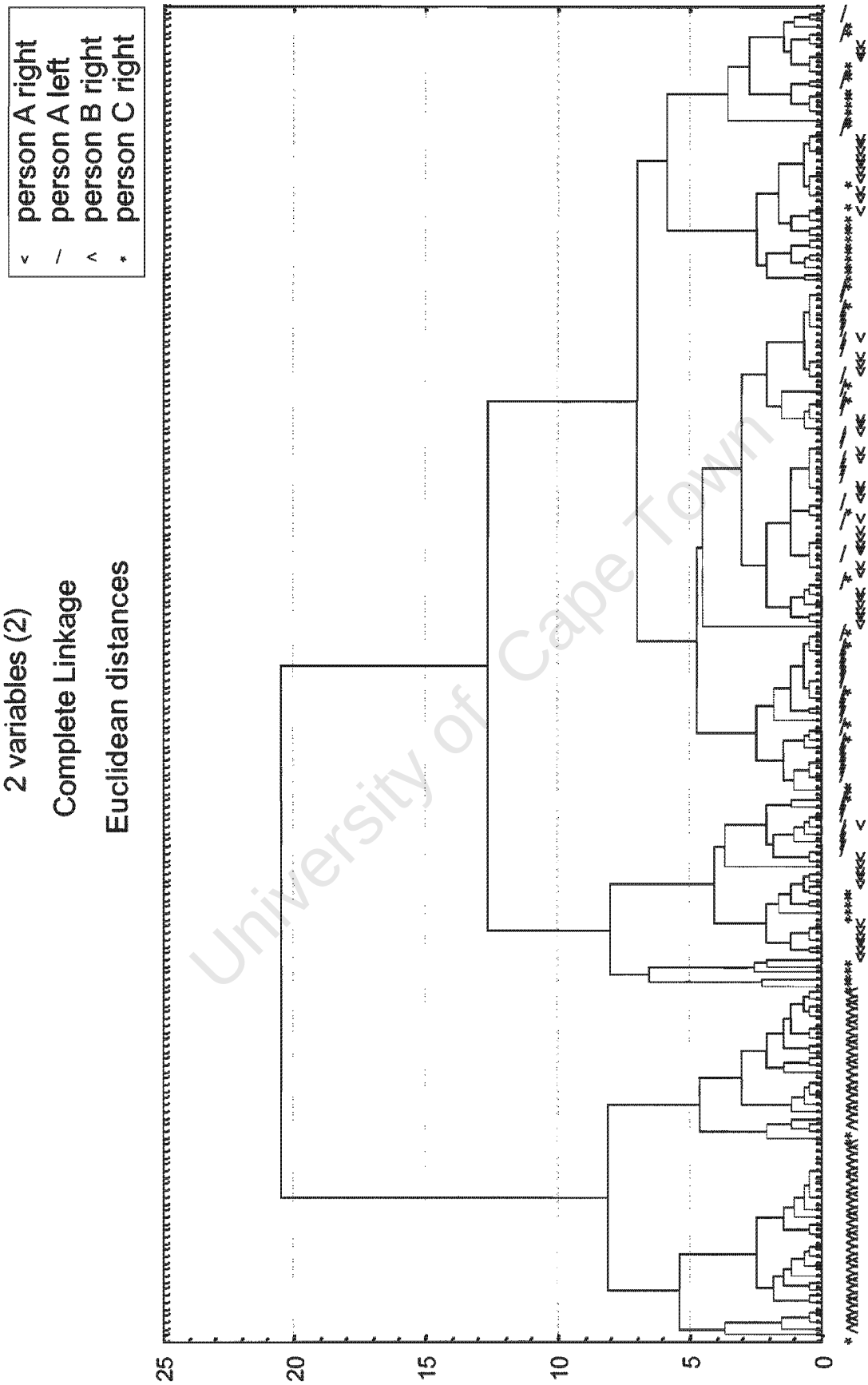


Figure 64: Cluster analysis of 2 handprint-variables (2) to distinguish between 3 persons - SETS A1, A2, B, C (2)

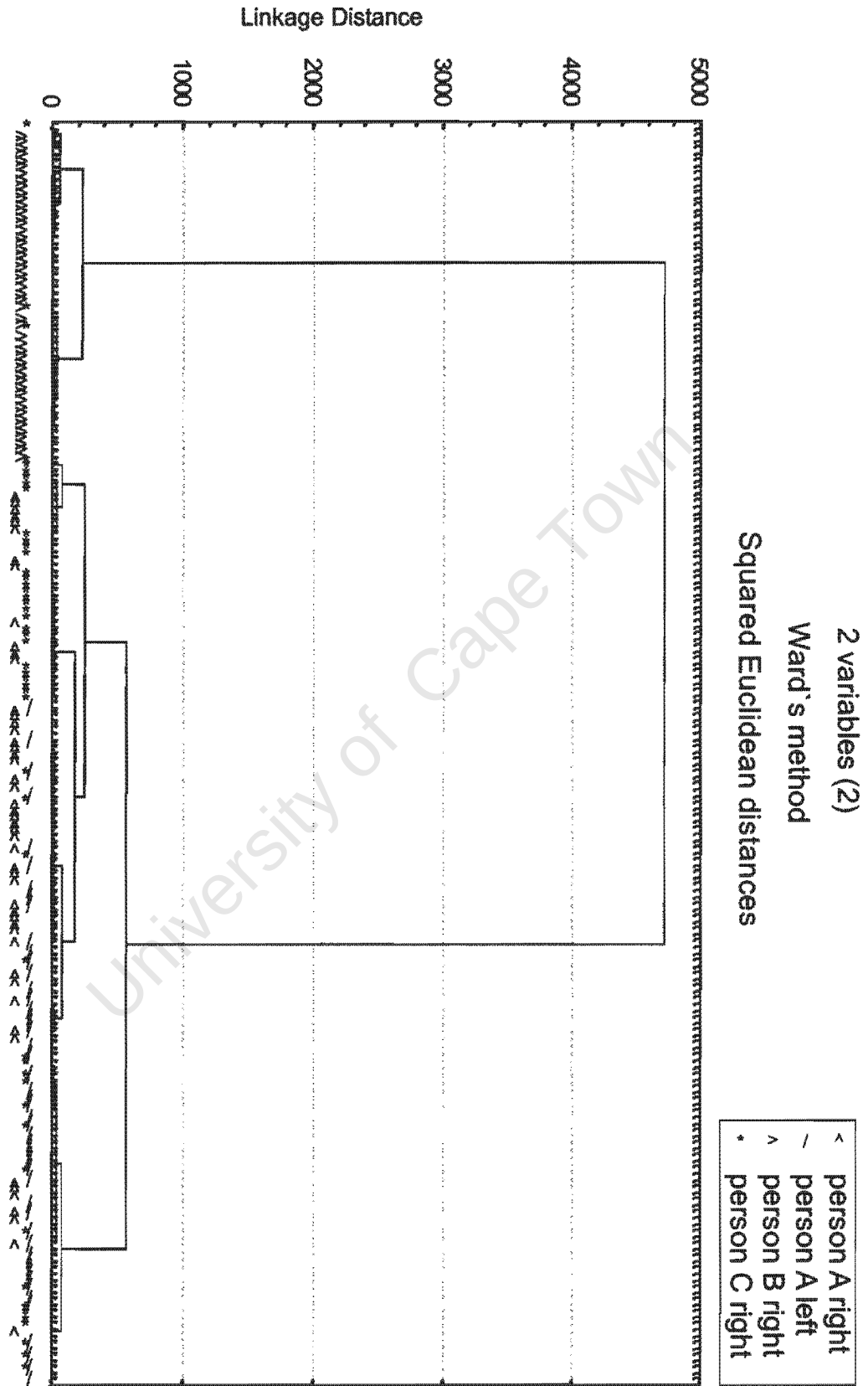


Figure 65: Cluster analysis of 2 handprint-variables (2) to distinguish between 3 persons - SETS A1, A2, B, C (3)

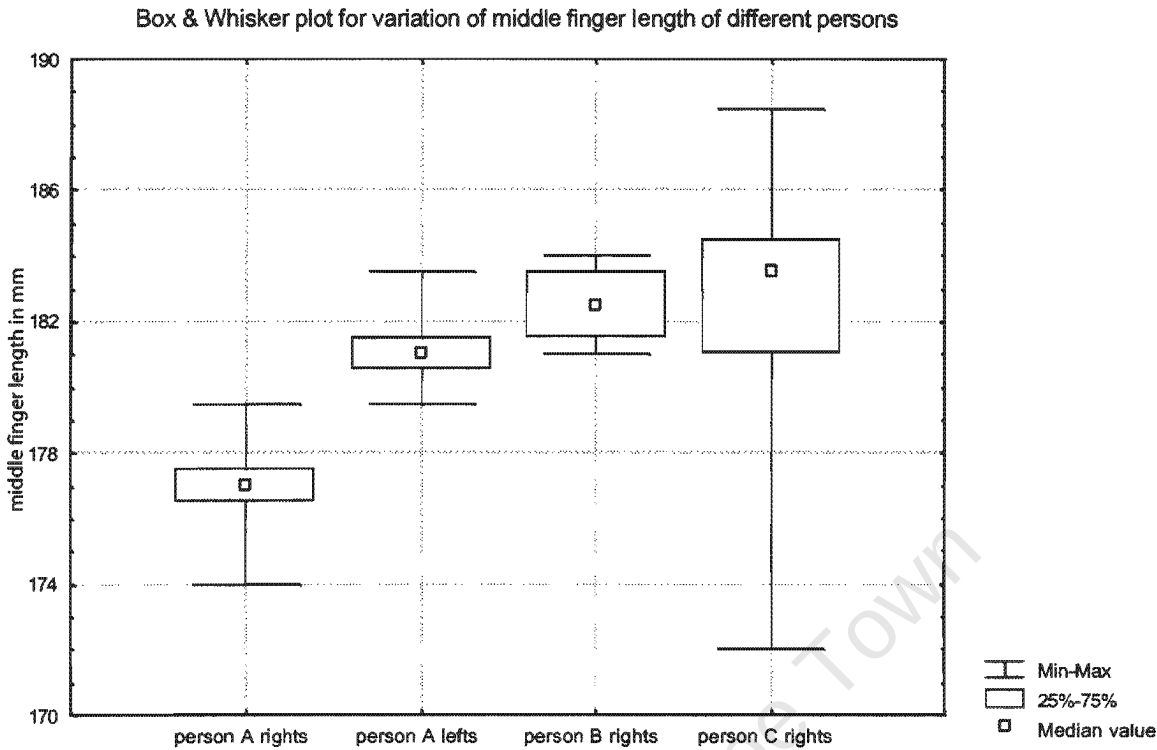


Figure 66: Box and whisker exhibiting middle finger length variation of 3 persons (A1, A2, B, C)

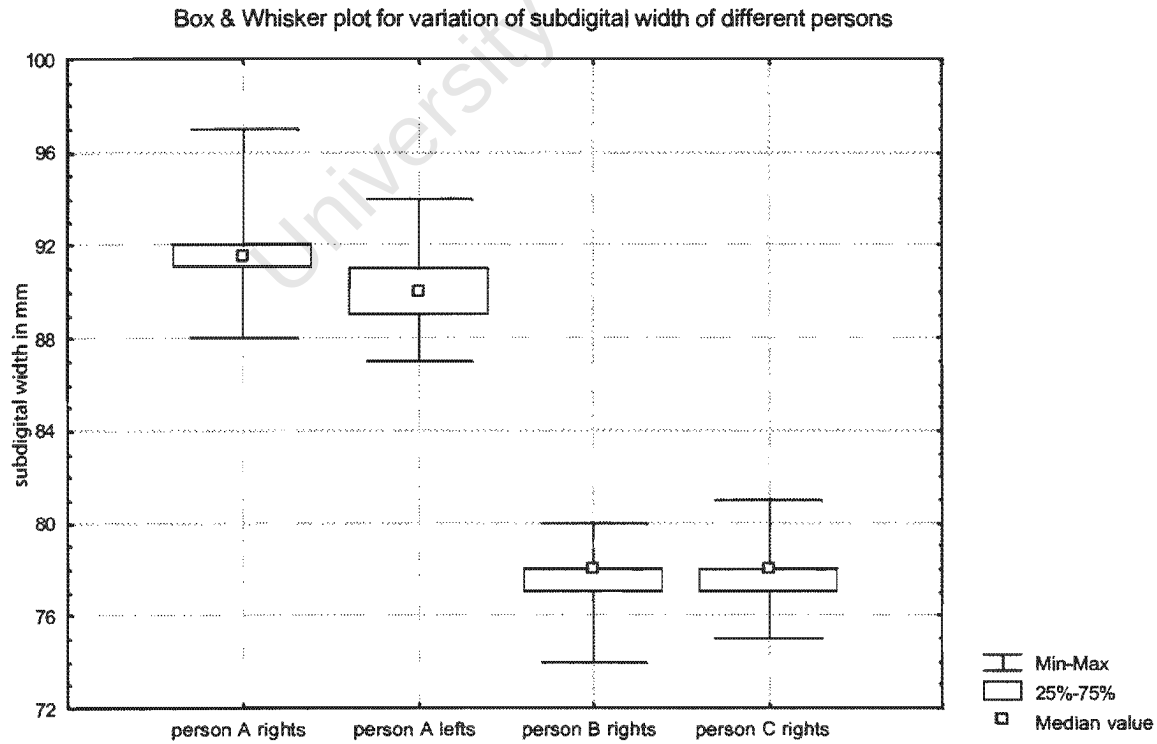


Figure 67: Box and whisker exhibiting subdigital width variation of 3 persons (A1, A2, B, C)

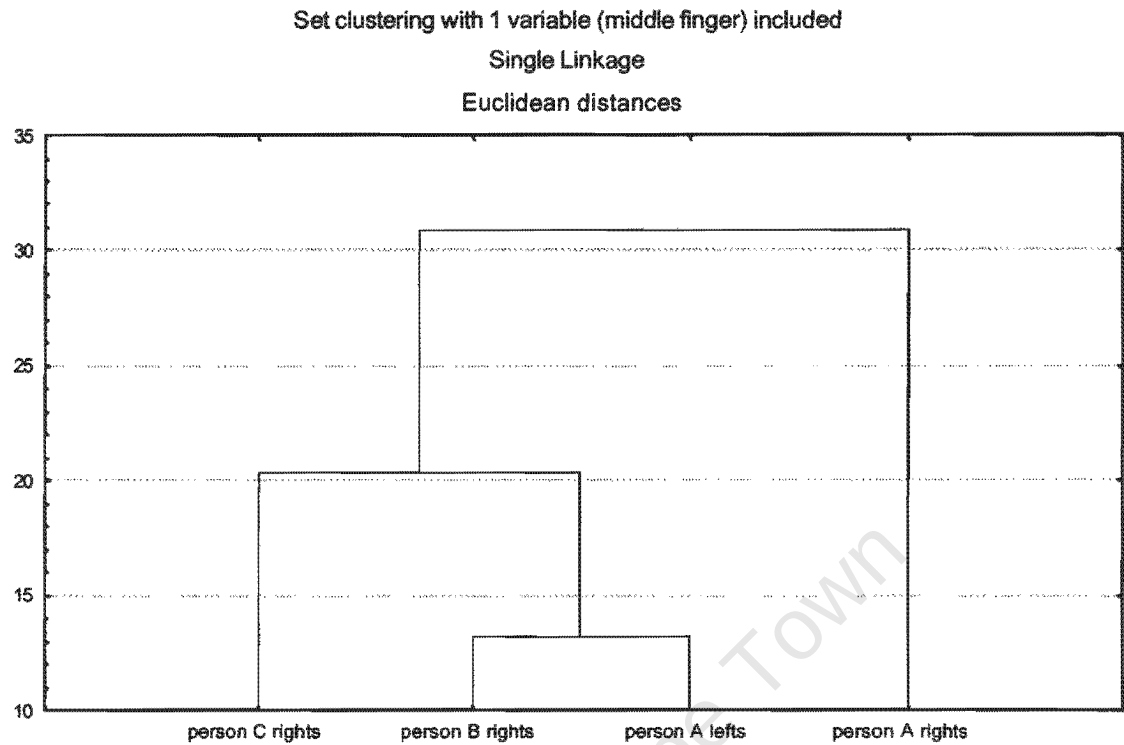


Figure 68: Cluster analysis of sets of 3 people (A1, A2, B, C) using middle finger (1)

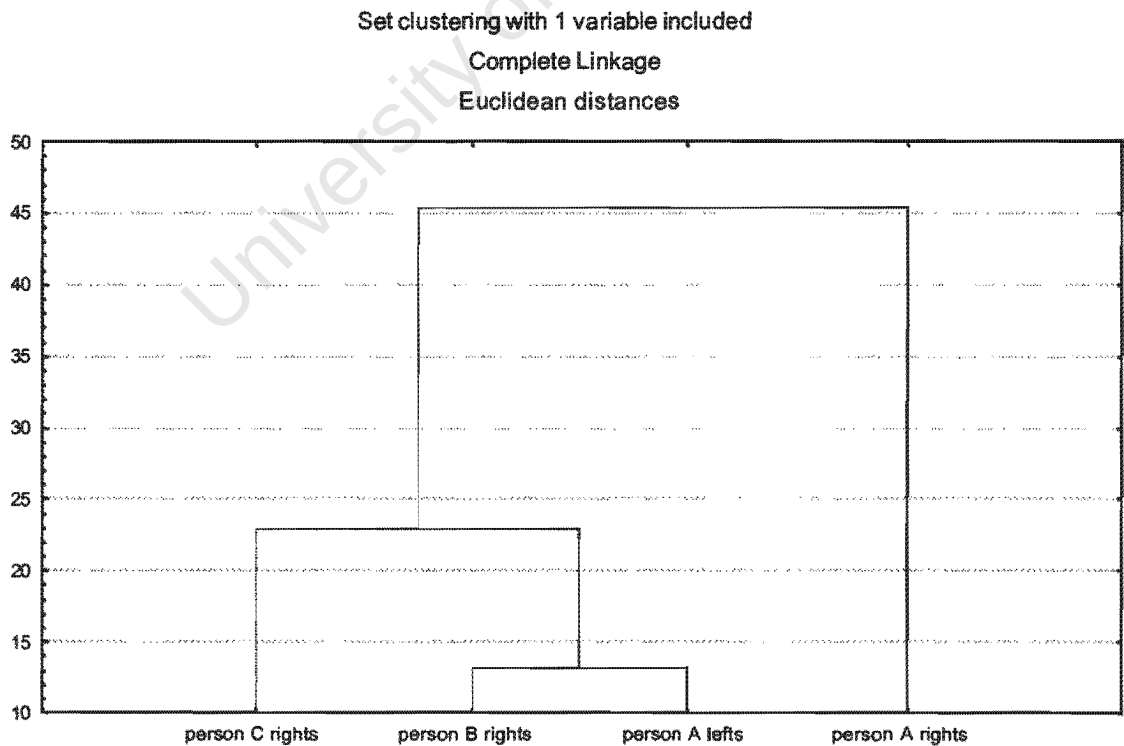


Figure 69: Cluster analysis of sets of 3 people (A1, A2, B, C) using middle finger (2)

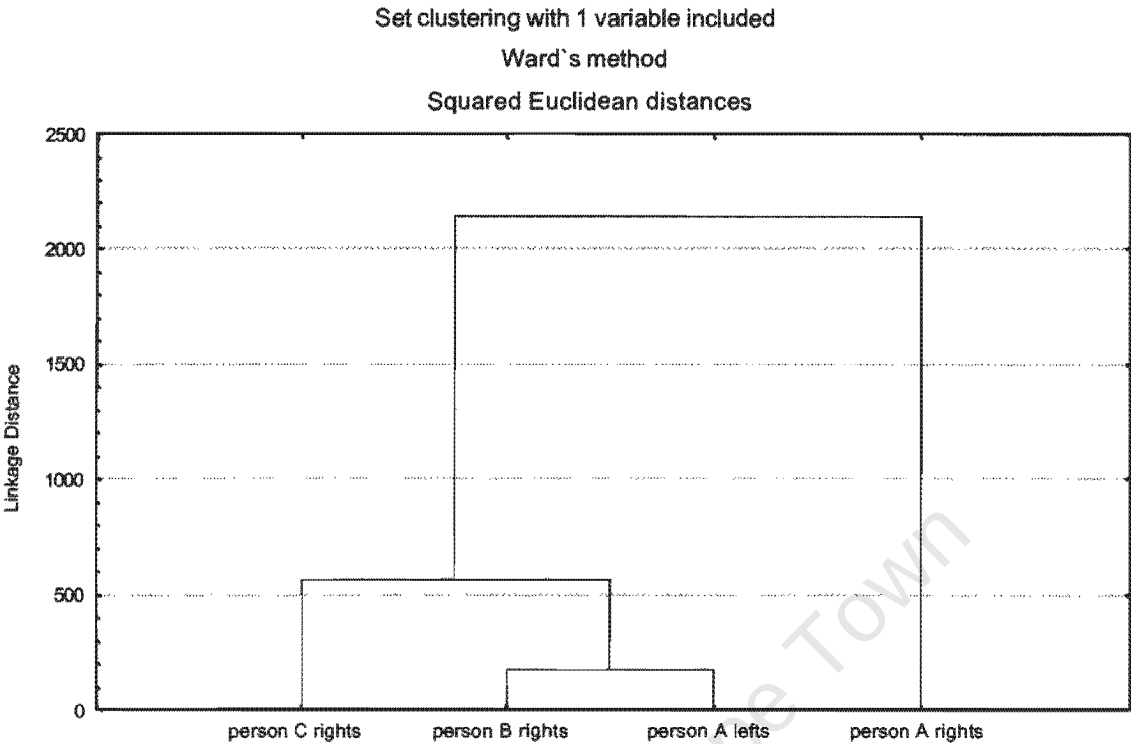


Figure 70: Cluster analysis of sets of 3 people (A1, A2, B, C) using middle finger (3)

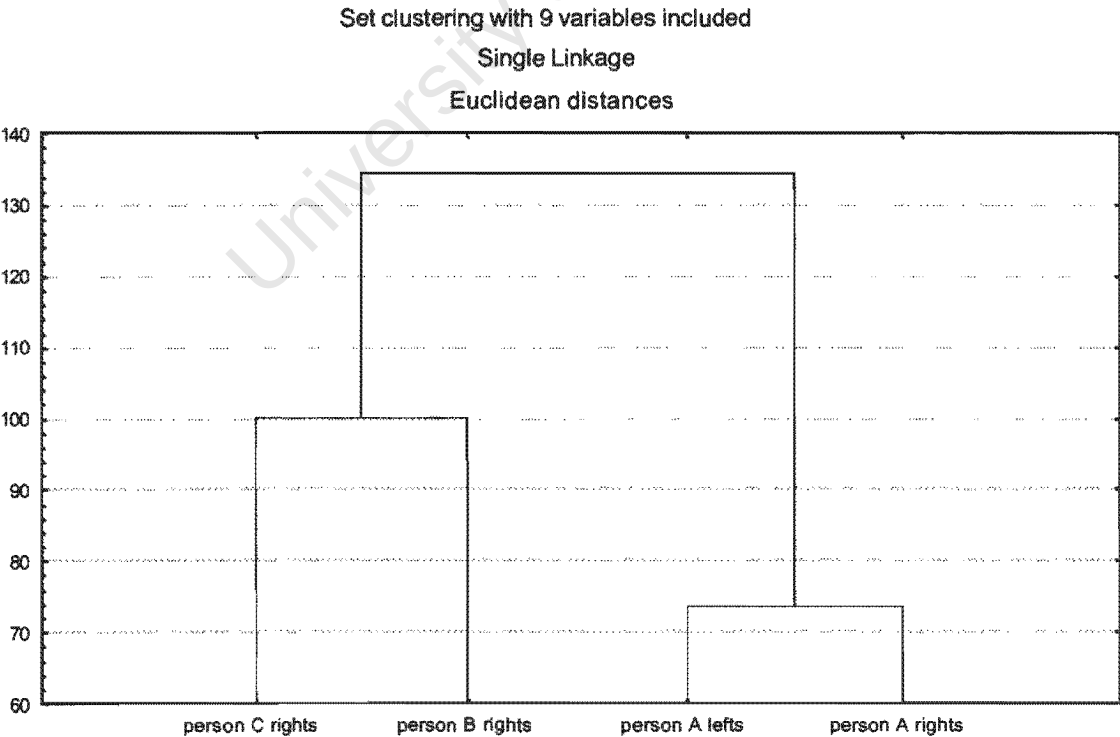


Figure 71: Cluster analysis of sets of 3 people (A1, A2, B, C) 1 using 9 variables (1)

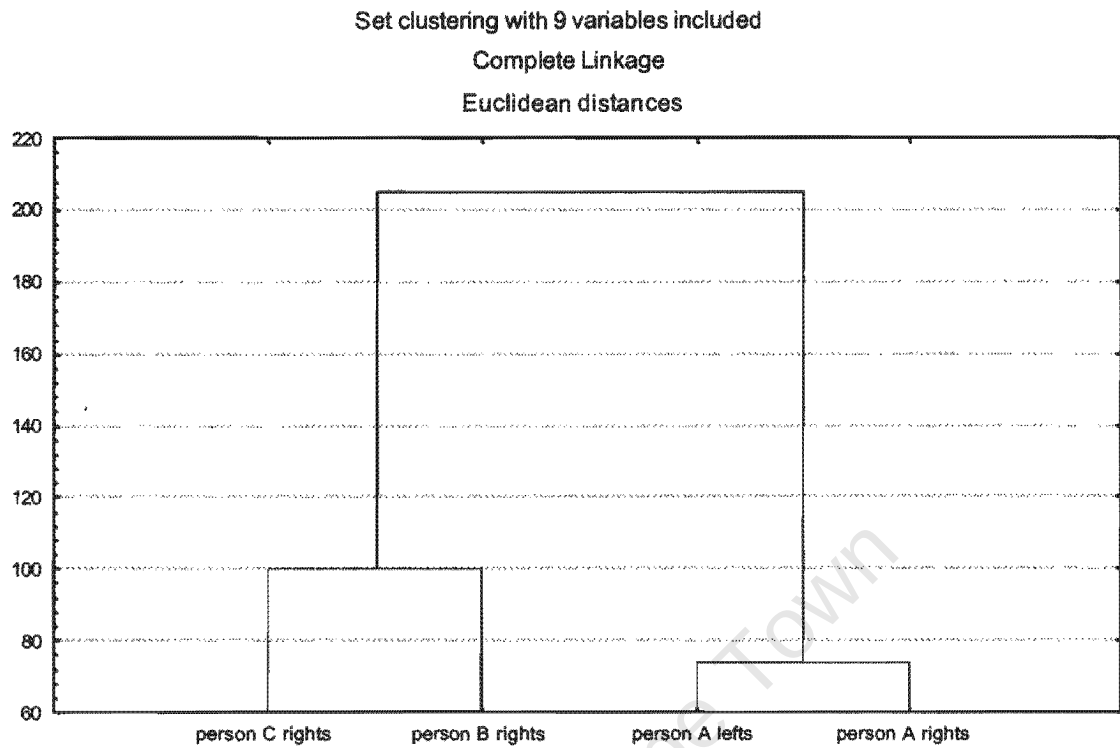


Figure 72: Cluster analysis of sets of 3 people (A1, A2, B, C) 1 using 9 variables (2)

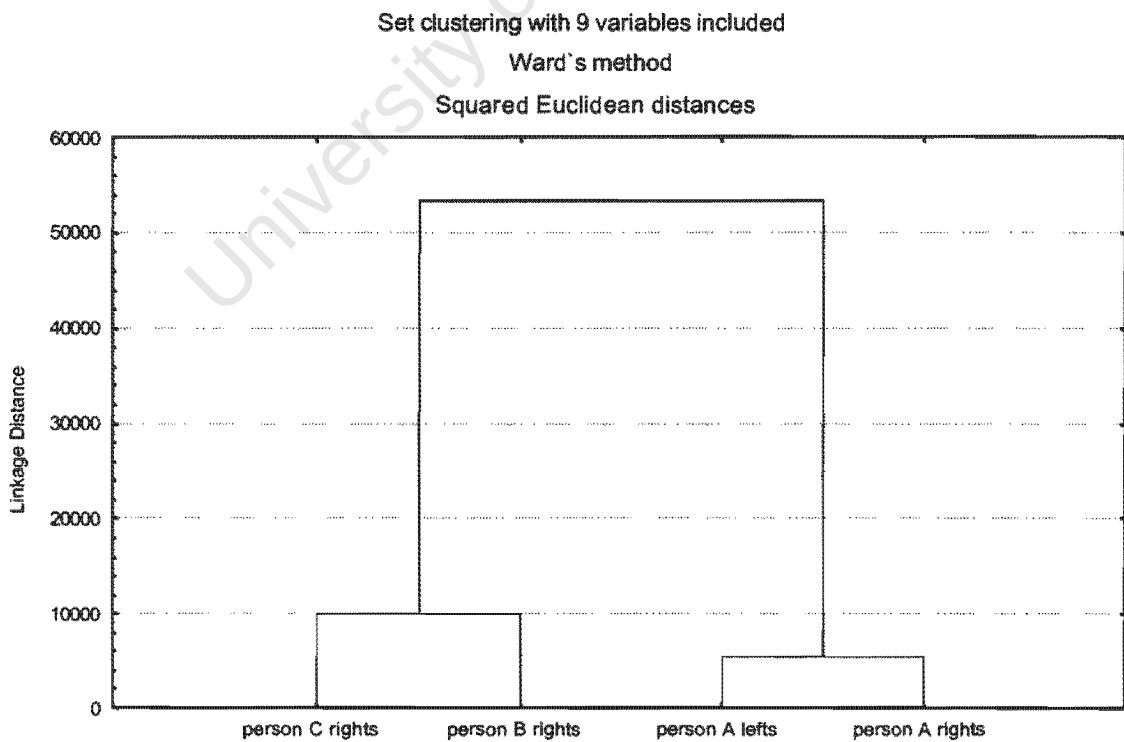
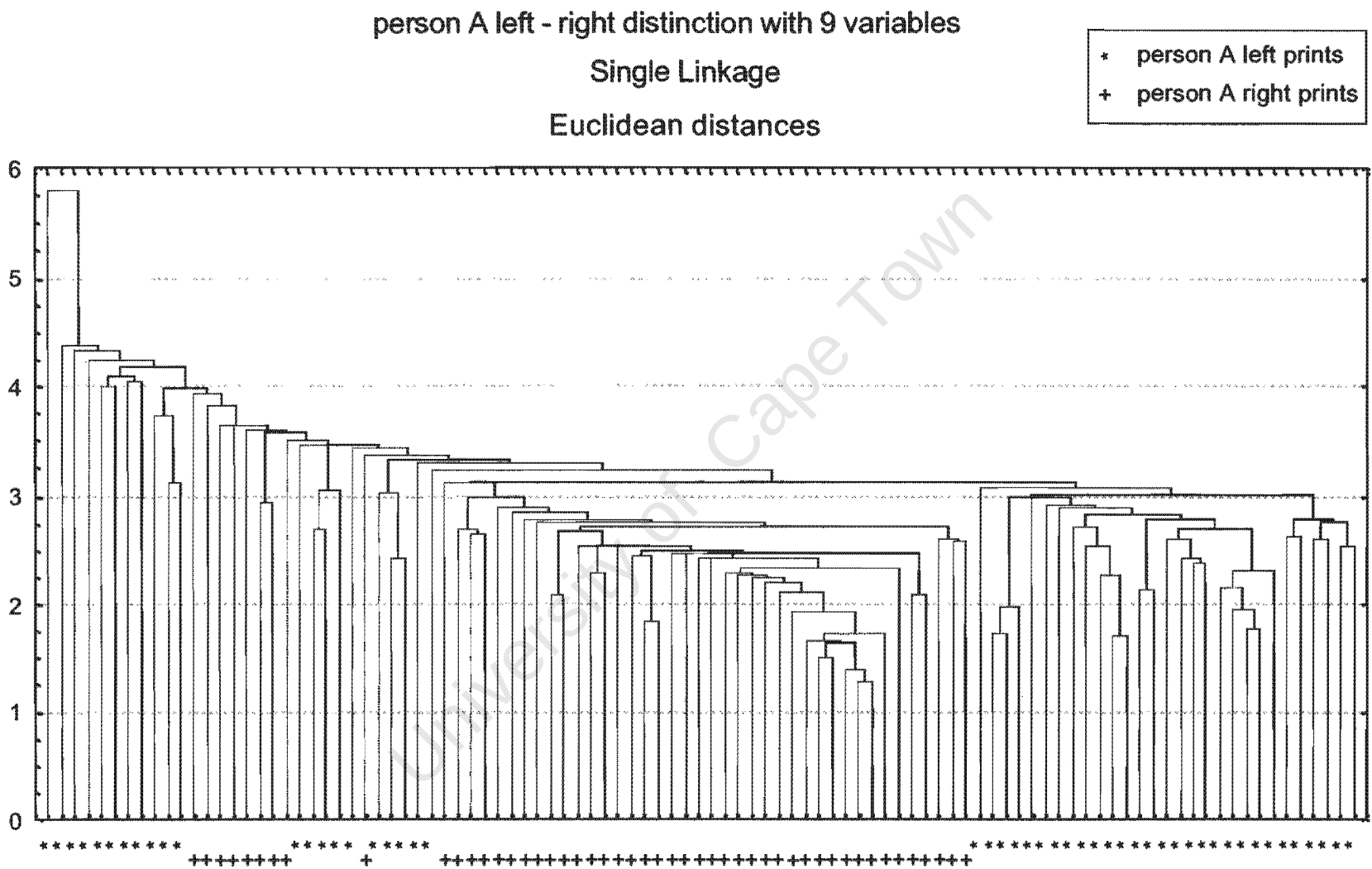


Figure 73: Cluster analysis of sets of 3 people (A1, A2, B, C) 1 using 9 variables (3)

Figure 74: Cluster analysis of 9 handprint-variables to distinguish left and right prints of person A (1)



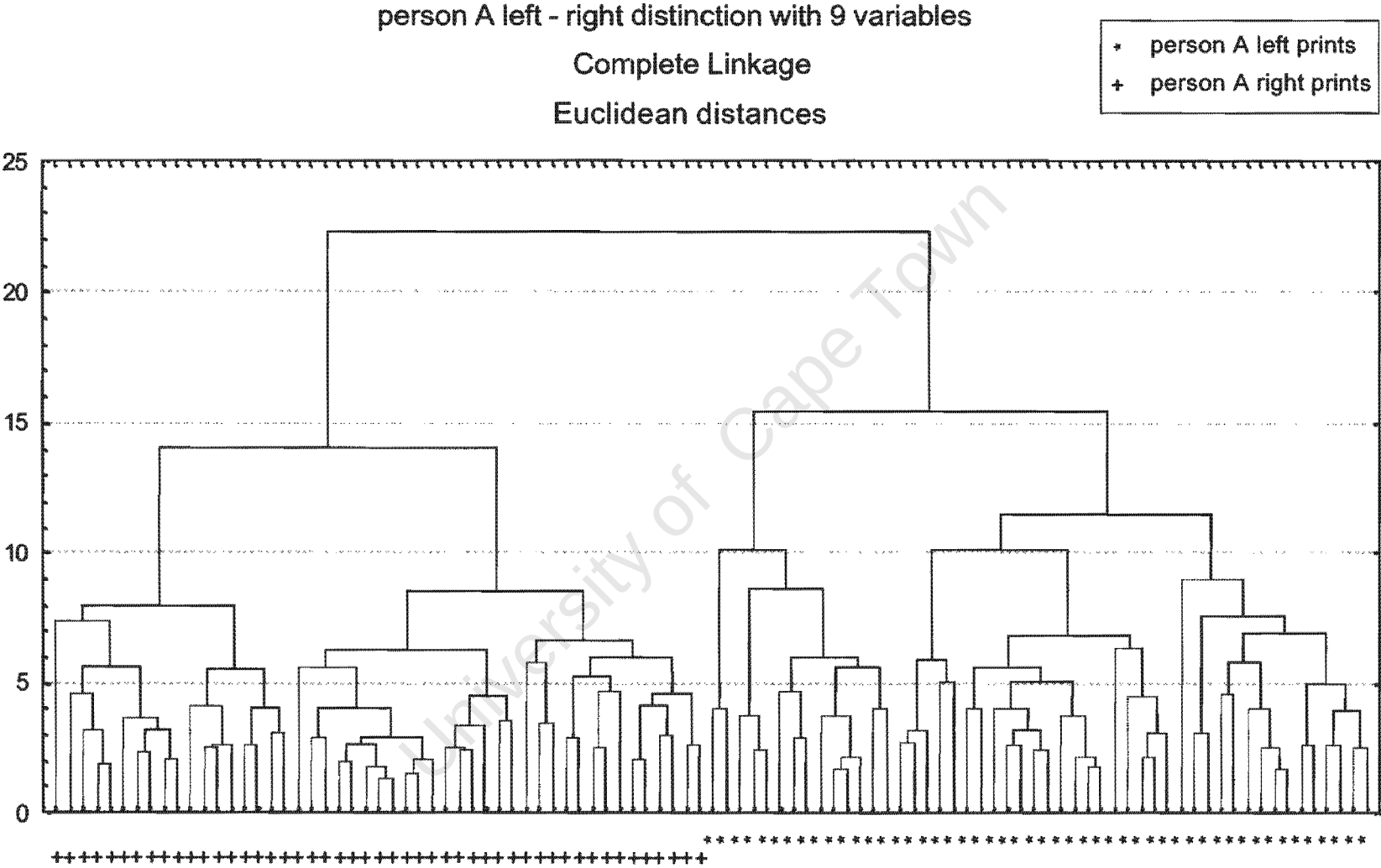


Figure 75: Cluster analysis of 9 handprint-variables to distinguish left and right prints of person A (2)

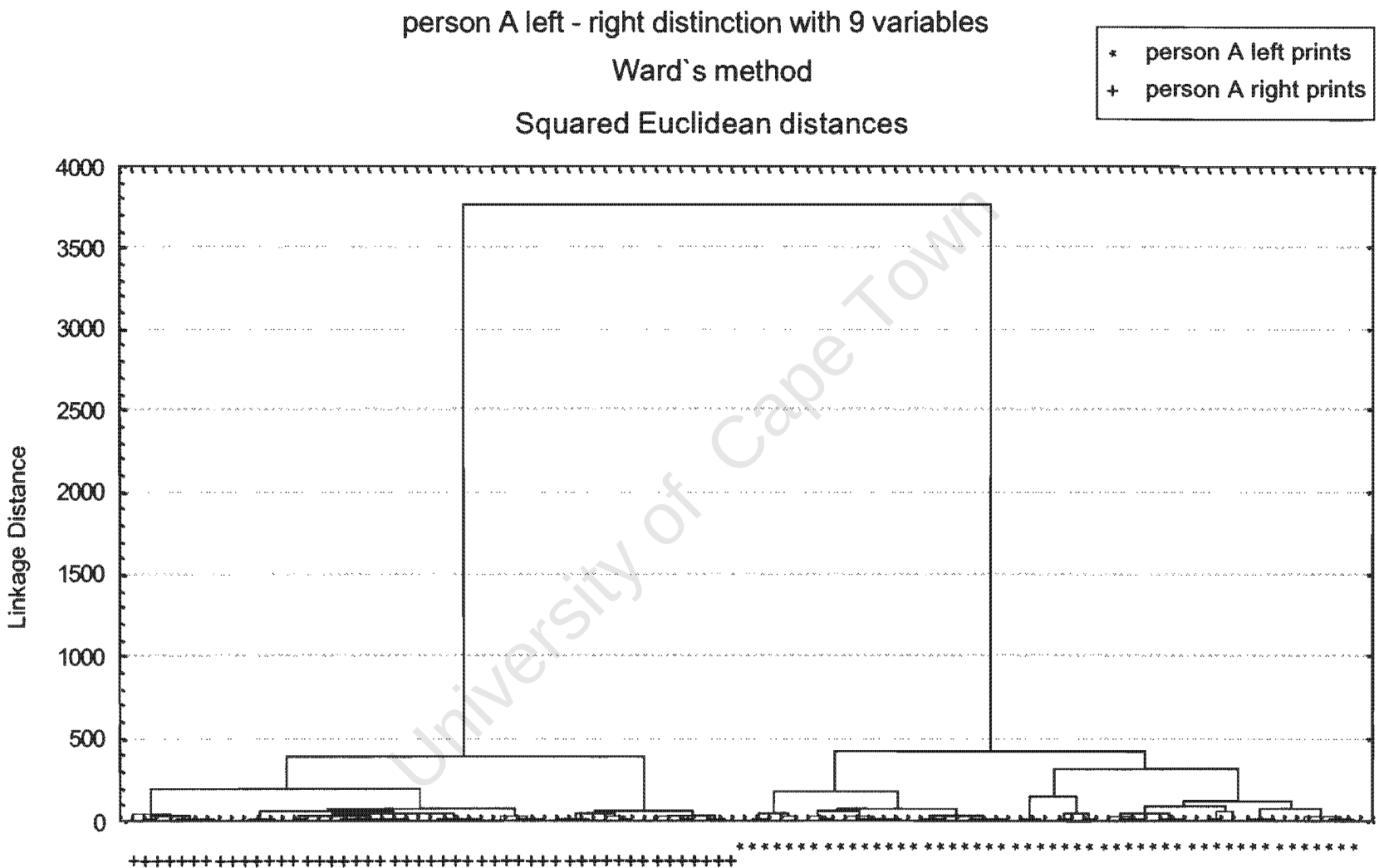


Figure 76: Cluster analysis of 9 handprint-variables to distinguish left and right prints of person A (3)

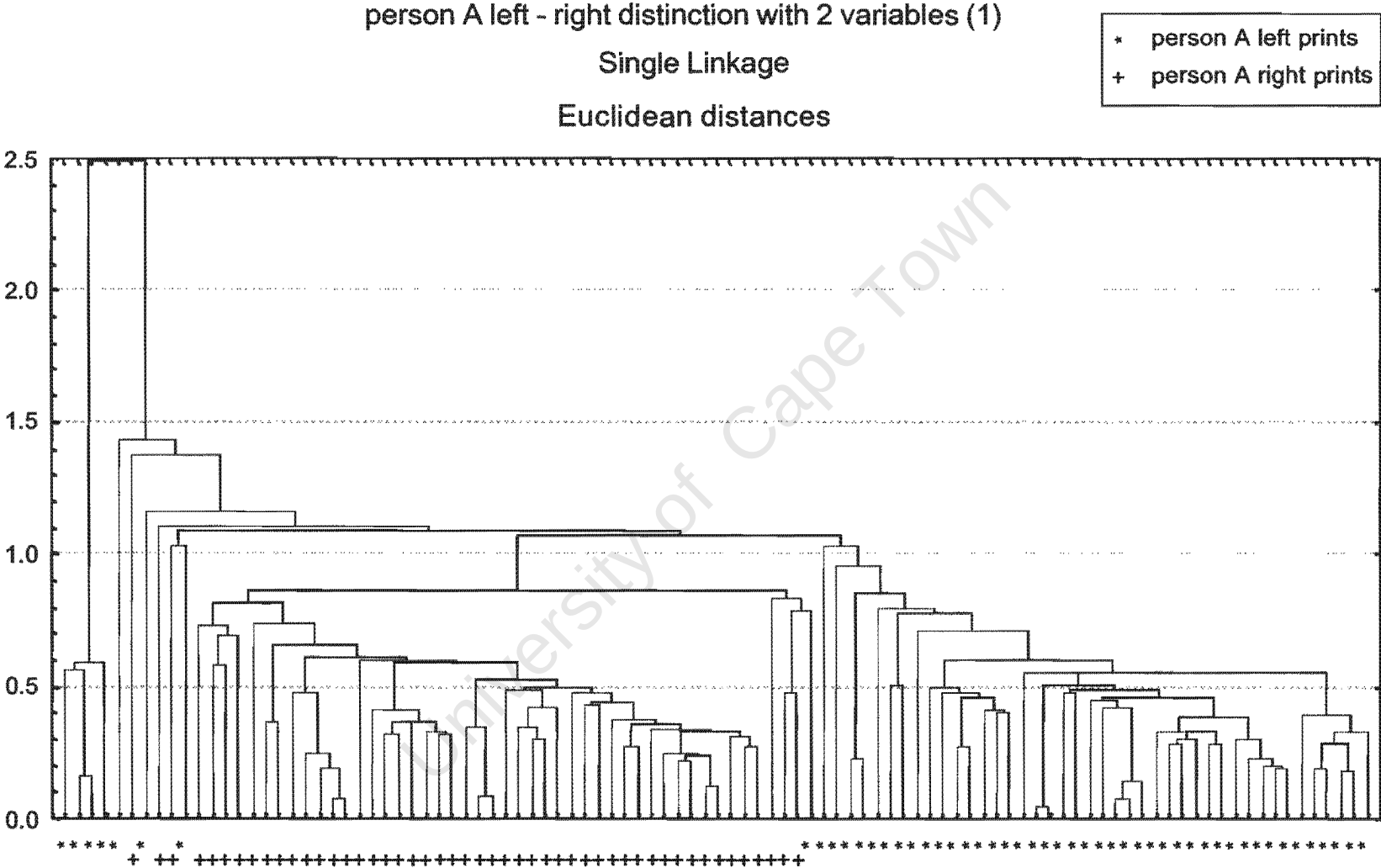


Figure 77: Cluster analysis of 2 handprint-variables (1) to distinguish left and right prints of person A (1)

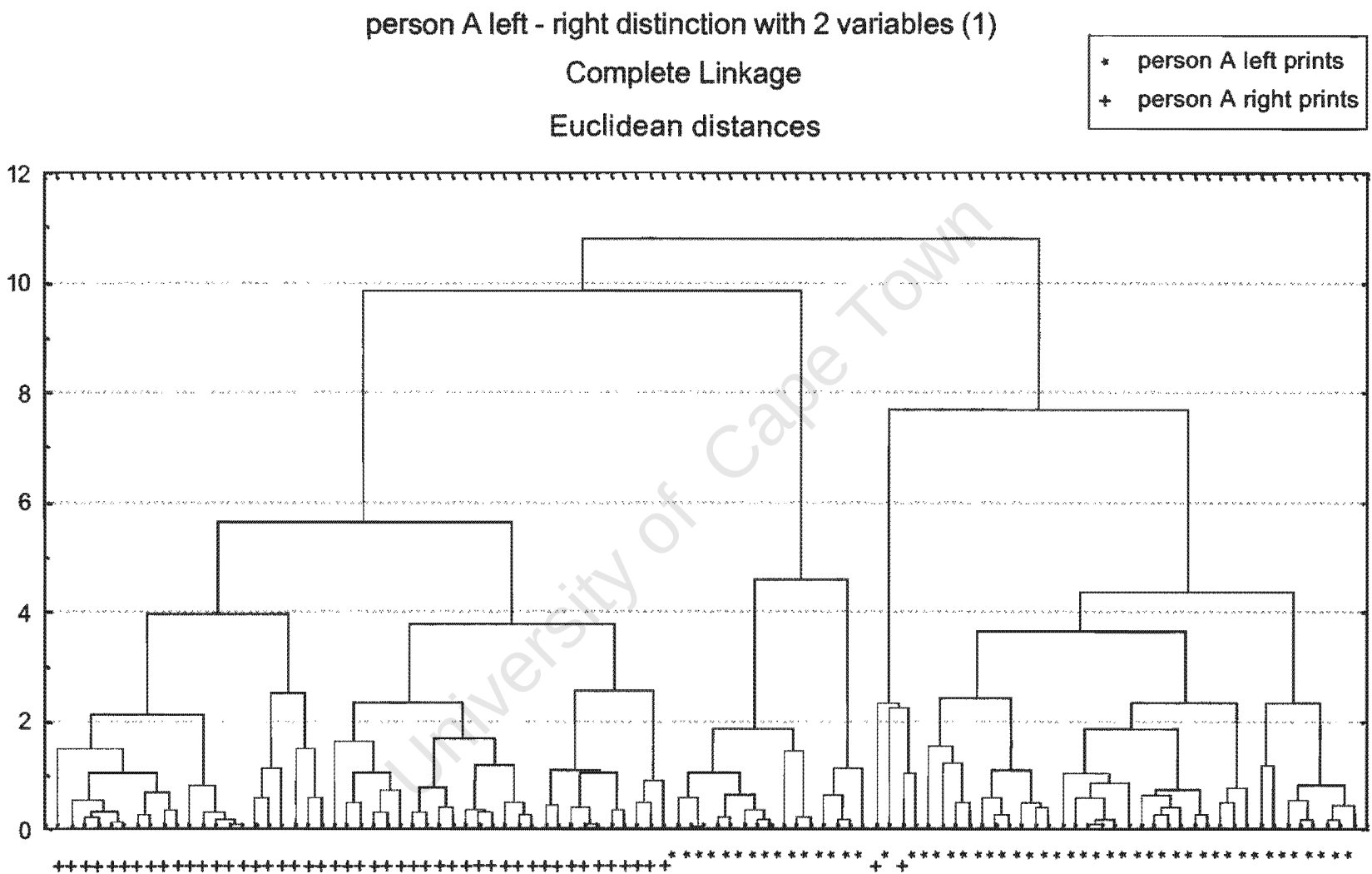


Figure 78: Cluster analysis of 2 handprint-variables (1) to distinguish left and right prints of person A (2)

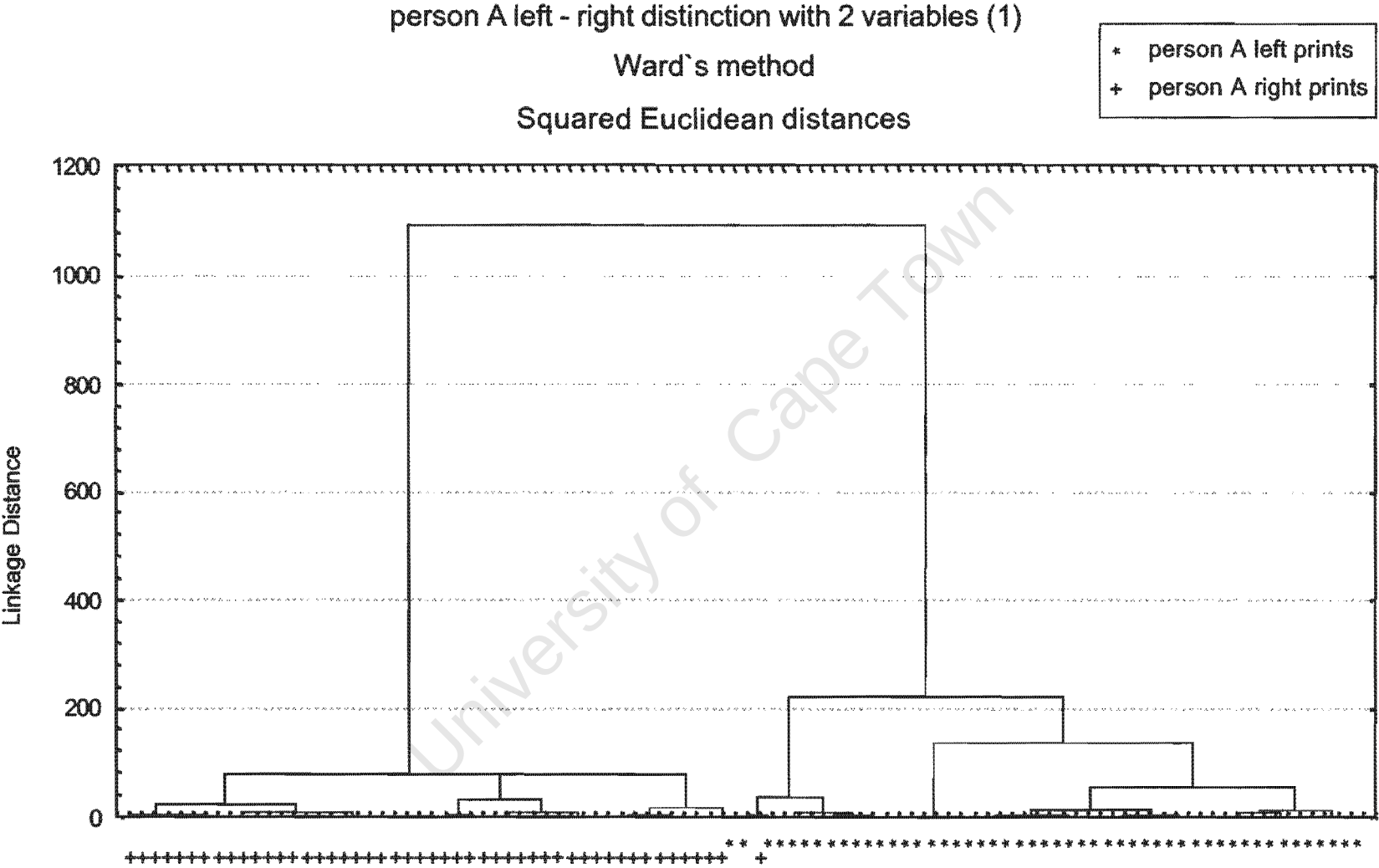


Figure 79: Cluster analysis of 2 handprint-variables (1) to distinguish left and right prints of person A (3)

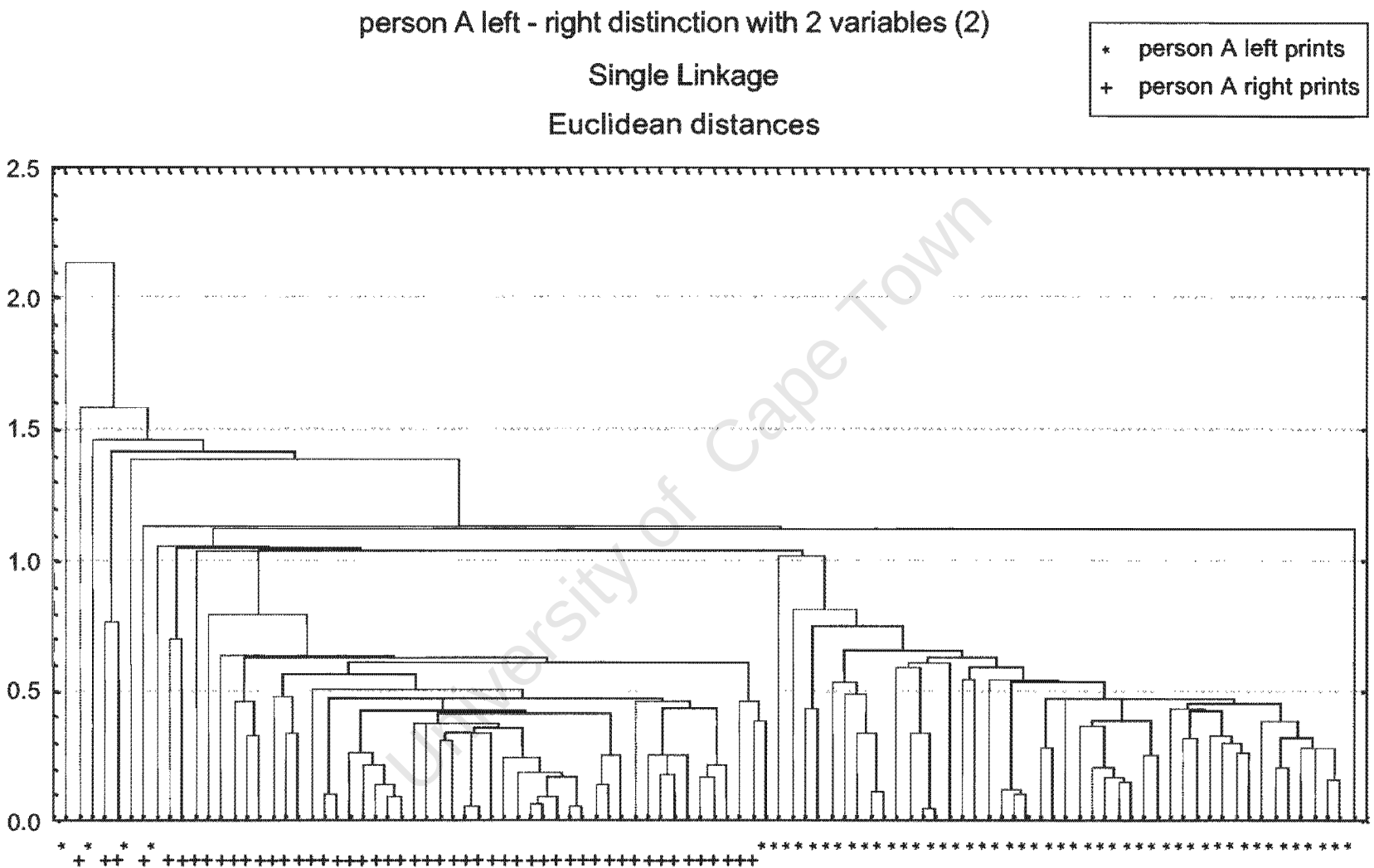


Figure 80: Cluster analysis of 2 handprint-variables (2) to distinguish left and right prints of person A (1)

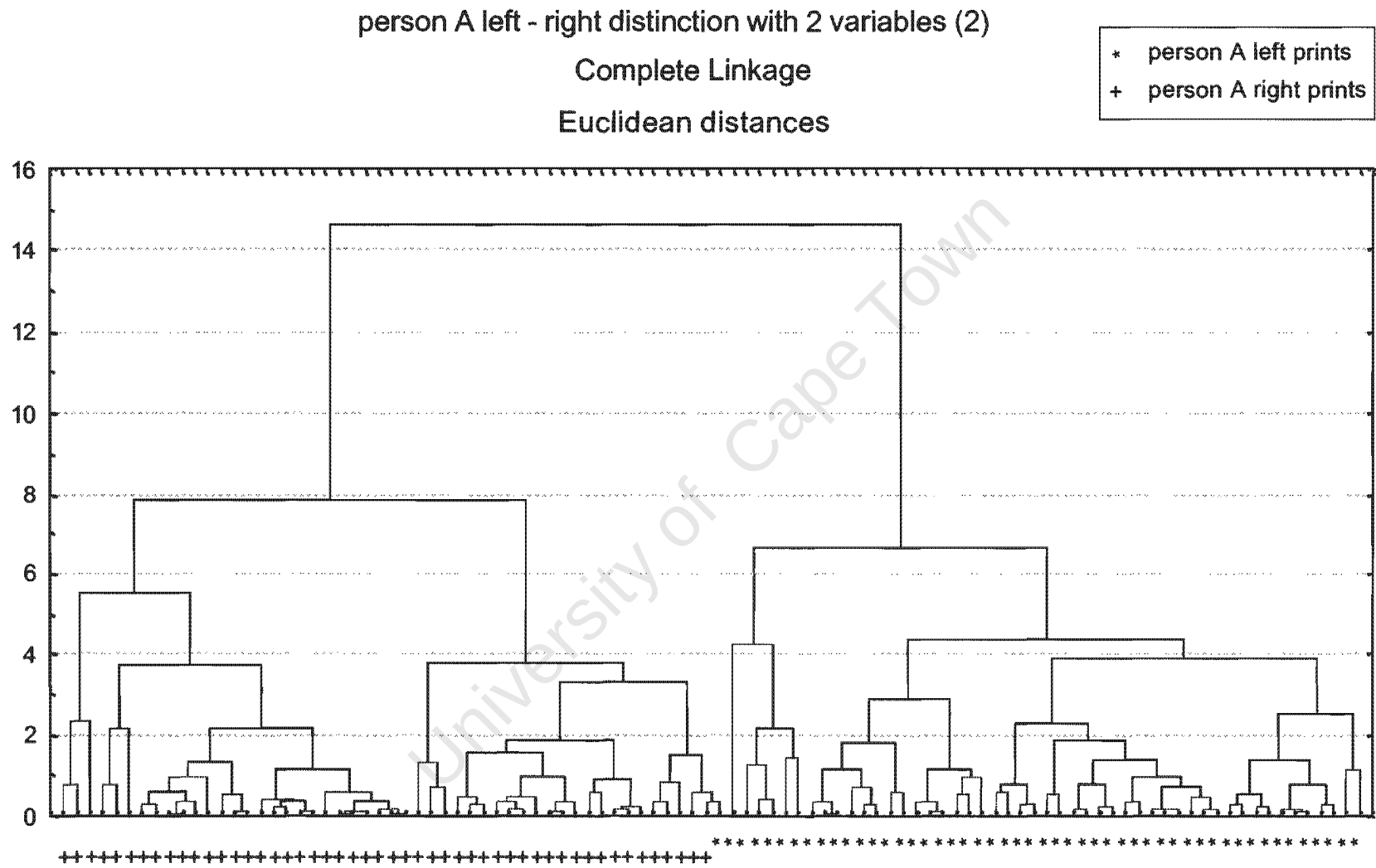


Figure 81: Cluster analysis of 2 handprint-variables (2) to distinguish left and right prints of person A (2)

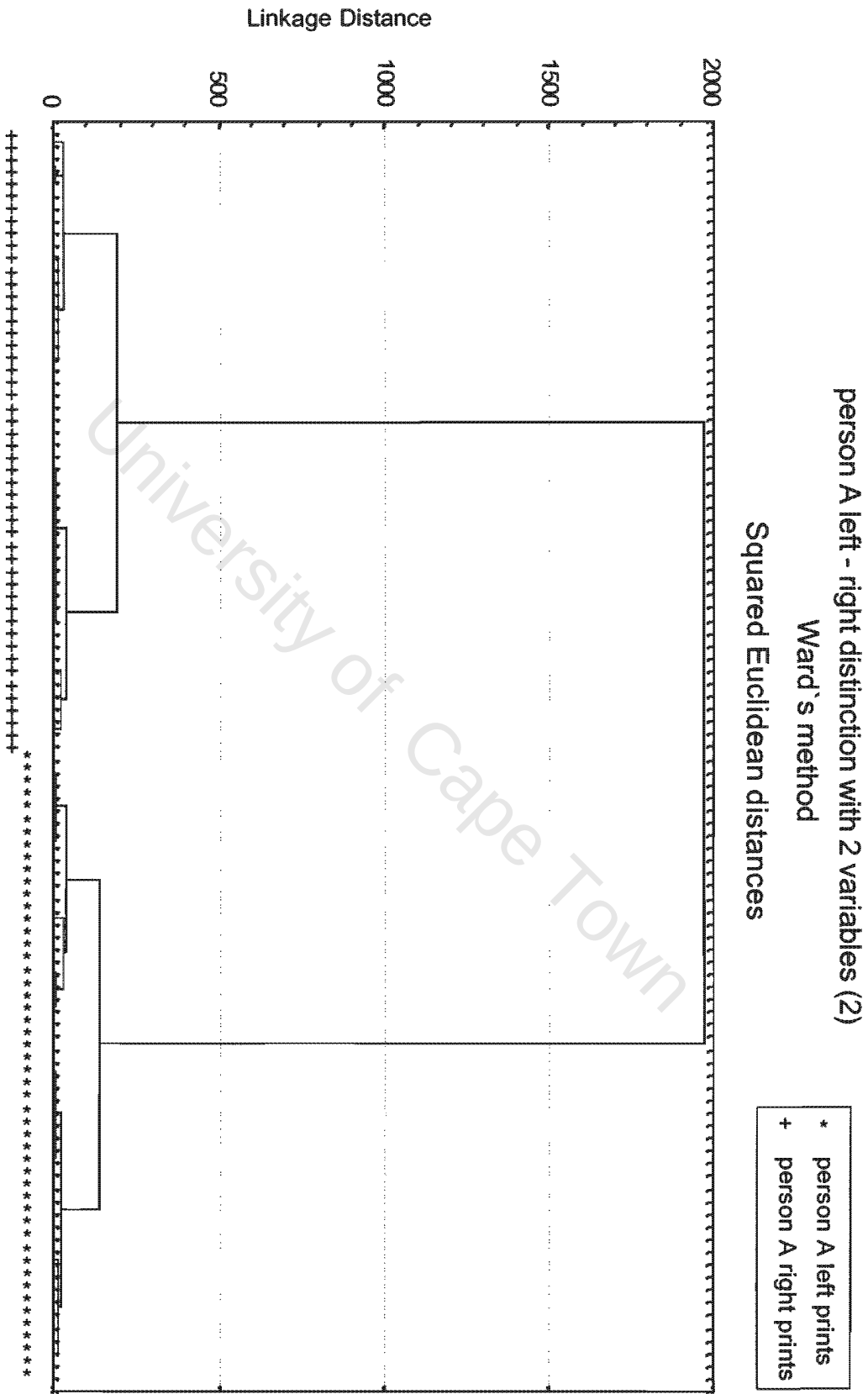


Figure 82: Cluster analysis of 2 handprint-variables (2) to distinguish left and right prints of person A (3)

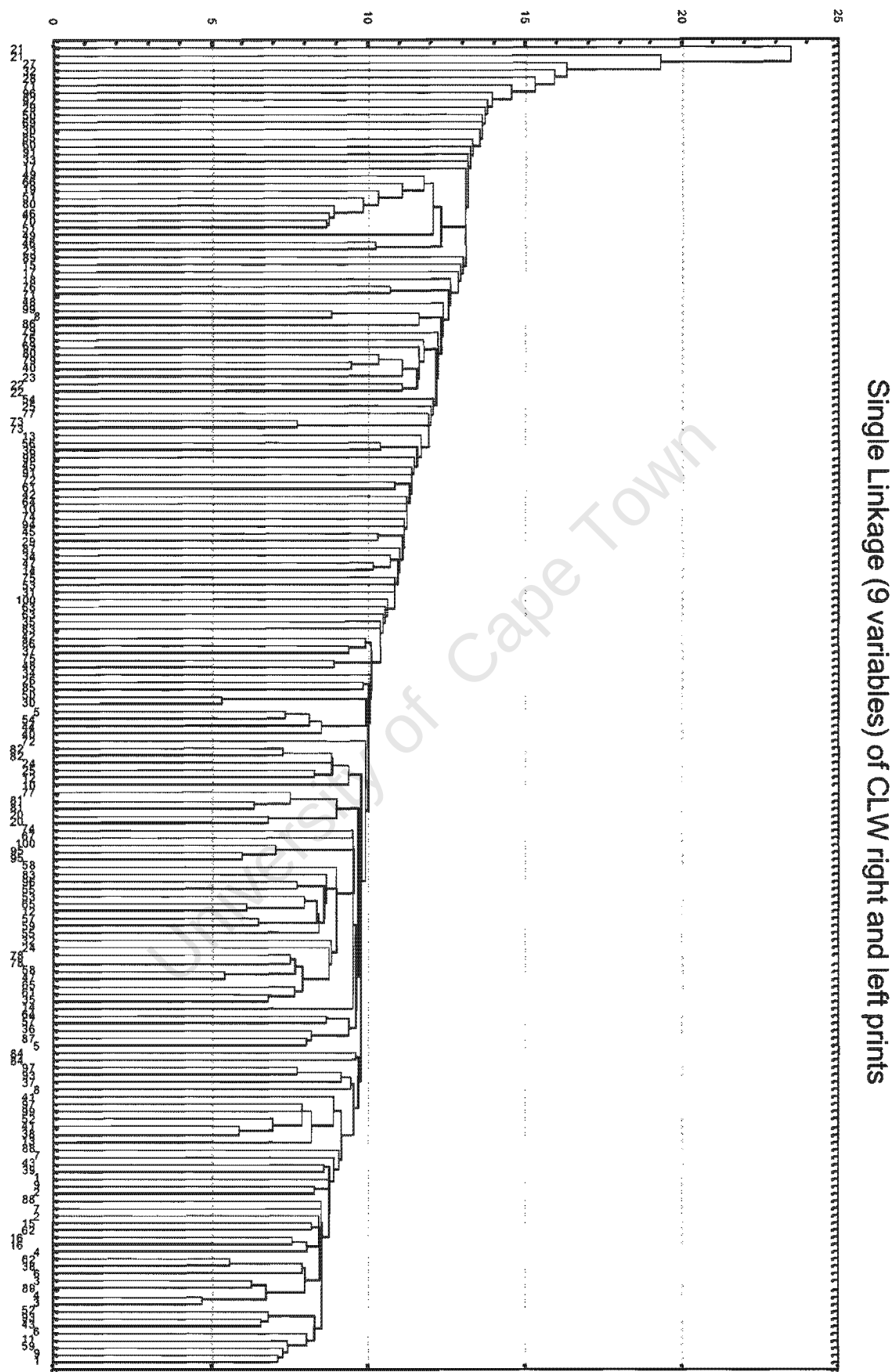


Figure 83: Cluster analysis of 9 handprint-variables to distinguish left and right prints of CLW (1)

Complete Linkage (9 variables) of CLW right and left prints

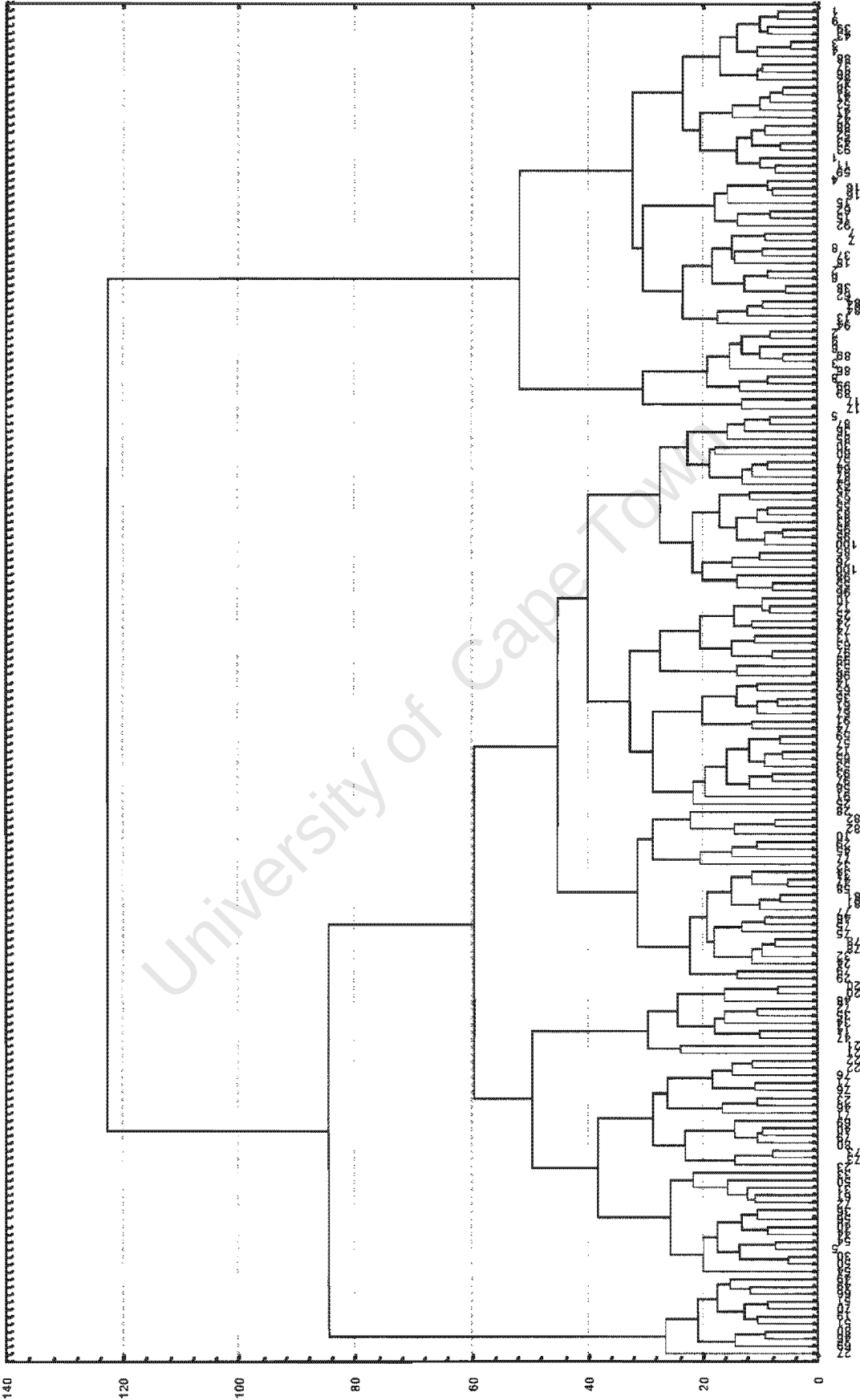


Figure 84: Cluster analysis of 9 handprint-variables to distinguish left and right prints of CLW (2)

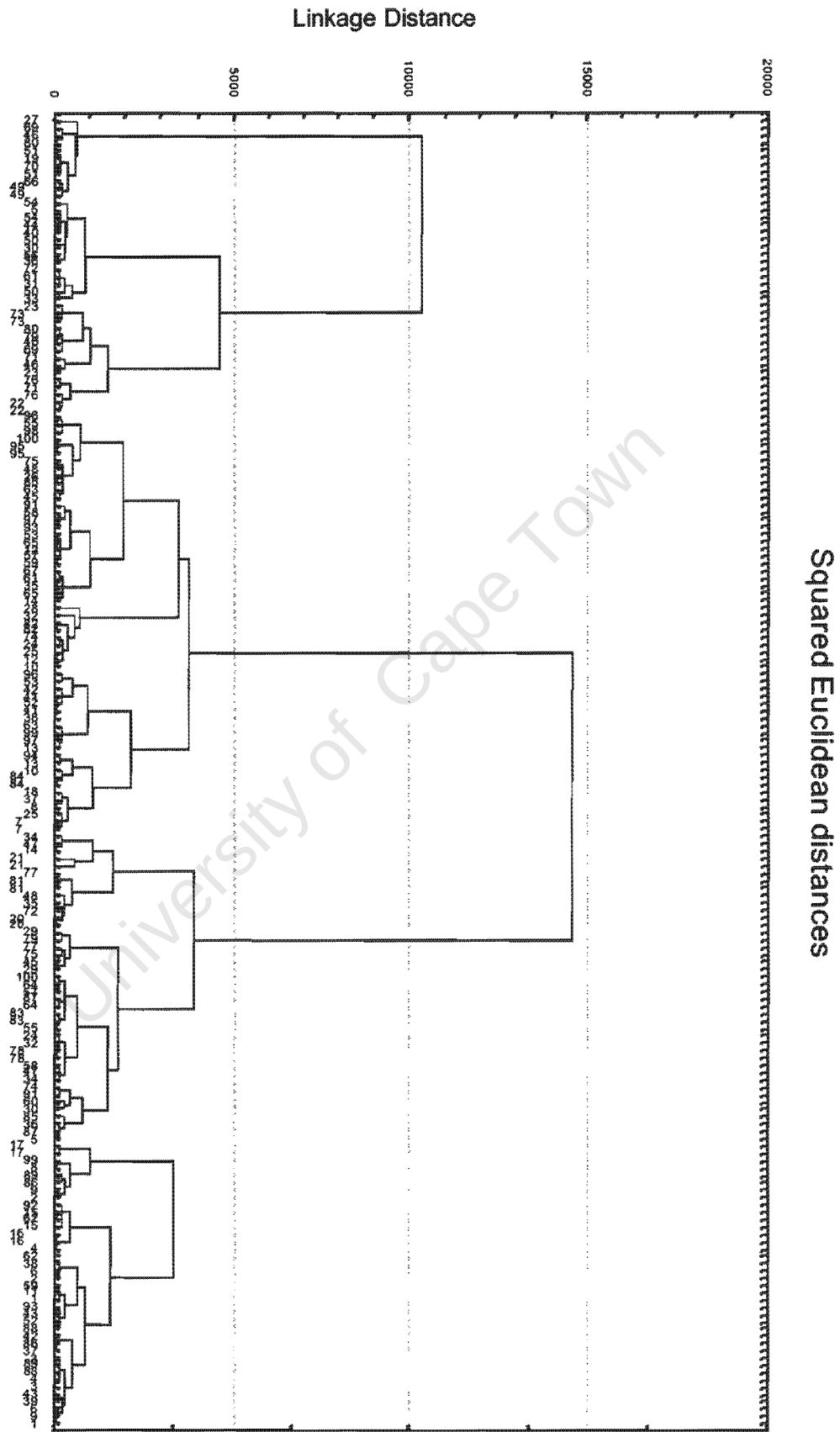


Figure 85: Cluster analysis of 9 handprint-variables to distinguish left and right prints of GLW (3)

Single Linkage 2 variables (1) of CLW right and left prints

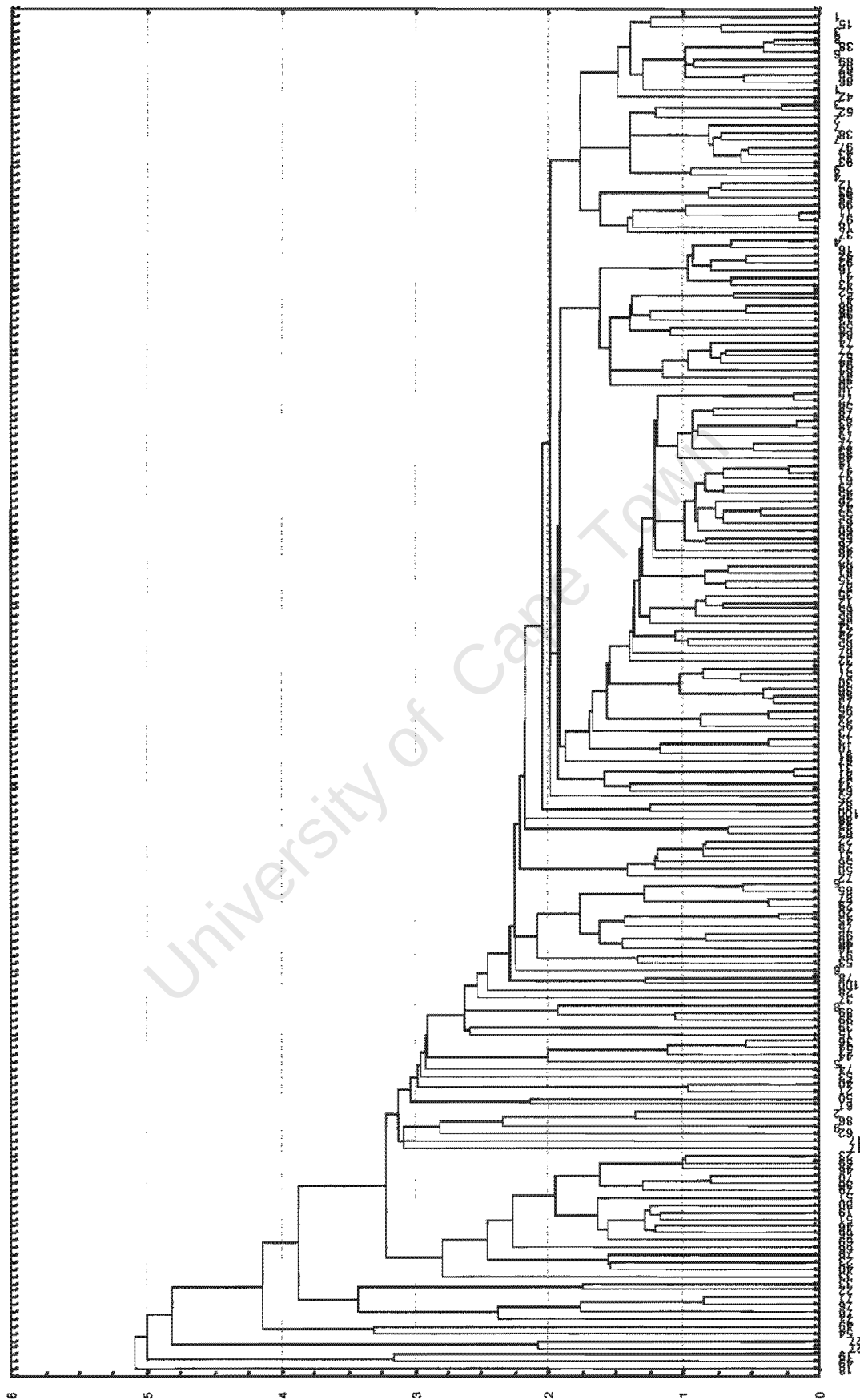


Figure 86: Cluster analysis of 2 handprint-variables (1) to distinguish left and right prints of CLW (1)

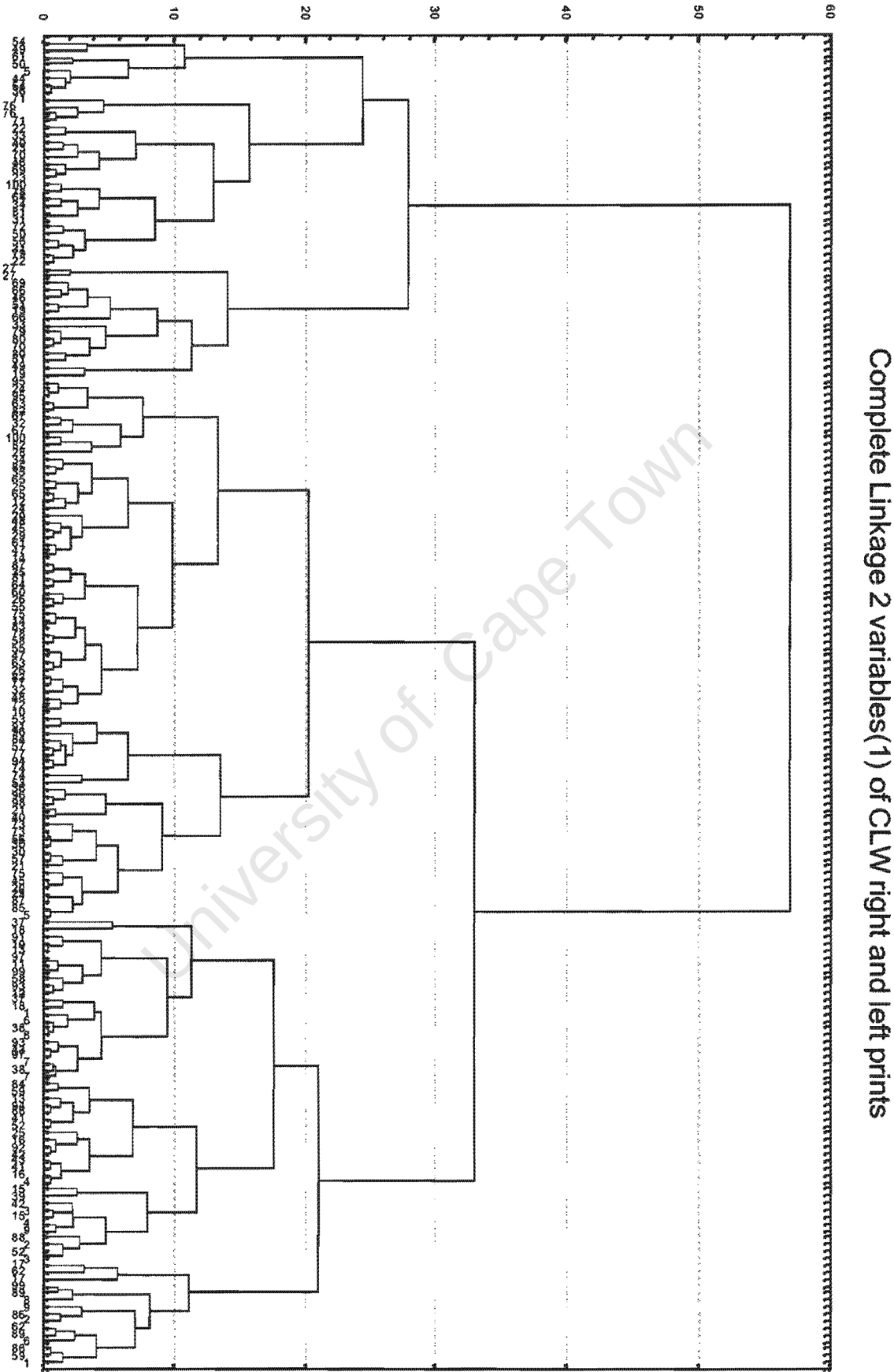


Figure 87: Cluster analysis of 2 handprint-variables (1) to distinguish left and right prints of CLW (2)

Ward's method 2 variables (1) on CLW right and left prints

Squared Euclidean distances

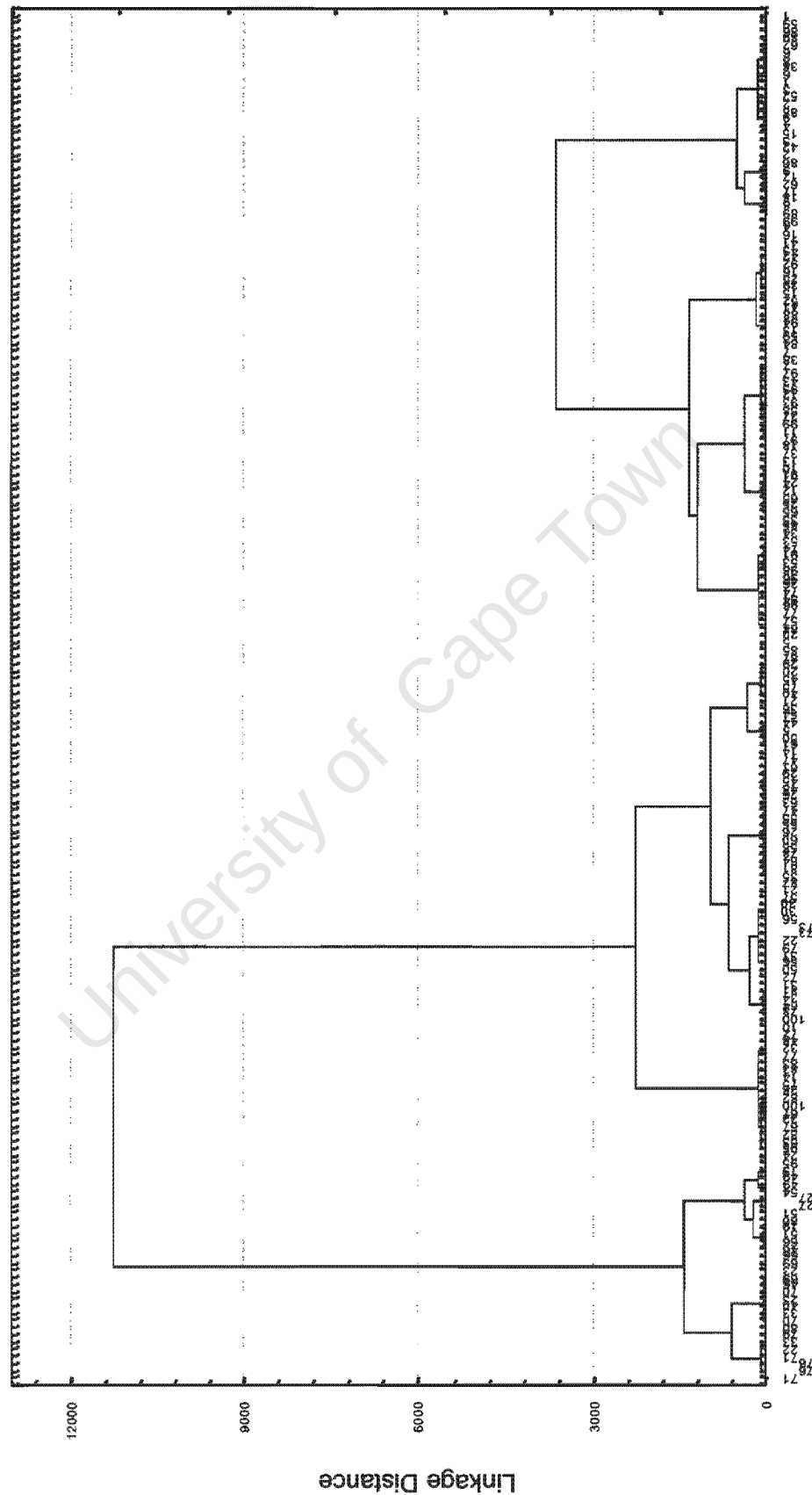


Figure 88: Cluster analysis of 2 handprint-variables (1) to distinguish left and right prints of CLW (3)

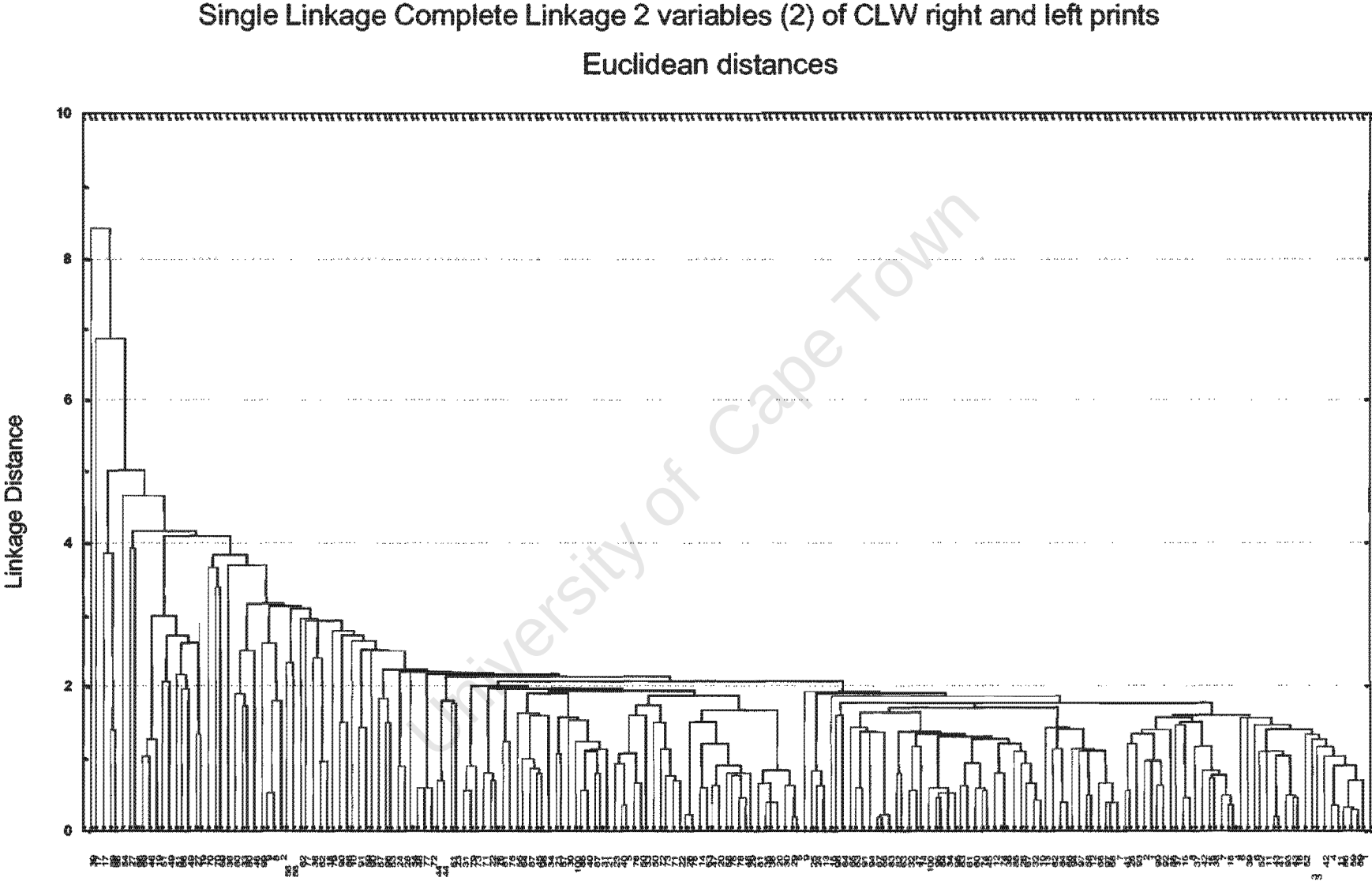


Figure 89: Cluster analysis of 2 handprint-variables (2) to distinguish left and right prints of CLW (1)

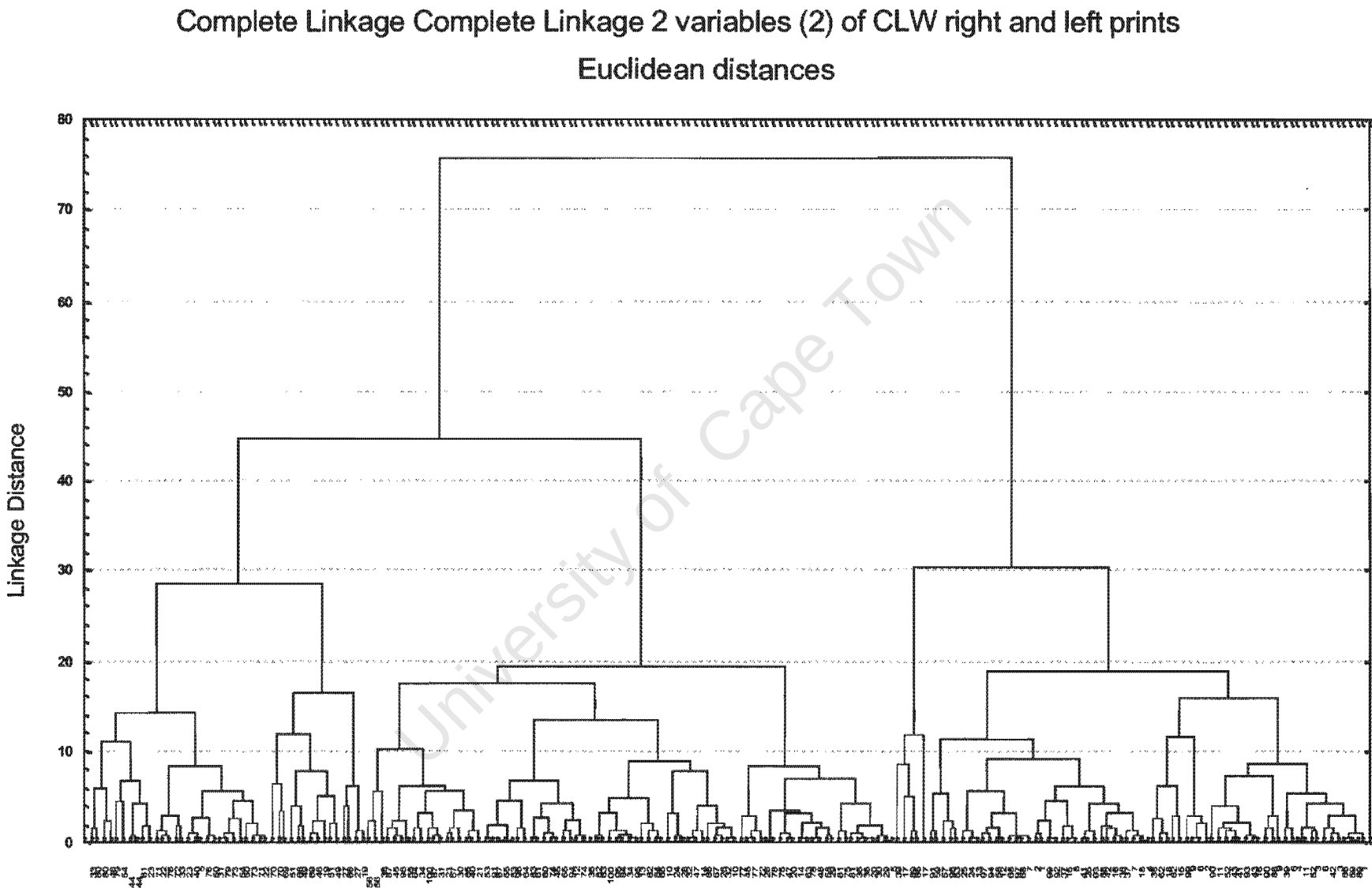


Figure 90: Cluster analysis of 2 handprint-variables (2) to distinguish left and right prints of CLW (2)

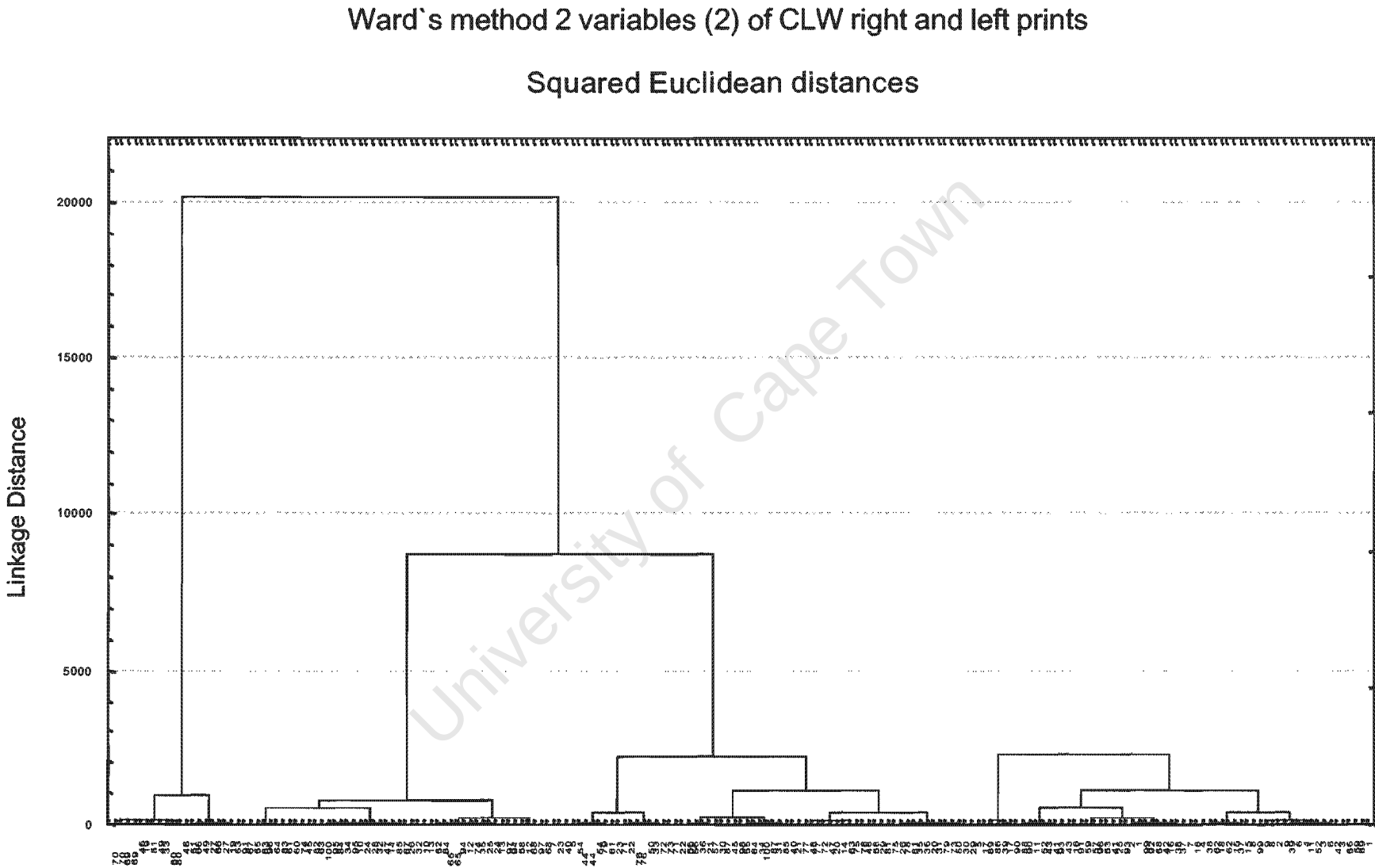
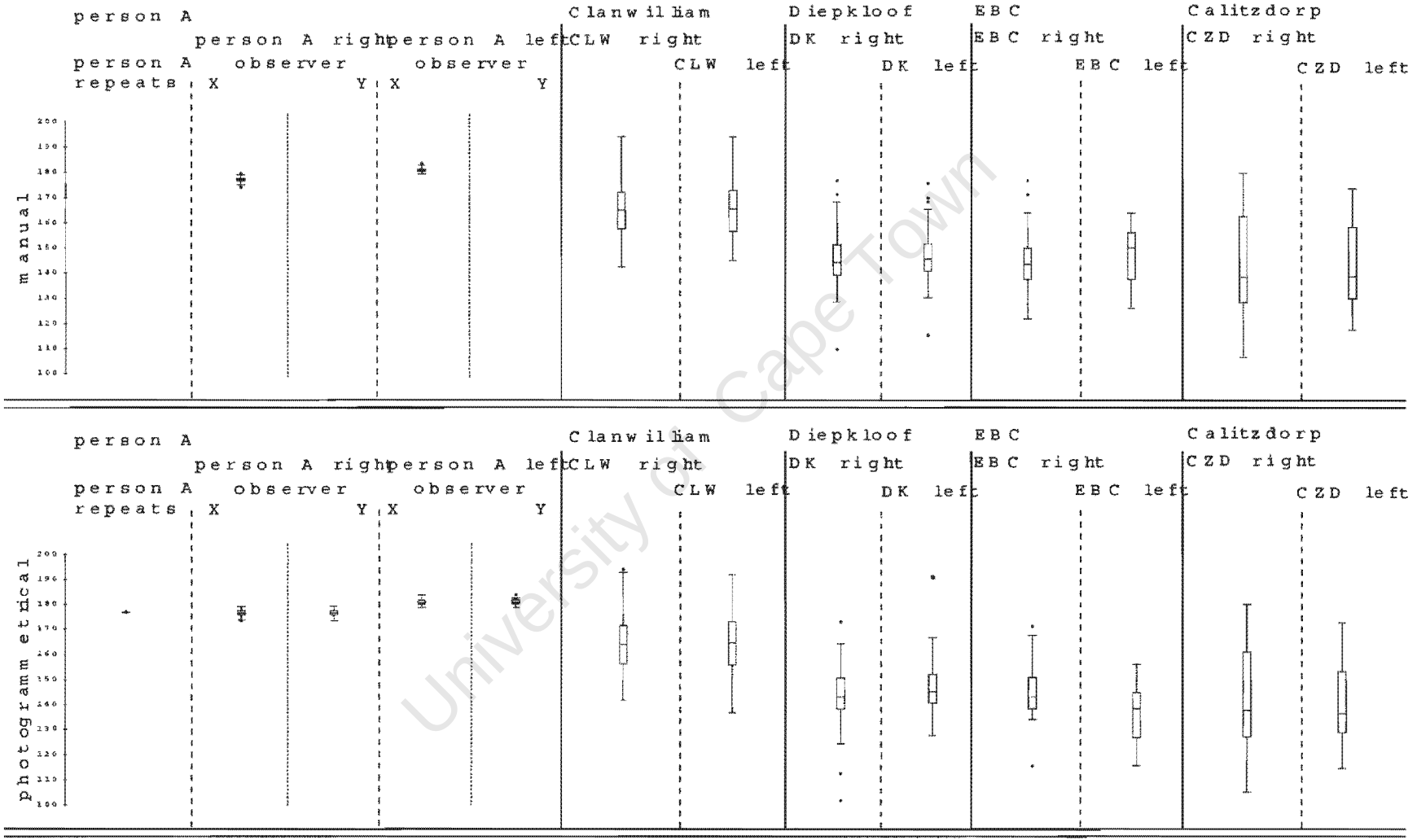


Figure 91: Cluster analysis of 2 handprint-variables (2) to distinguish left and right prints of CLW (3)

Figure 92: Middle finger measurements for left and right handprints individually



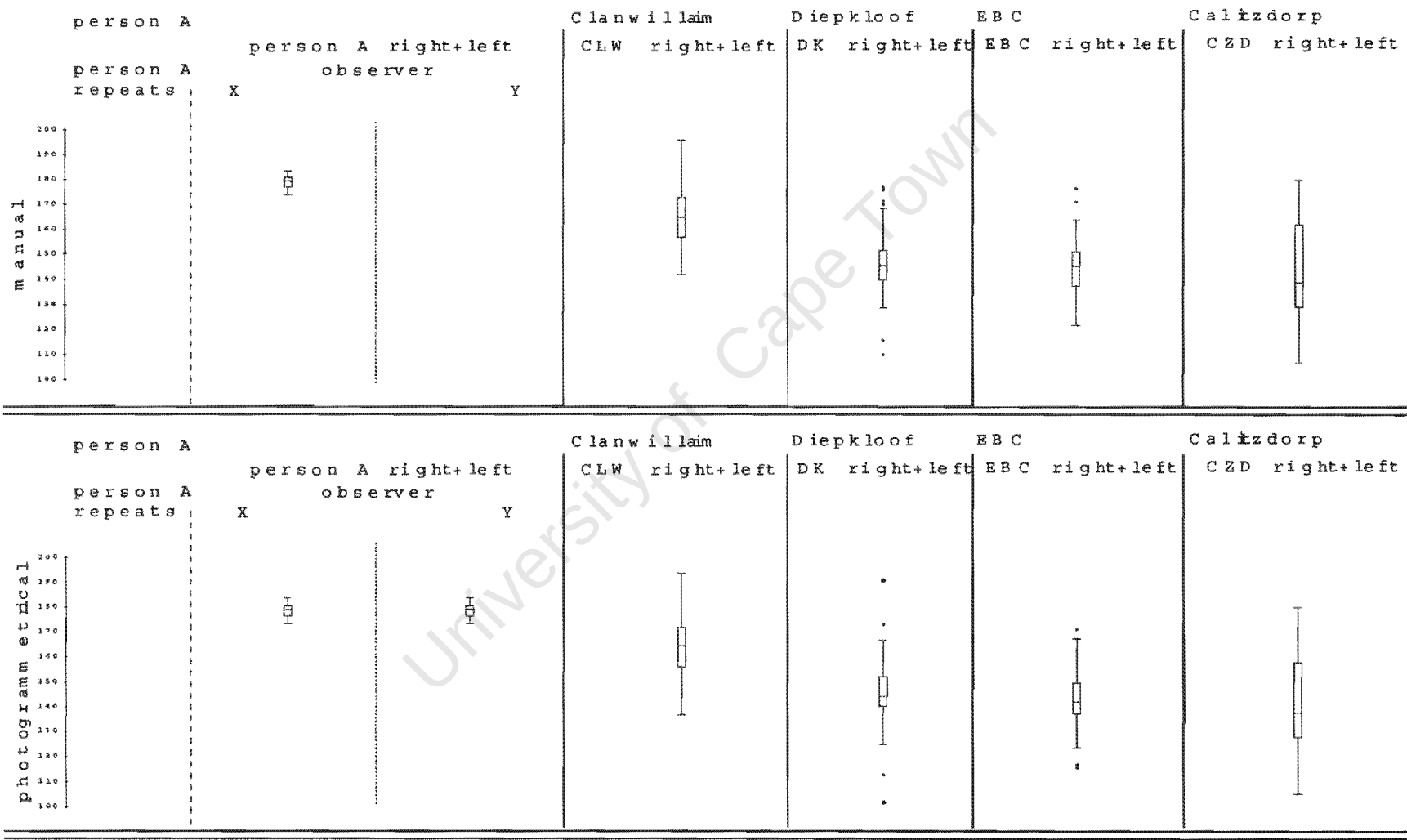


Figure 93: Middle finger measurements for left and right handprints together

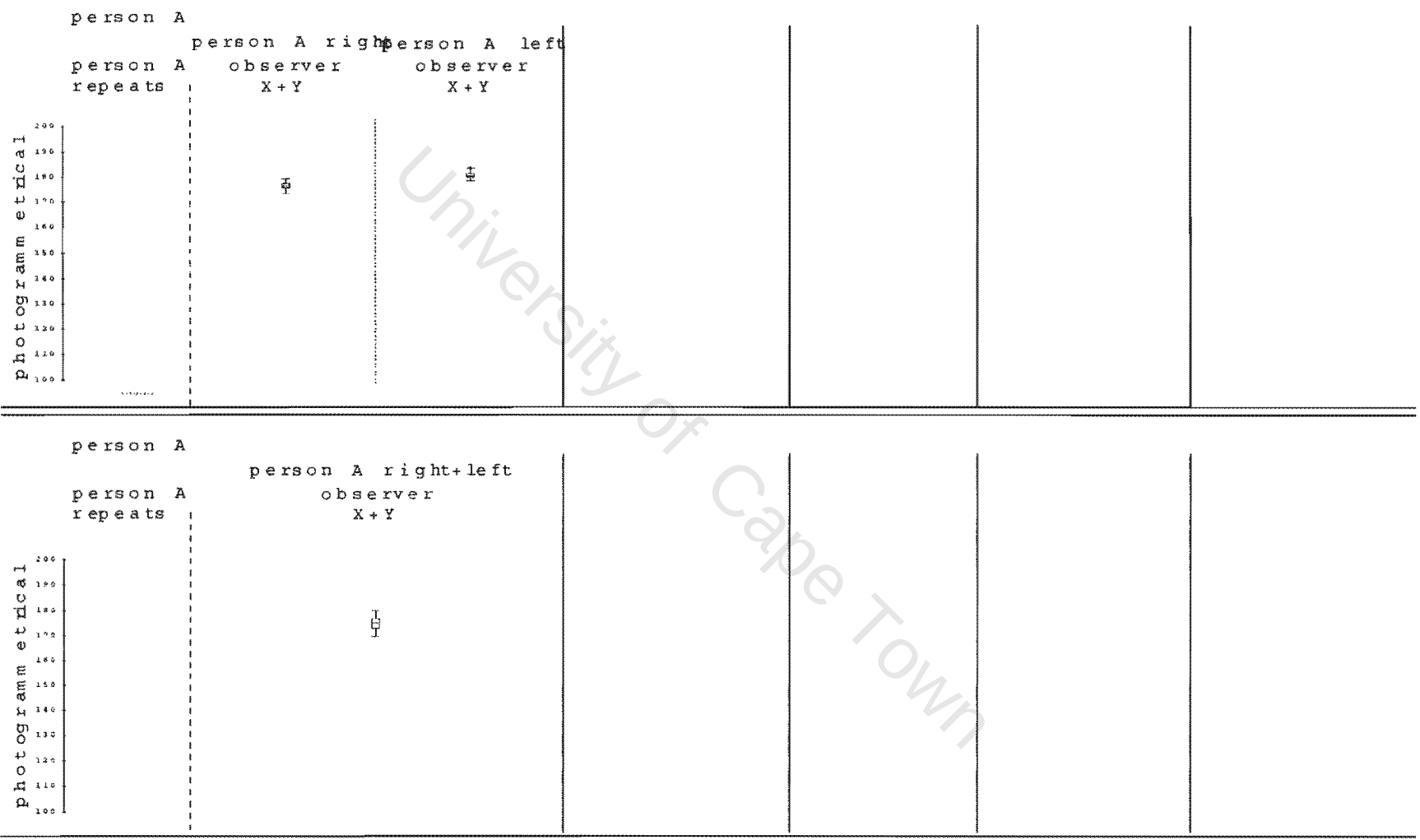


Figure 94: Middle finger measurements for observers X and Y together (and left and right together)

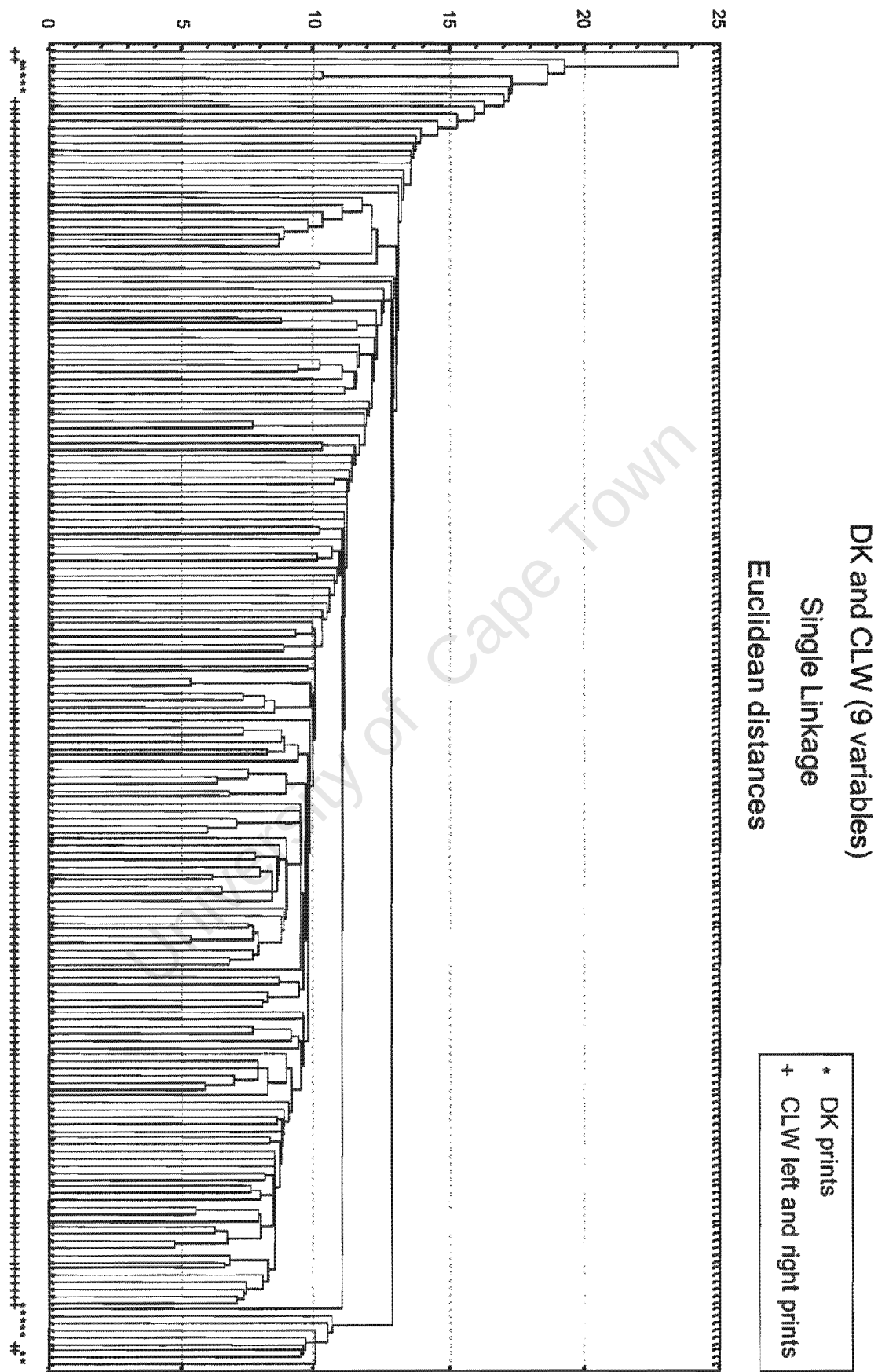


Figure 95: Cluster analysis of 9 handprint-variables of DK and CLW sets (1)

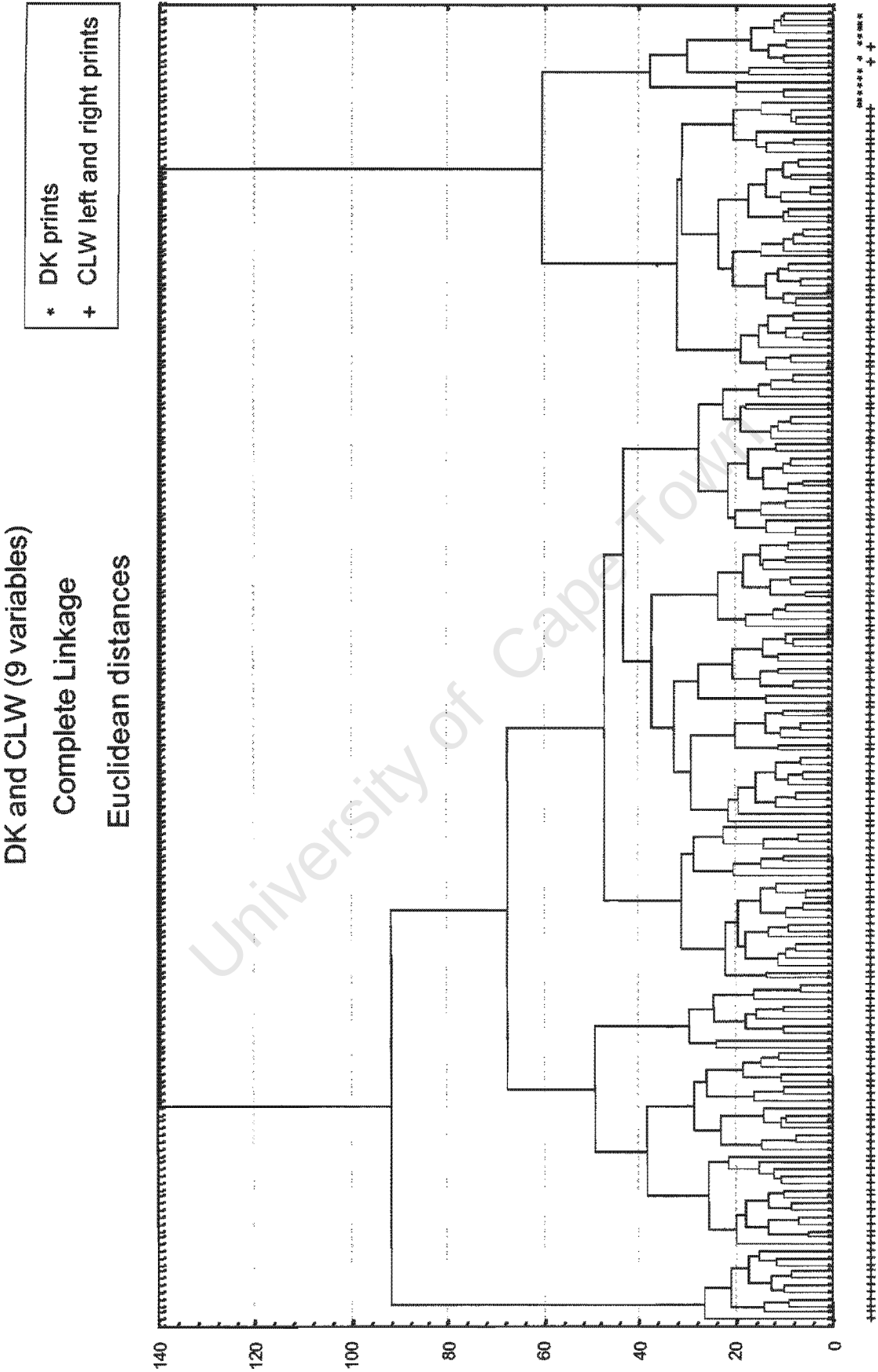


Figure 96: Cluster analysis of 9 handprint-variables of DK and CLW sets (2)

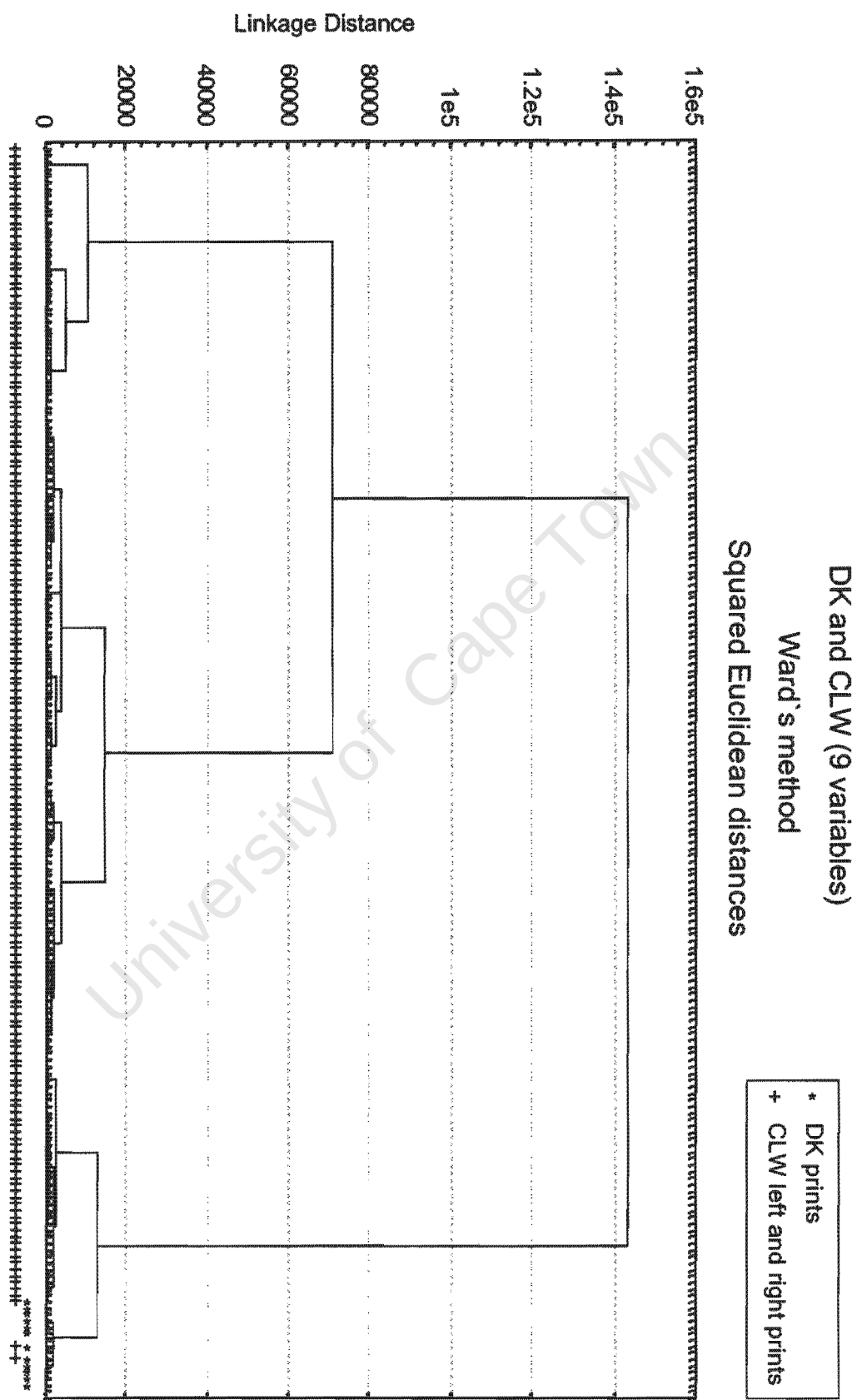


Figure 97: Cluster analysis of 9 handprint-variables of DK and CLW sets (3)

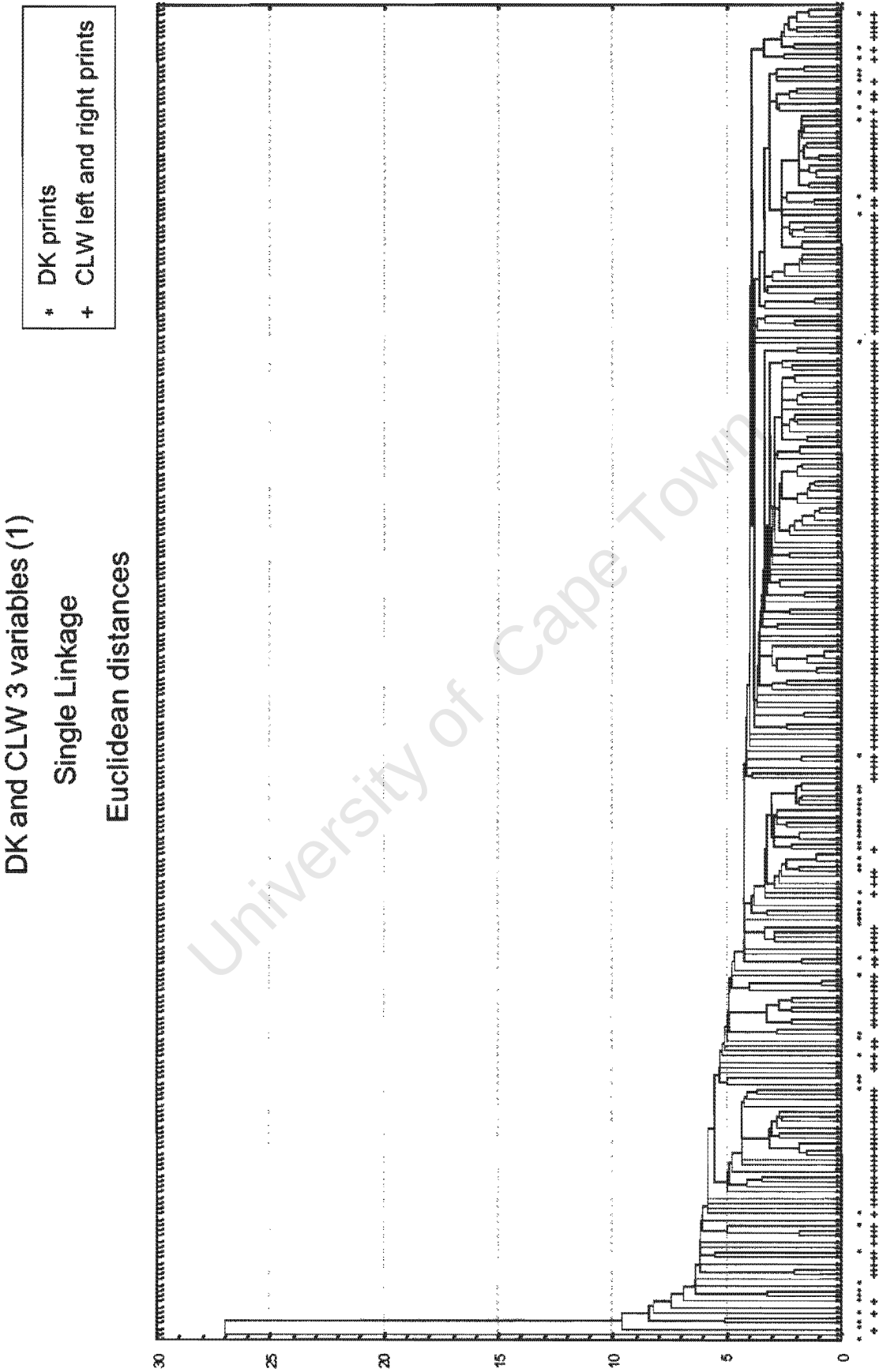


Figure 98: Cluster analysis of 3 handprint-variables (1) of DK and CLW sets (1)

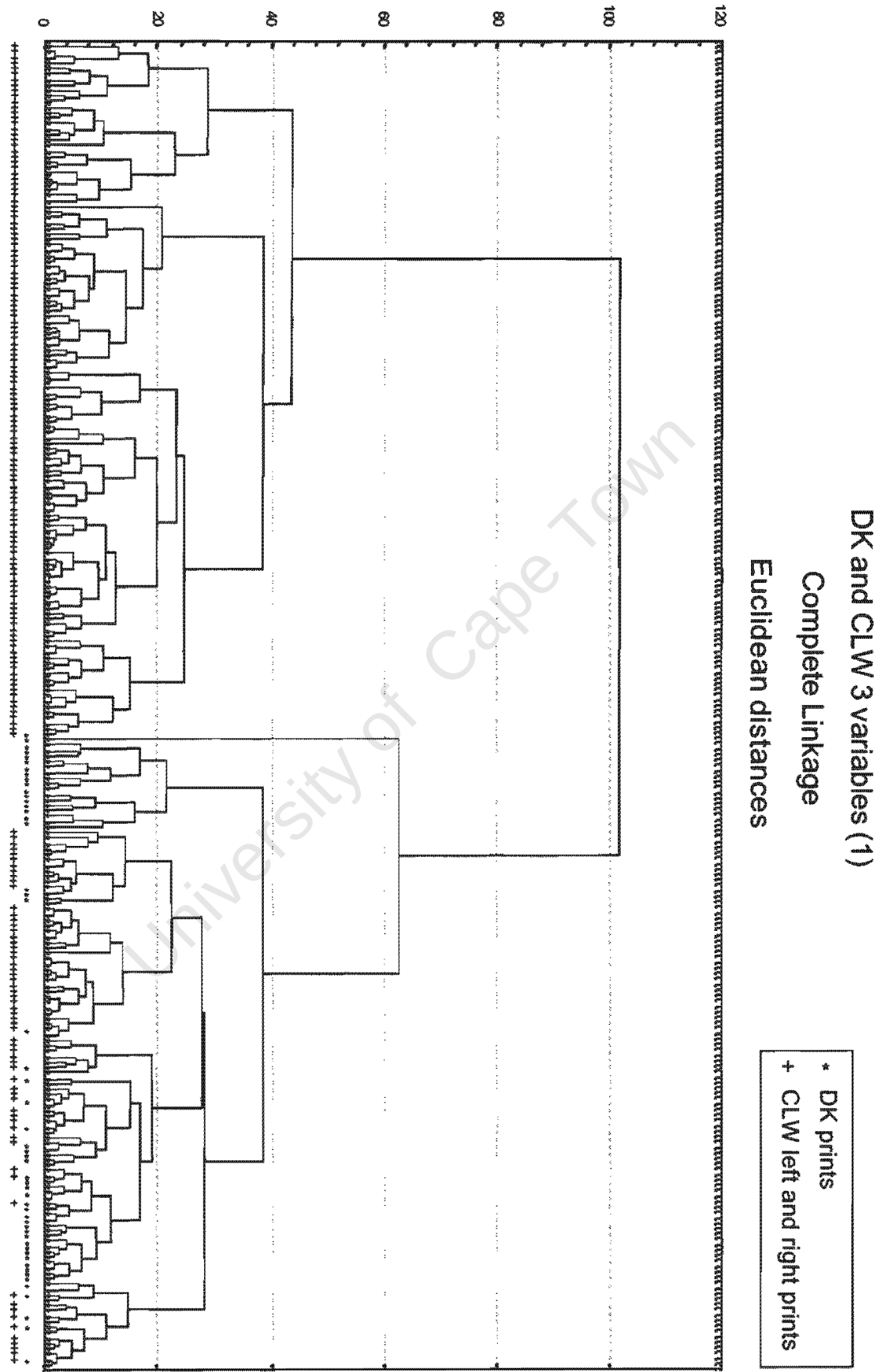


Figure 99: Cluster analysis of 3 handprint-variables (1) of DK and CLW sets (2)

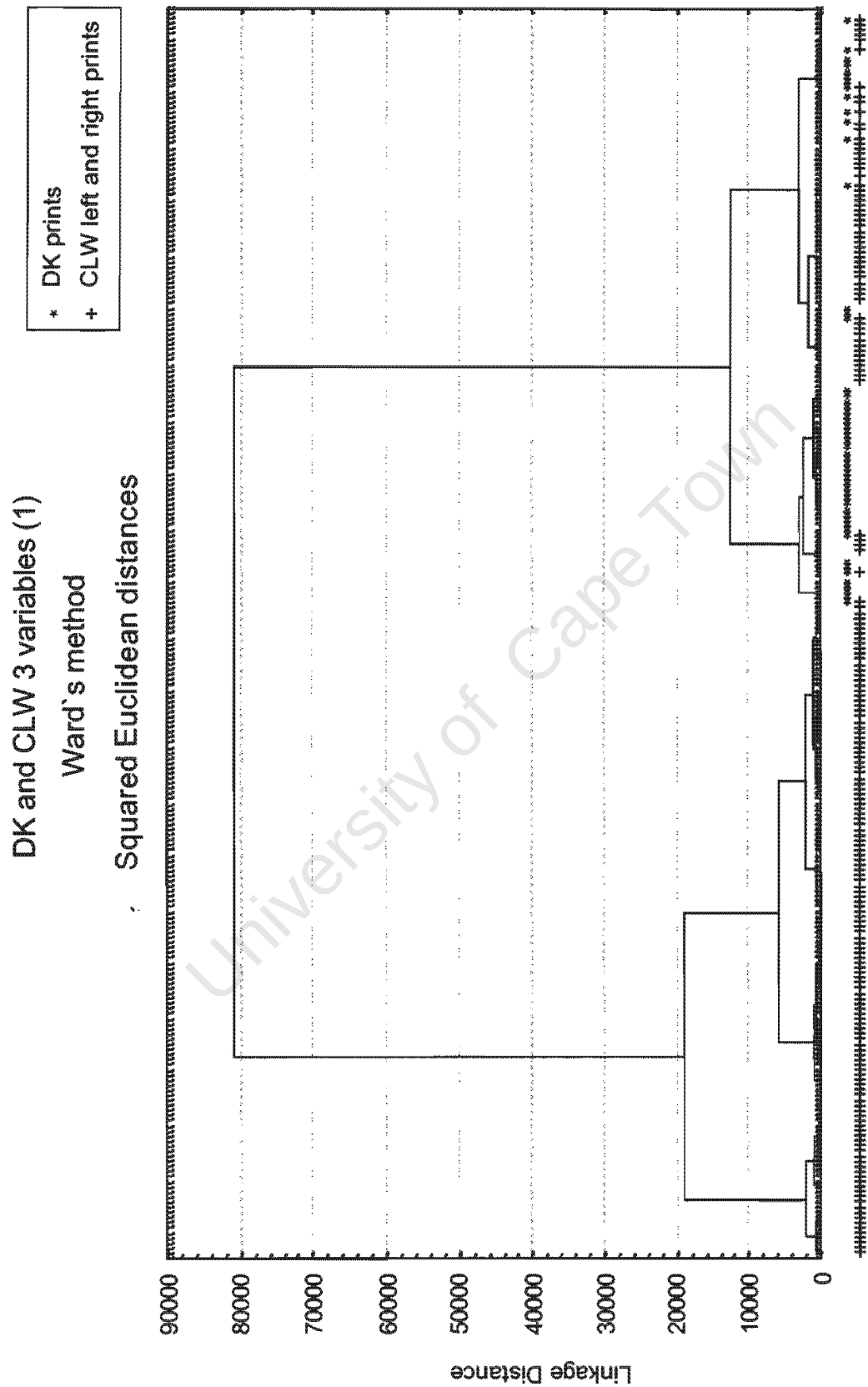


Figure 100: Cluster analysis of 3 handprint-variables (1) of DK and CLW sets (3)

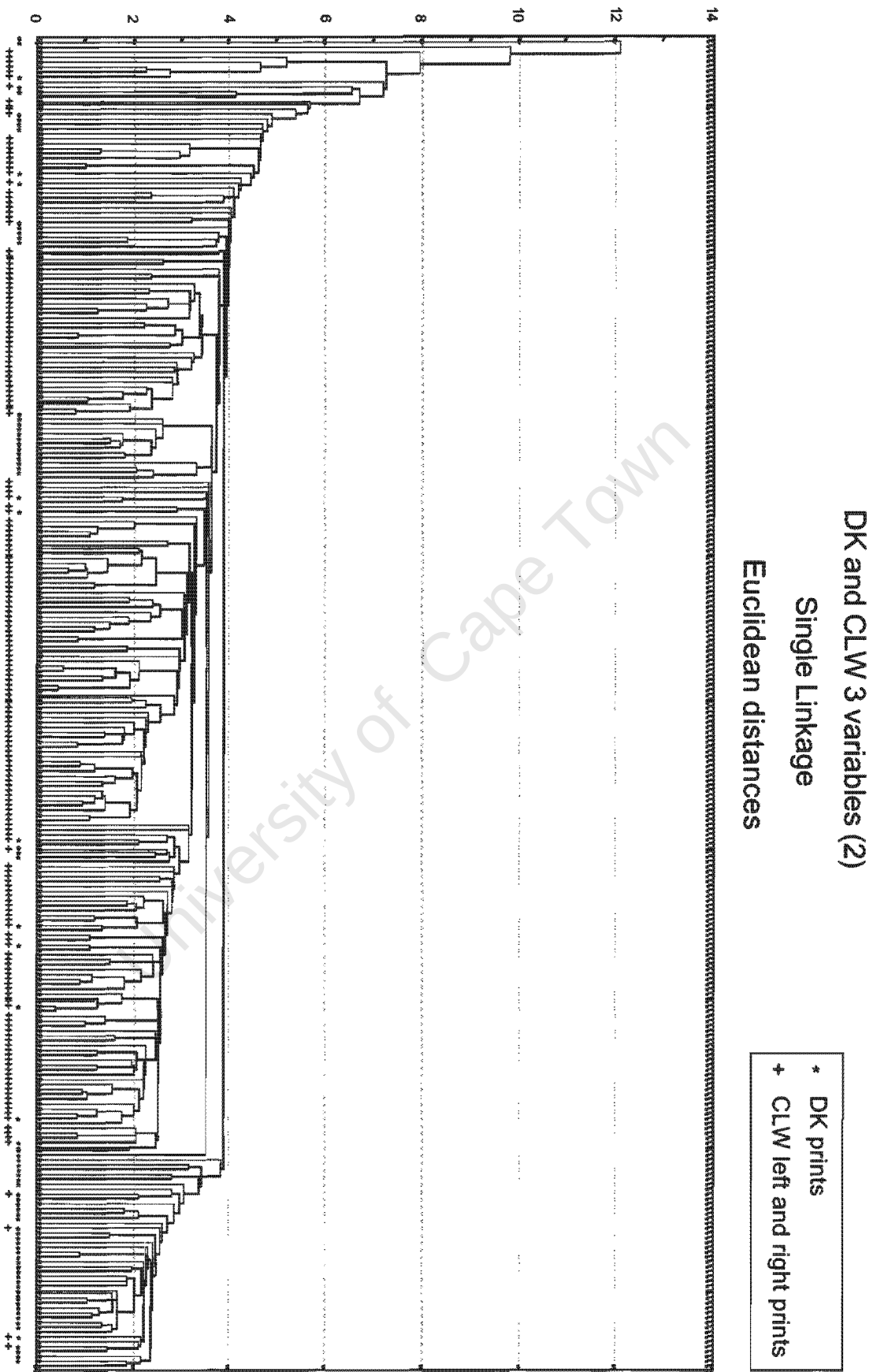


Figure 101: Cluster analysis of 3 handprint-variables (2) of DK and CLW sets (1)

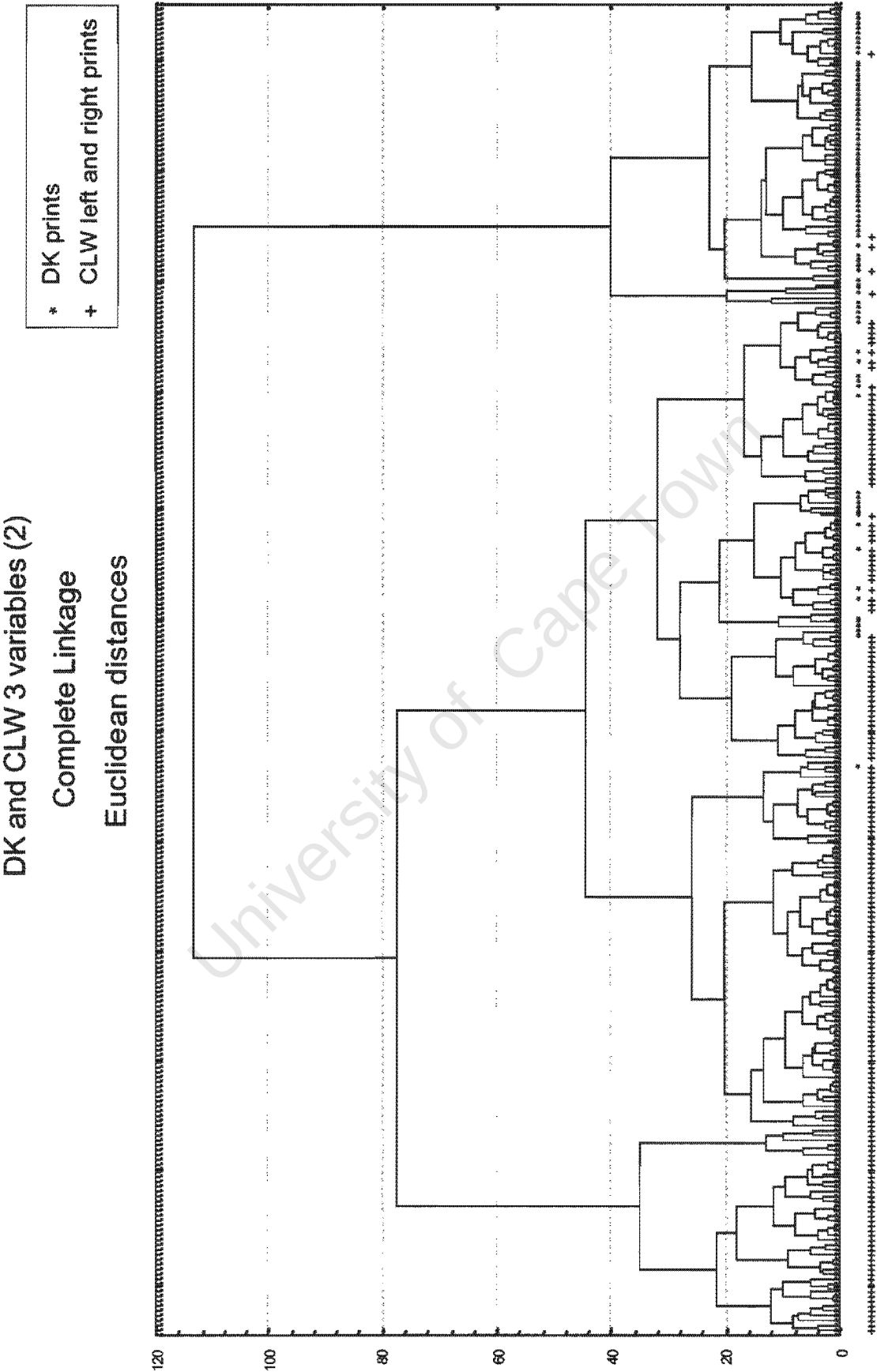


Figure 102: Cluster analysis of 3 handprint-variables (2) of DK and CLW sets (2)

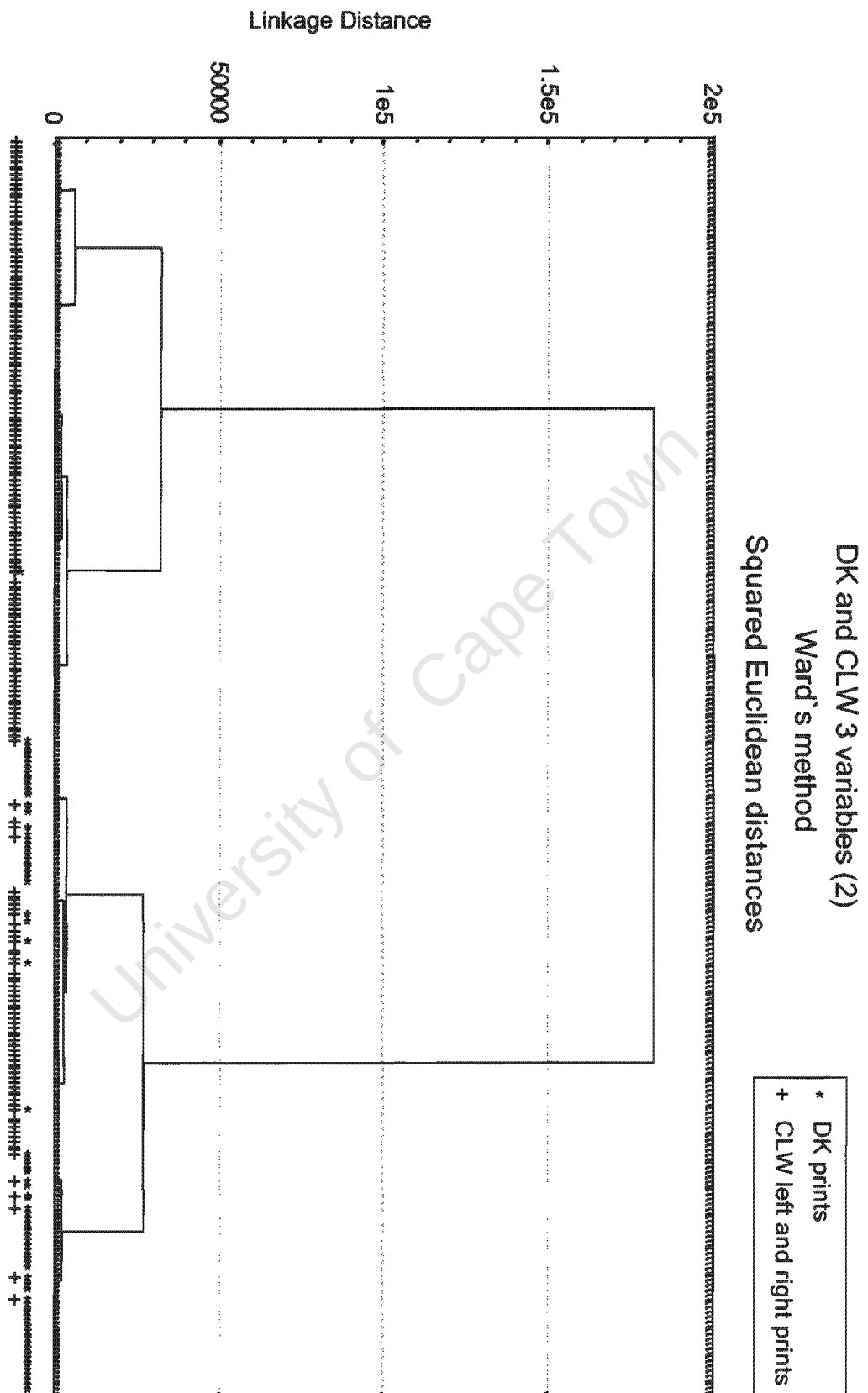


Figure 103: Cluster analysis of 3 handprint-variables (2) of DK and CLW sets (3)

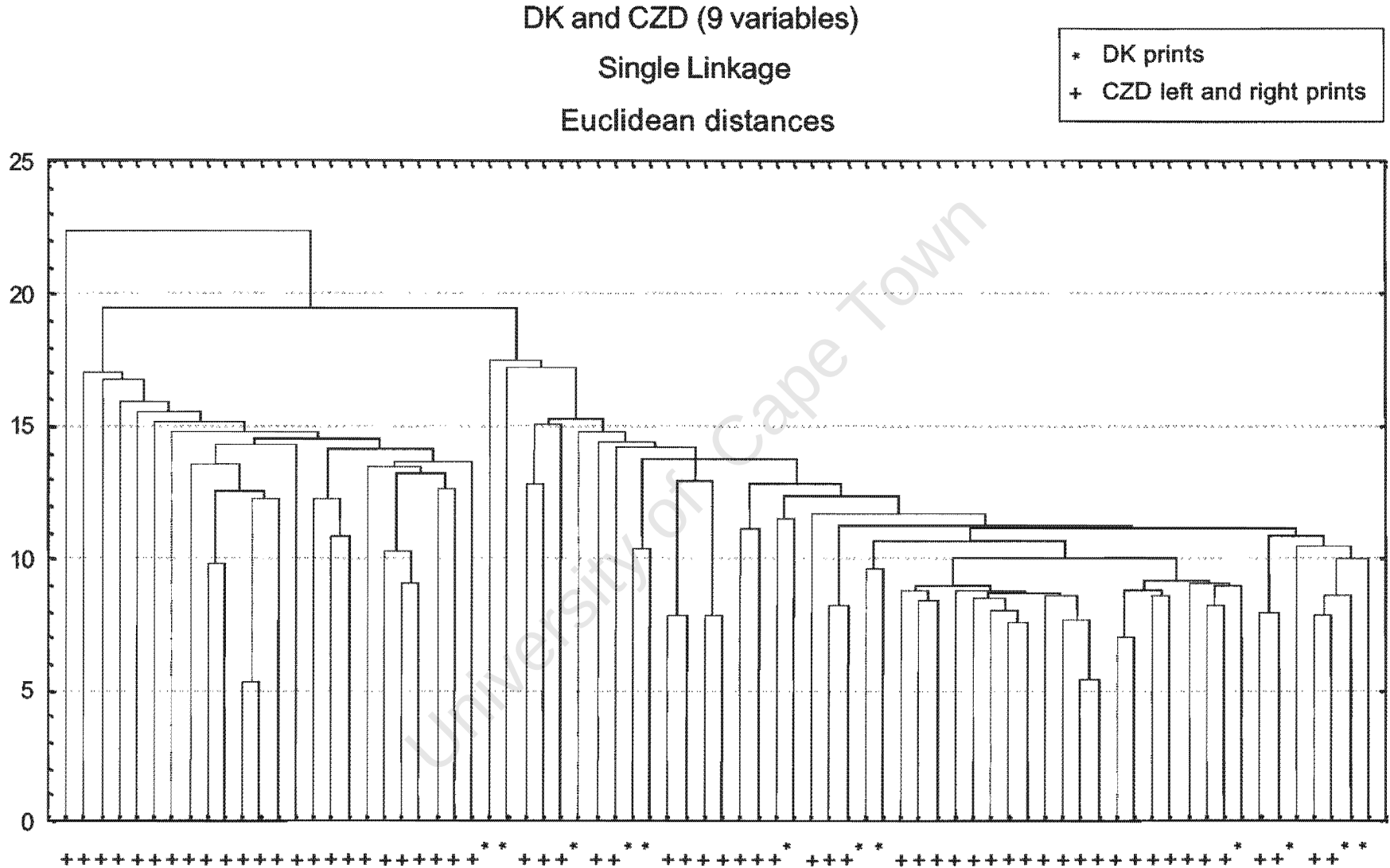


Figure 104: Cluster analysis of 9 handprint-variables of DK and CZD sets (1)

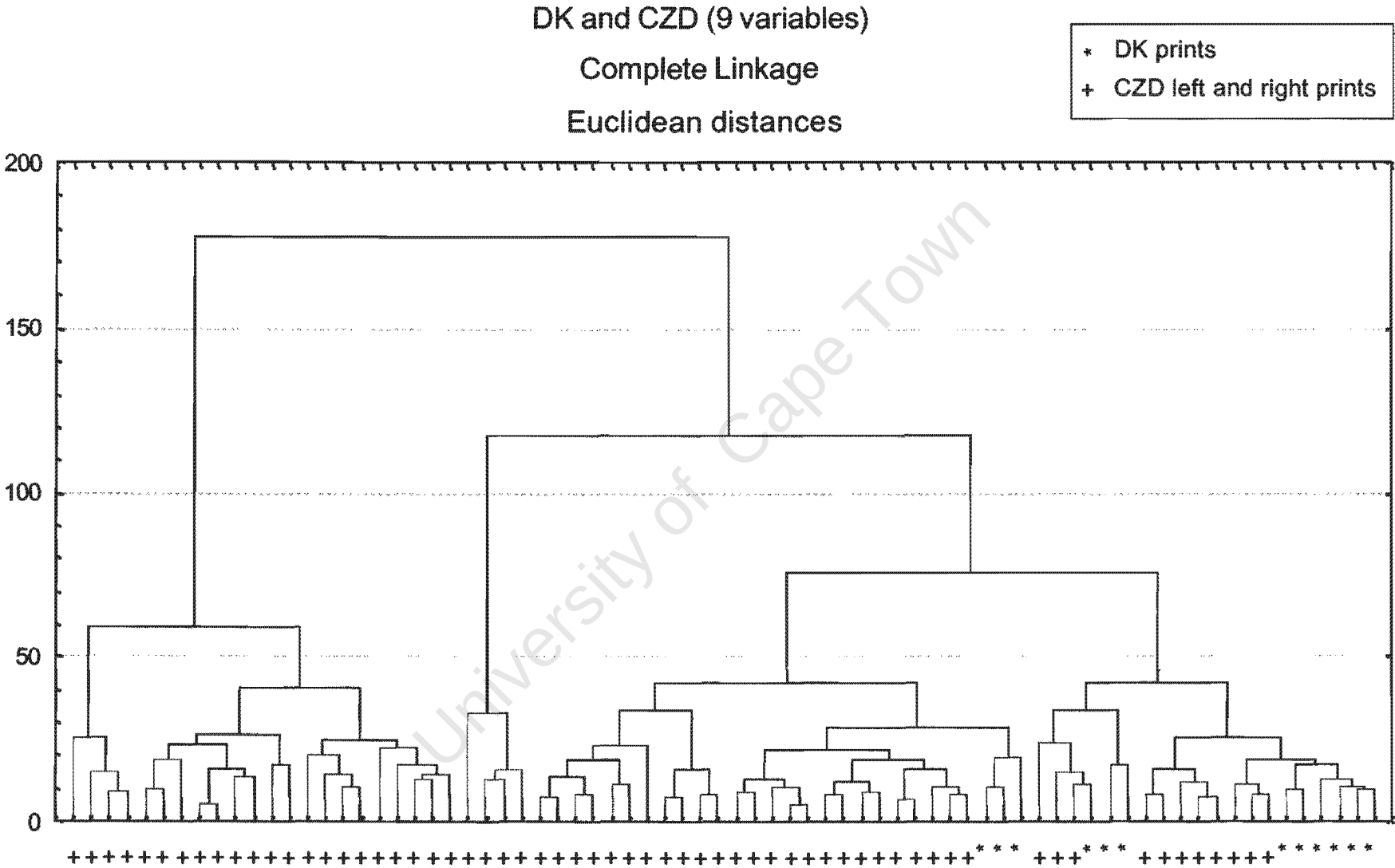


Figure 105: Cluster analysis of 9 handprint-variables of DK and CZD sets (2)

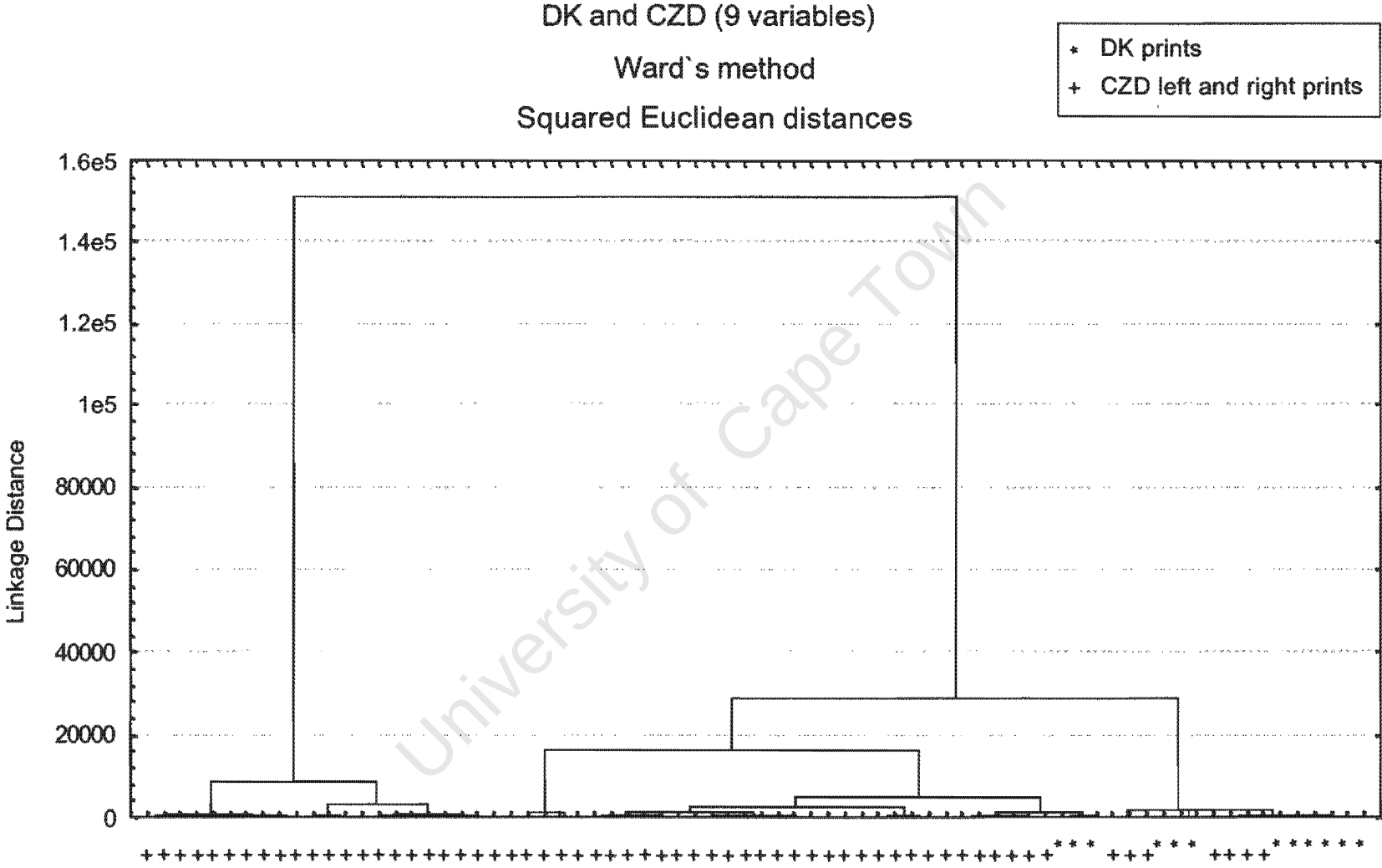


Figure 106: Cluster analysis of 9 handprint-variables of DK and CZD sets (3)

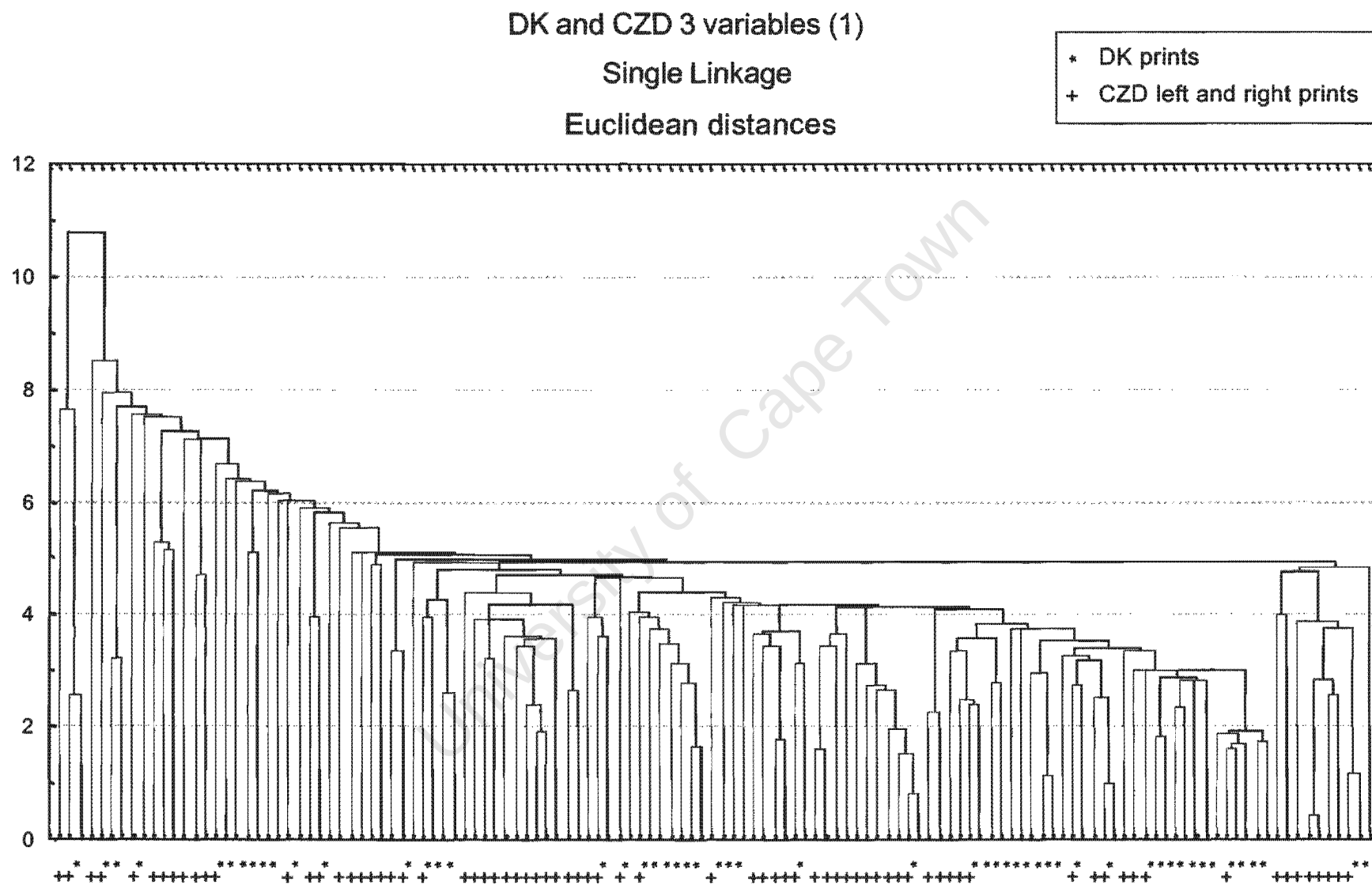


Figure 107: Cluster analysis of 3 handprint-variables (1) of DK and CZD sets (1)

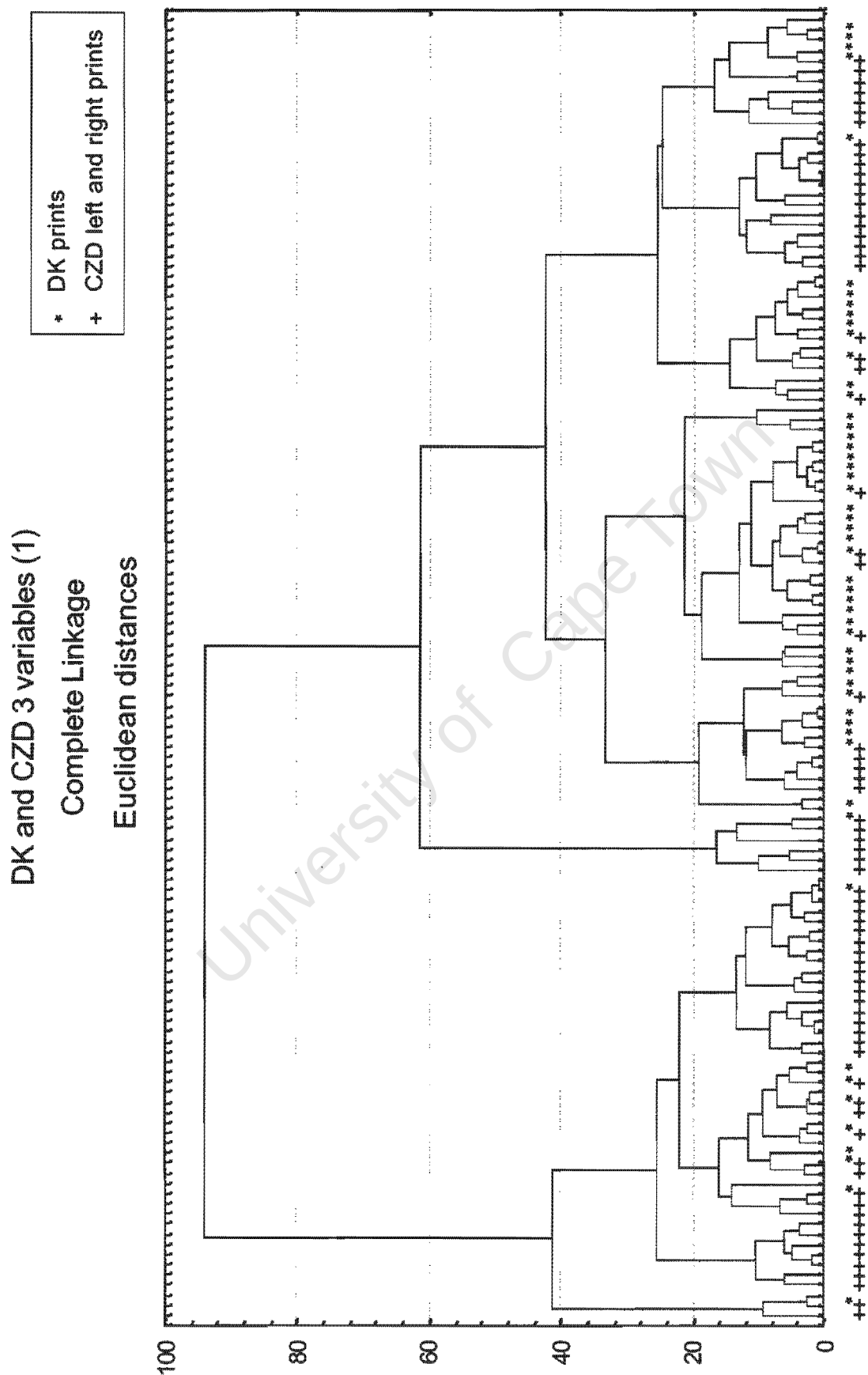


Figure 108: Cluster analysis of 3 handprint-variables (1) of DK and CZD sets (2)

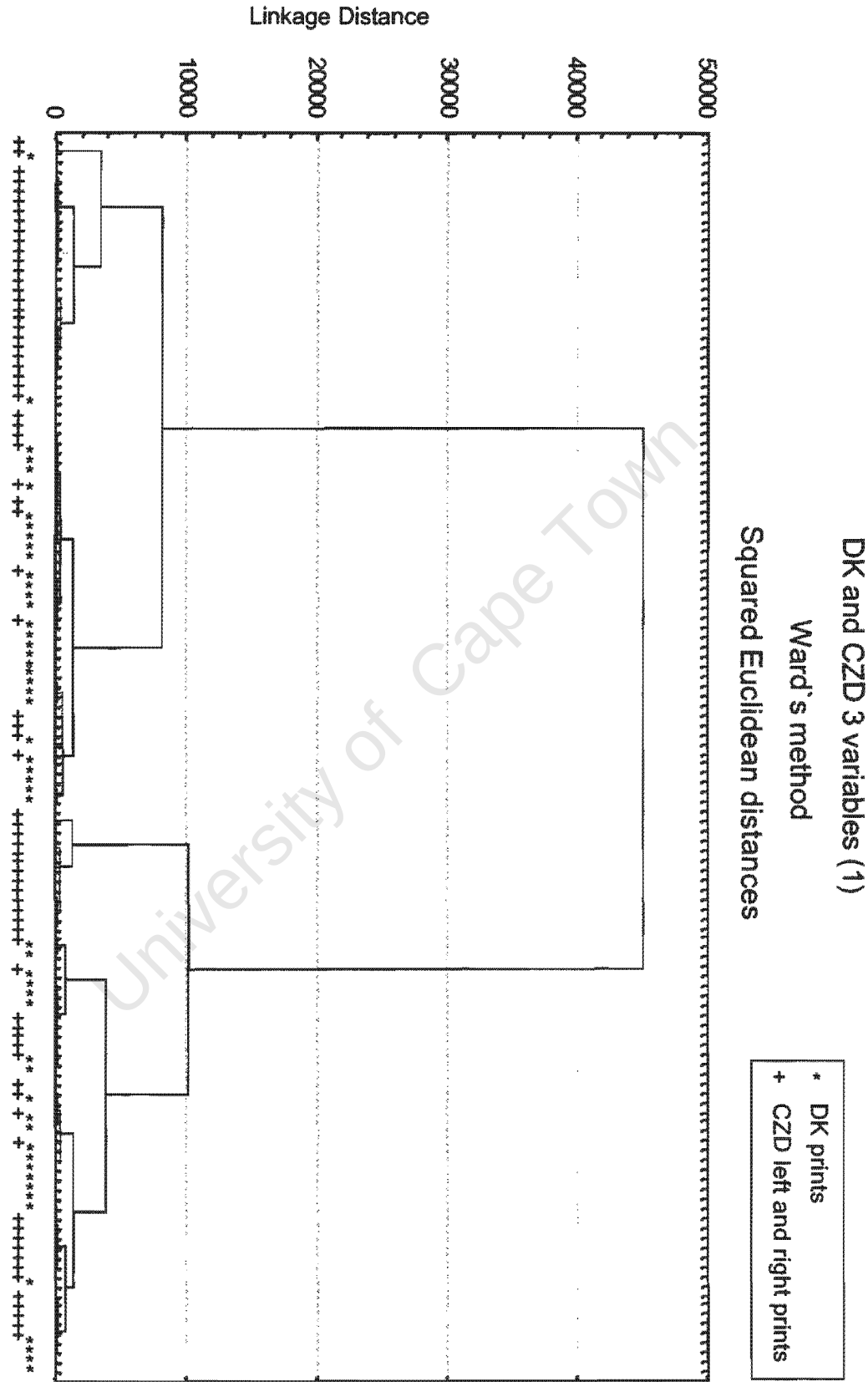


Figure 109: Cluster analysis of 3 handprint-variables (1) of DK and CZD sets (3)

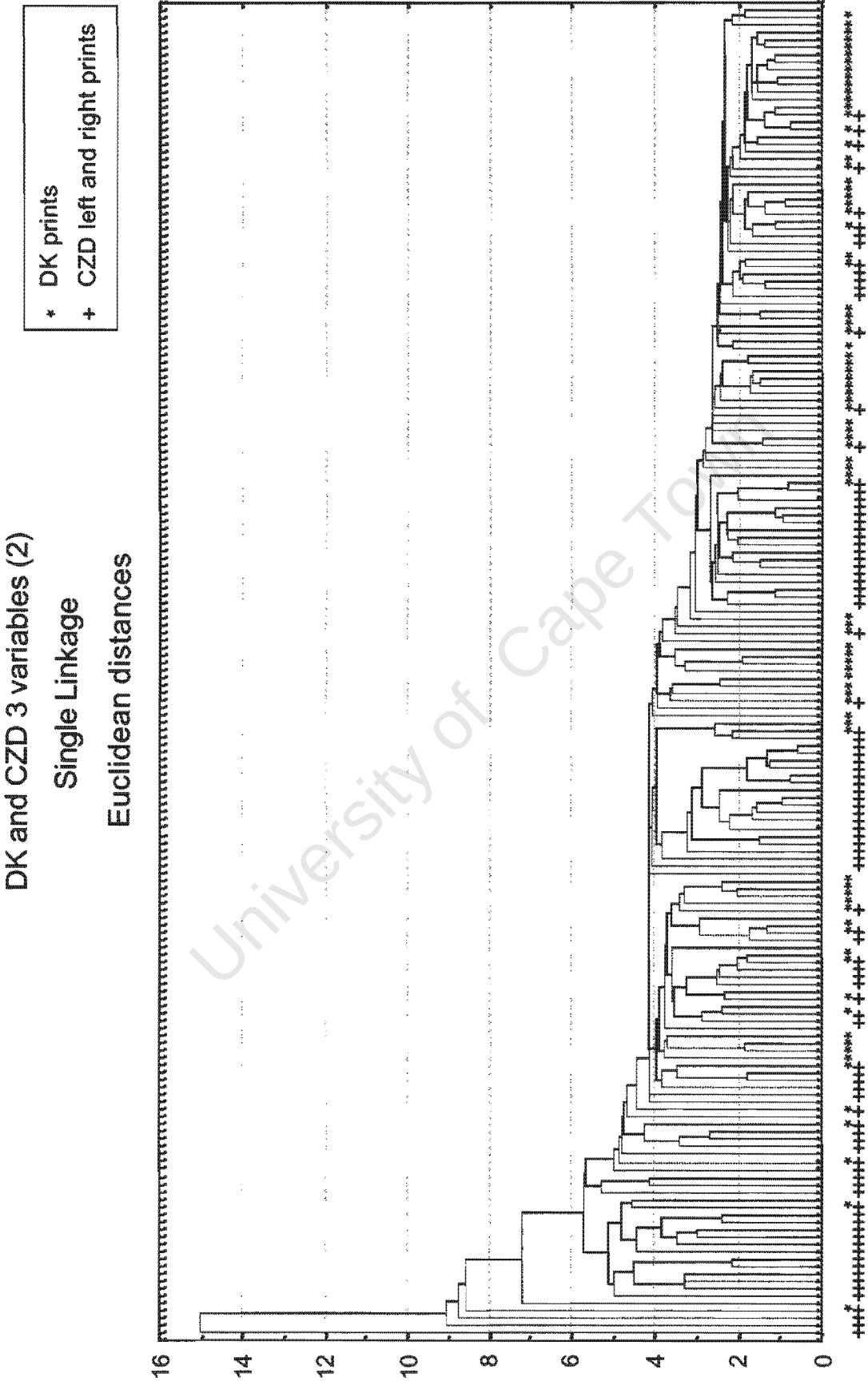


Figure 110: Cluster analysis of 3 handprint-variables (2) of DK and CZD sets (1)

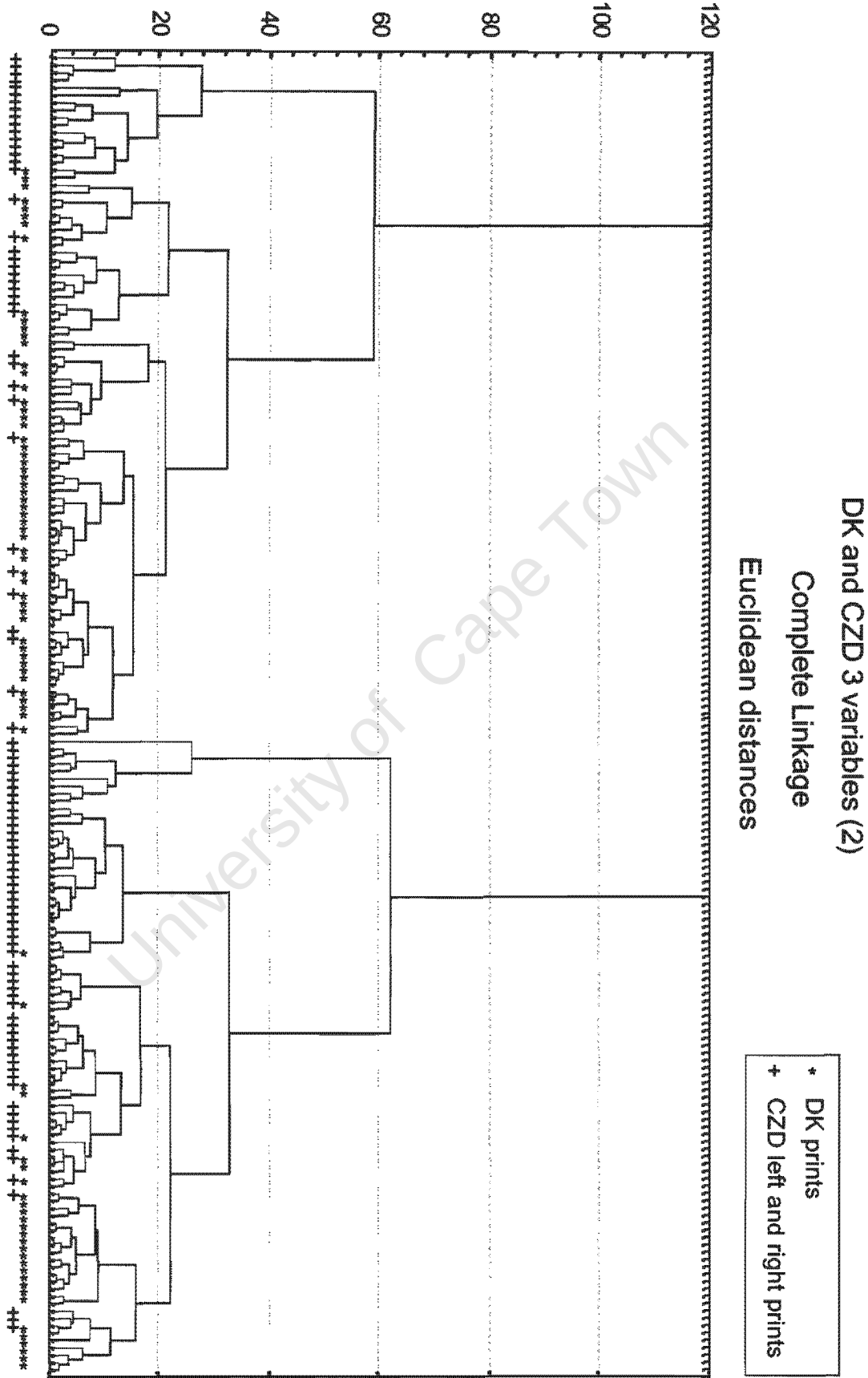


Figure 111: Cluster analysis of 3 handprint-variables (2) of DK and CZD sets (2)

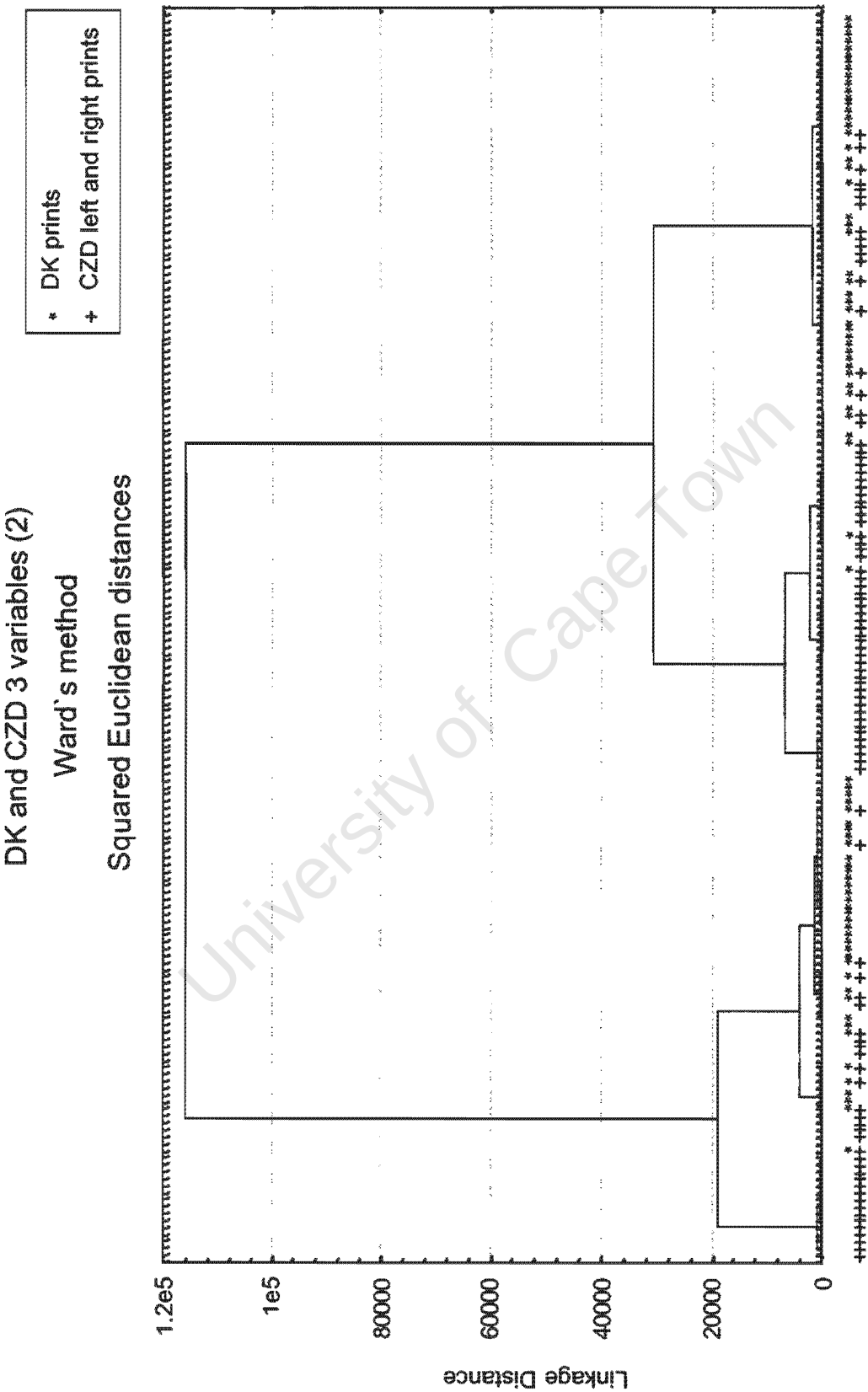


Figure 112: Cluster analysis of 3 handprint-variables (2) of DK and CZD sets (3)

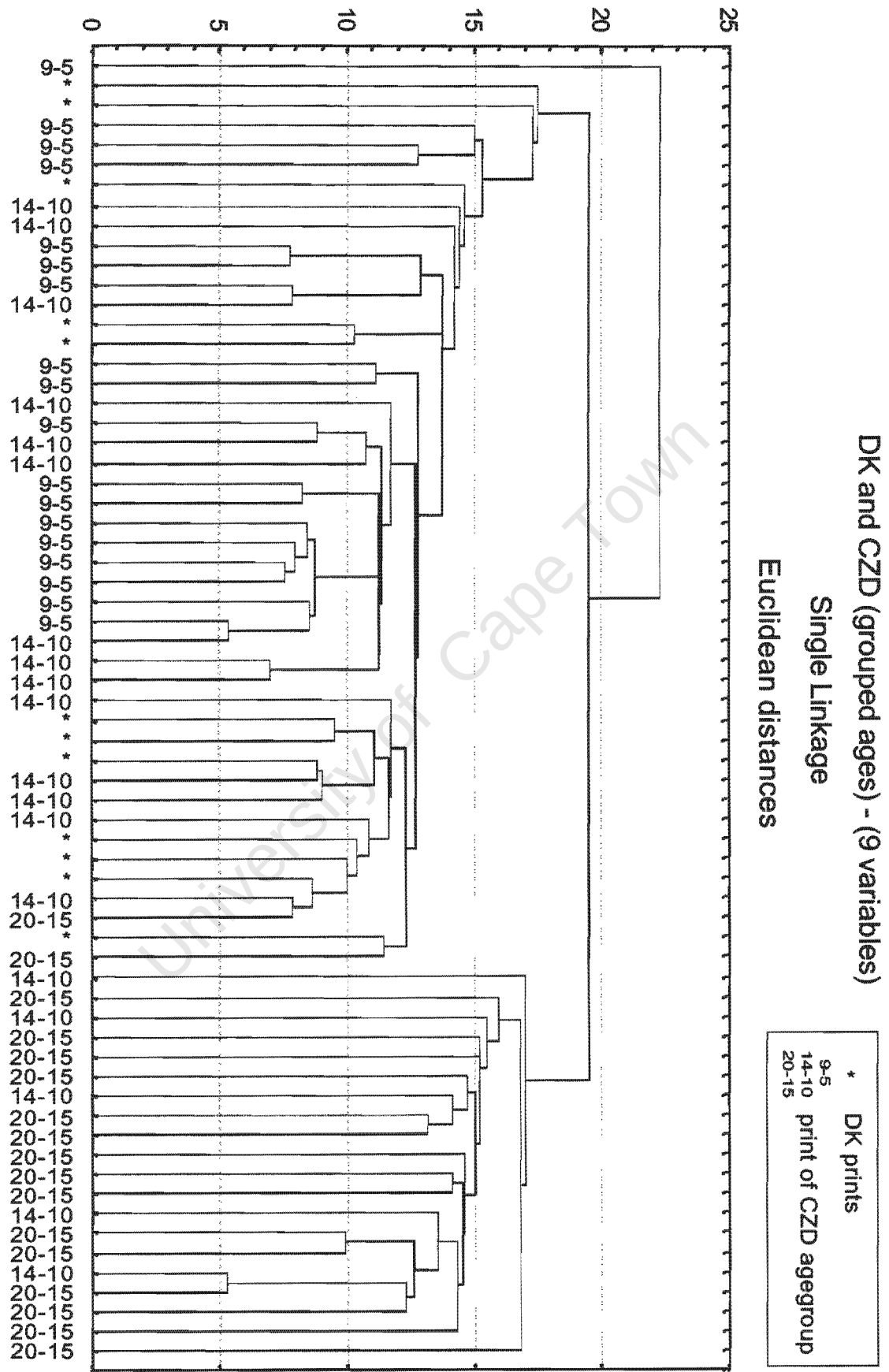
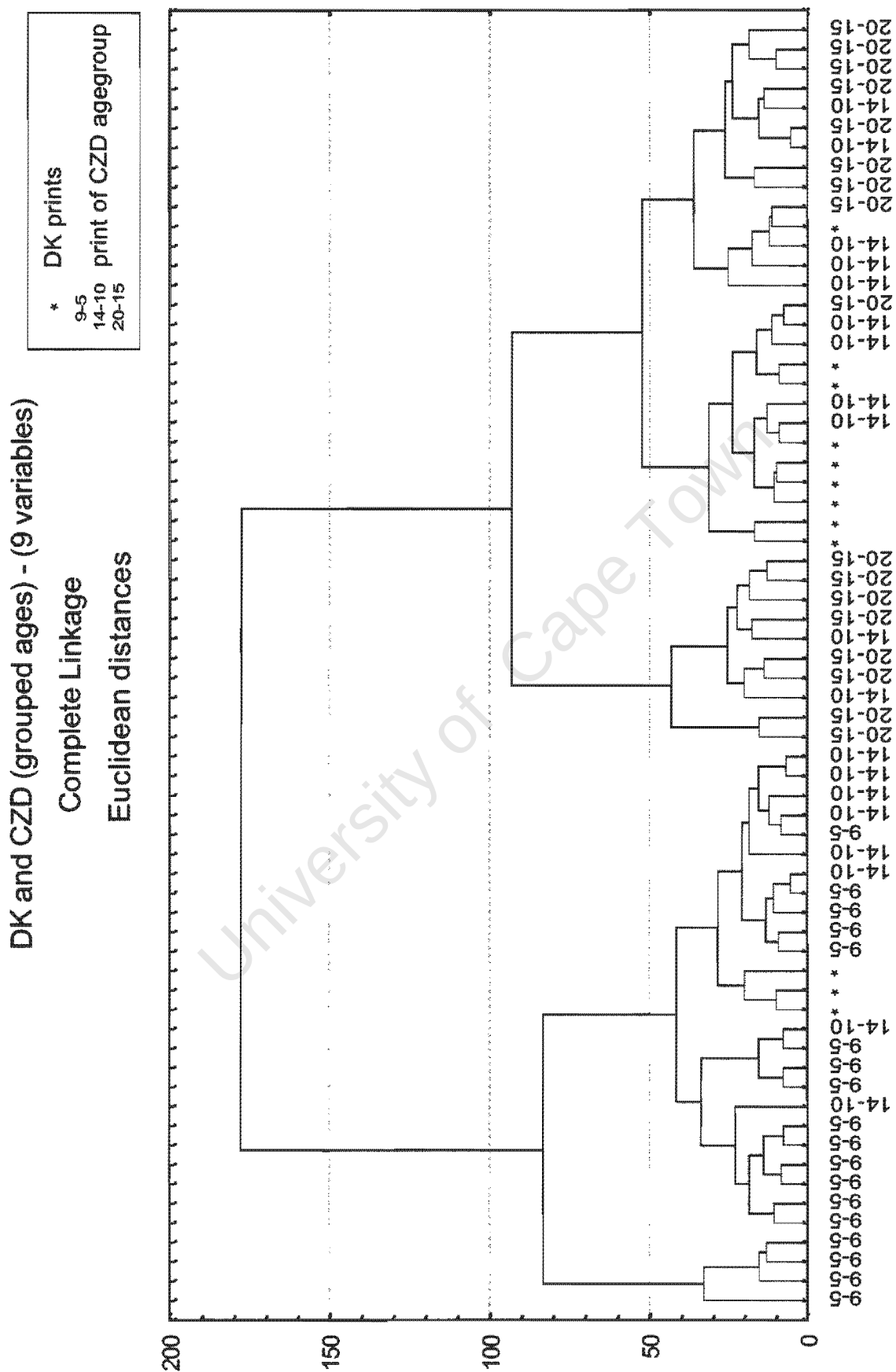


Figure 113: Cluster analysis of 9 handprint-variables of DK and CZD (grouped ages) sets (1)



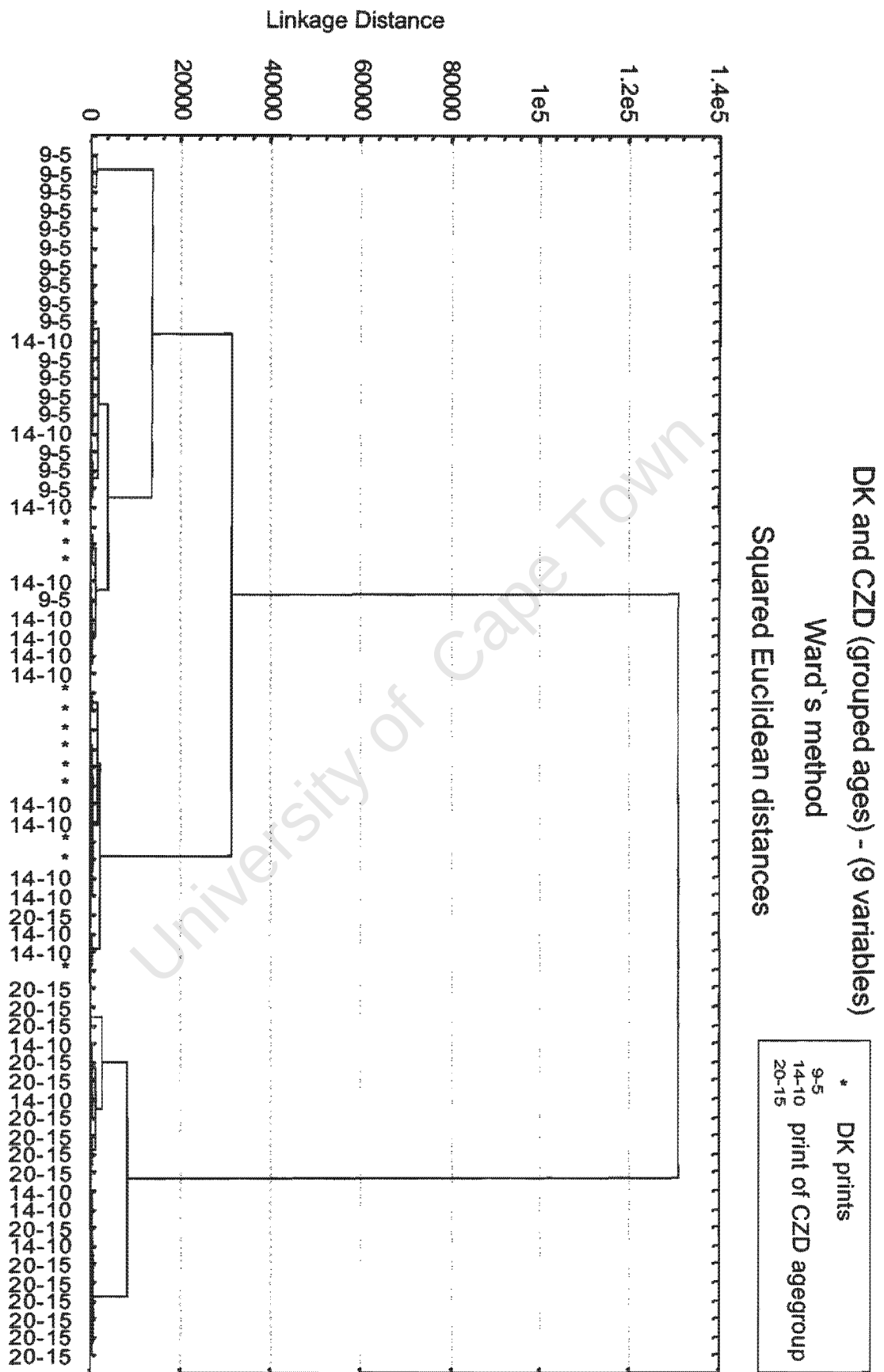


Figure 115: Cluster analysis of 9 handprint-variables of DK and CZD (grouped ages) sets (3)

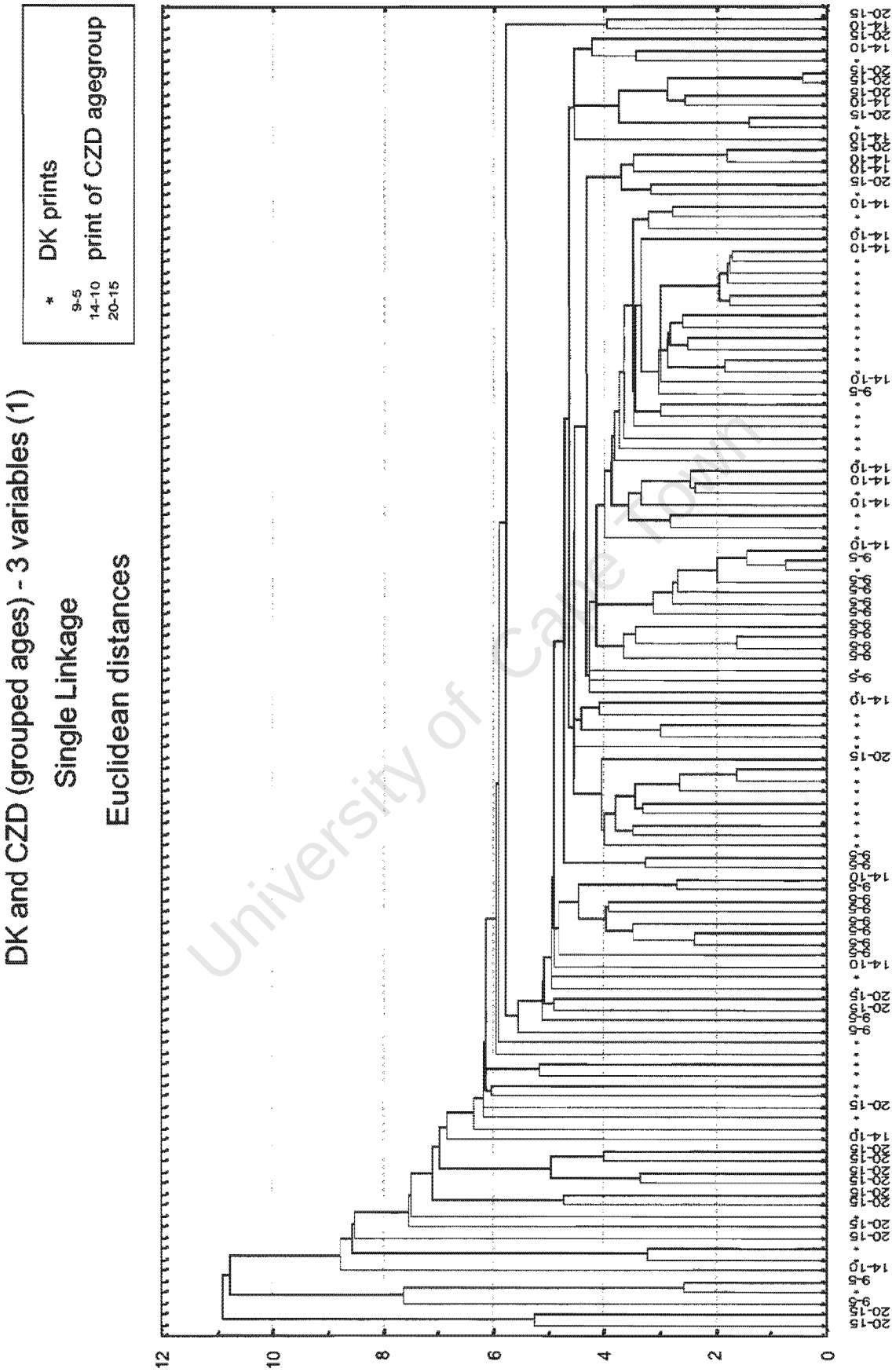


Figure 116: Cluster analysis of 3 handprint-variables (1) of DK and CZD (grouped ages) sets (1)

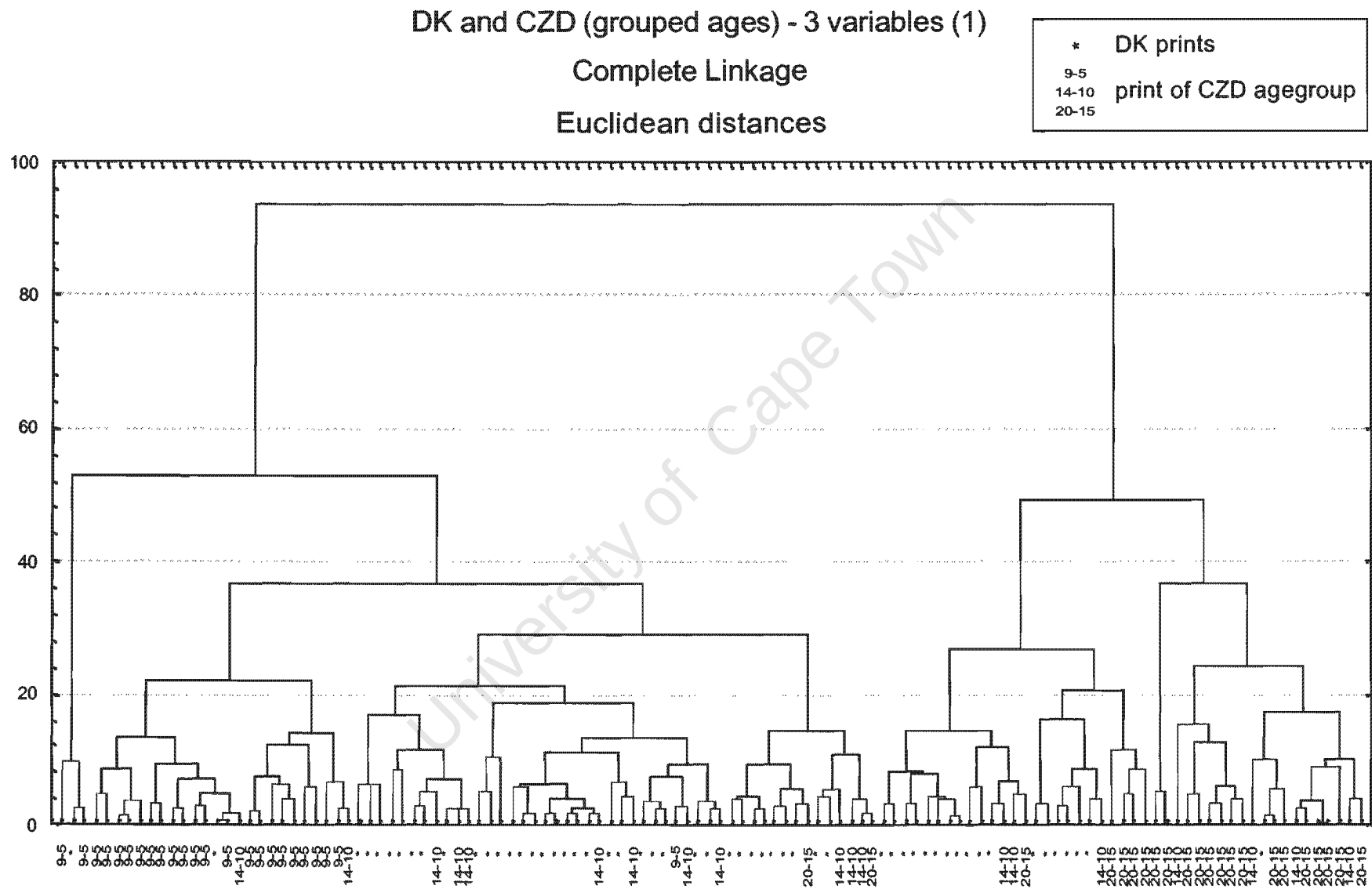
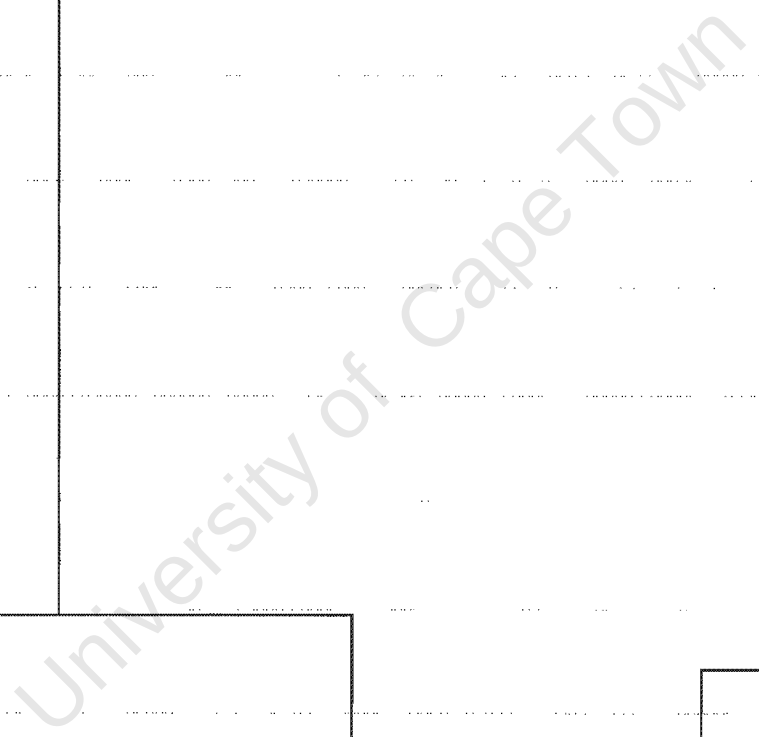


Figure 117: Cluster analysis of 3 handprint-variables (1) of DK and CZD (grouped ages)



Sets (3)

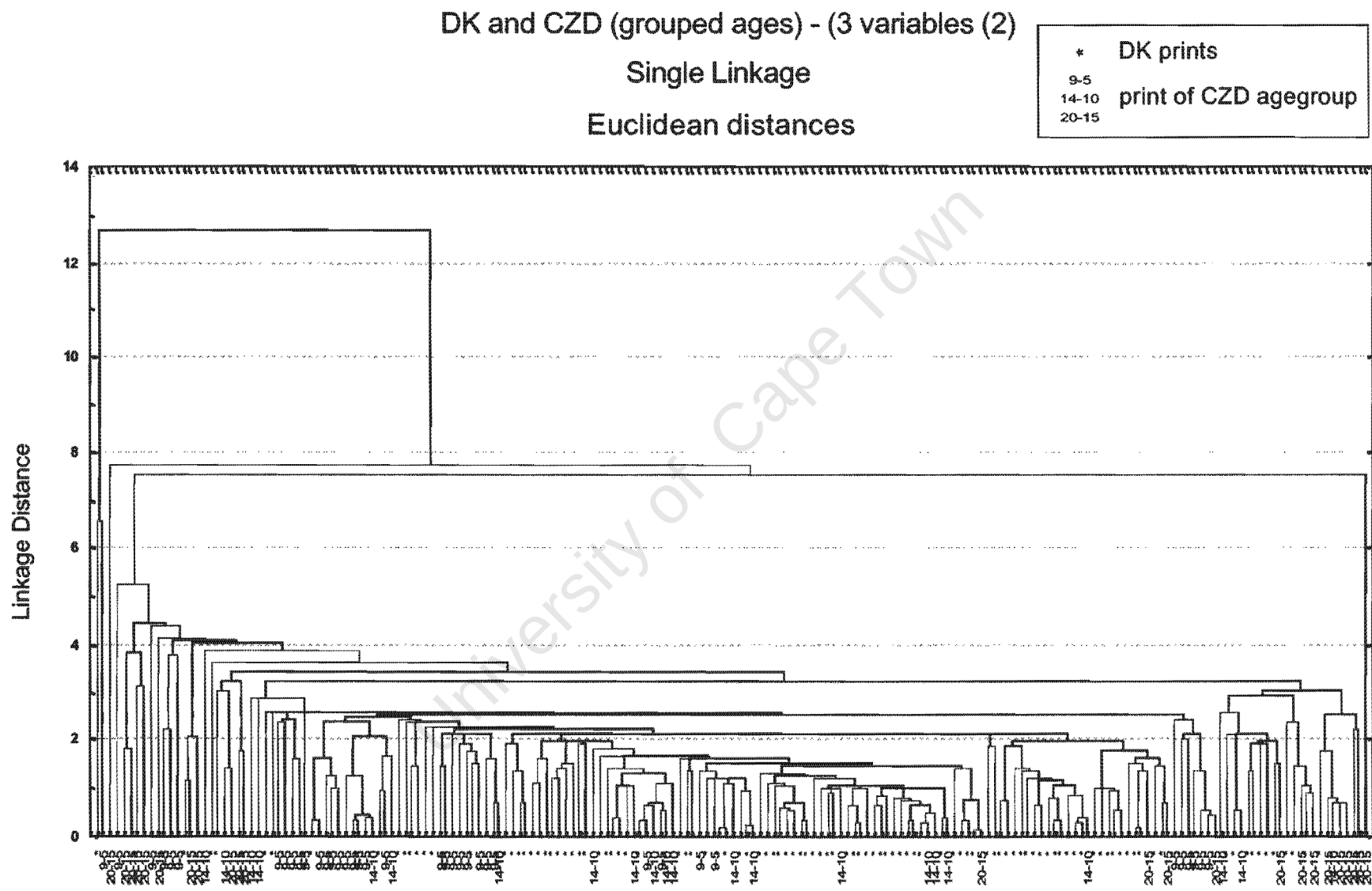


Figure 119: Cluster analysis of 3 handprint-variables (2) of DK and CZD (grouped ages) sets (1)

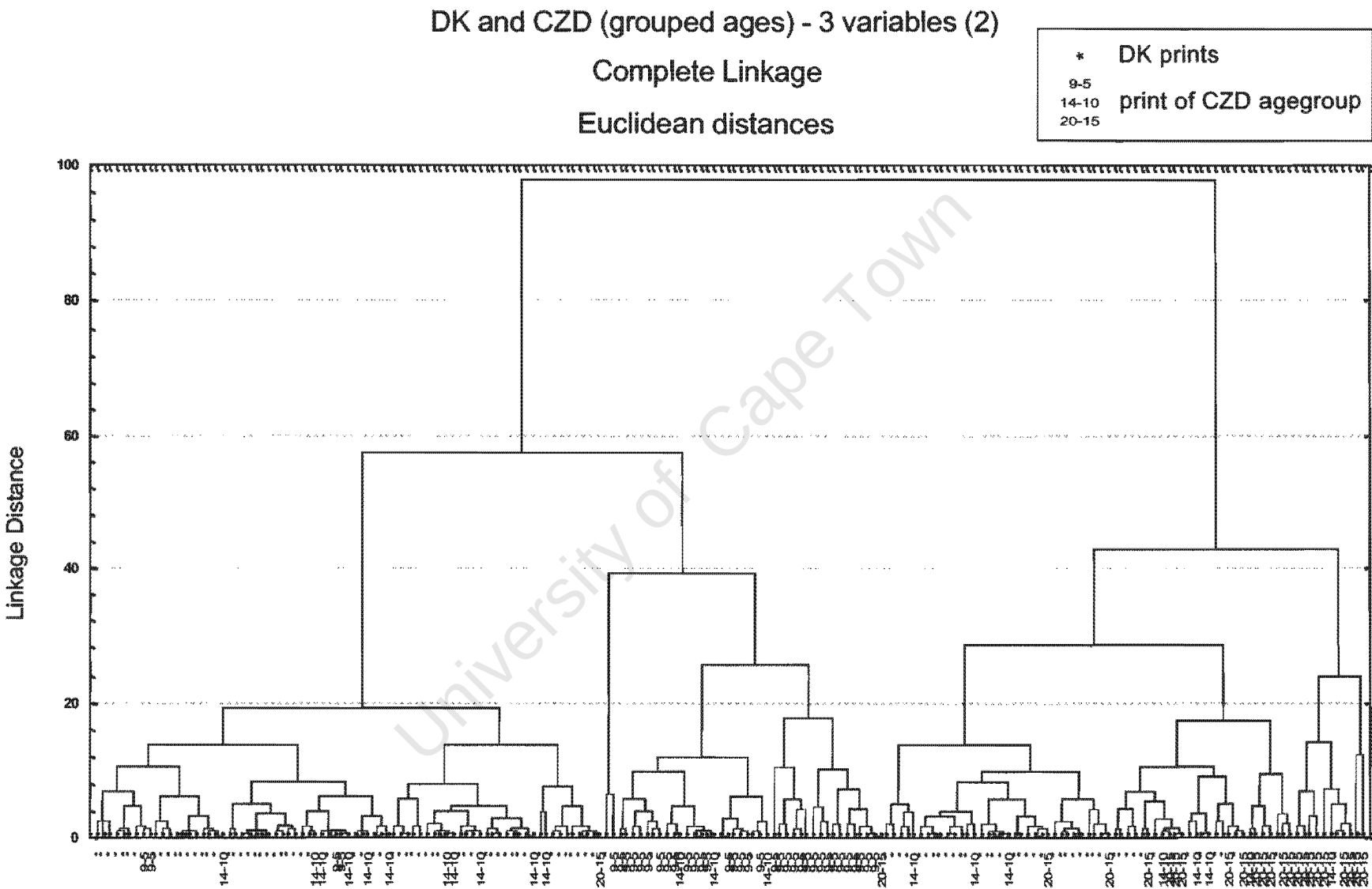


Figure 120: Cluster analysis of 3 handprint-variables (2) of DK and CZD (grouped ages) sets (2)

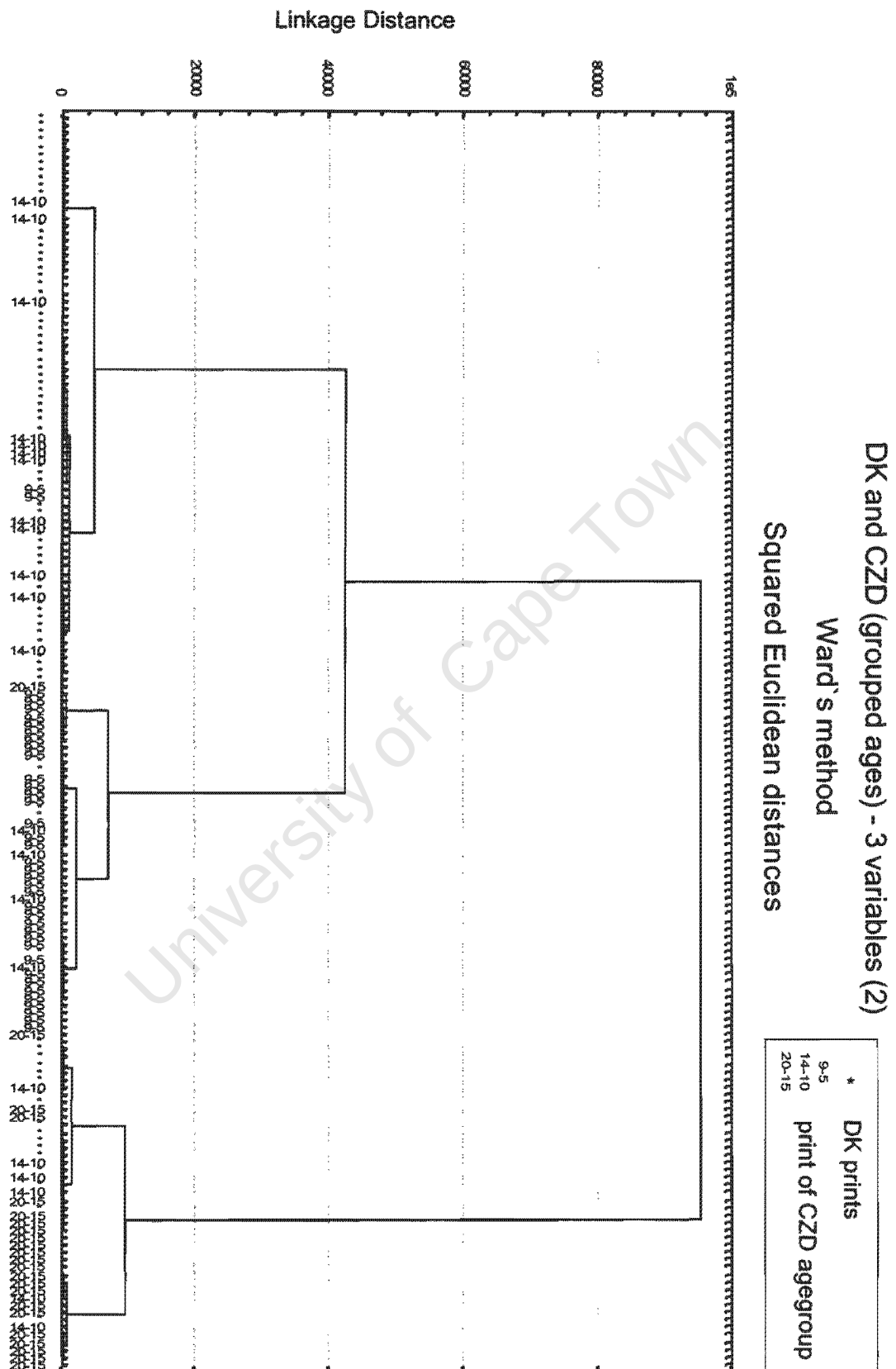


Figure 121: Cluster analysis of 3 handprint-variables (2) of DK and CZD (grouped ages) sets (3)

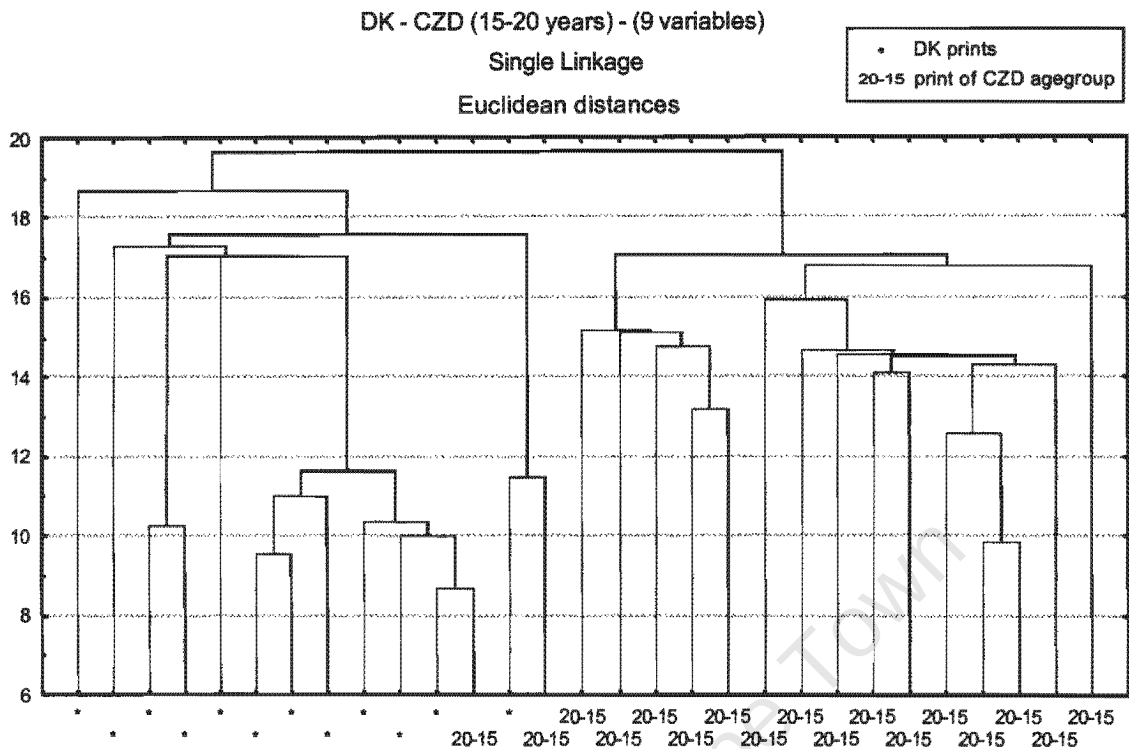


Figure 122: Cluster analysis of 9 handprint-variables of DK and CZD (15 to 20 year olds) sets (1)

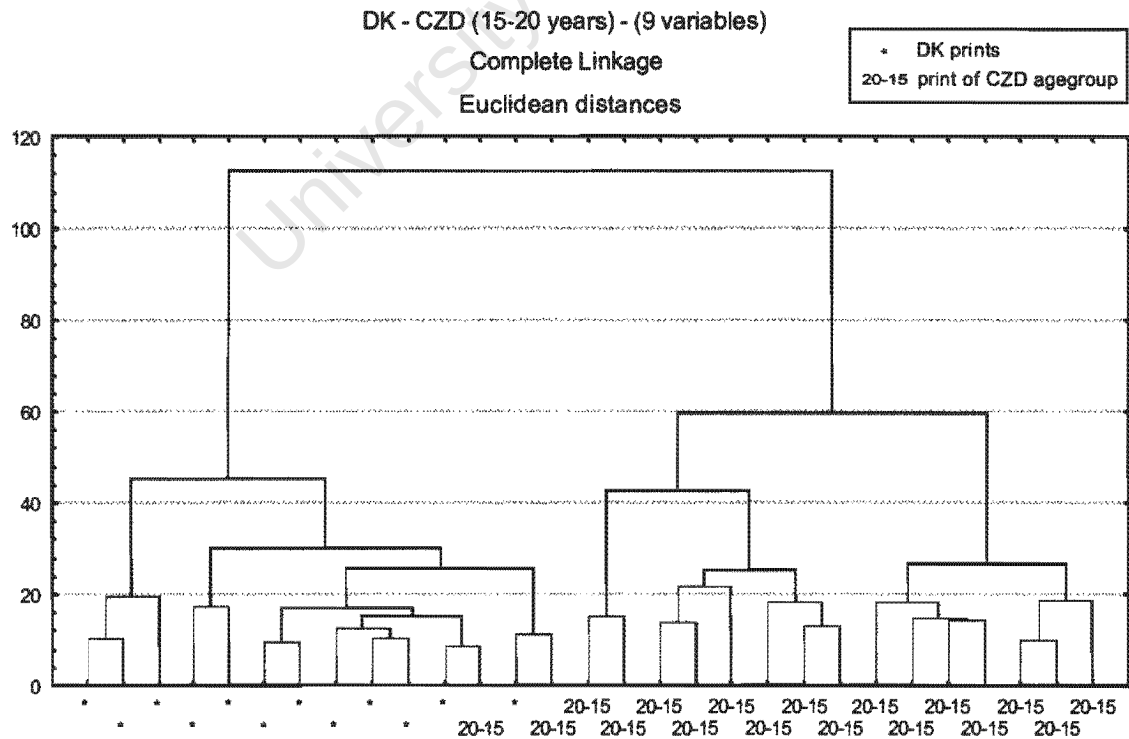


Figure 123: Cluster analysis of 9 handprint-variables of DK and CZD (15 to 20 year olds) sets (2)

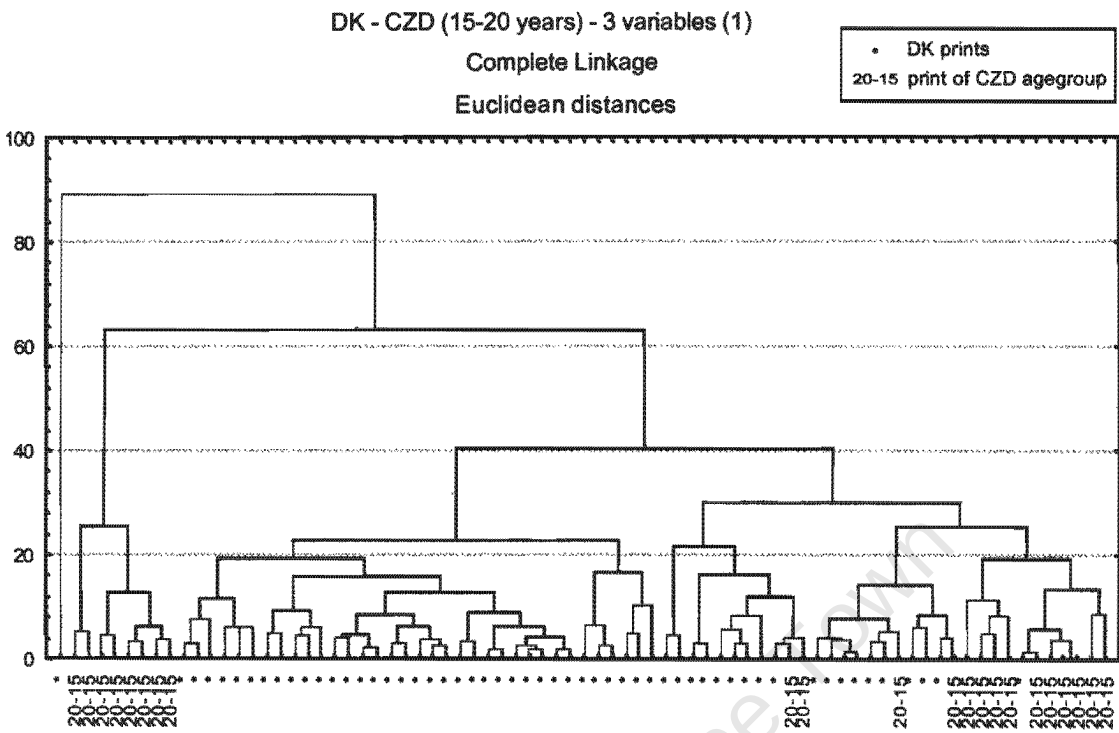


Figure 126: Cluster analysis of 3 handprint-variables (1) of DK and CZD (15 to 20 year olds) sets (2)

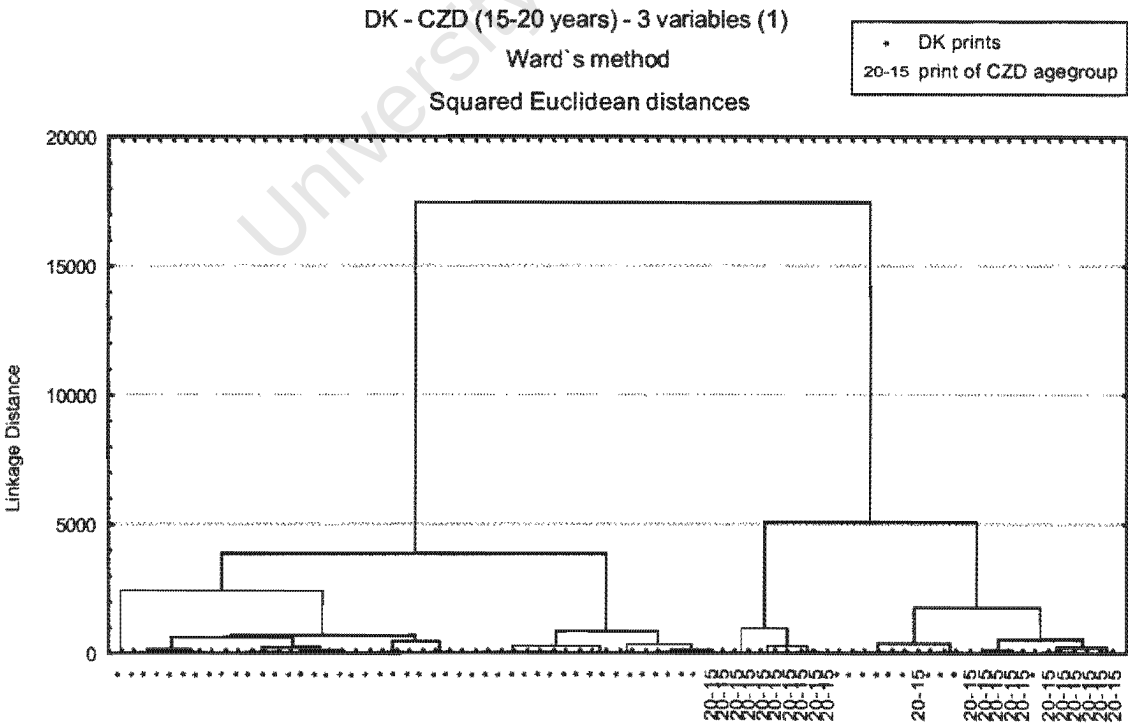


Figure 127: Cluster analysis of 3 handprint-variables (1) of DK and CZD (15 to 20 year olds) sets (3)

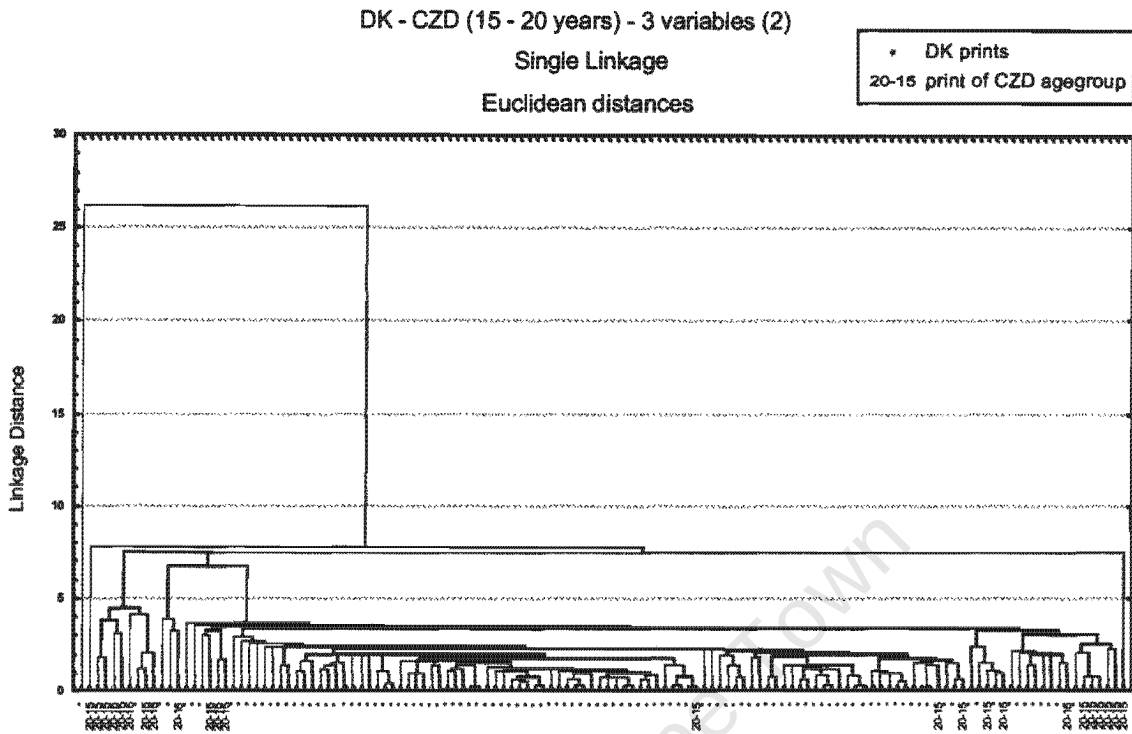


Figure 128: Cluster analysis of 3 handprint-variables (2) of DK and CZD (15 to 20 year olds) sets (1)

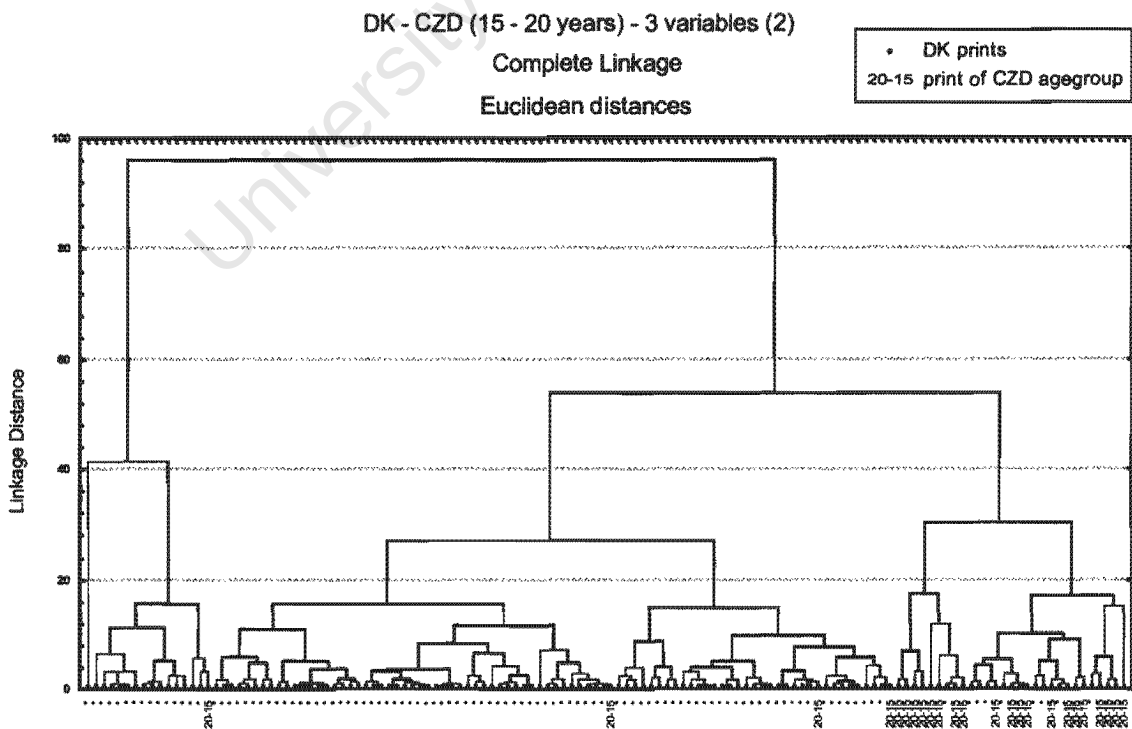


Figure 129: Cluster analysis of 3 handprint-variables (2) of DK and CZD (15 to 20 year olds) sets (2)

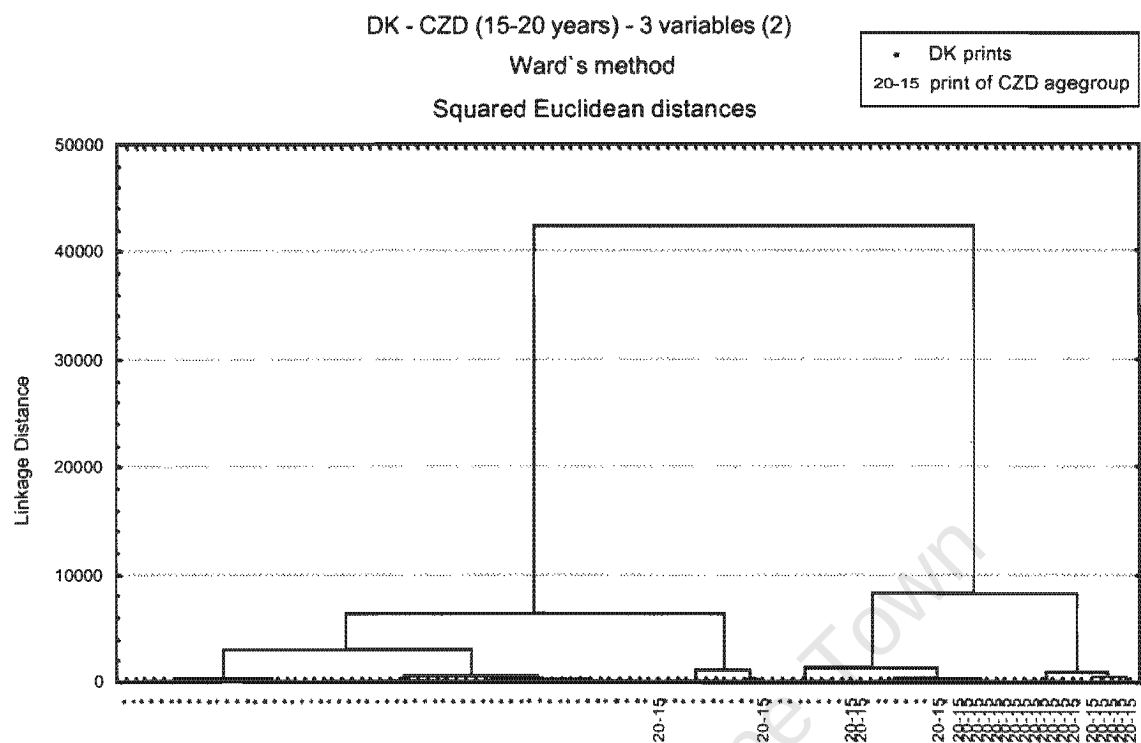


Figure 130: Cluster analysis of 3 handprint-variables (2) of DK and CZD (15 to 20 year olds) sets (3)

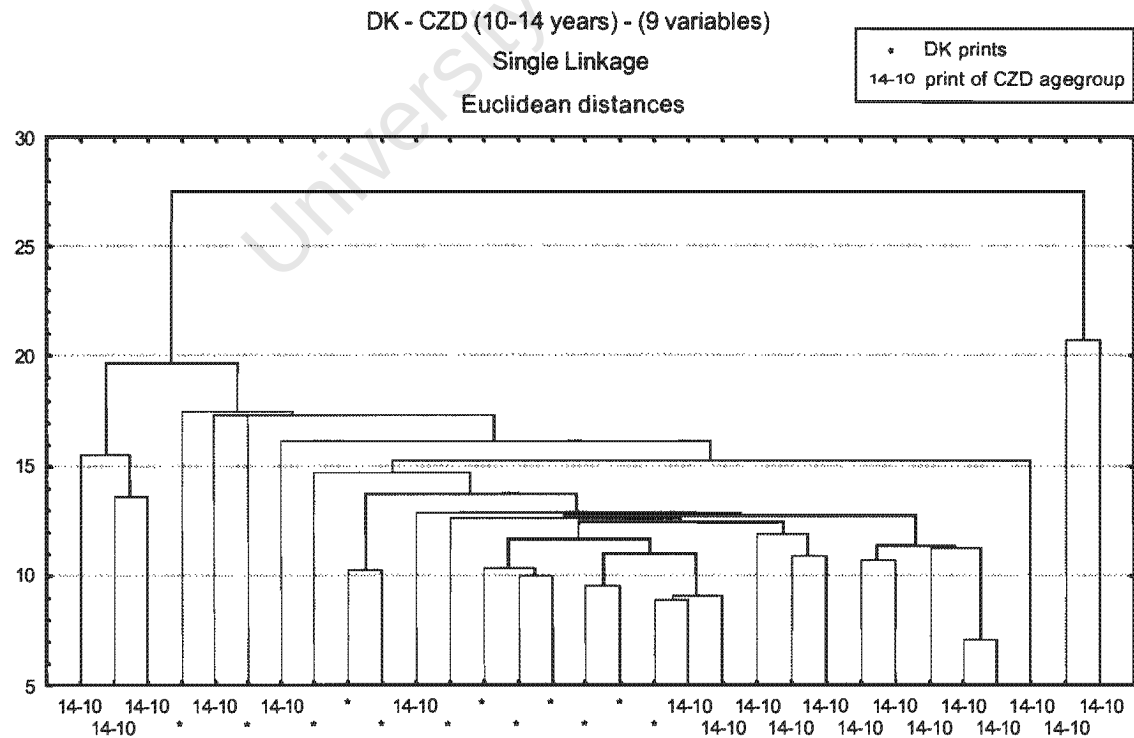


Figure 131: Cluster analysis of 9 handprint-variables of DK and CZD (10 to 14 year olds) sets (1)

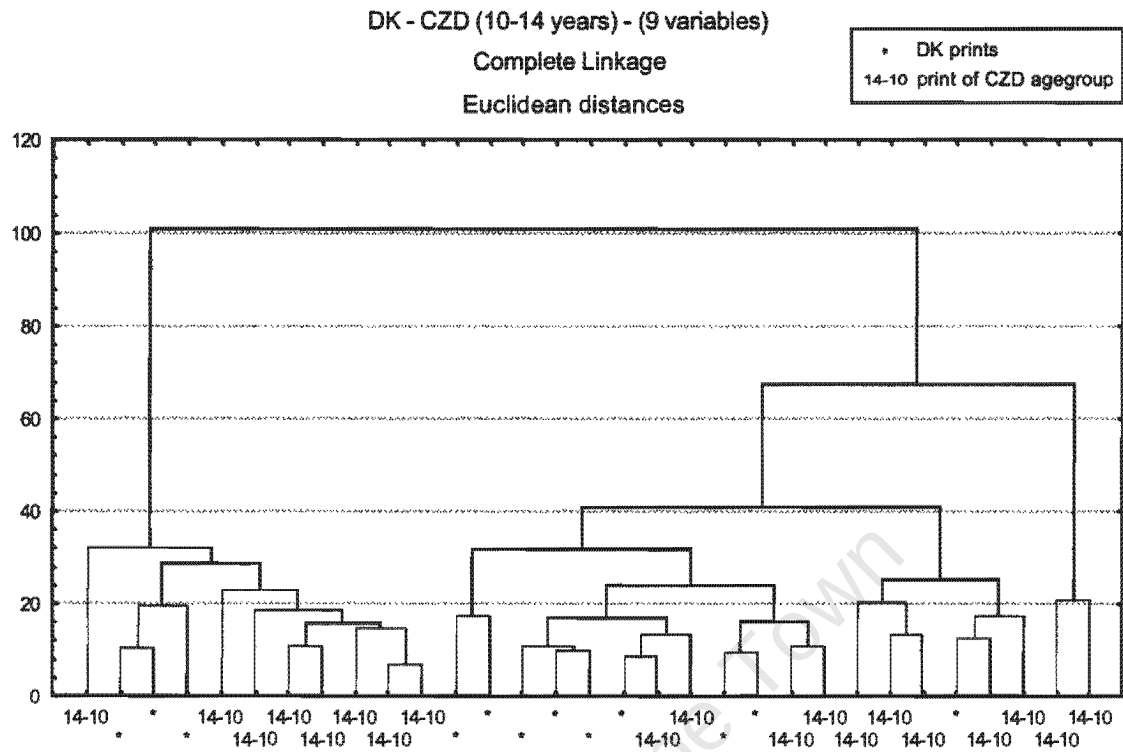


Figure 132: Cluster analysis of 9 handprint-variables of DK and CZD (10 to 14 year olds) sets (2)

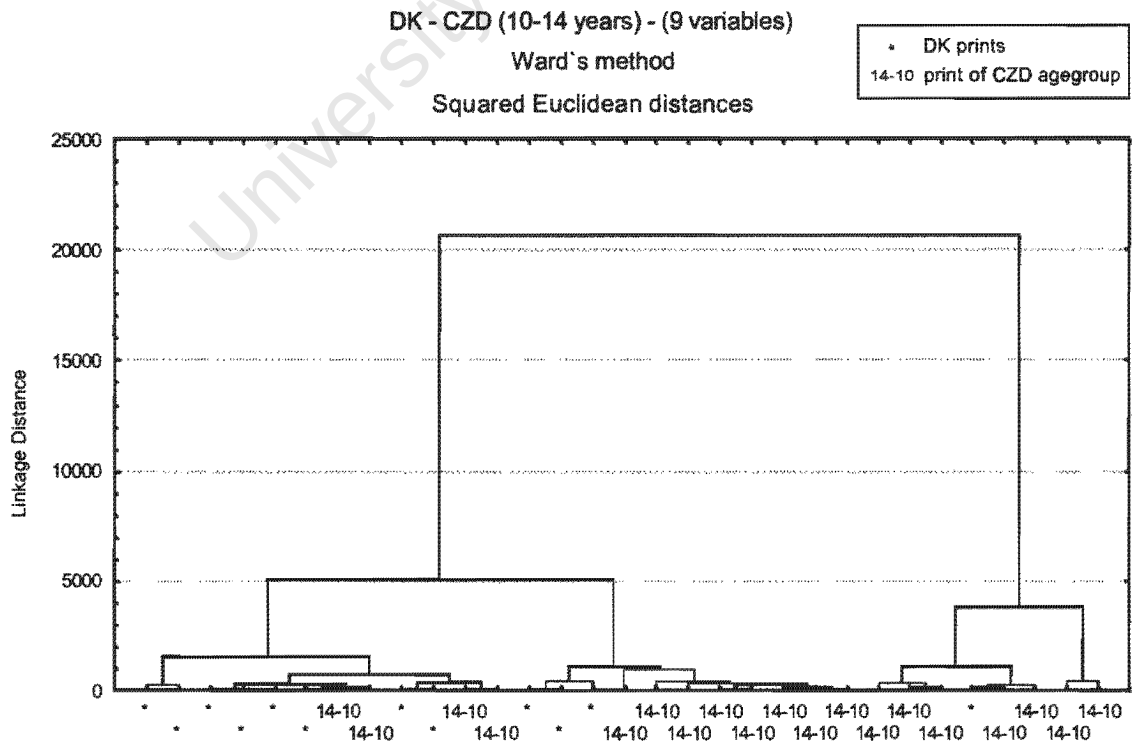


Figure 133: Cluster analysis of 9 handprint-variables of DK and CZD (10 to 14 year olds) sets (3)

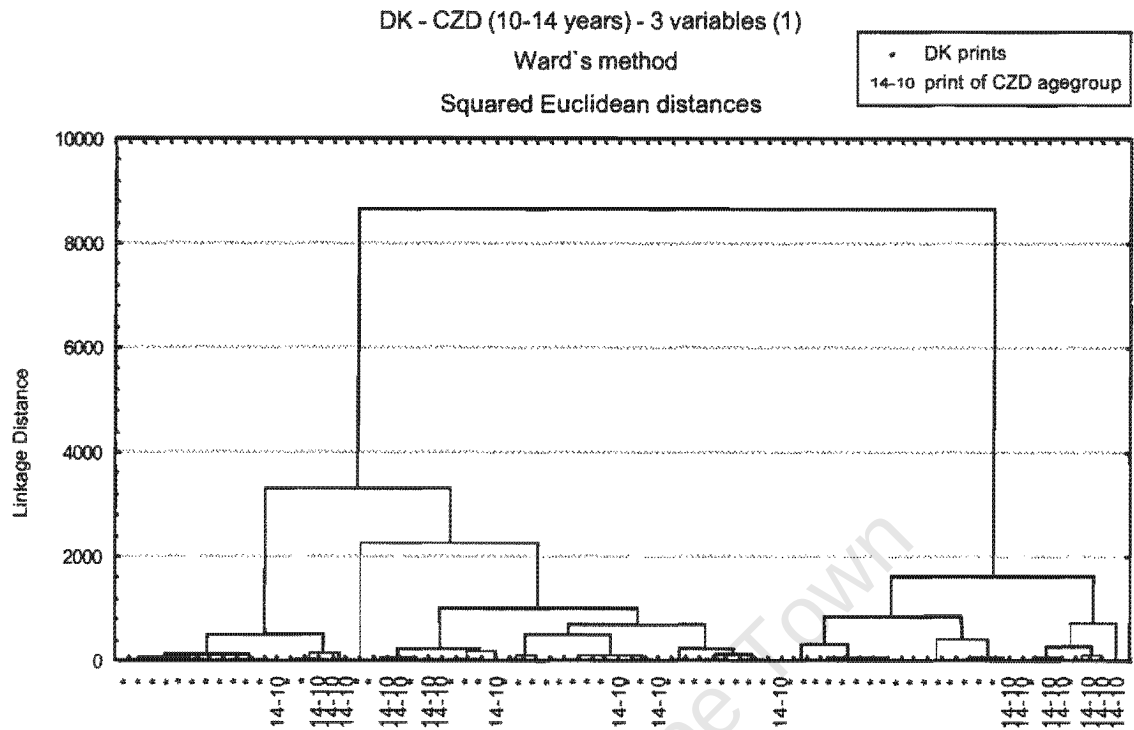


Figure 136: Cluster analysis of 3 handprint-variables (1) of DK and CZD (10 to 14 year olds) sets (3)

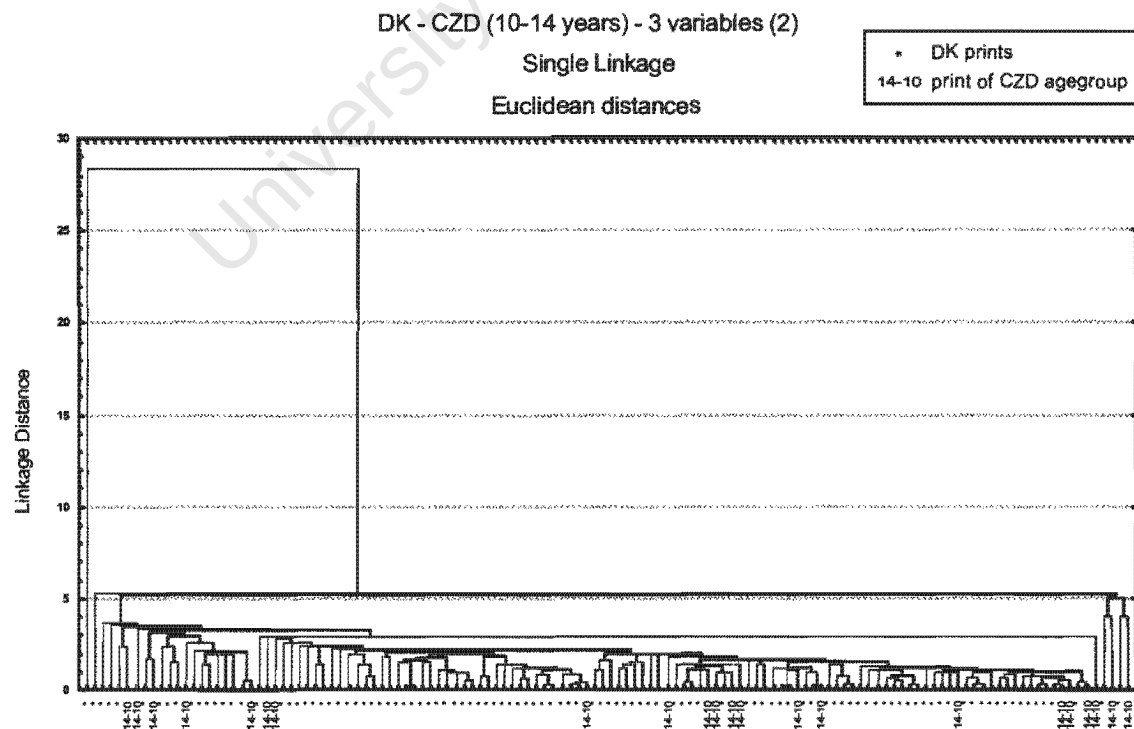


Figure 137: Cluster analysis of 3 handprint-variables (2) of DK and CZD (10 to 14 year olds) sets (1)

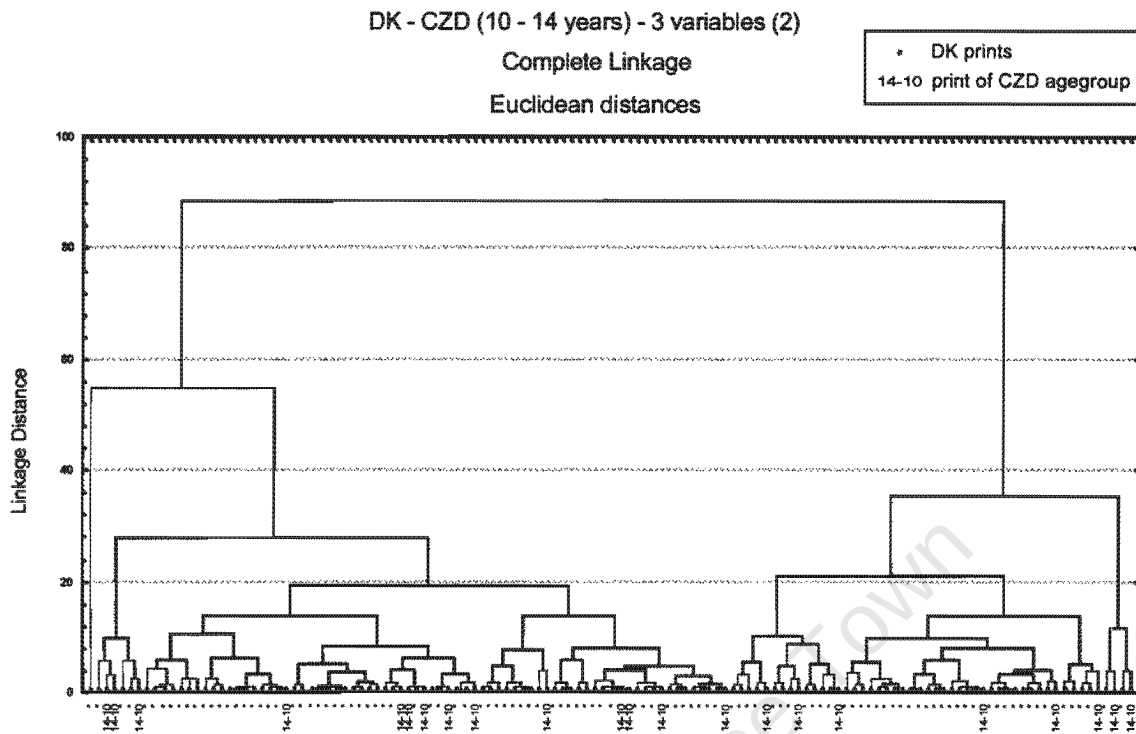


Figure 138: Cluster analysis of 3 handprint-variables (2) of DK and CZD (10 to 14 year olds) sets (2)

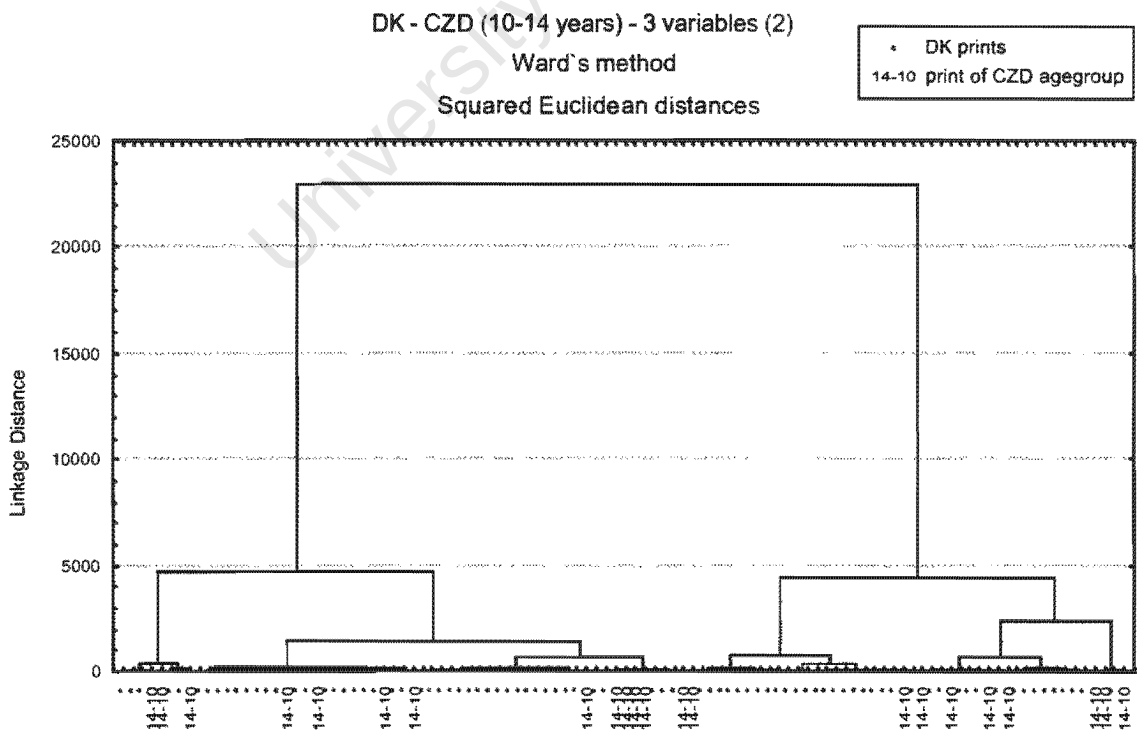


Figure 139: Cluster analysis of 3 handprint-variables (2) of DK and CZD (10 to 14 year olds) sets (3)

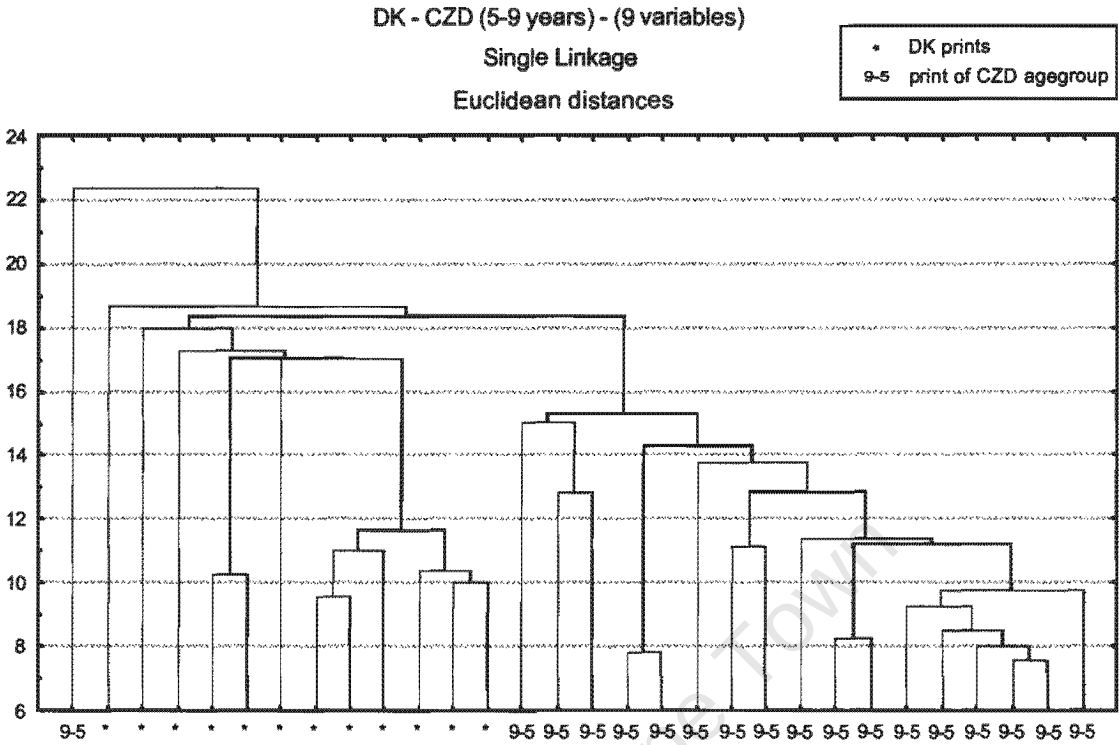


Figure 140: Cluster analysis of 9 handprint-variables of DK and CZD (5 to 9 year olds) sets (1)

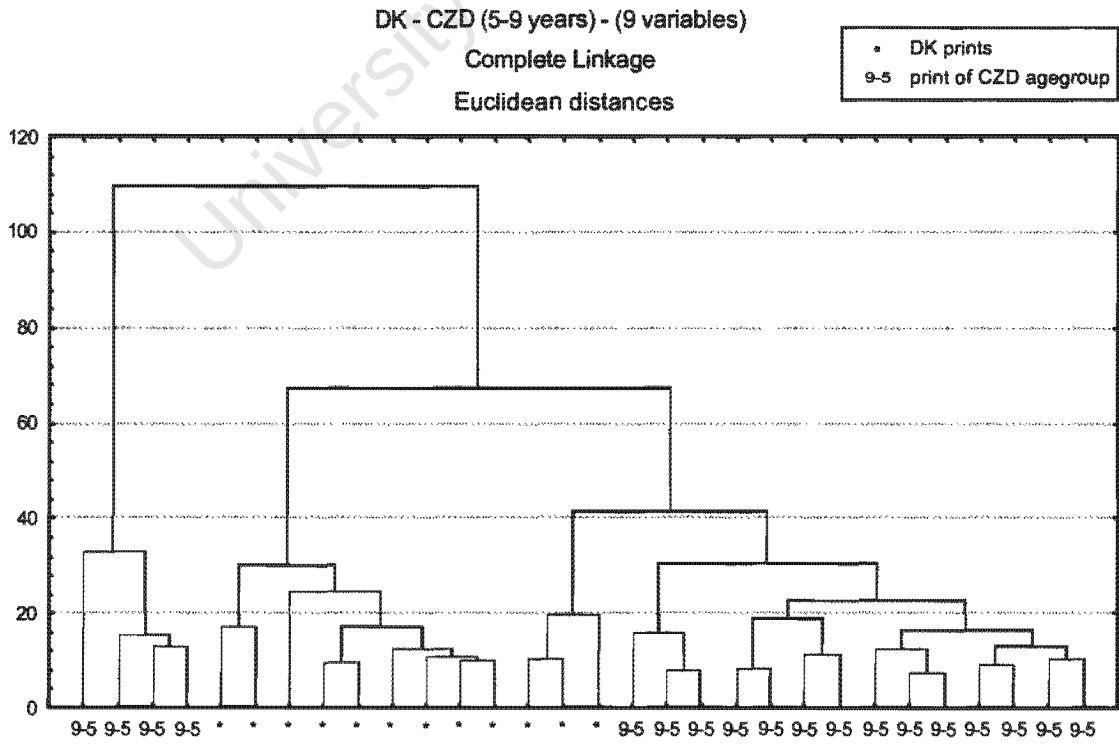


Figure 141: Cluster analysis of 9 handprint-variables of DK and CZD (5 to 9 year olds) sets (2)

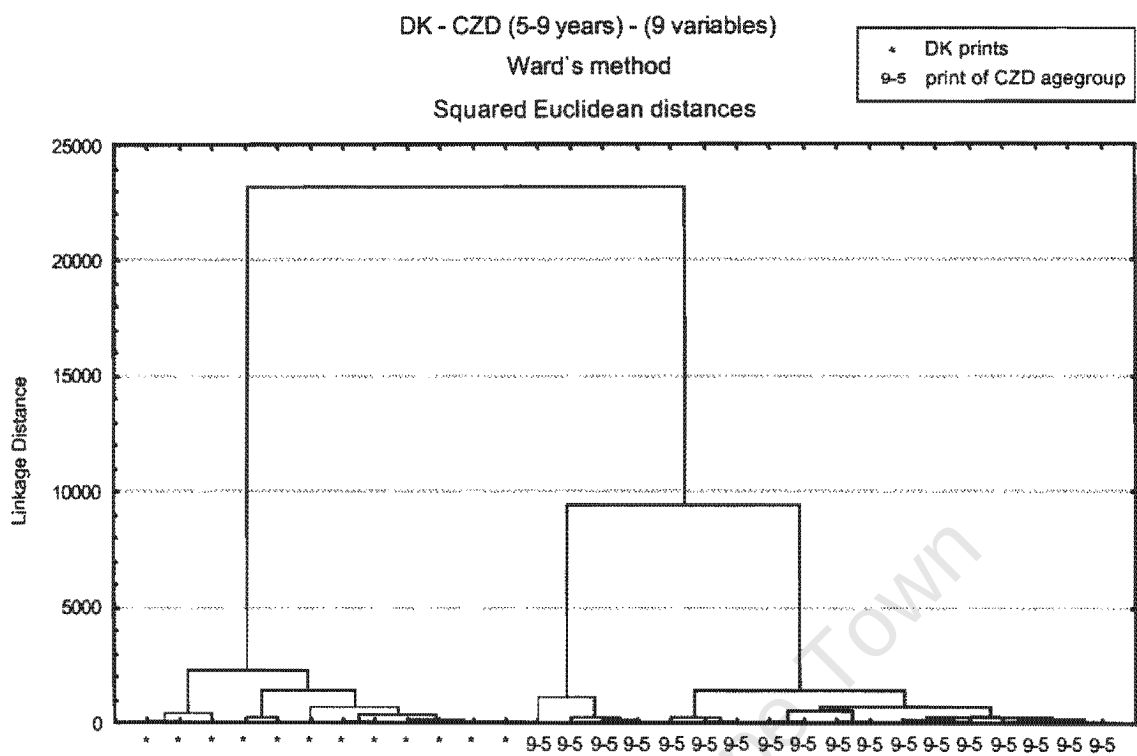


Figure 142: Cluster analysis of 9 handprint-variables of DK and CZD (5 to 9 year olds) sets (3)

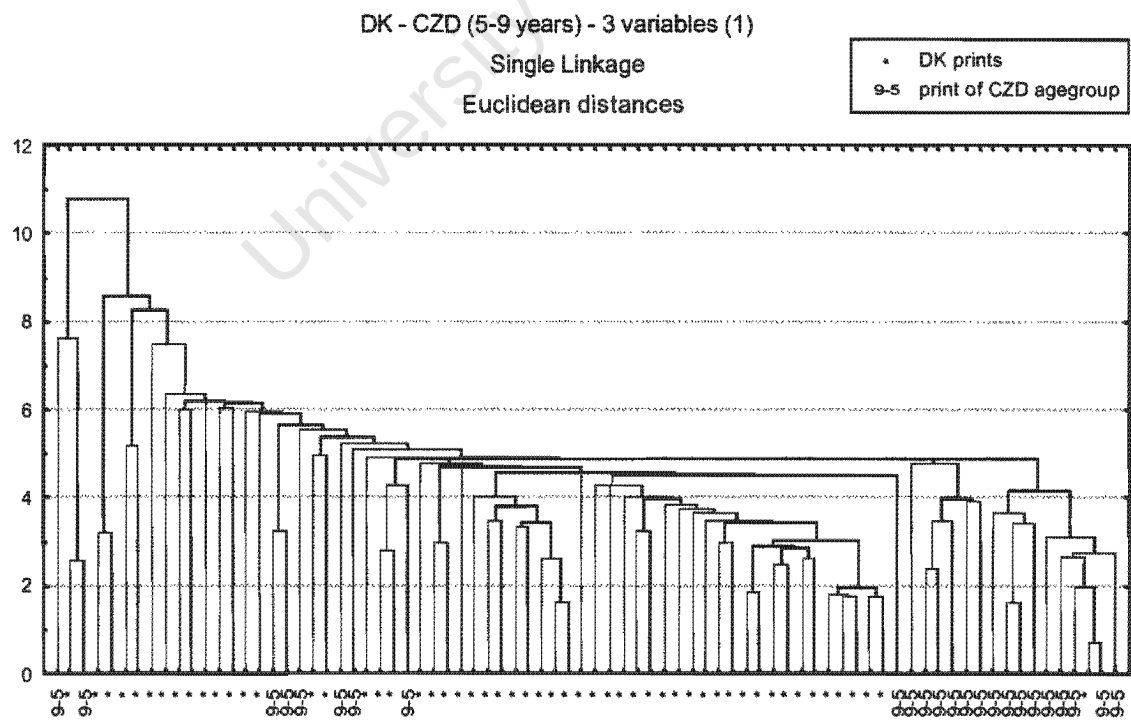


Figure 143: Cluster analysis of 3 handprint-variables (1) of DK and CZD (5 to 9 year olds) sets (1)

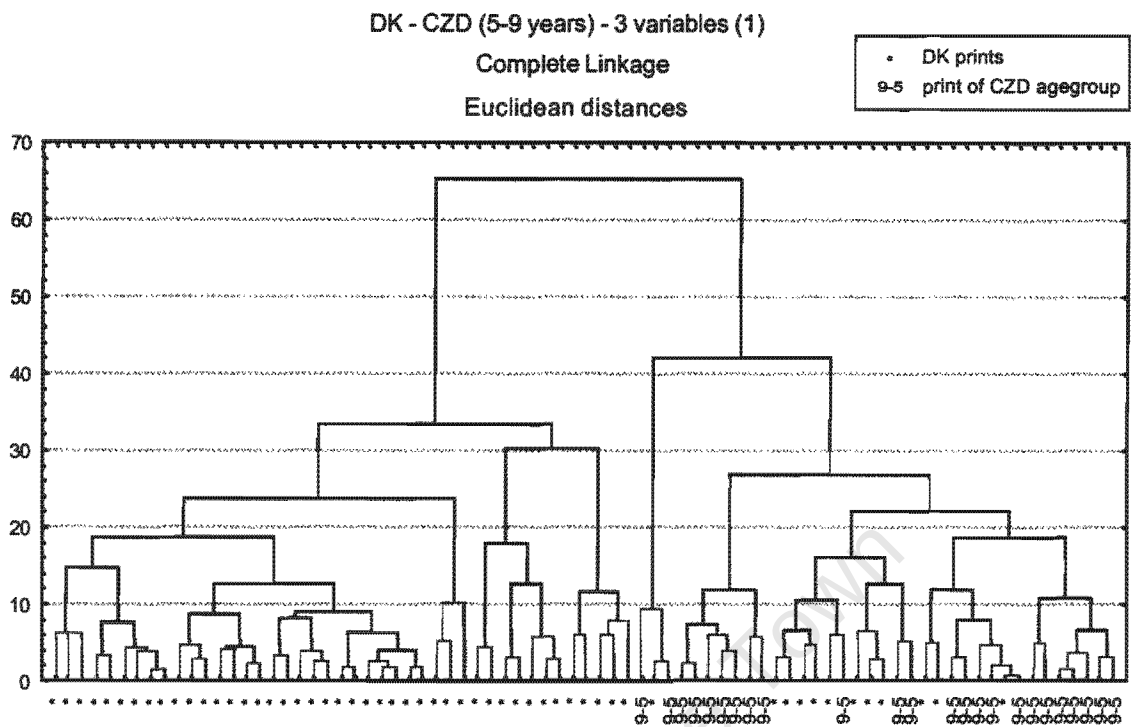


Figure 144: Cluster analysis of 3 handprint-variables (1) of DK and CZD (5 to 9 year olds) sets (2)

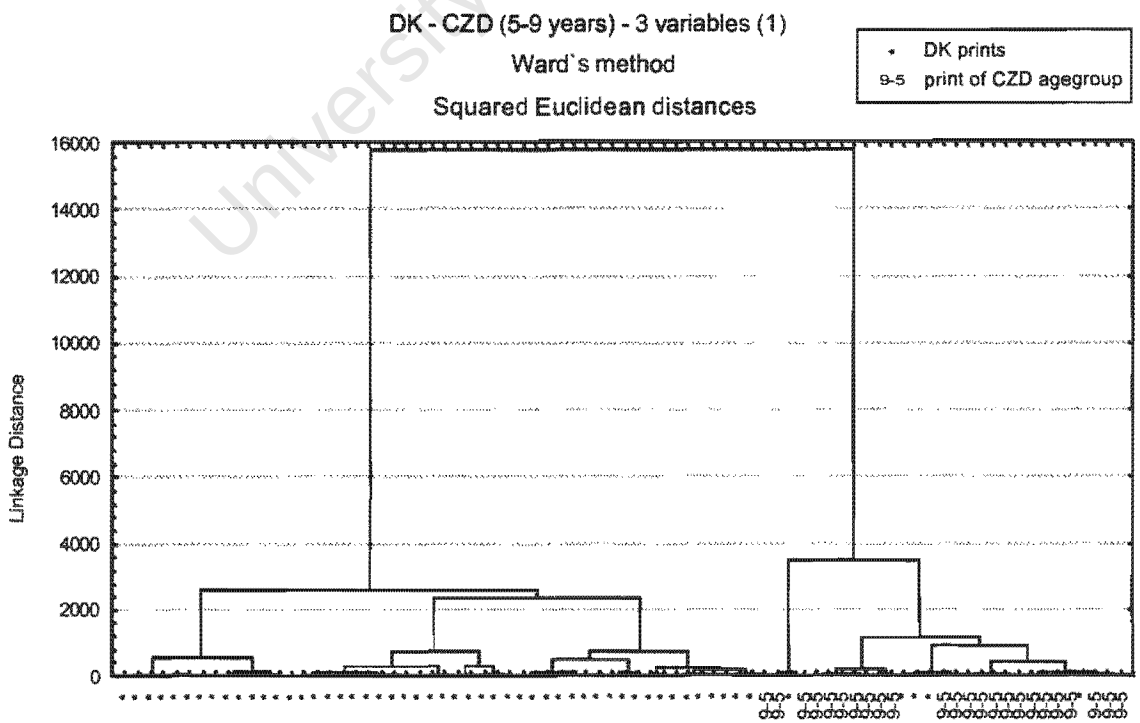


Figure 145: Cluster analysis of 3 handprint-variables (1) of DK and CZD (5 to 9 year olds) sets (3)

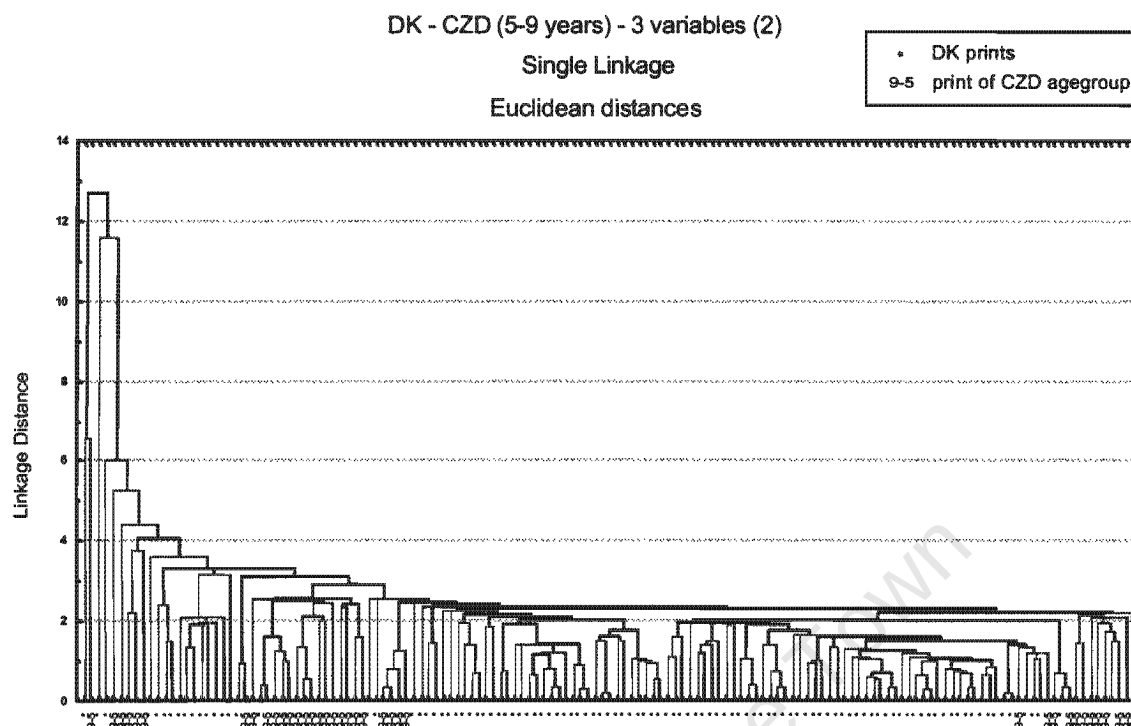


Figure 146: Cluster analysis of 3 handprint-variables (2) of DK and CZD (5 to 9 year olds) sets (1)

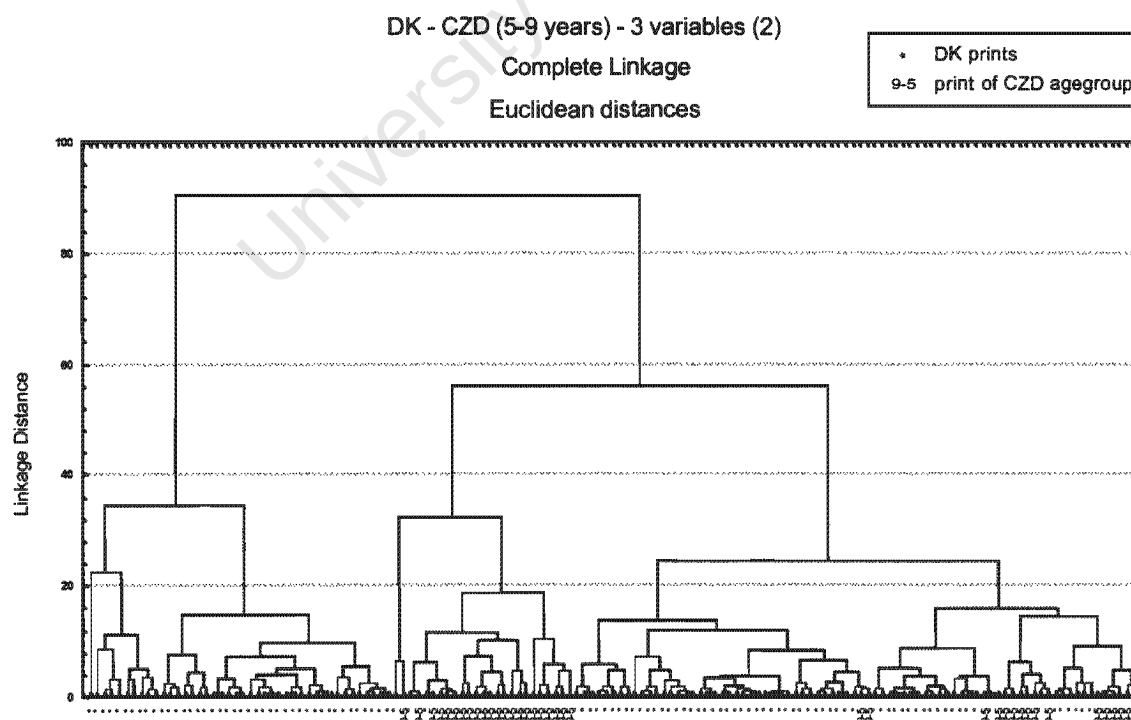


Figure 147: Cluster analysis of 3 handprint-variables (2) of DK and CZD (5 to 9 year olds) sets (2)

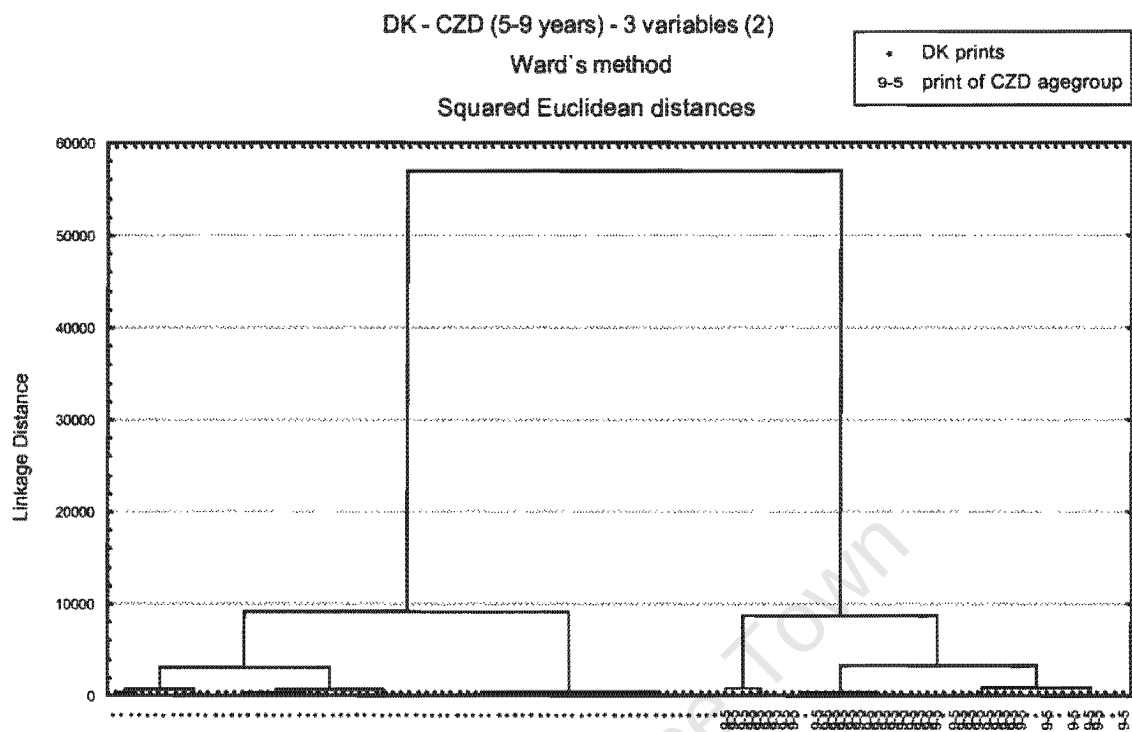


Figure 148: Cluster analysis of 3 handprint-variables (2) of DK and CZD (5 to 9 year olds) sets (3)

CLW - person A (9 variables)
Single Linkage
Euclidean distances

- + person A prints
- * CLW left and right prints

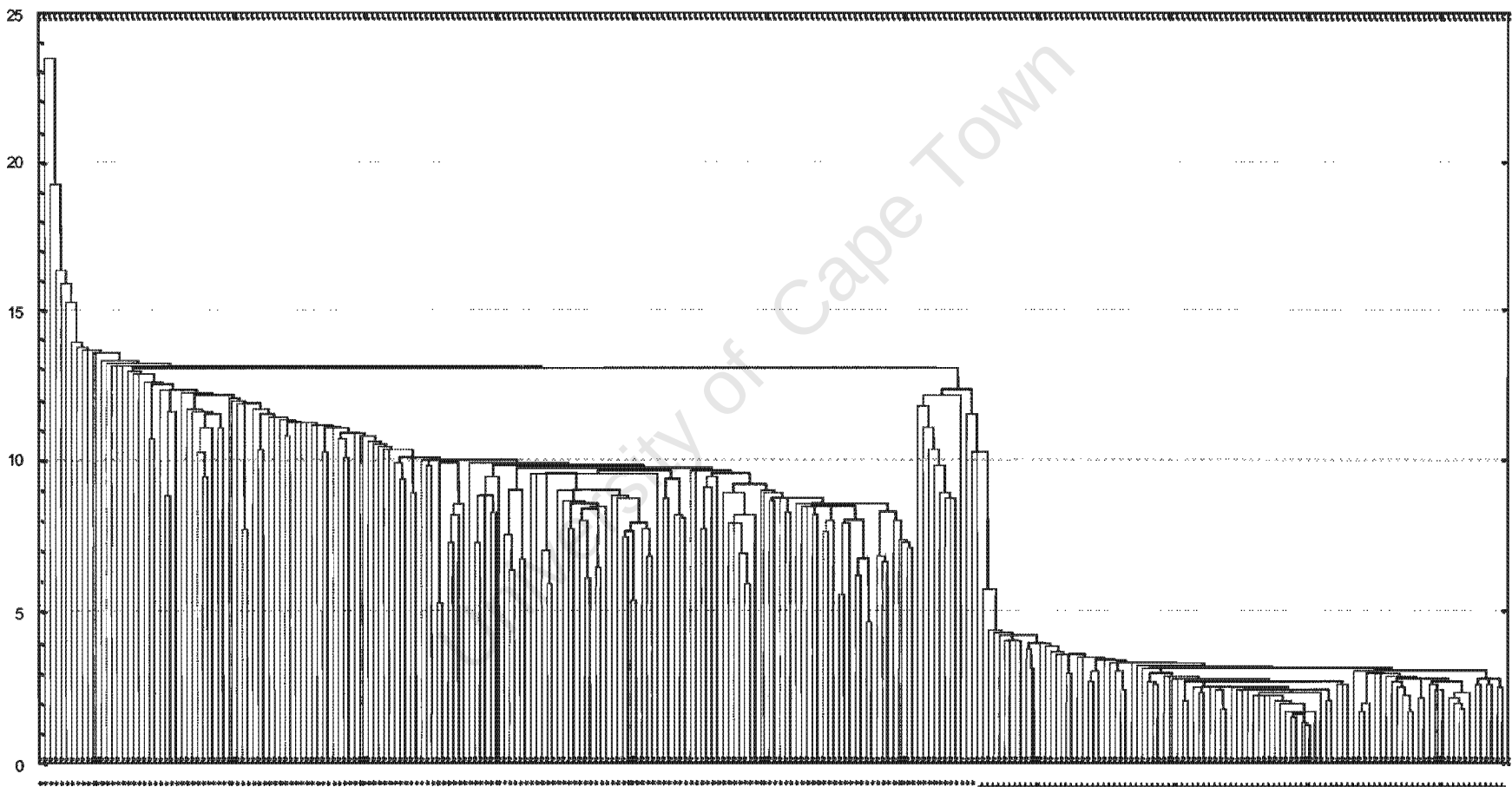


Figure 149: Cluster analysis of 9 handprint-variables of CLW and person A sets (1)

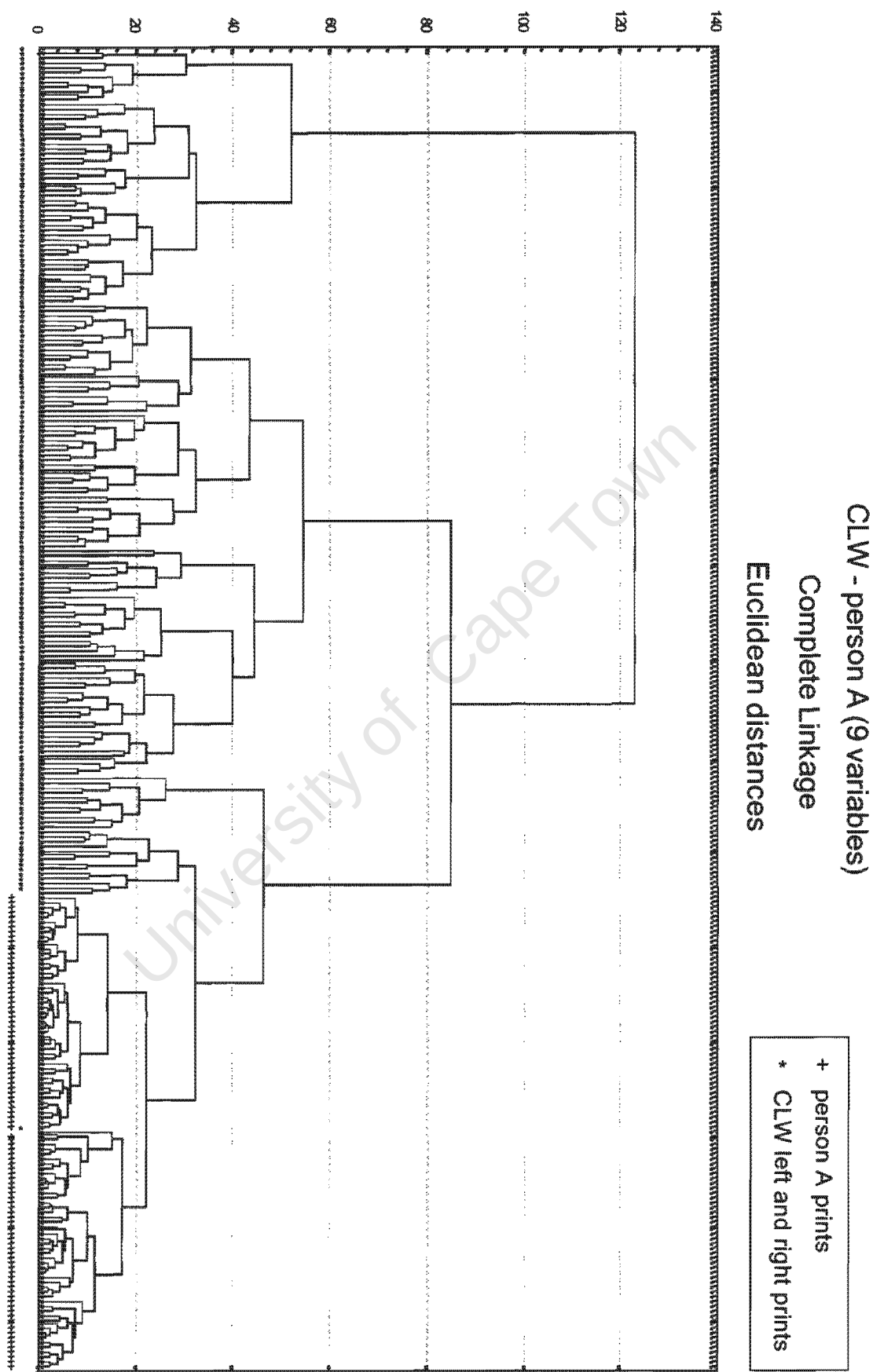


Figure 150: Cluster analysis of 9 handprint-variables of CLW and person A sets (2)

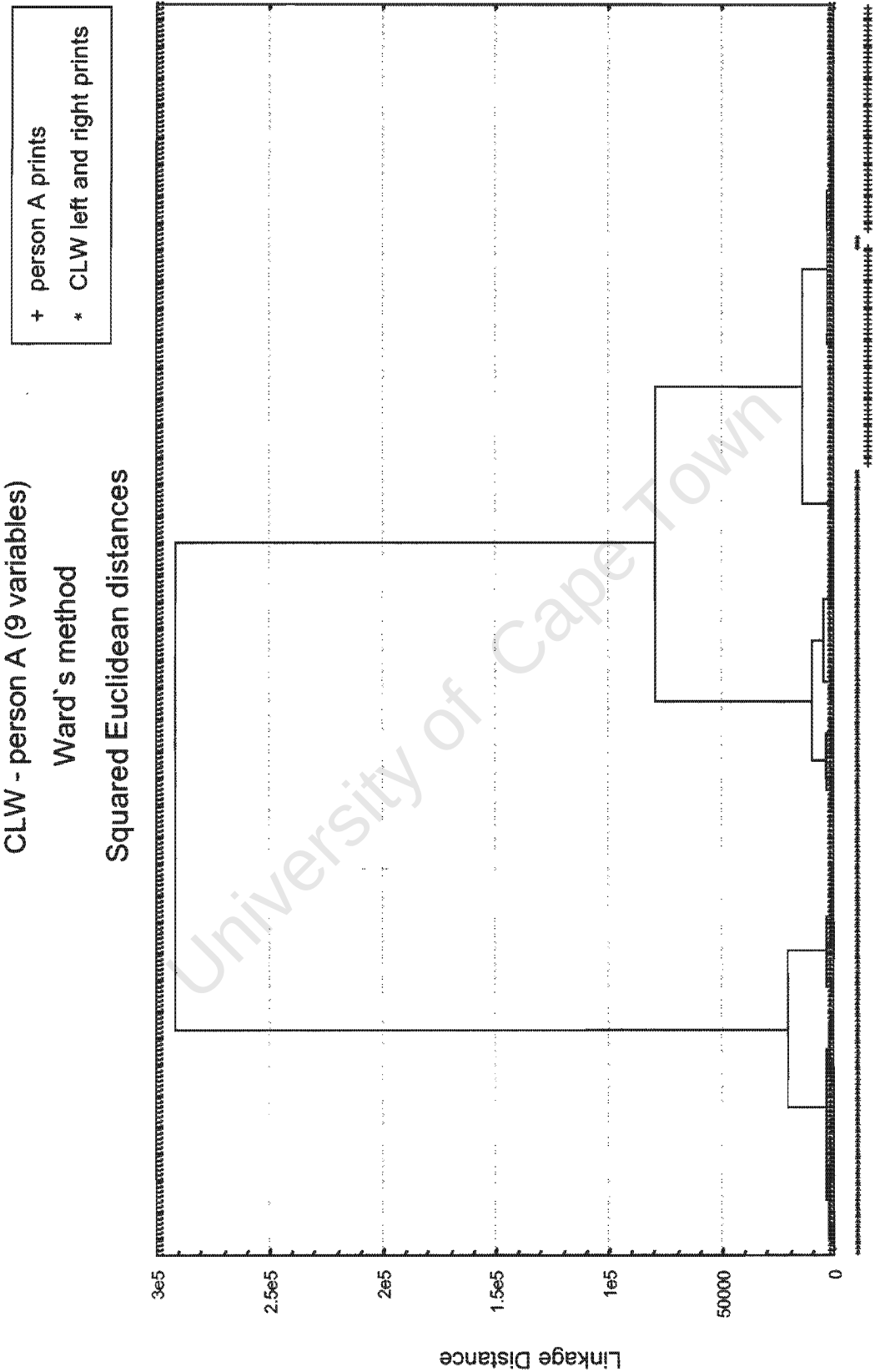


Figure 151: Cluster analysis of 9 handprint-variables of CLW and person A sets (3)

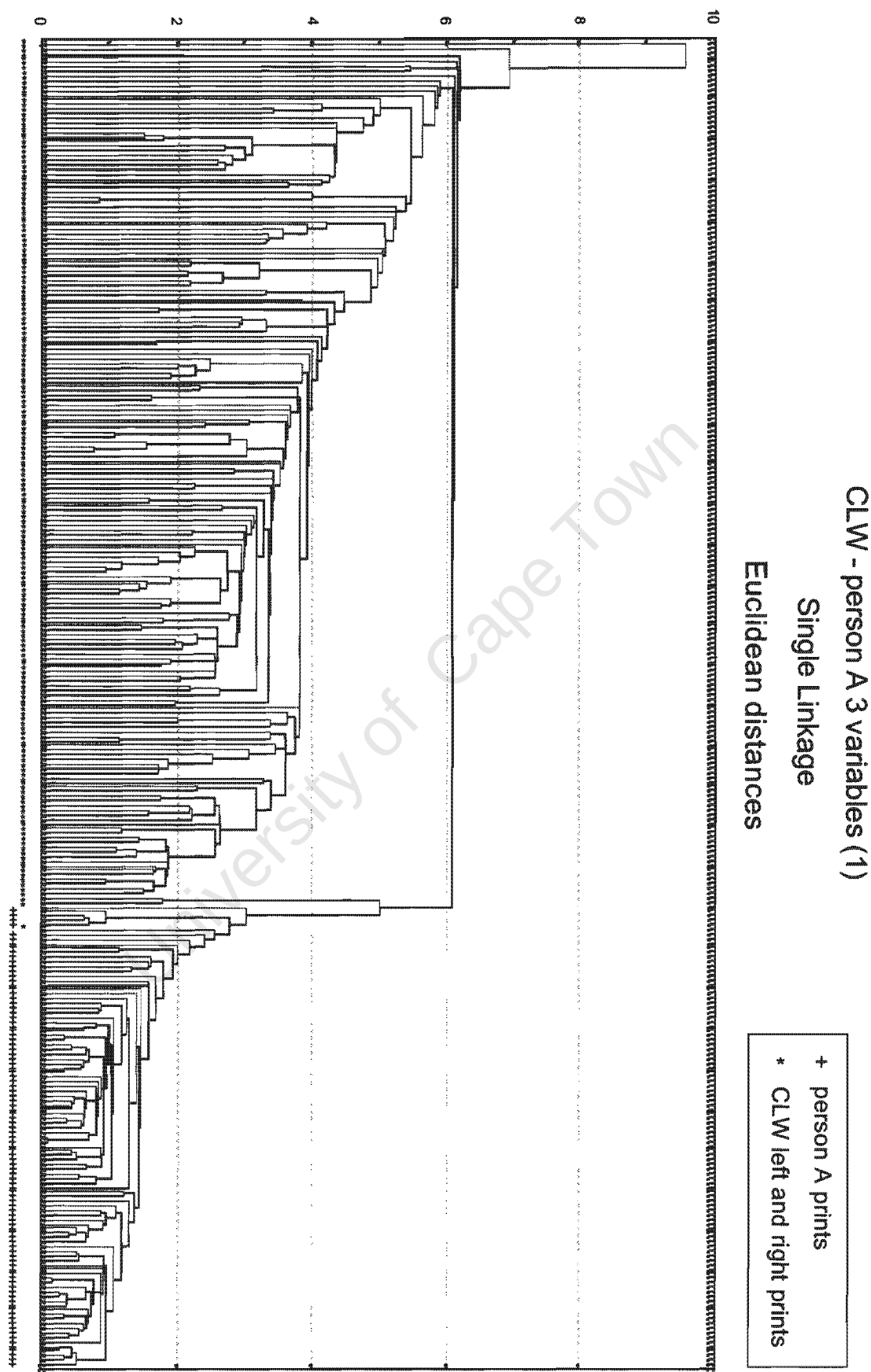


Figure 152: Cluster analysis of 3 handprint-variables (1) of CLW and person A sets (1)

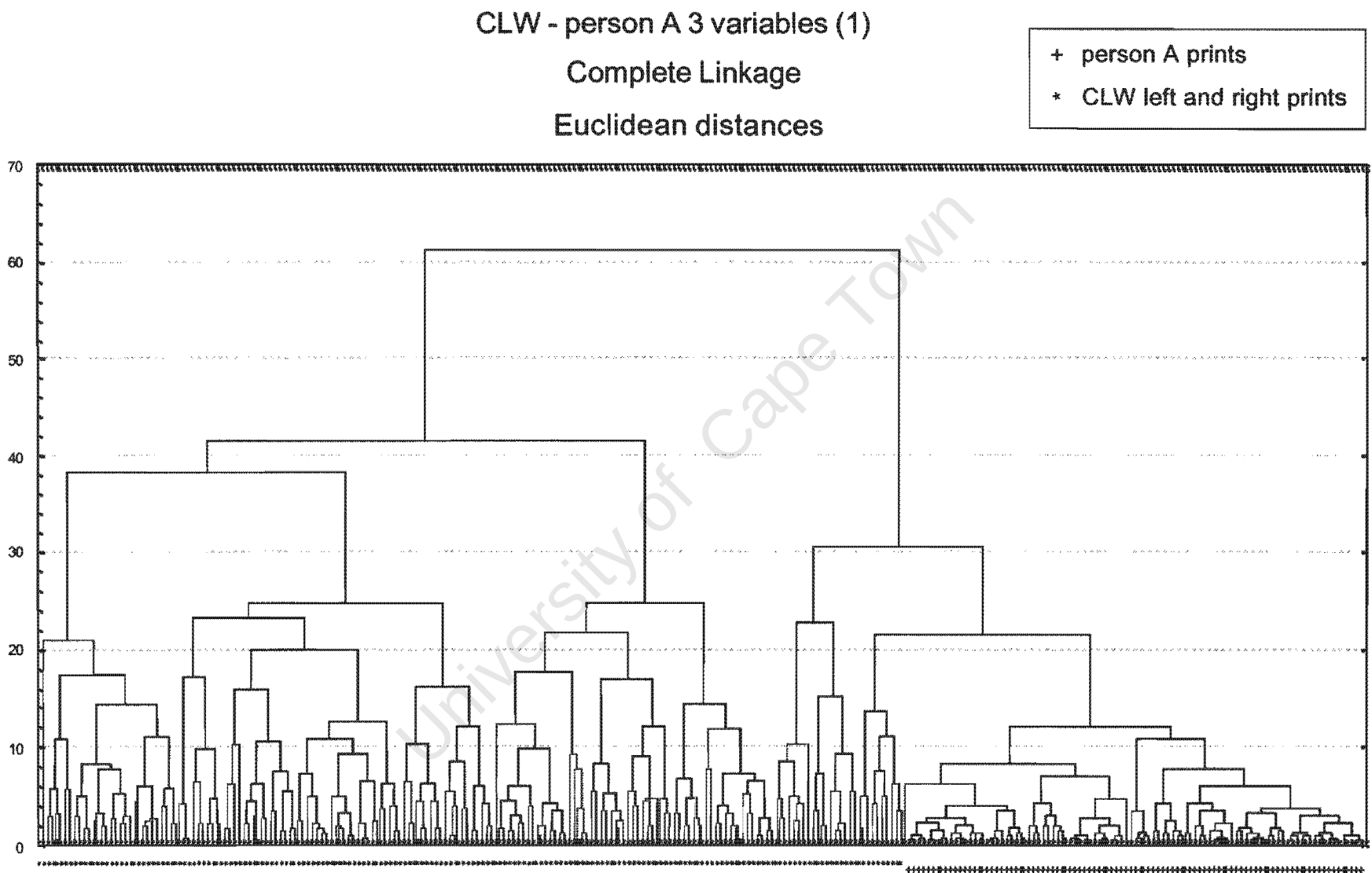


Figure 153: Cluster analysis of 3 handprint-variables (1) of CLW and person A sets (2)

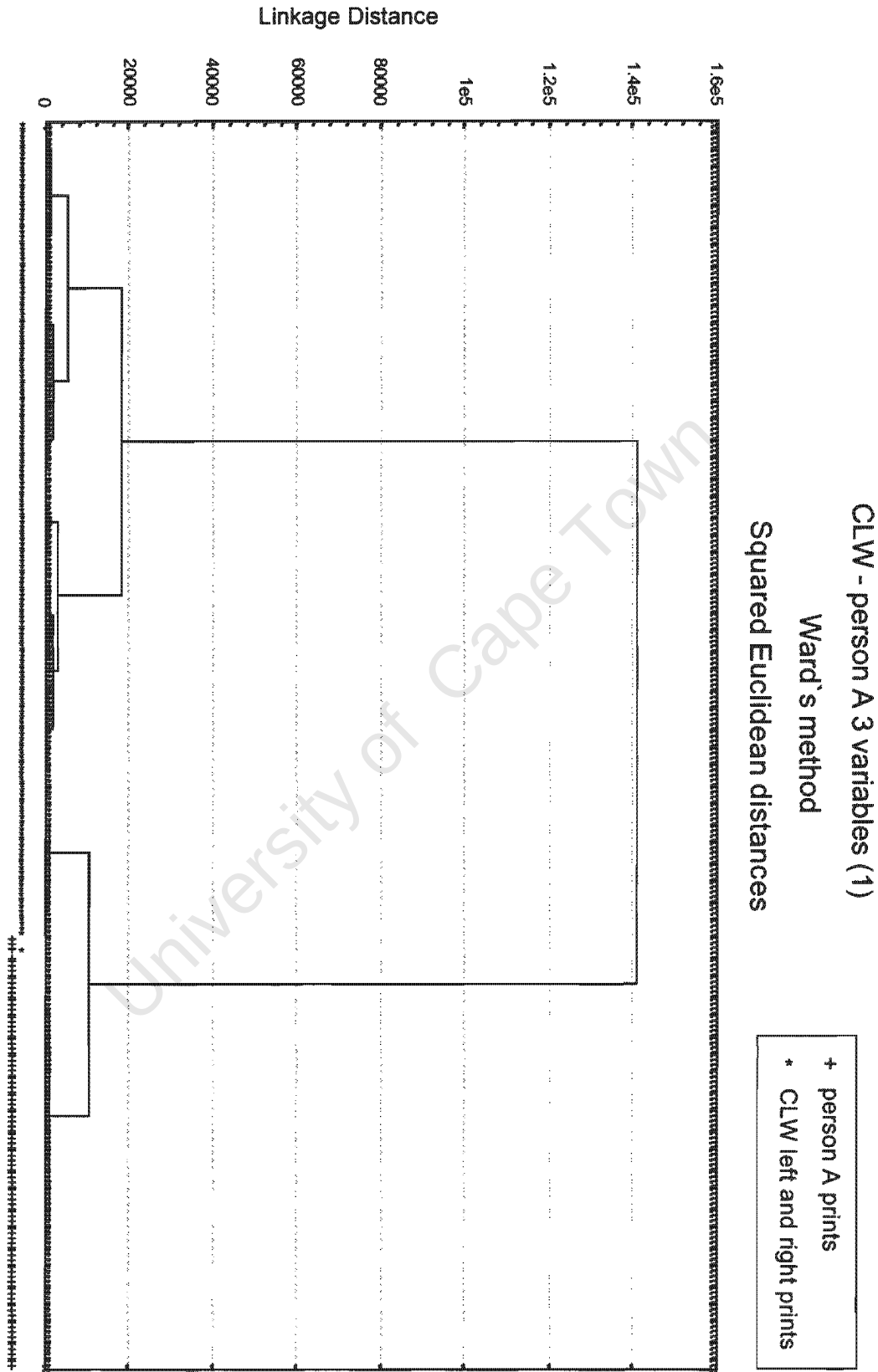


Figure 154: Cluster analysis of 3 handprint-variables (1) of CLW and person A sets (3)

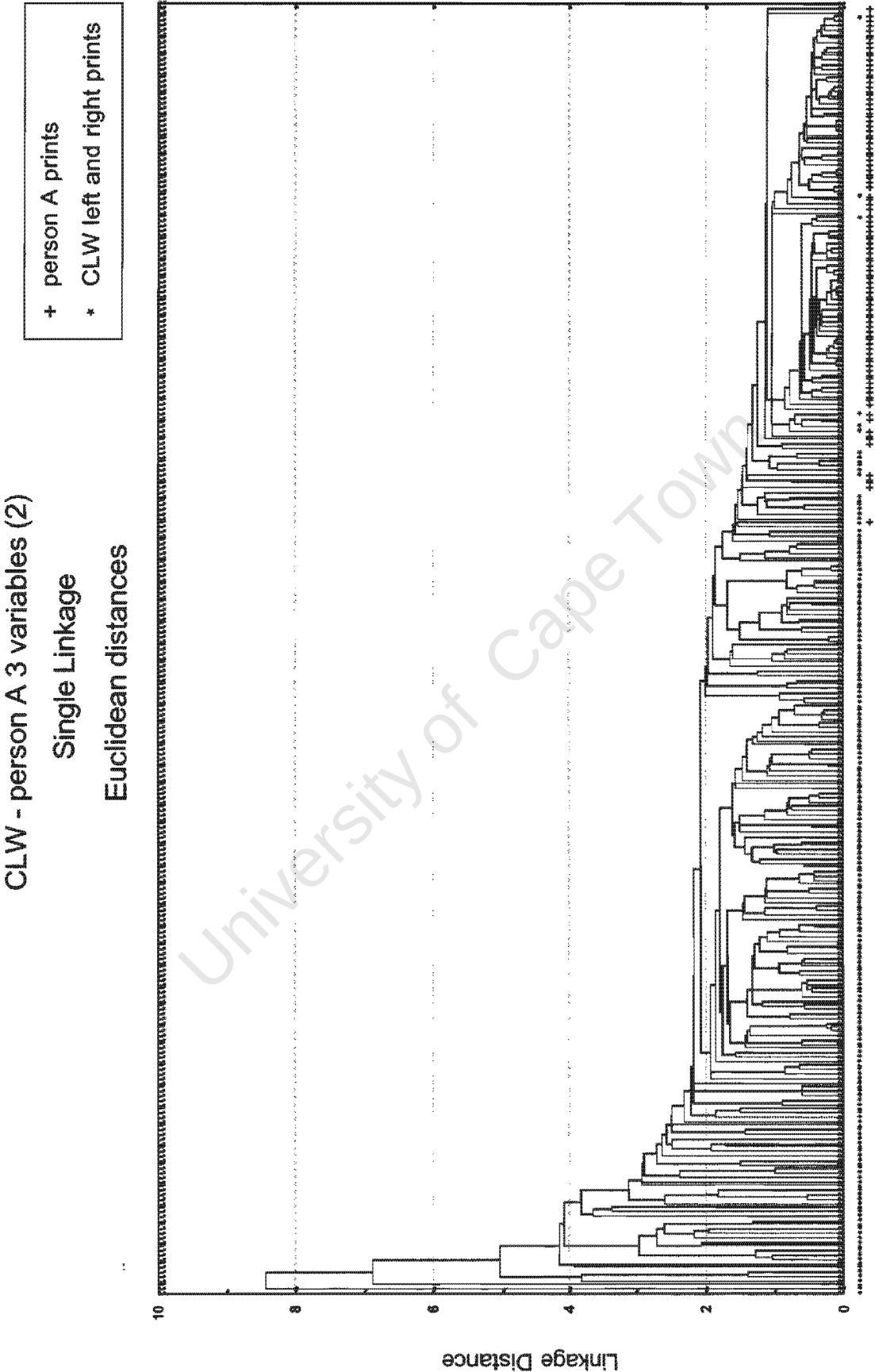


Figure 155: Cluster analysis of 3 handprint-variables (2) of CLW and person A sets (1)

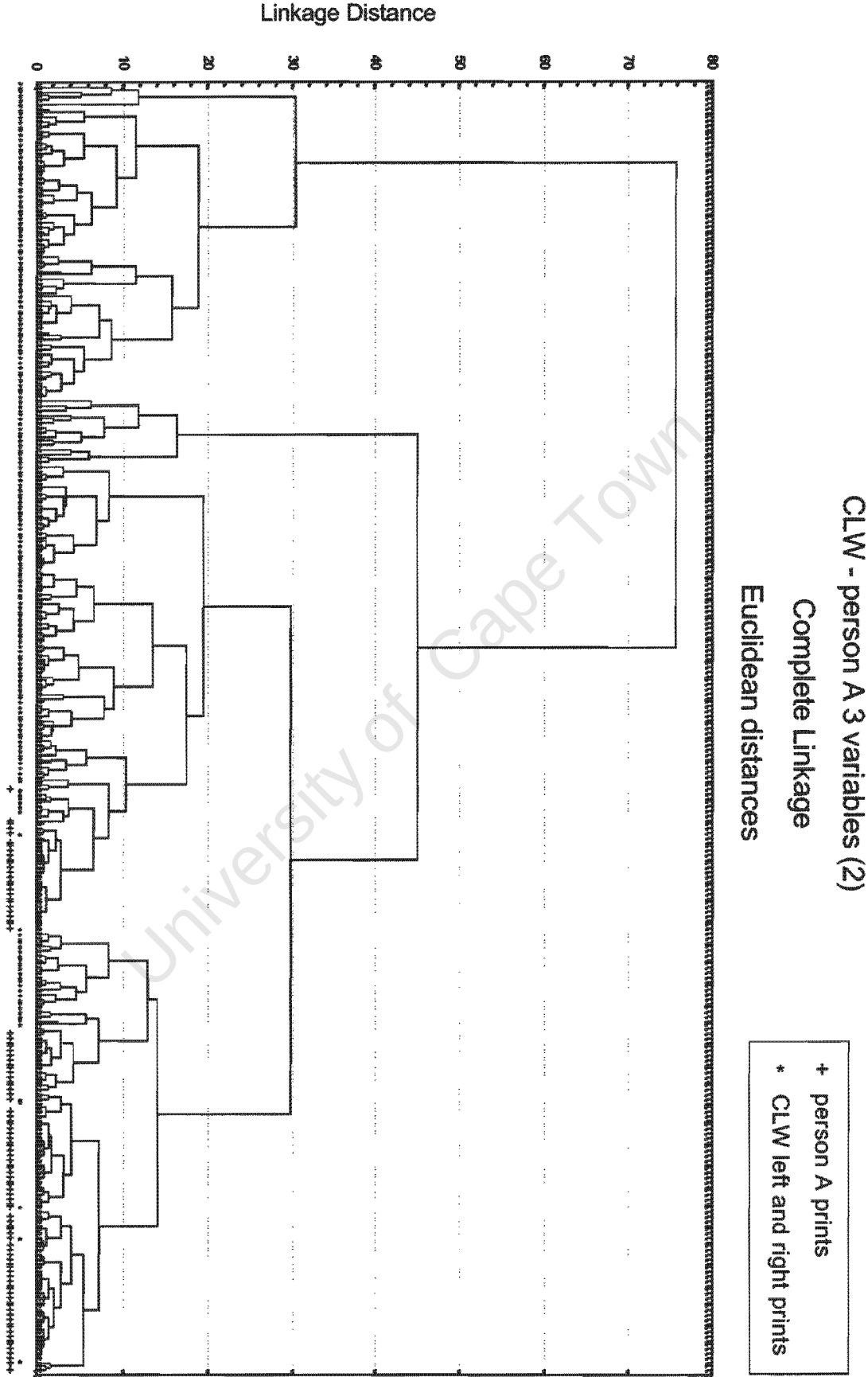


Figure 156: Cluster analysis of 3 handprint-variables (2) of CLW and person A sets (2)

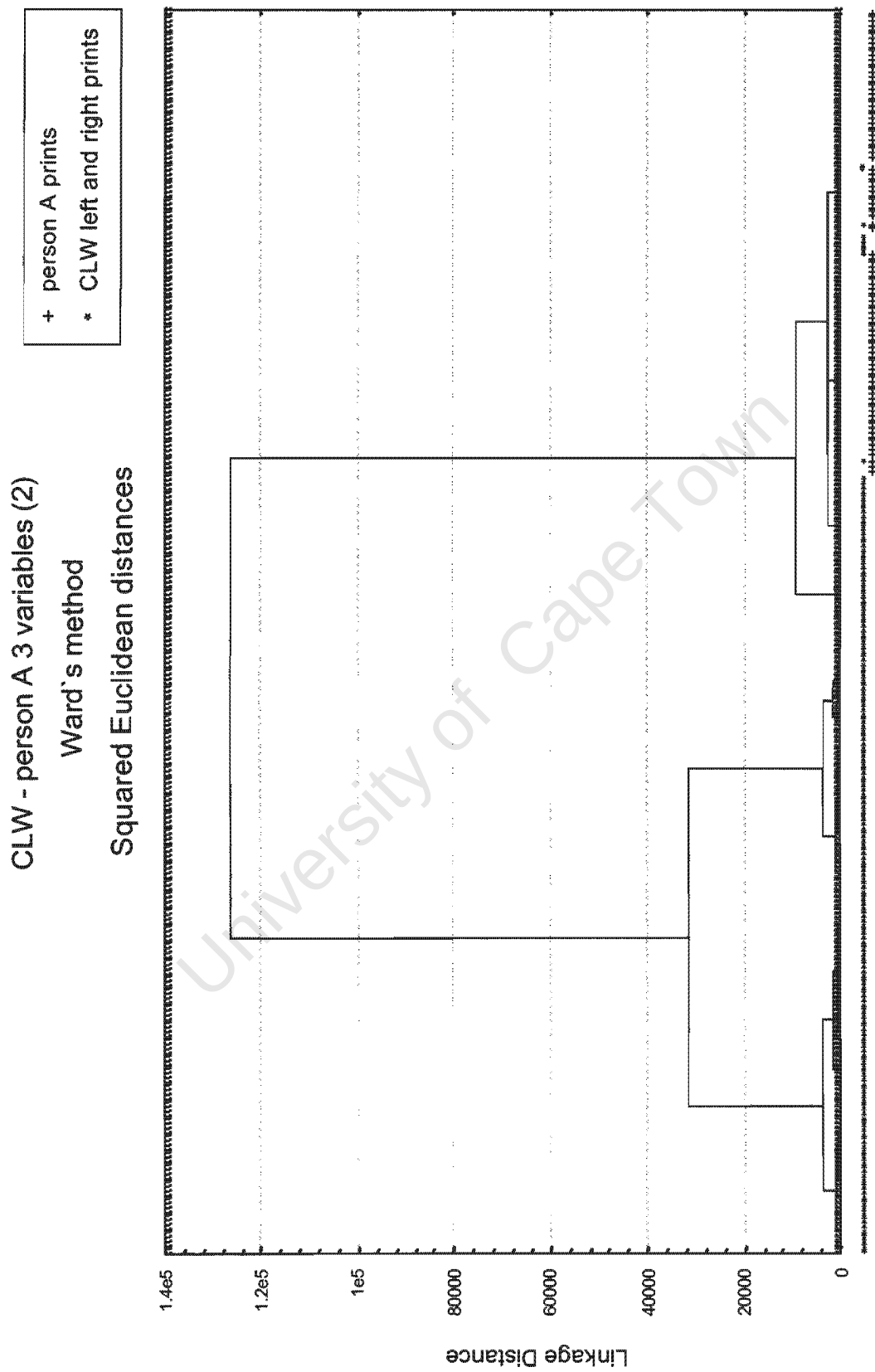


Figure 157: Cluster analysis of 3 handprint-variables (2) of CLW and person A sets (3)

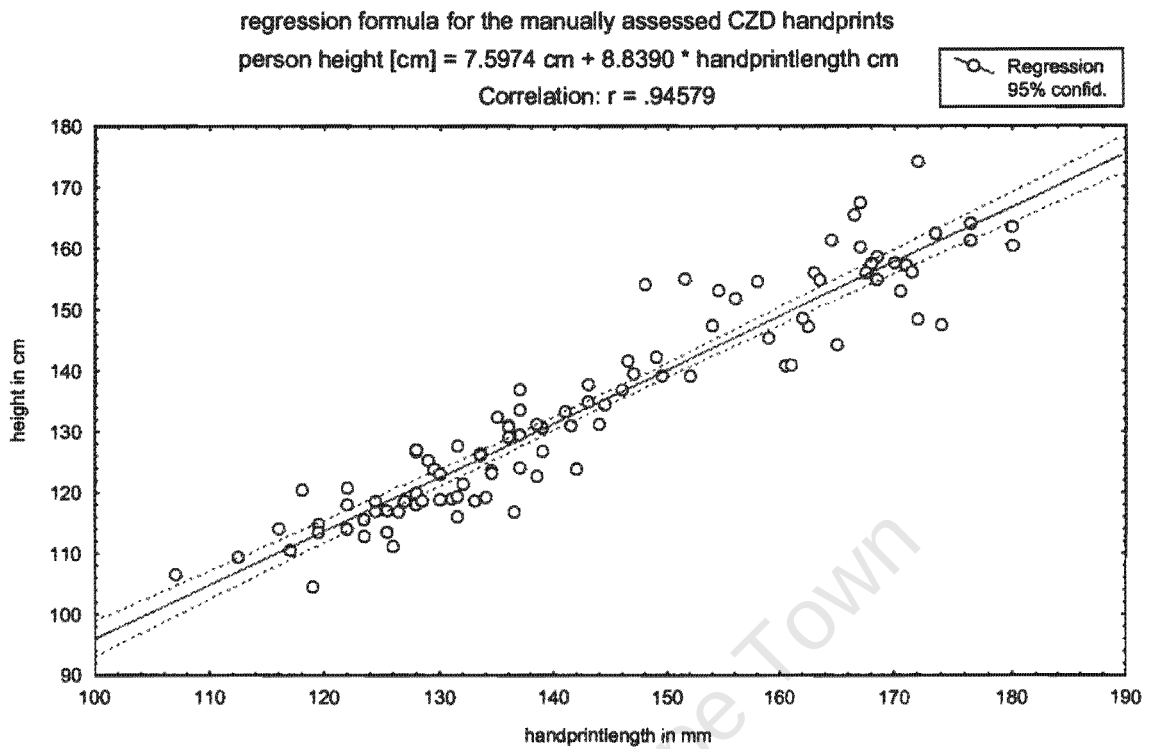


Figure 158: Regression formula for CZD (5-20 year olds) to estimate height from manually assessed middle finger length of the handprints

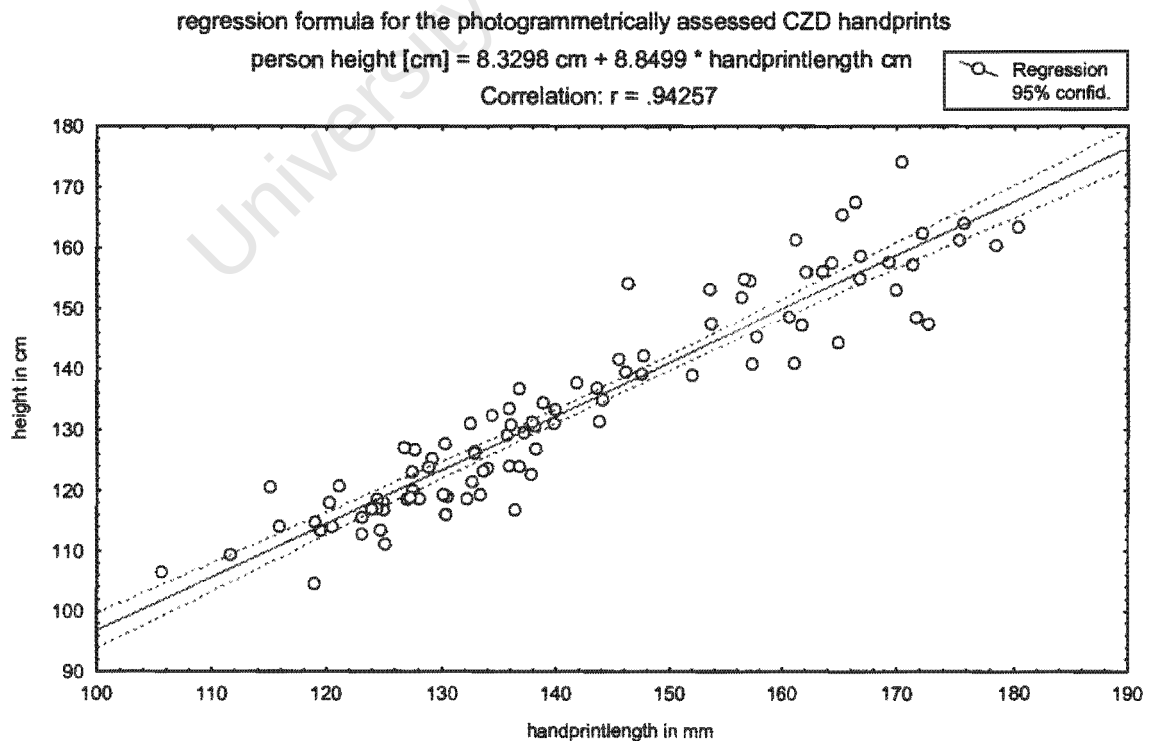


Figure 159: Regression formula for CZD (5-20 year olds) to estimate height from photogrammetrically assessed middle finger length of the handprints

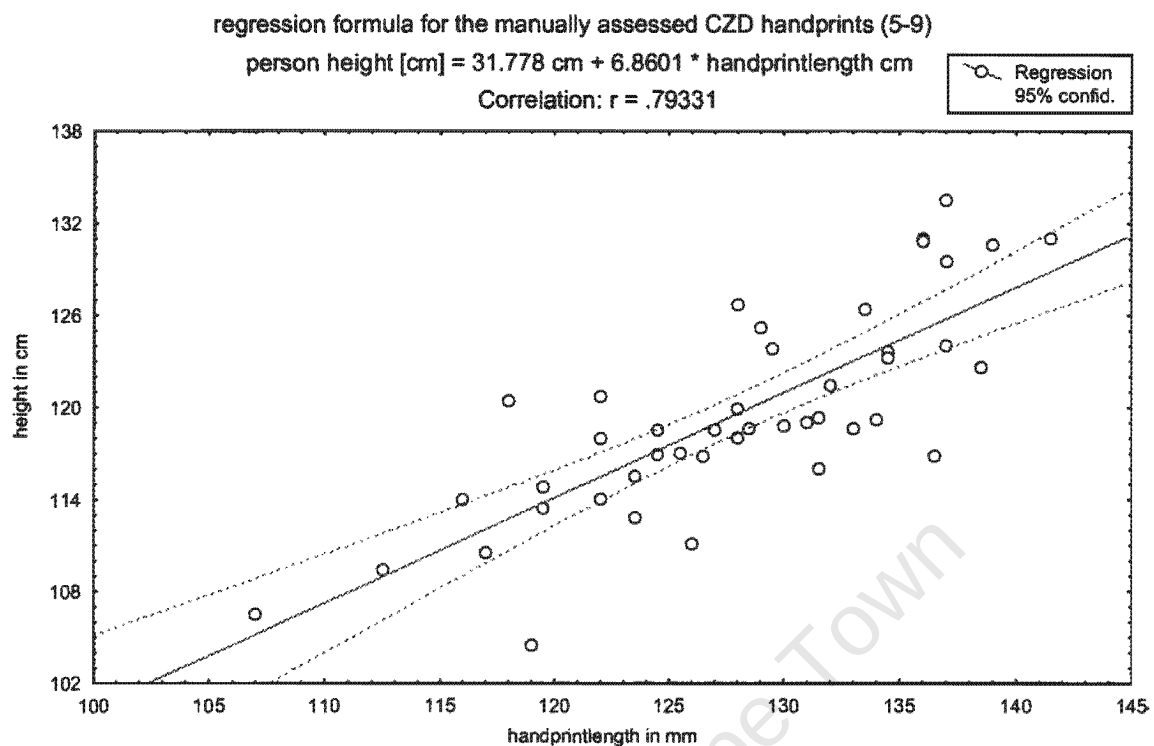


Figure 160: Regression formula for CZD (5 to 9 year olds) to estimate height from manually assessed middle finger length of the handprints

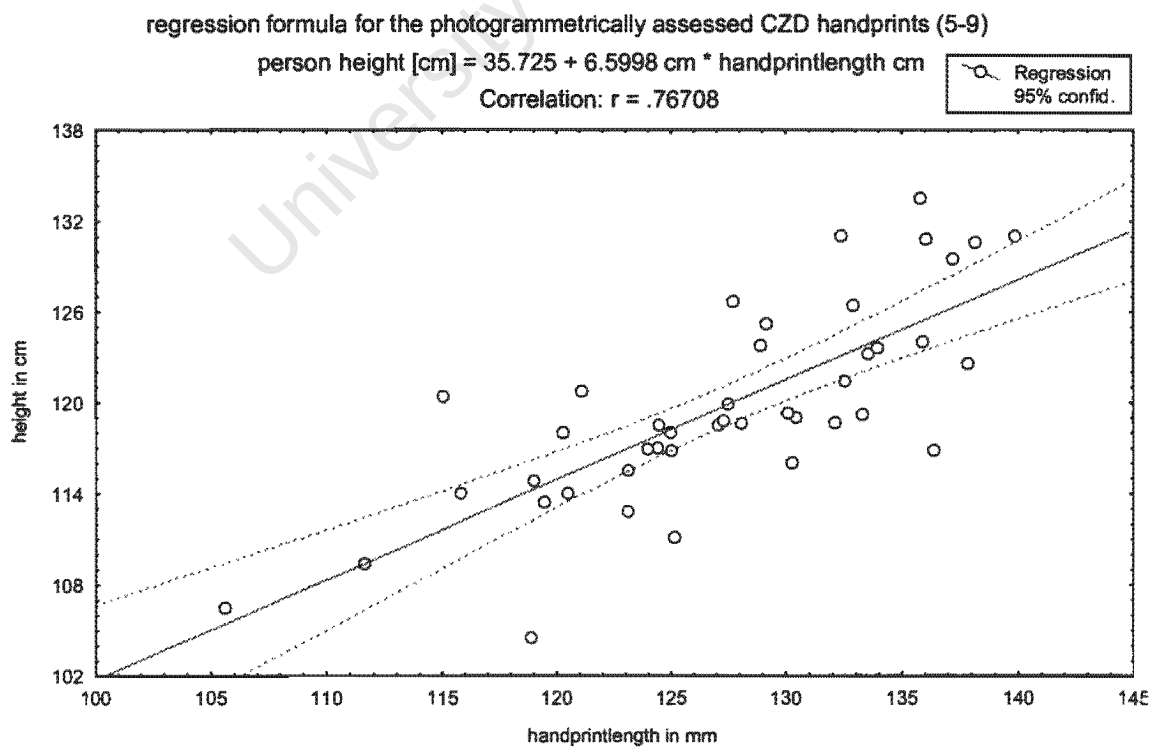


Figure 161: Regression formula for CZD (5 to 9 year olds) to estimate height from photogrammetrically assessed middle finger length of the handprints

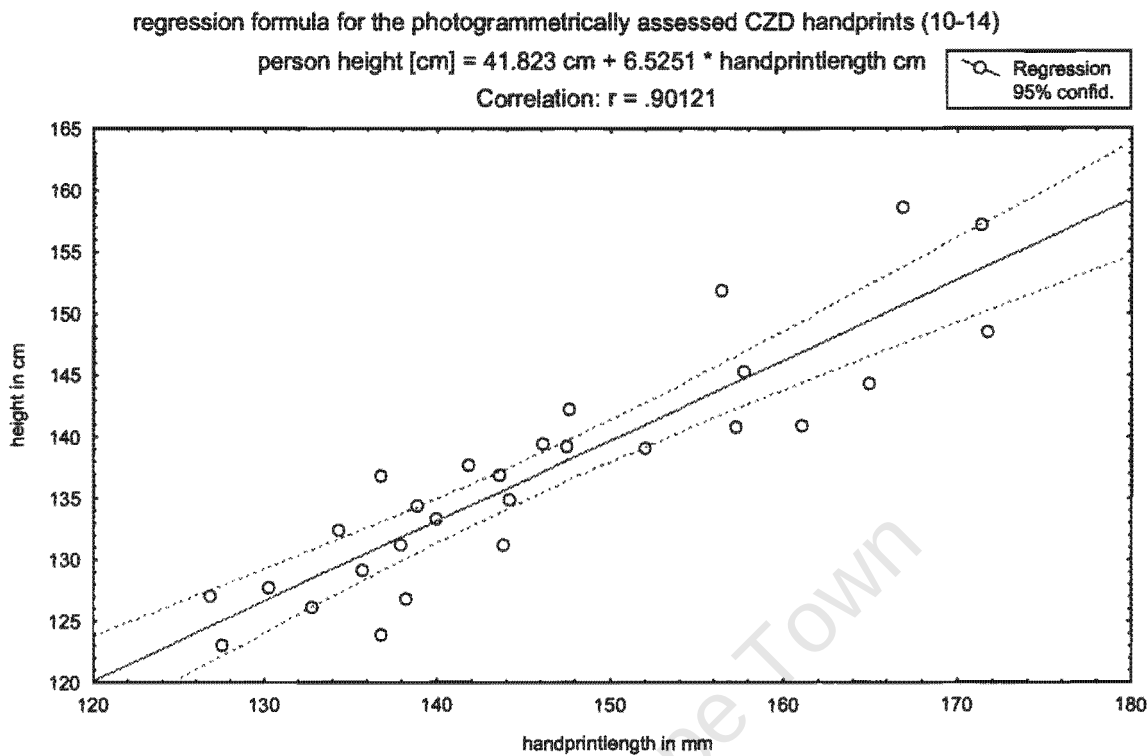


Figure 162: Regression formula for CZD (10 to 14 year olds) to estimate height from manually assessed middle finger length of the handprints

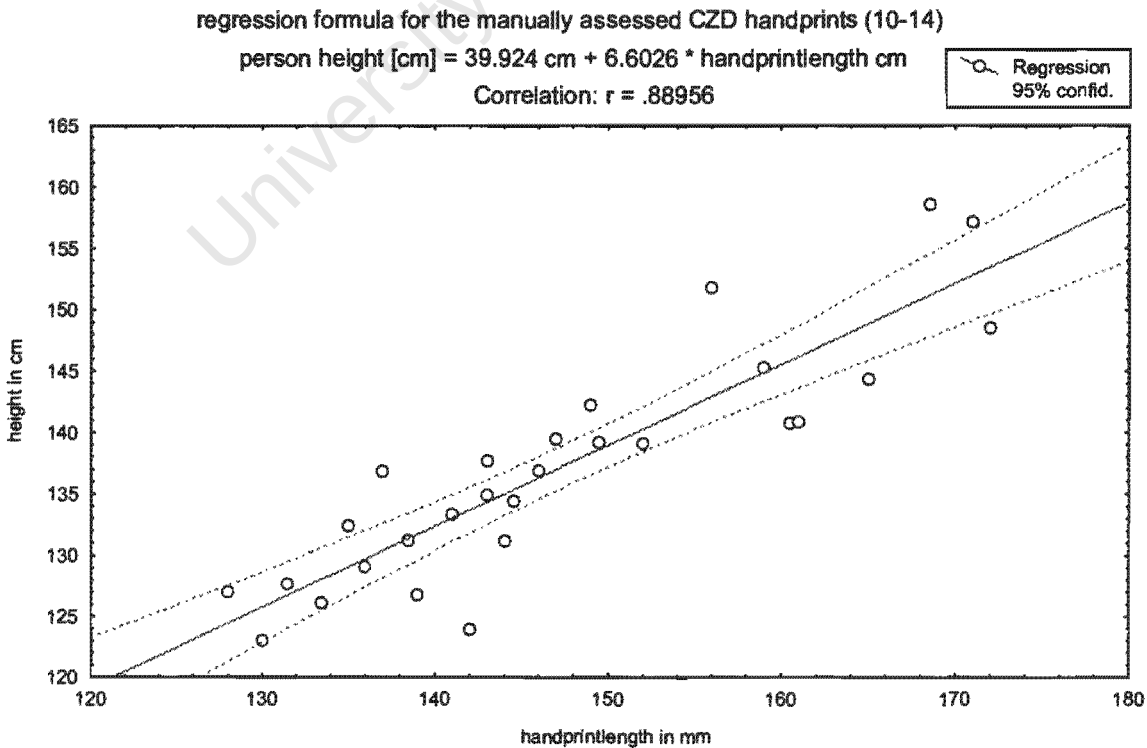


Figure 163: Regression formula for CZD (10 to 14 year olds) to estimate height from photogrammetrically assessed middle finger length of the handprints

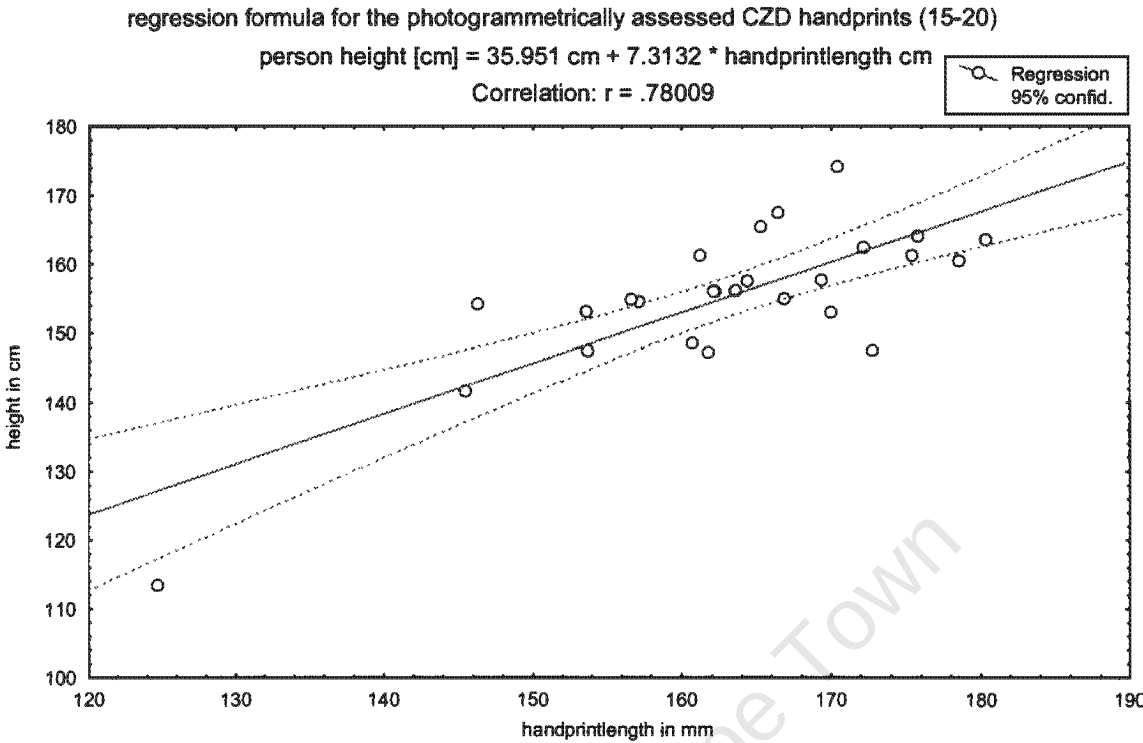


Figure 164: Regression formula for CZD (15 to 20 year olds) to estimate height from manually assessed middle finger length of the handprints

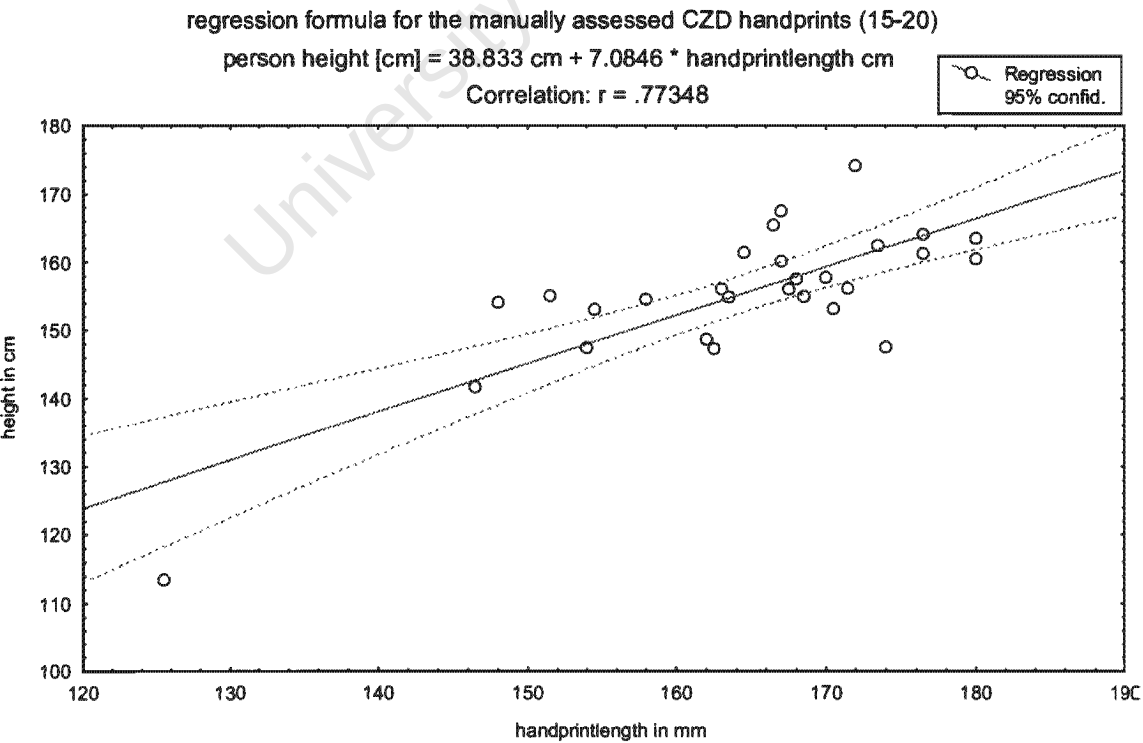


Figure 165: Regression formula for CZD (15 to 20 year olds) to estimate height from photogrammetrically assessed middle finger length of the handprints

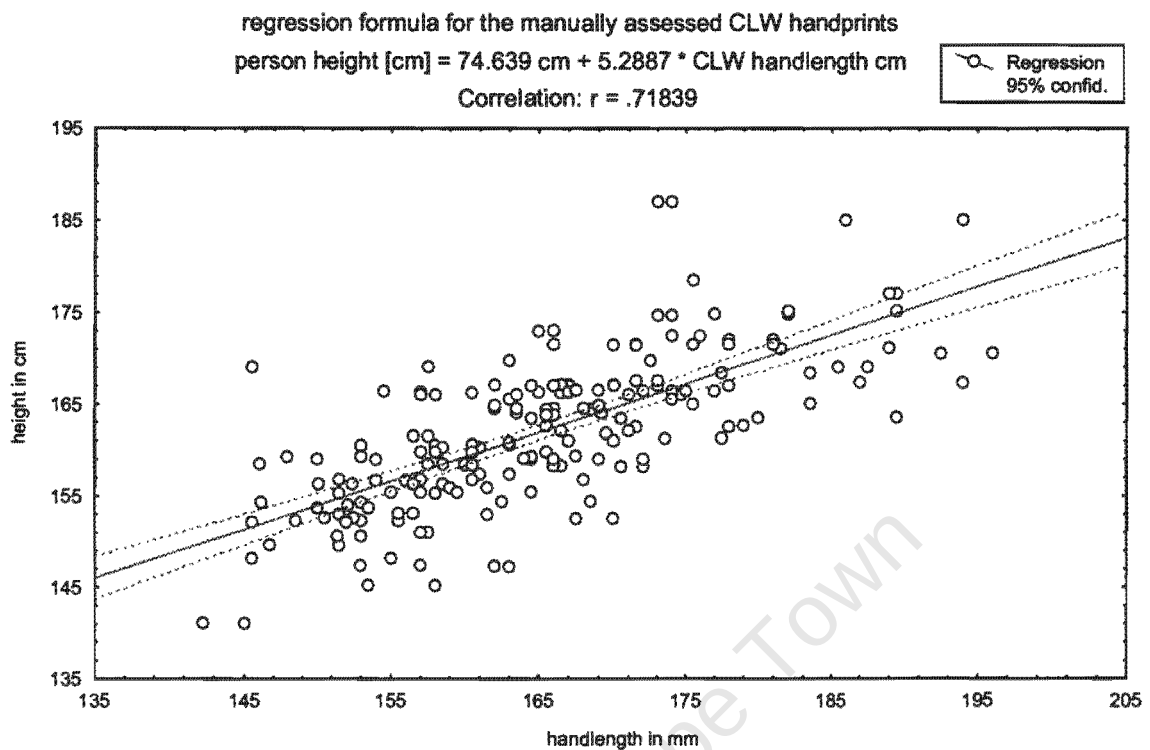


Figure 166: Regression formula for CLW (15 to 21 year olds) to estimate height from manually assessed middle finger length of the handprints

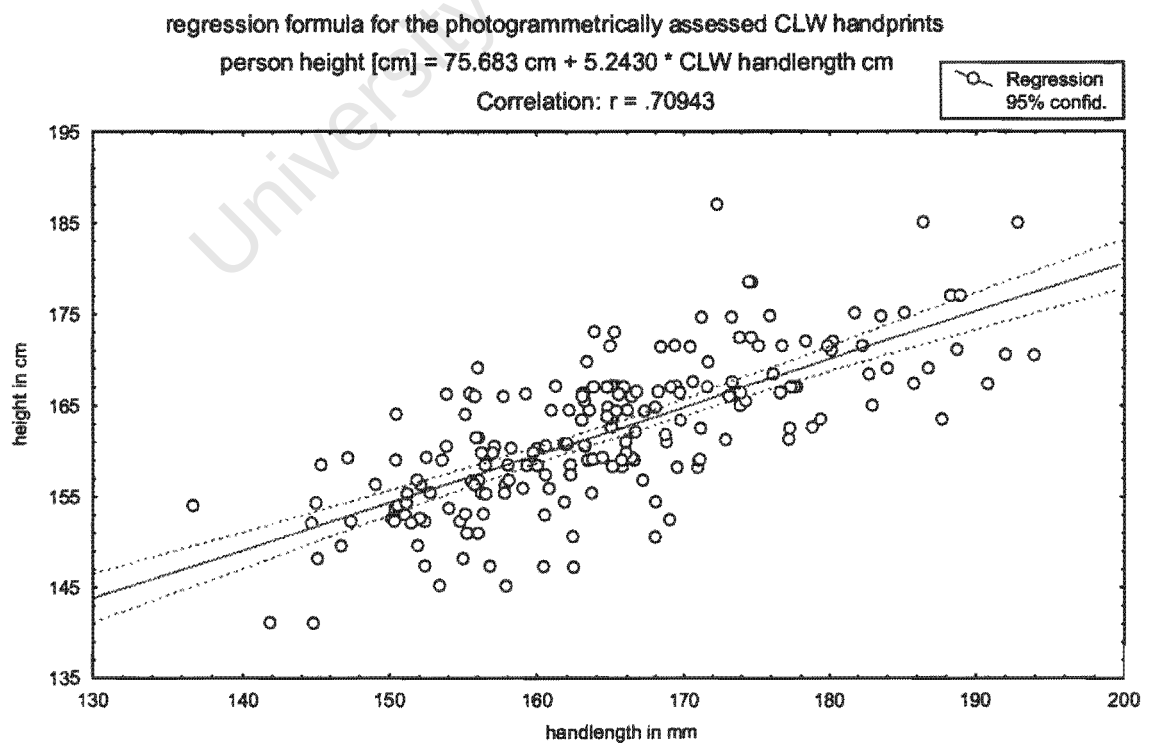


Figure 167: Regression formula for CLW (15 to 21 year olds) to estimate height from photogrammetrically assessed middle finger length of the handprints

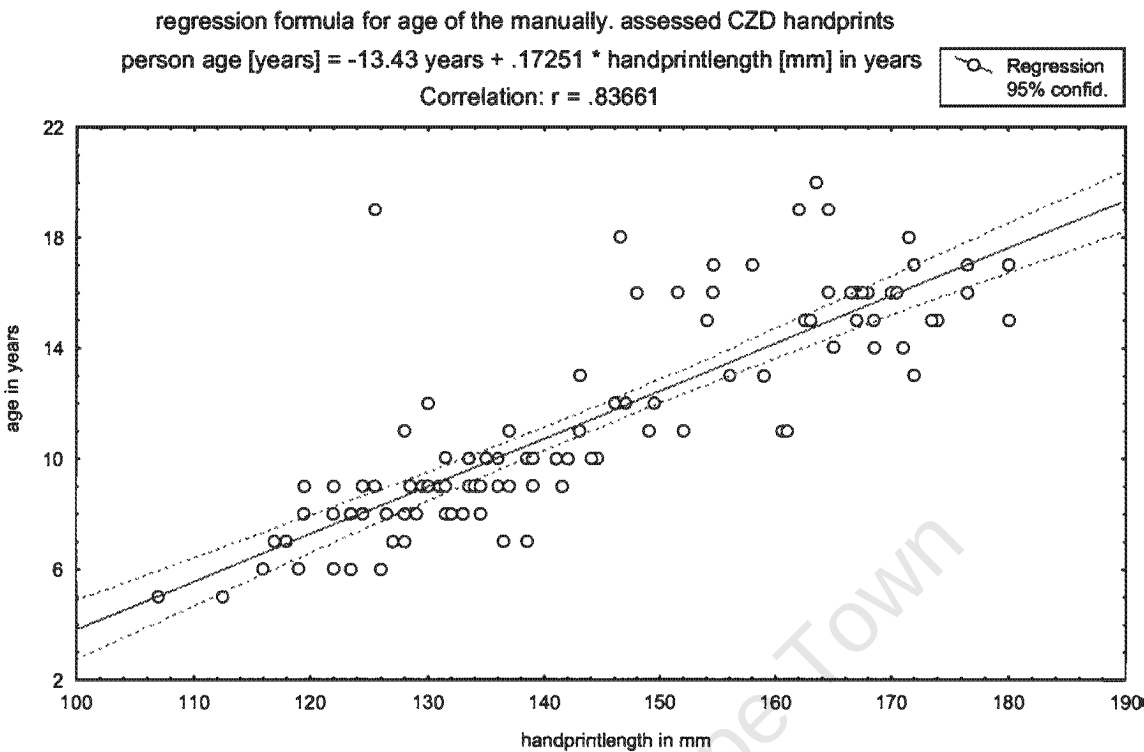


Figure 168: Regression formula for CZD (5-20 year olds) to estimate age from manually assessed middle finger length of the handprints

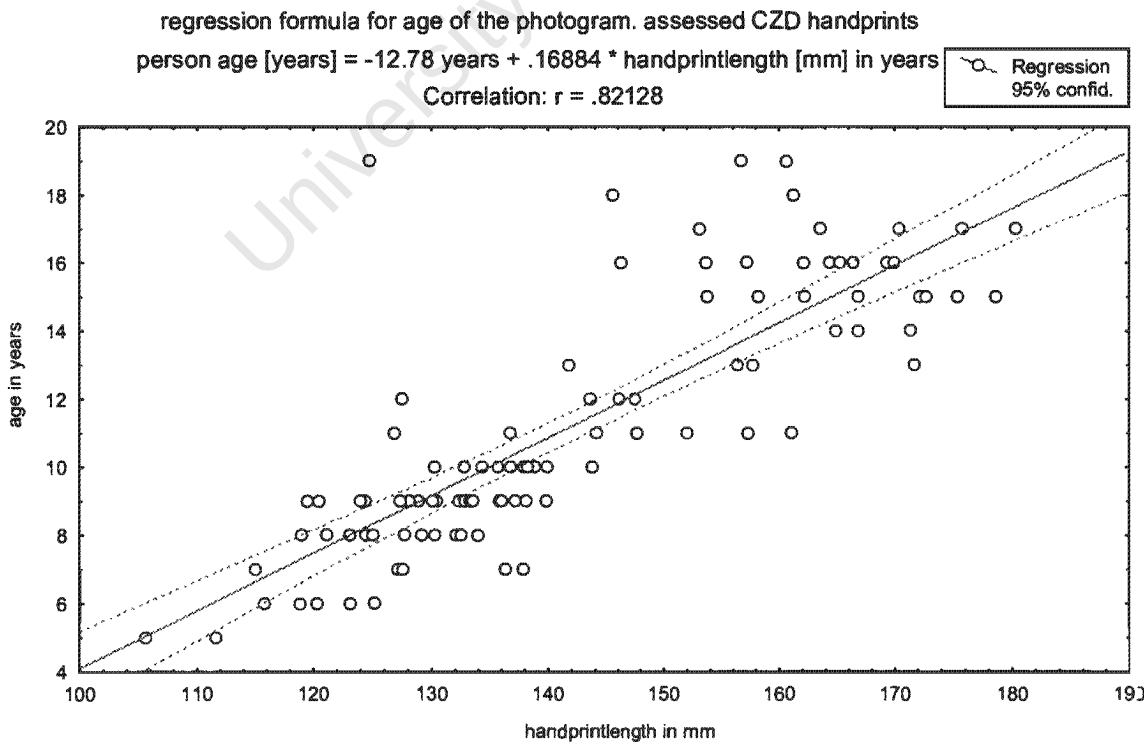


Figure 169: Regression formula for CZD (5-20 year olds) to estimate age from photogrammetrically assessed middle finger length of the handprints

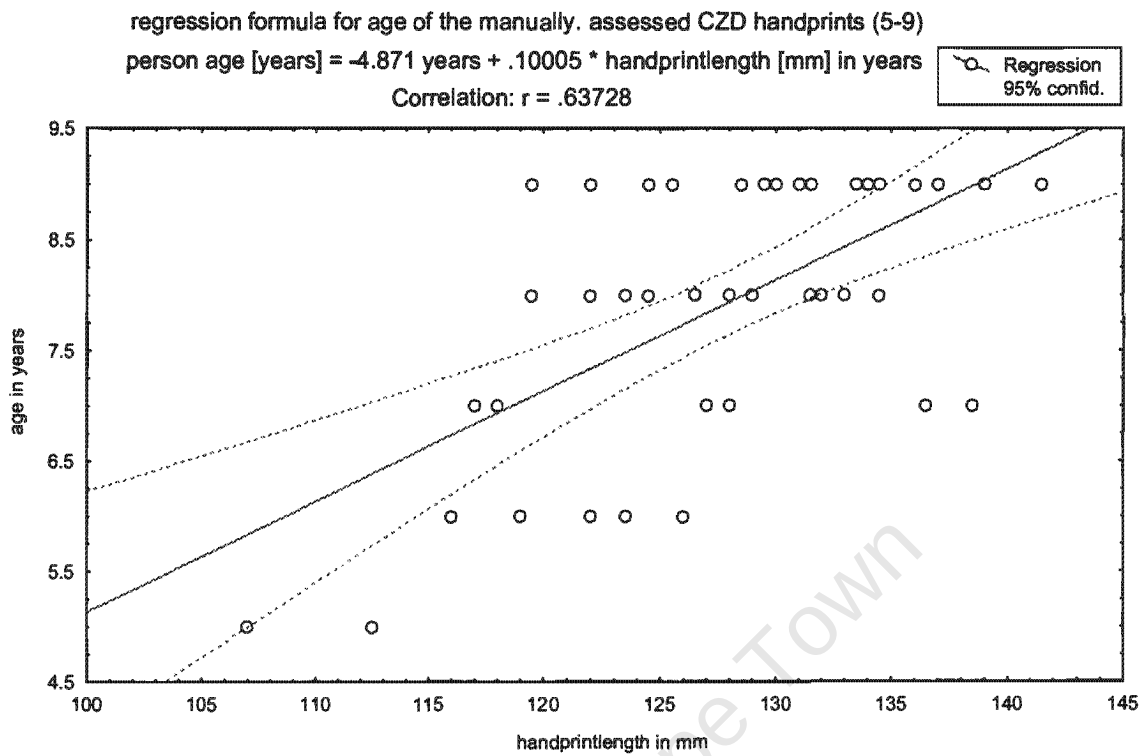


Figure 170: Regression formula for CZD (5 to 9 year olds) to estimate age from manually assessed middle finger length of the handprints

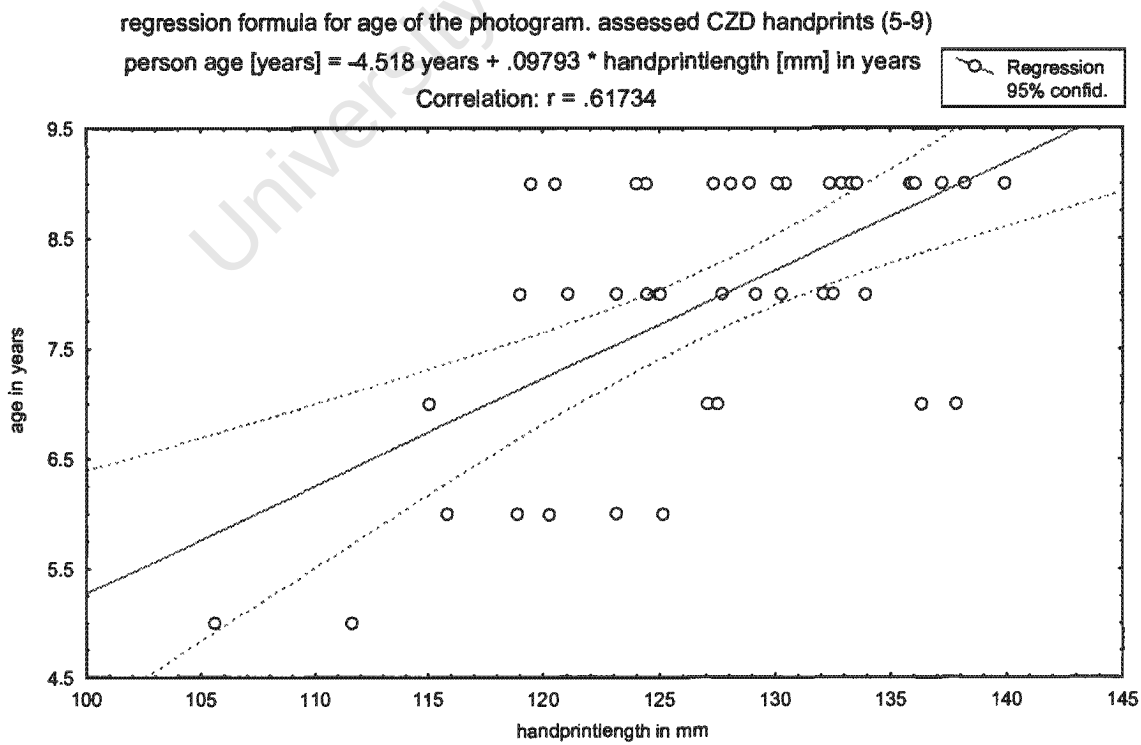


Figure 171: Regression formula for CZD (5 to 9 year olds) to estimate age from photogrammetrically assessed middle finger length of the handprints

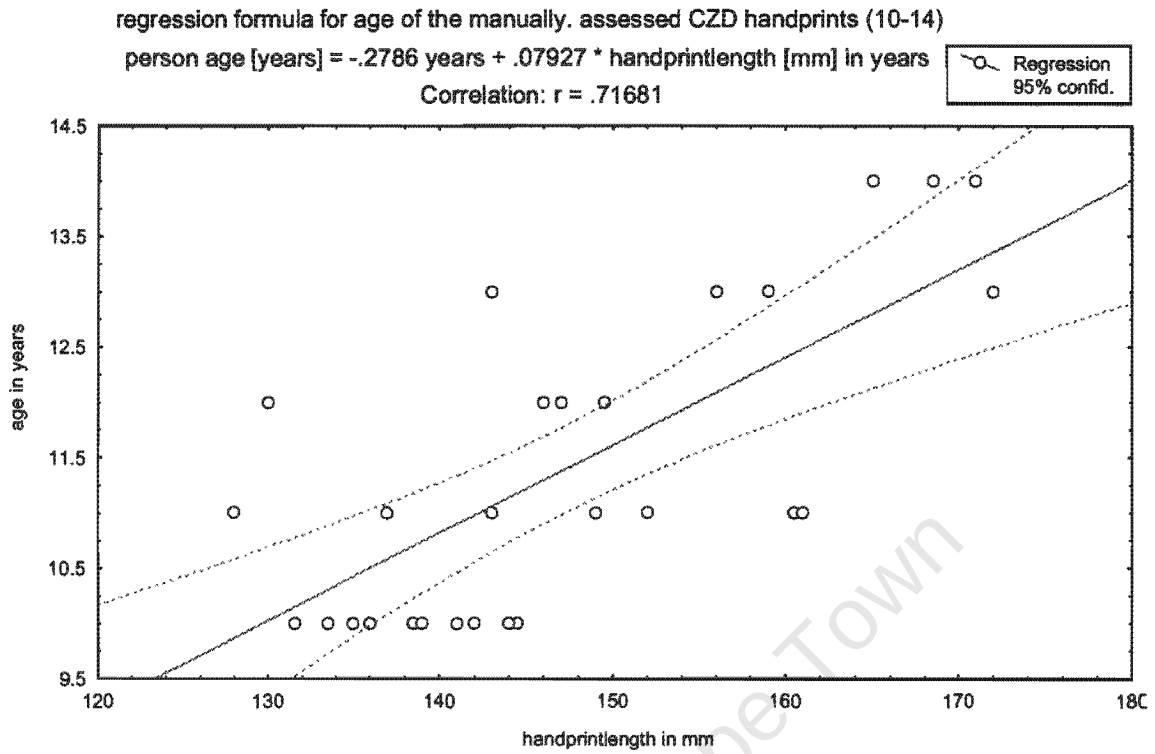


Figure 172: Regression formula for CZD (10 to 14 year olds) to estimate age from manually assessed middle finger length of the handprints

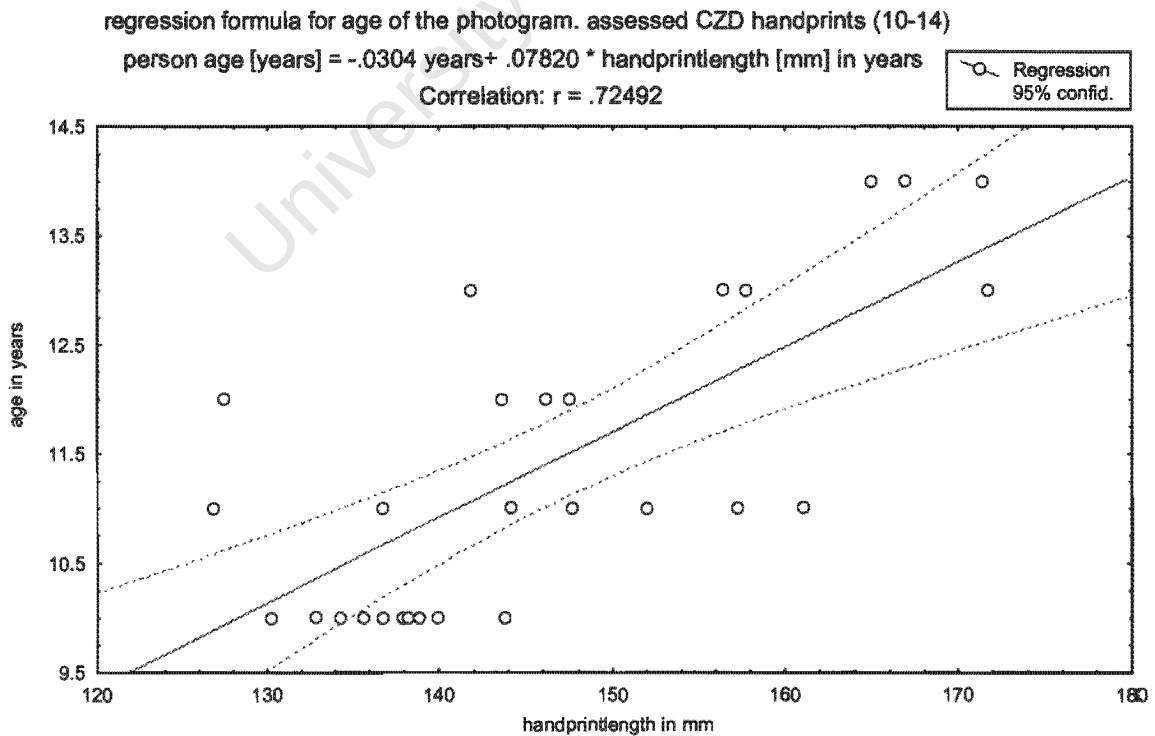


Figure 173: Regression formula for CZD (10 to 14 year olds) to estimate age from photogrammetrically assessed middle finger length of the handprints

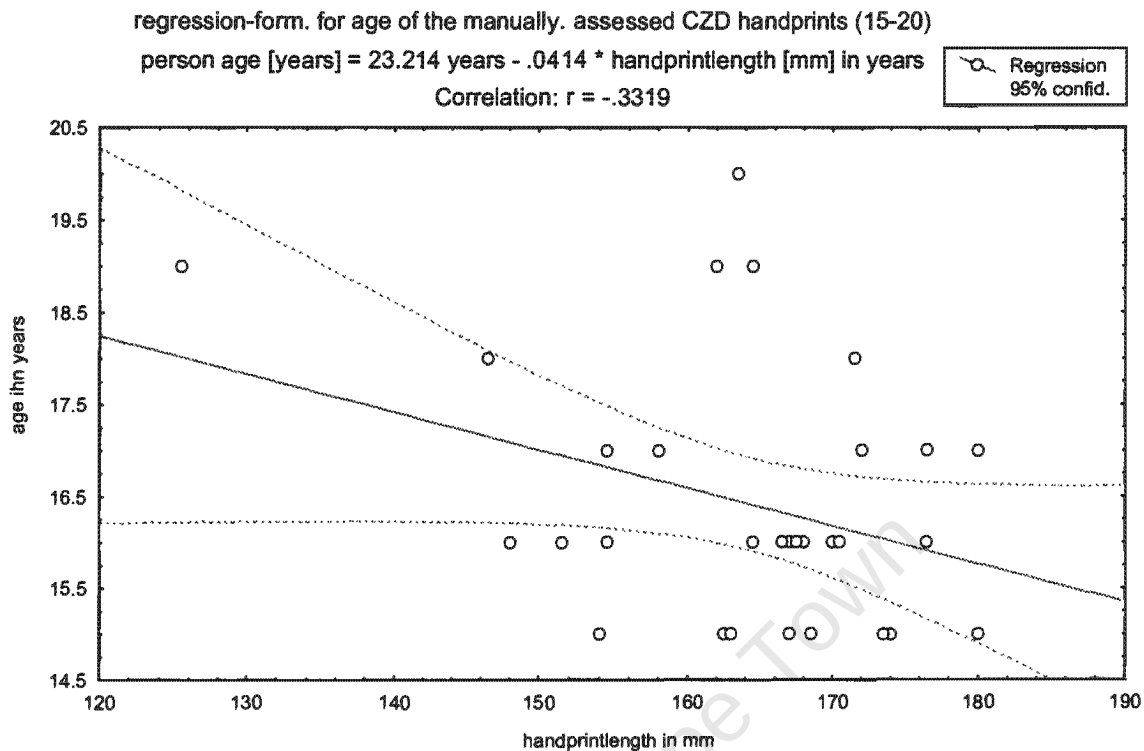


Figure 174: Regression formula for CZD (15 to 20 year olds) to estimate age from manually assessed middle finger length of the handprints

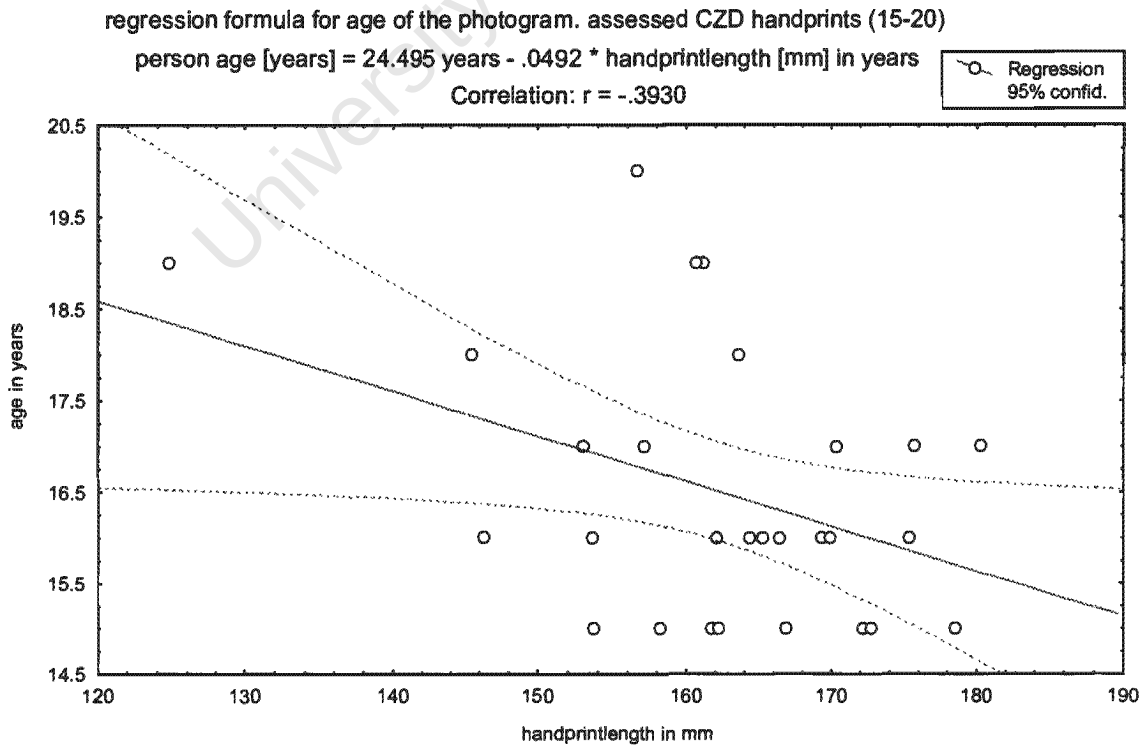


Figure 175: Regression formula for CZD (15 to 20 year olds) to estimate age from photogrammetrically assessed middle finger length of the handprints

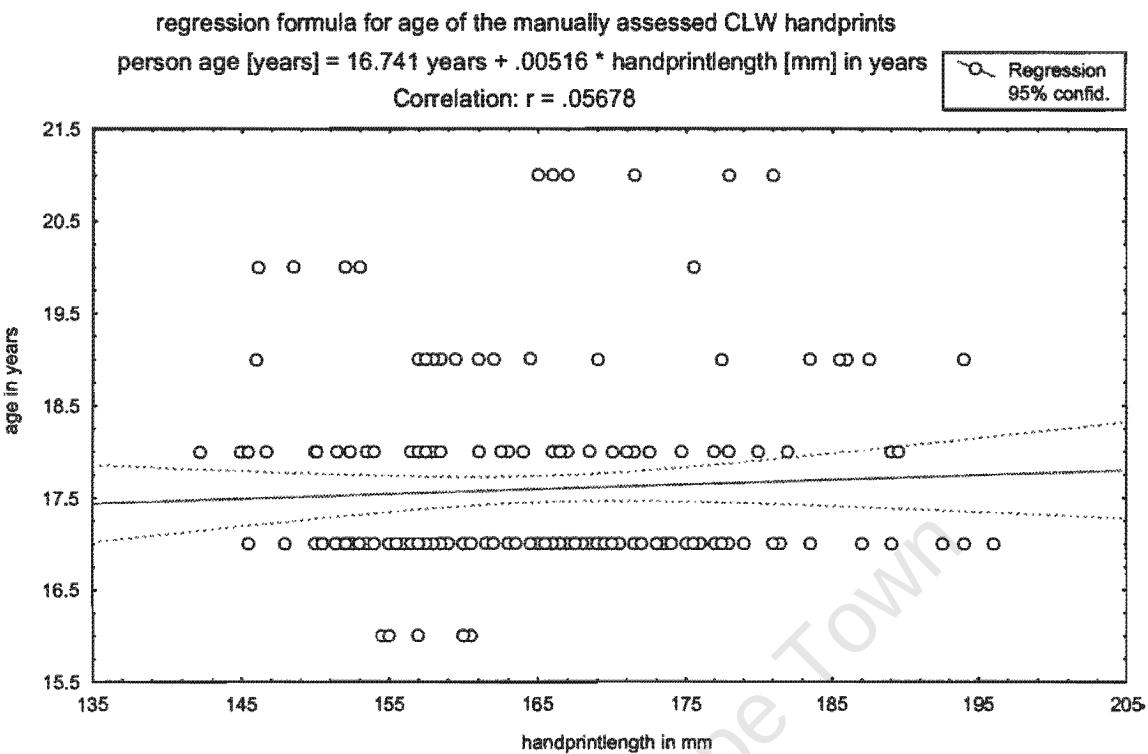


Figure 176: Regression formula for CLW (15 to 21 year olds) to estimate age from manually assessed middle finger length of the handprints

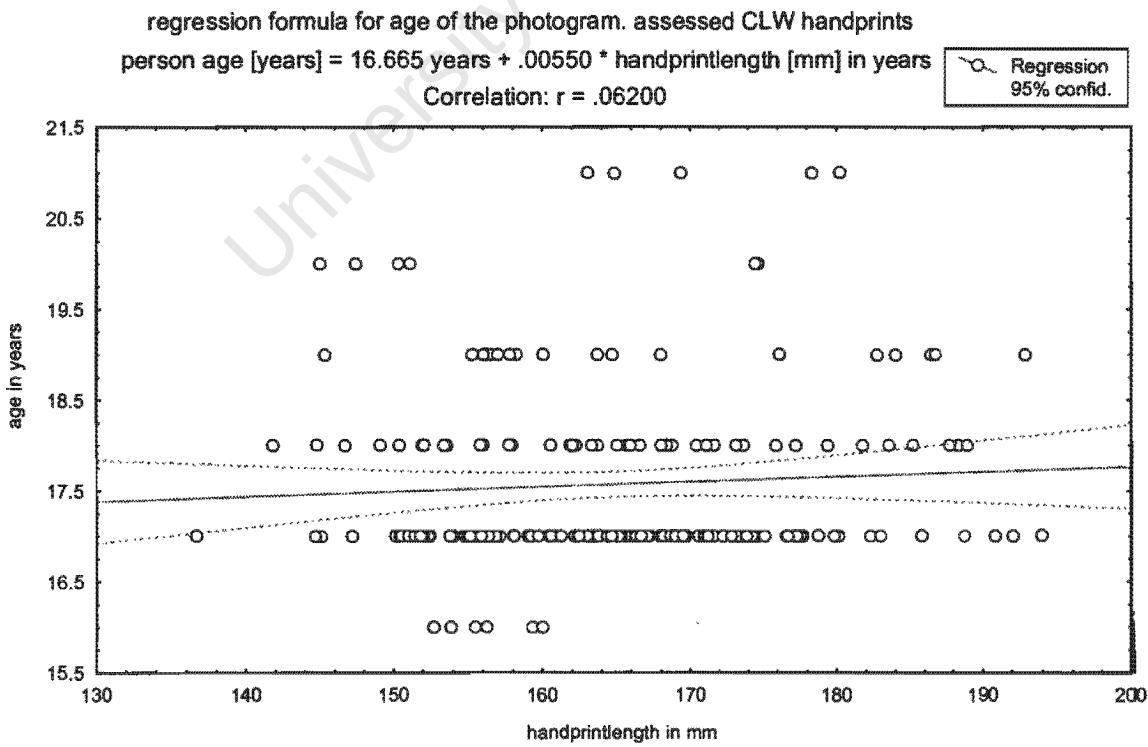


Figure 177: Regression formula for CZD (15 to 21 year olds) to estimate age from photogrammetrically assessed middle finger length of the handprints

difference of known vs. calculated age (in years)

regression formula derived from:	dataset analysed:	mean deviation in years	regression formula derived from:	dataset analysed:	mean deviation in years
CLW 15-21 man	CLW 15-21 man	0.794733	CZD 5-20 man	CZD 5-20 man	1.425810874
H & M 5-20 man	CLW 15-21 man	2.644843434	H & M 5-20 man	CZD 5-20 man	1.42223301
CZD 15-20 man	CLW 15-21 man	1.285072424			

regression formula derived from:	dataset analysed:	mean deviation in years	regression formula derived from:	dataset analysed:	mean deviation in years
CLW 15-21 pho	CLW 15-21 pho	0.776270441	CZD 5-20 pho	CZD 5-20 pho	1.471312653
H & M 5-20 man	CLW 15-21 pho	2.716128617	H & M 5-20 man	CZD 5-20 pho	1.469858141
CZD 15-20 pho	CLW 15-21 pho	1.260965315			

regression formula derived from:	dataset analysed:	mean deviation in years	regression formula derived from:	dataset analysed:	mean deviation in years
CZD 5-9 man	5-9 czd man	0.731048295	CZD 5-9 pho	5-9 czd pho	0.76660641
H & M 5-20 man	5-9 czd man	0.948977273	H & M 5-20 man	5-9 czd pho	0.949004419
			CLW 15-21 pho	5-9 czd pho	9.411943126

regression formula derived from:	dataset analysed:	mean deviation in years	regression formula derived from:	dataset analysed:	mean deviation in years
CZD 10-14 man	10-14 czd man	0.832291964	CZD 10-14 pho	10-14 czd pho	0.827193759
H & M 5-20 man	10-14 czd man	1.351964286	H & M 5-20 man	10-14 czd pho	1.299969214
			CLW 15-21 pho	10-14 czd pho	6.075534064

regression formula derived from:	dataset analysed:	mean deviation in years	regression formula derived from:	dataset analysed:	mean deviation in years
CZD 15-20 man	15-20 czd man	1.042412903	CZD 15-20 pho	15-20 czd pho	1.056667529
H & M 5-20 man	15-20 czd man	2.157419355	H & M 5-20 man	15-20 czd pho	2.439629571
			CLW 15-21 pho	15-20 czd pho	1.629174543

CZD = Calitzdorp - set

CLW = Clanwilliam - set

H & M = regression formula derived from sample set Henneberg & Mathers (1994) analysed

5-9 / 10-14 / 15-20 / 15-21 / 5-20 = age groups (5 to 9 years / 10 to 14 years / 15 to 21 years / 5 to 20 years)

pho = photogrammetrically assessed handprints

man = manually assessed prints (caliper)

Figure 178: Regression formulas for age derived from experimental datasets applied on various experimental datasets

difference of known vs. calculated height (in cm)

regression formula derived from:	dataset analysed:	mean deviation in years	regression formula derived from:	dataset analysed:	mean deviation in years
CLW 15-21 man	CLW 15-21 man	4.362669005	CZD 5-20 man	CZD 5-20 man	4.2908575
H & M 5-20 man	CLW 15-21 man	10.8047	H & M 5-20 man	CZD 5-20 man	4.57613
CZD 15-20 man	CLW 15-21 man	6.565466121			

regression formula derived from:	dataset analysed:	mean deviation in years	regression formula derived from:	dataset analysed:	mean deviation in years
CLW 15-21 pho	CLW 15-21 pho	4.50267236	CZD 5-20 pho	CZD 5-20 pho	4.37049779
H & M 5-20 man	CLW 15-21 pho	11.26873226	H & M 5-20 man	CZD 5-20 pho	4.948433118
CZD 15-20 pho	CLW 15-21 pho	6.977471045			

regression formula derived from:	dataset analysed:	mean deviation in years	regression formula derived from:	dataset analysed:	mean deviation in years
CZD 5-9 man	5-9 czd man	3.16015875	CZD 5-9 pho	5-9 czd pho	3.205008956
H & M 5-20 man	5-9 czd man	3.530431818	H & M 5-20 man	5-9 czd pho	3.825462558
			CLW 15-21 pho	5-9 czd pho	22.6788058

regression formula derived from:	dataset analysed:	mean deviation in years	regression formula derived from:	dataset analysed:	mean deviation in years
CZD 10-14 man	10-14 czd man	3.292411071	CZD 10-14 pho	10-14 czd pho	3.299604468
H & M 5-20 man	10-14 czd man	4.428178571	H & M 5-20 man	10-14 czd pho	4.783332814
			CLW 15-21 pho	10-14 czd pho	15.13237842

regression formula derived from:	dataset analysed:	mean deviation in years	regression formula derived from:	dataset analysed:	mean deviation in years
CZD 15-20 man	15-20 czd man	5.110346071	CZD 15-20 pho	15-20 czd pho	5.081287962
H & M 5-20 man	15-20 czd man	6.367321429	H & M 5-20 man	15-20 czd pho	6.908082844
			CLW 15-21 pho	15-20 czd pho	7.219159002

CZD = Callitzdorp - set

CLW = Clanwilliam - set

H & M = regression formula derived from sample set Henneberg & Mathers (1994) analysed

5-9 / 10-14 / 15-20 / 15-21 / 5-20 = age groups (5 to 9 years / 10 to 14 years / 15 to 21 years / 5 to 20 years)

pho = photogrammetrically assessed handprints

man = manually assessed prints (calliper)

Figure 179: Regression formulas for height derived from experimental datasets applied on various experimental datasets

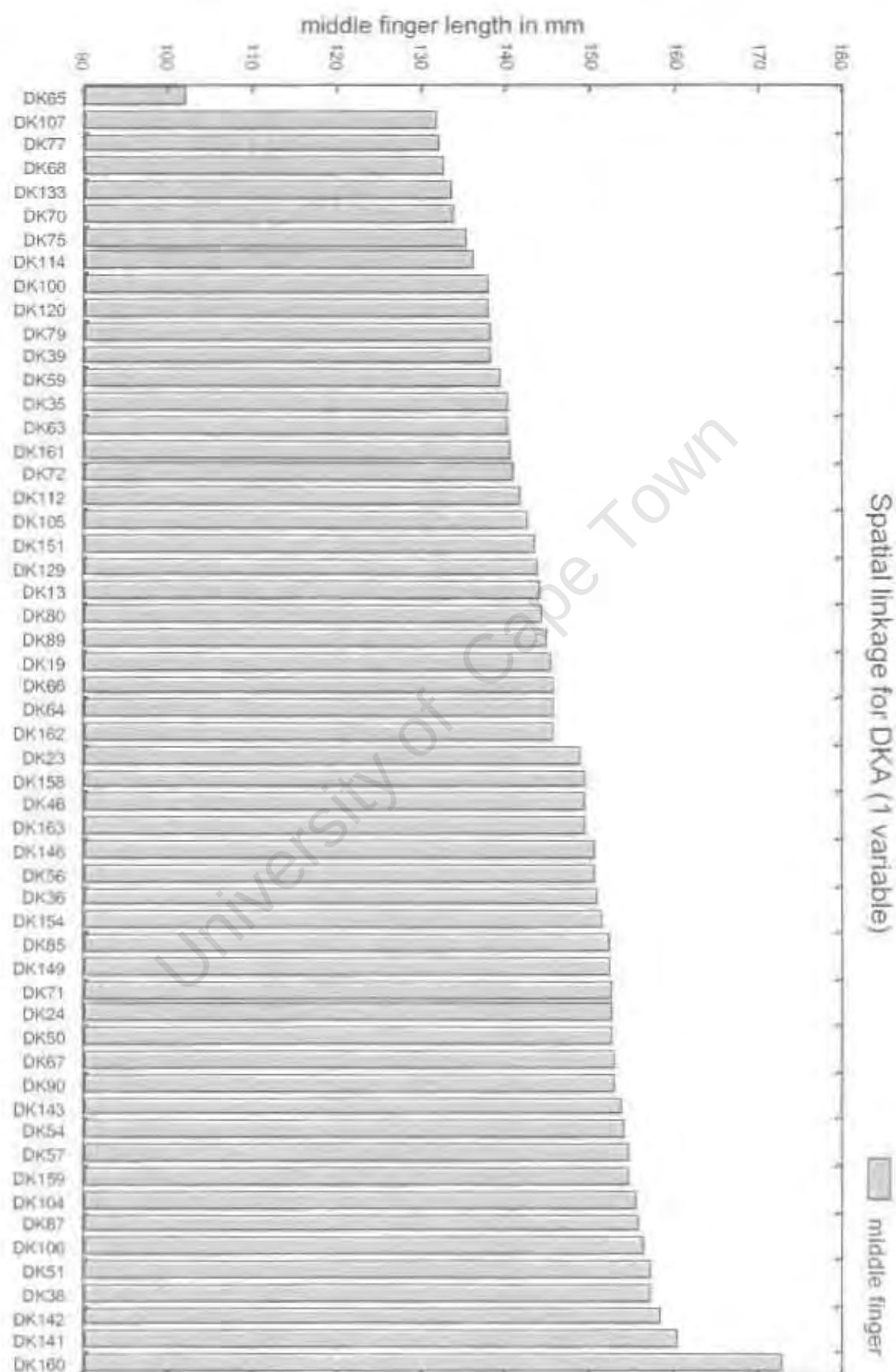


Figure 180: Bar-plot of middlefinger length for spatial proximity of DKA handprints

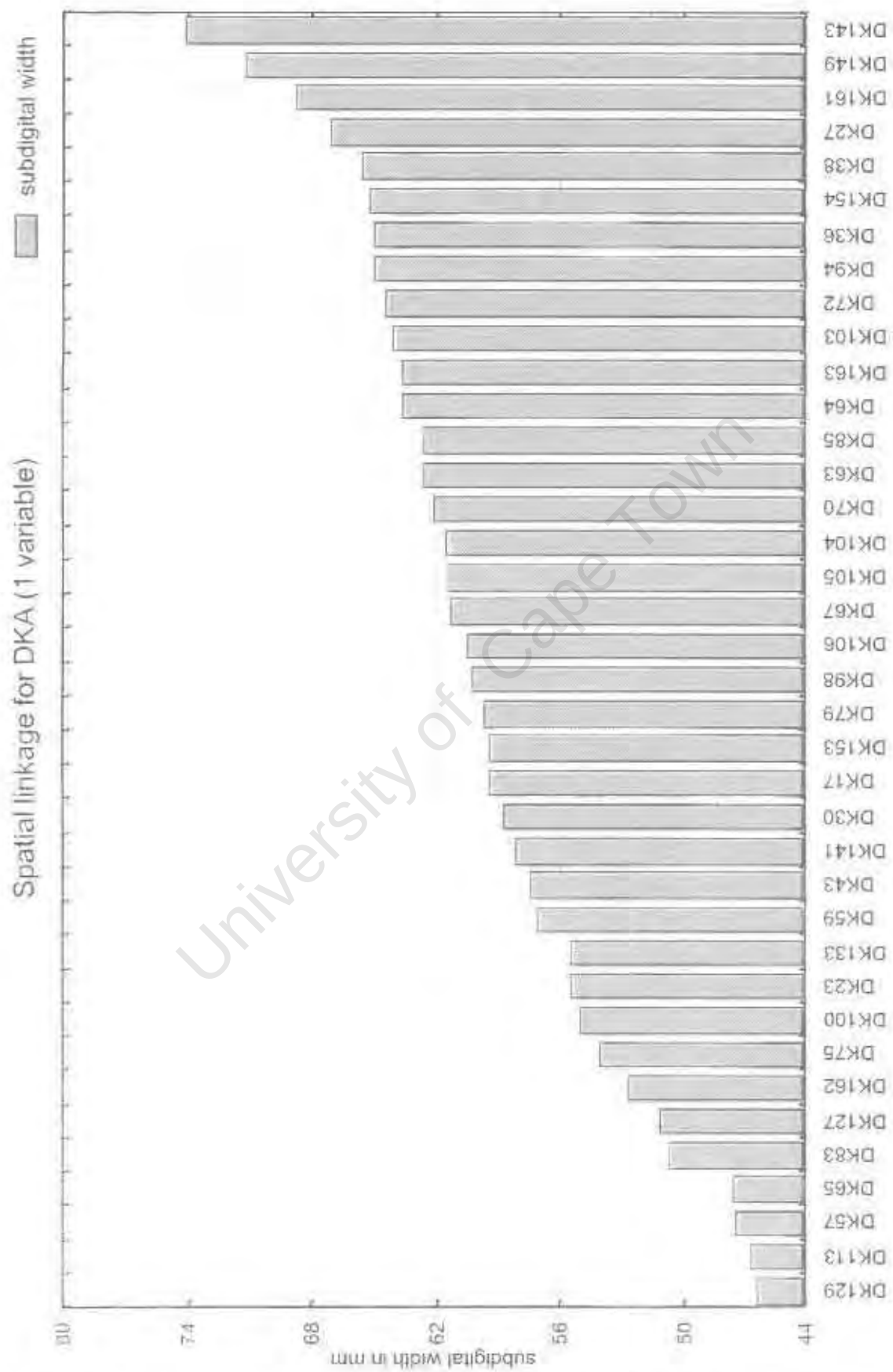


Figure 181: Bar-plot of subdigital width for spatial proximity of DKA handprints

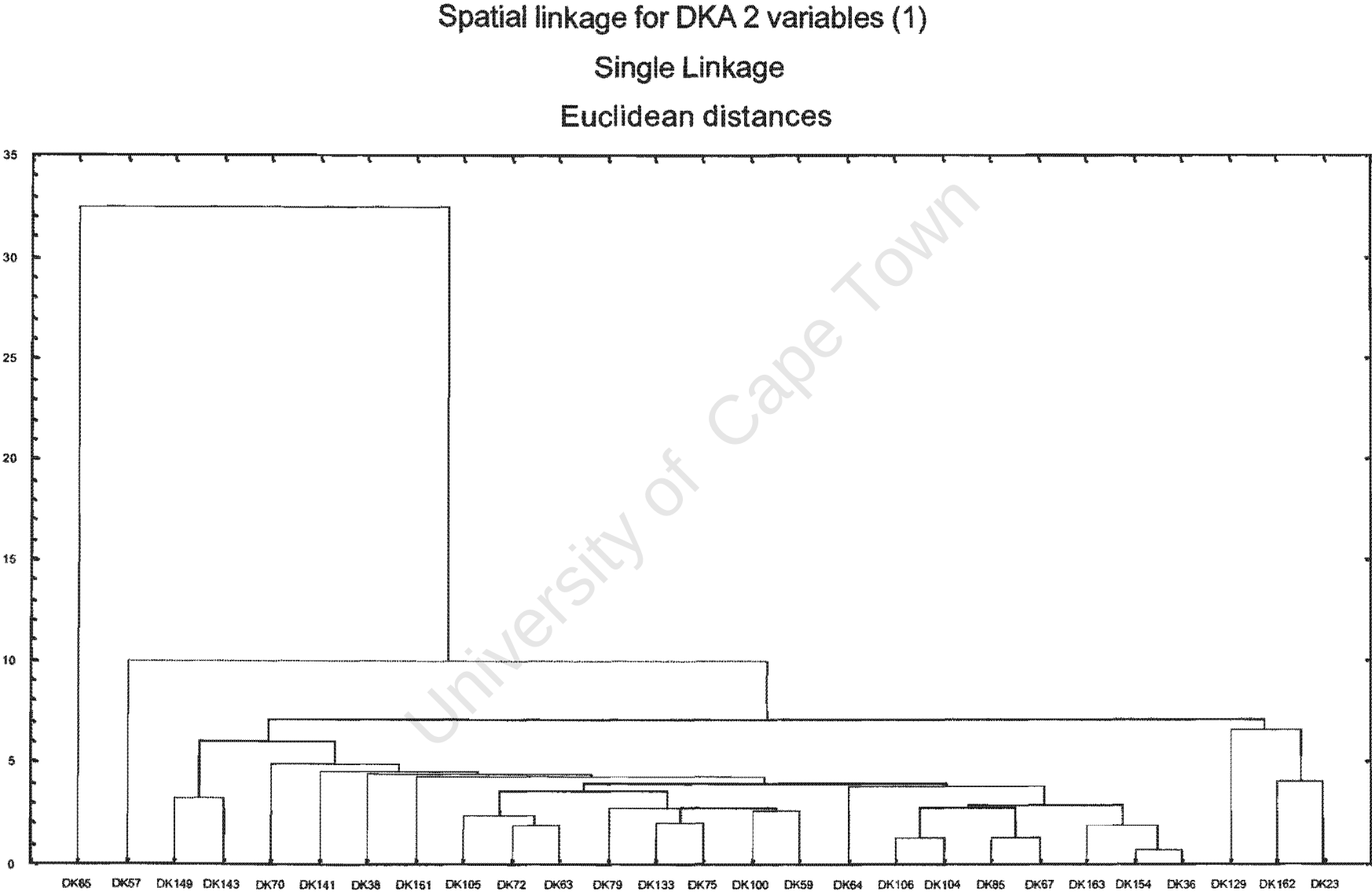


Figure 182: Cluster analysis of 2 variables (1) showing spatial relations of DKA prints (1)

Spatial linkage for DKA 2 variables (1)

Complete Linkage

Euclidean distances

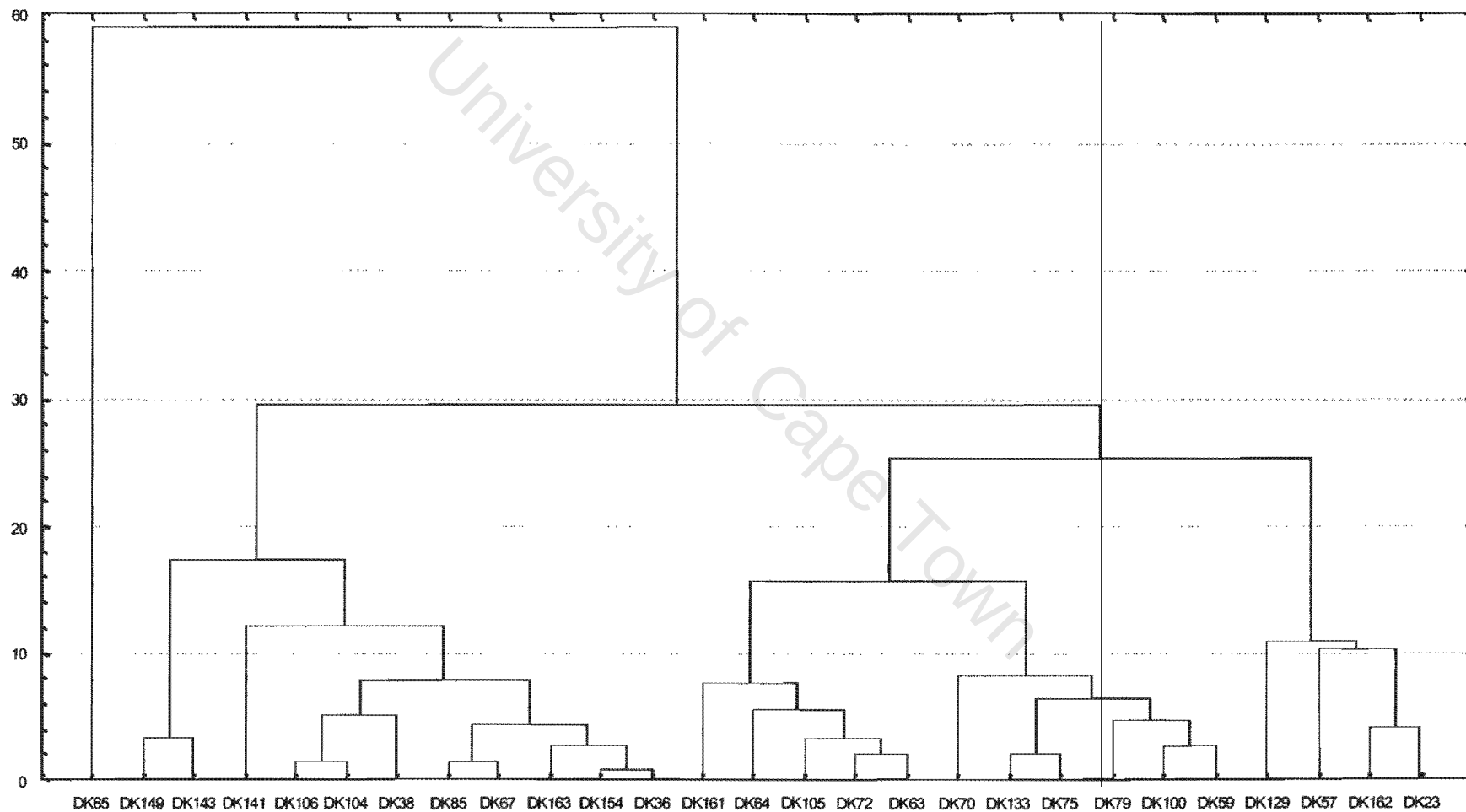


Figure 183: Cluster analysis of 2 variables (1) showing spatial relations of DKA prints (2)

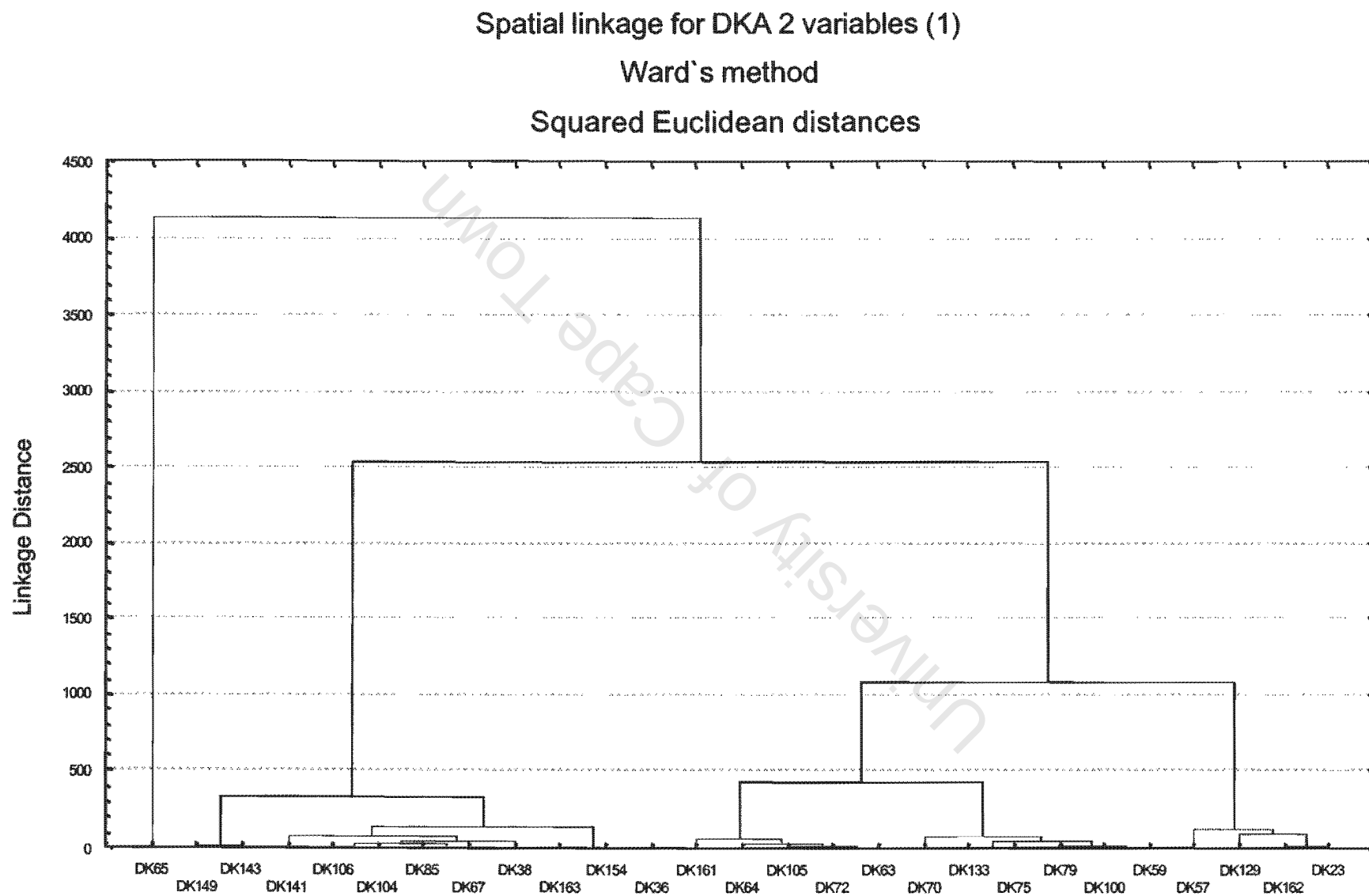


Figure 184: Cluster analysis of 2 variables (1) showing spatial relations of DKA prints (3)

Spatial linkage for DKA 2 variables (2)
Single Linkage
Euclidean distances

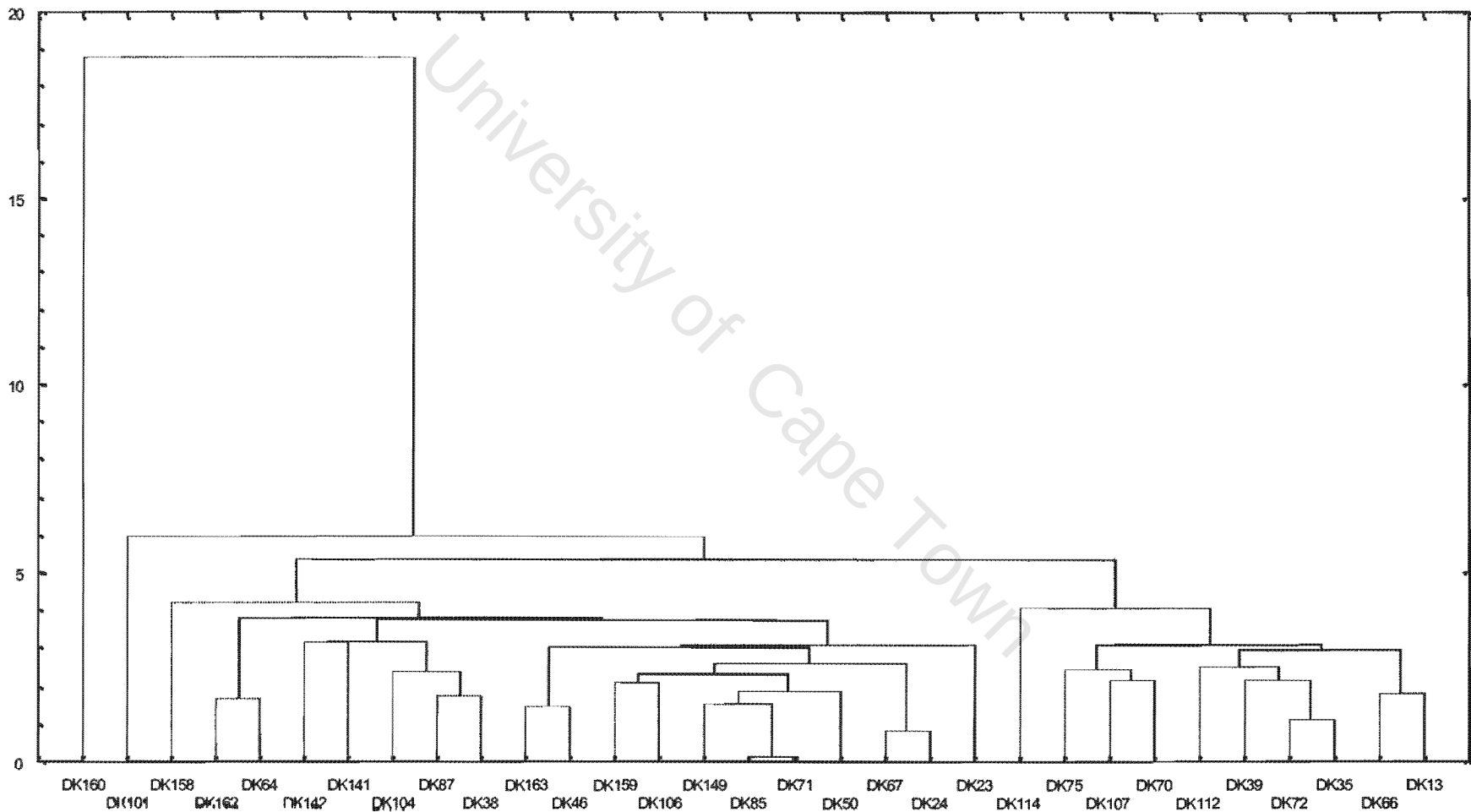


Figure 185: Cluster analysis of 2 variables (2) showing spatial relations of DKA prints (1)

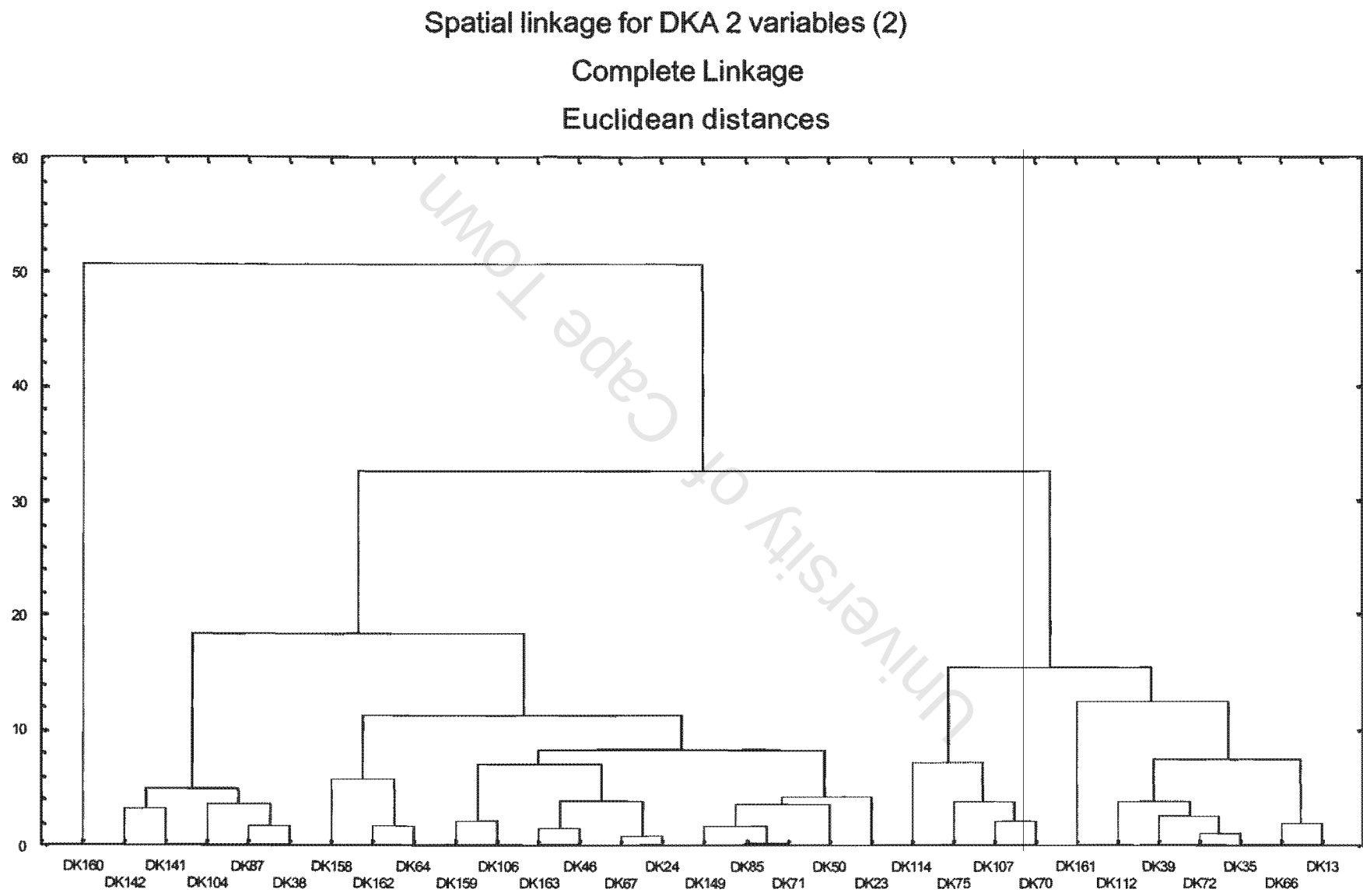


Figure 186: Cluster analysis of 2 variables (2) showing spatial relations of DKA prints (2)

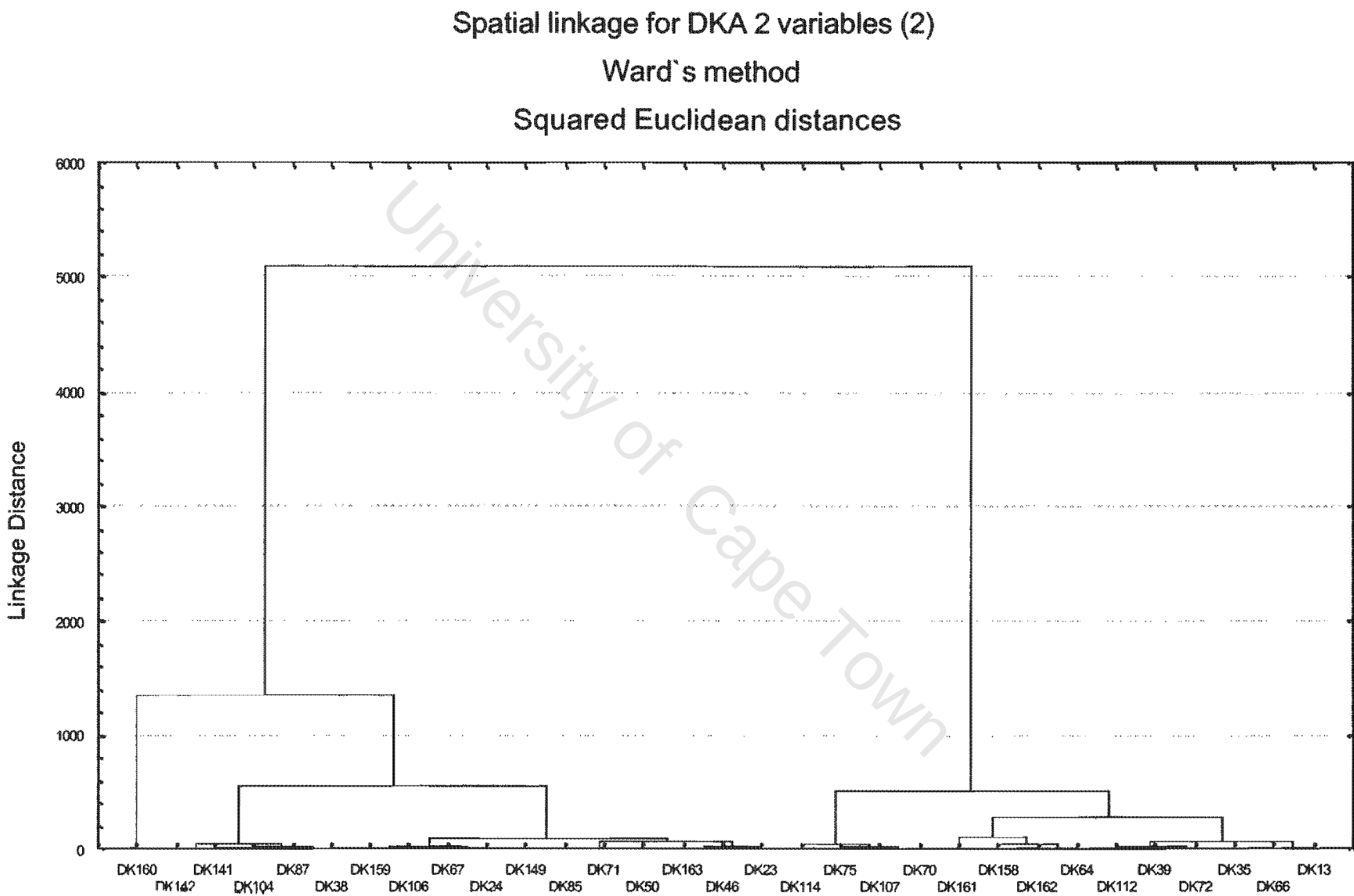


Figure 187: Cluster analysis of 2 variables (2) showing spatial relations of DKA prints (3)

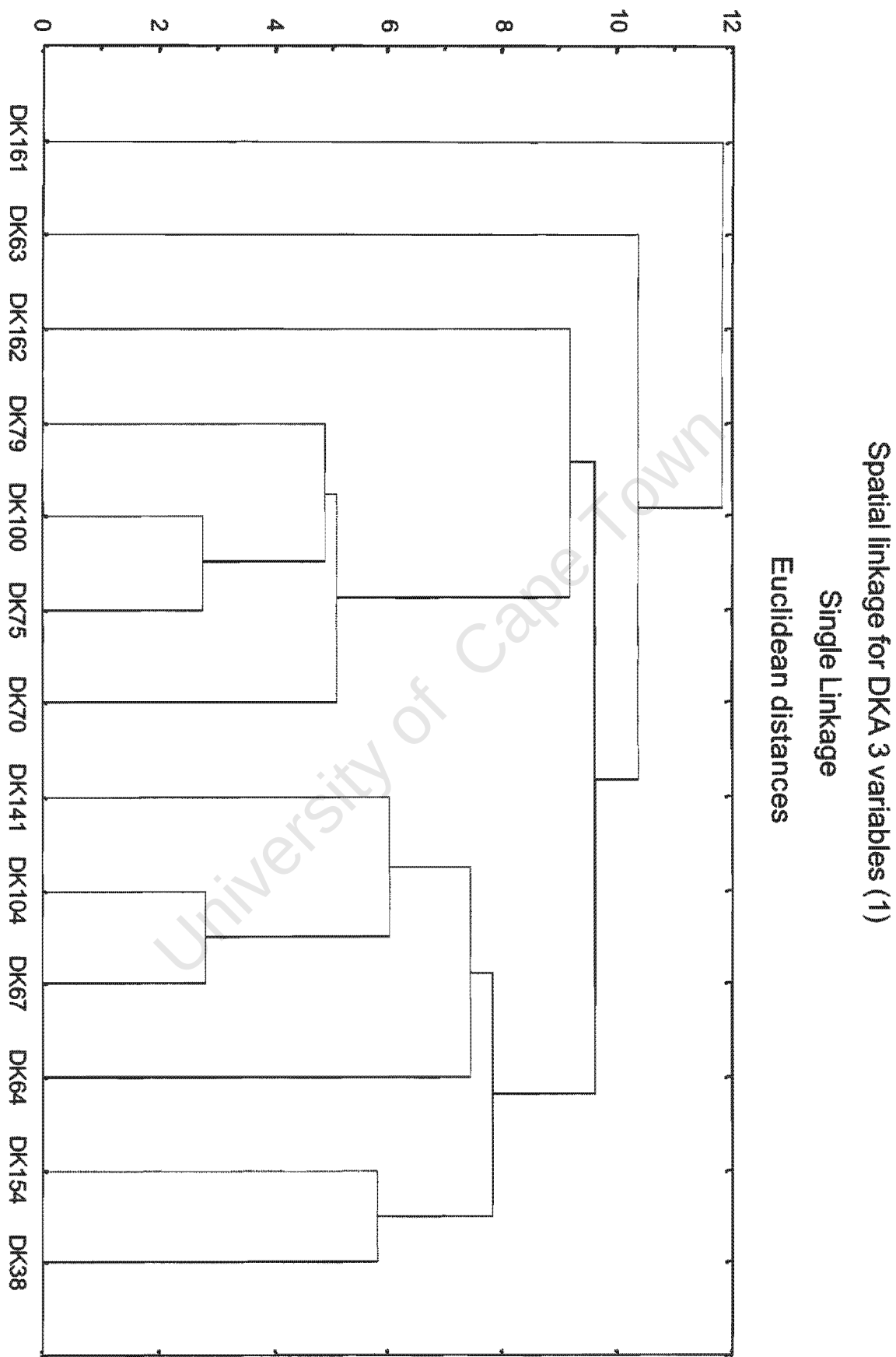


Figure 188: Cluster analysis of 3 variables (1) showing spatial relations of DKA prints (1)

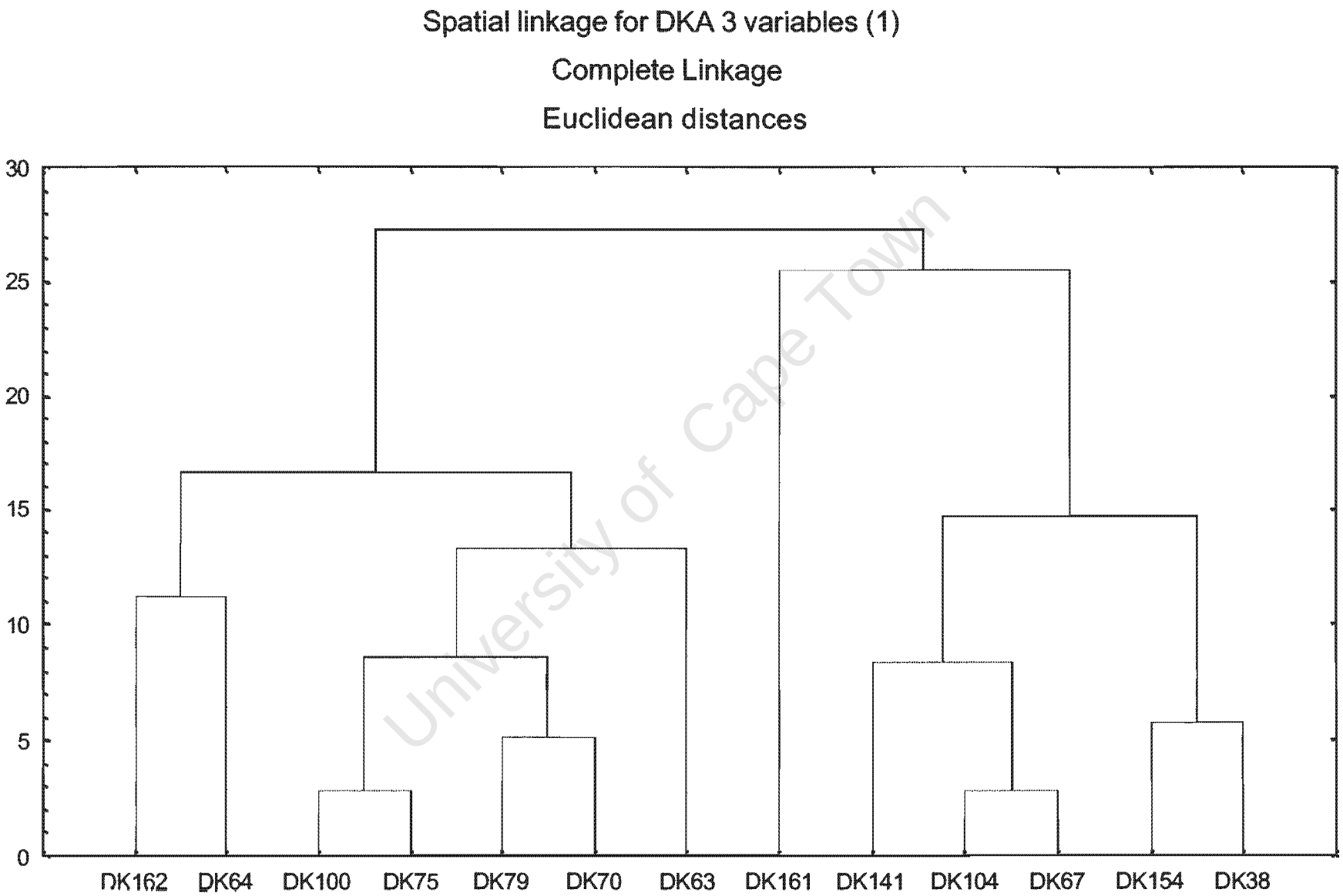


Figure 189: Cluster analysis of 3 variables (1) showing spatial relations of DKA prints (2)

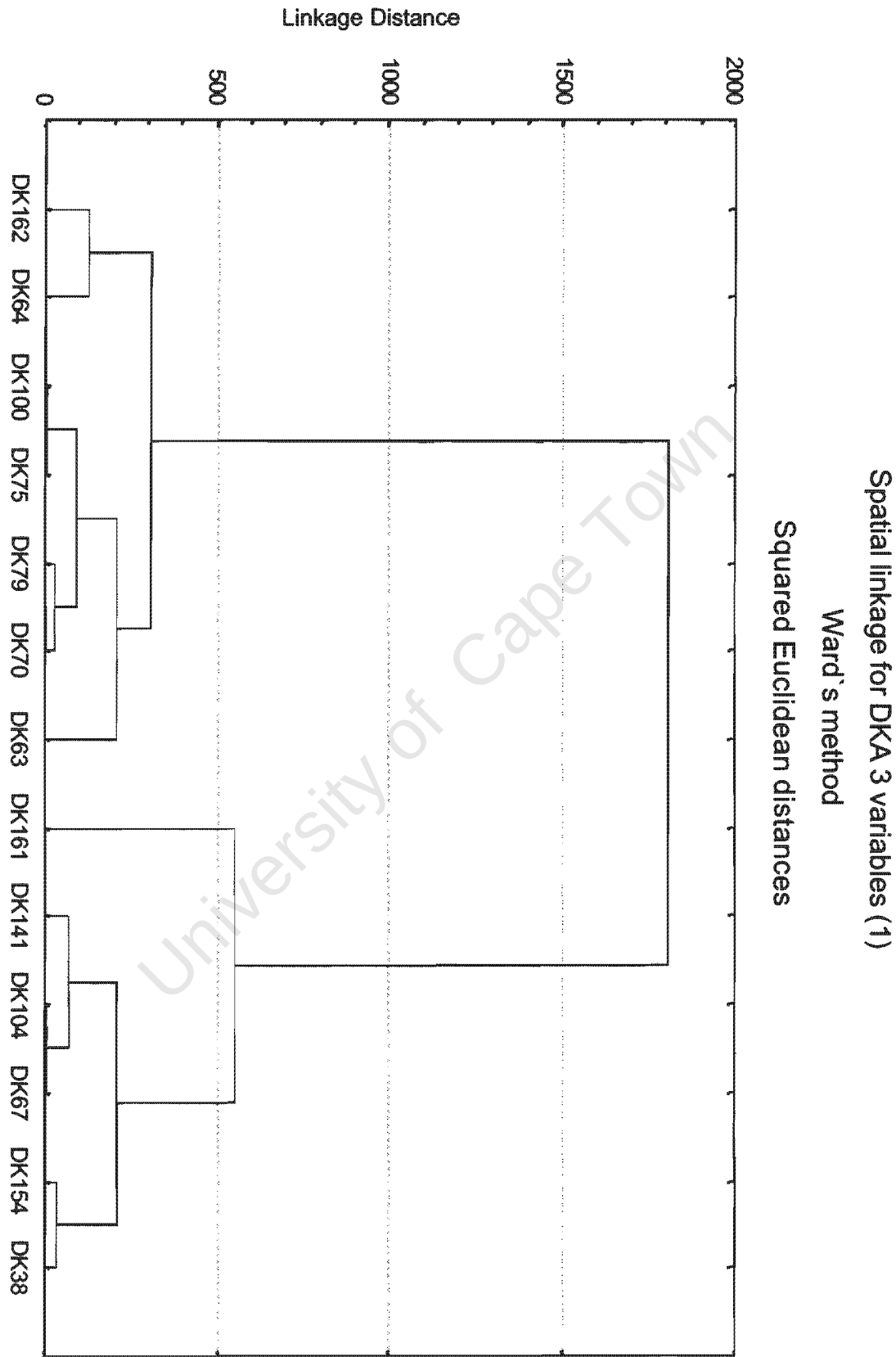


Figure 190: Cluster analysis of 3 variables (1) showing spatial relations of DKA prints (3)

Spatial linkage for DKA 3 variables (2)

Single Linkage

Euclidean distances

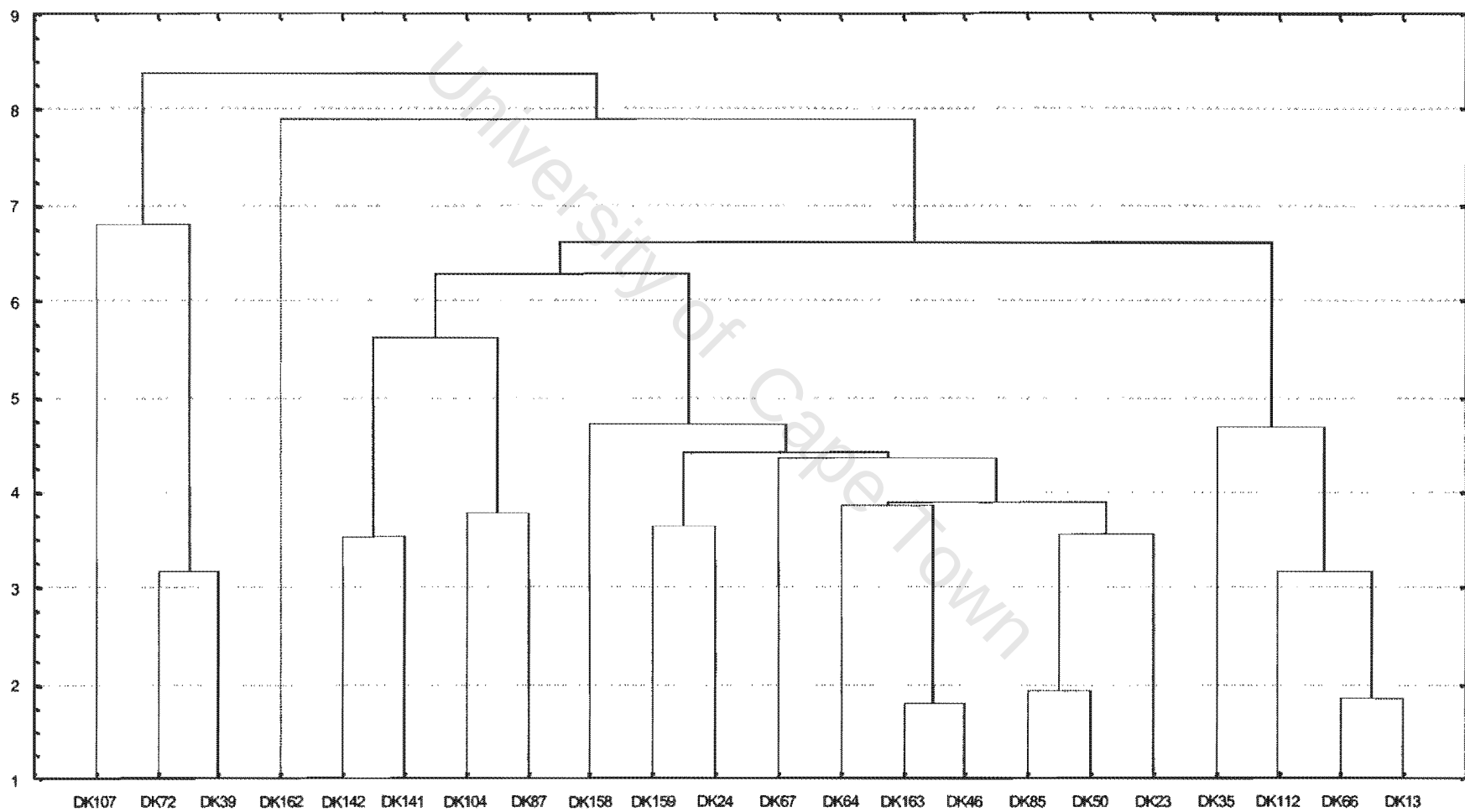


Figure 191: Cluster analysis of 3 variables (2) showing spatial relations of DKA prints
(1)

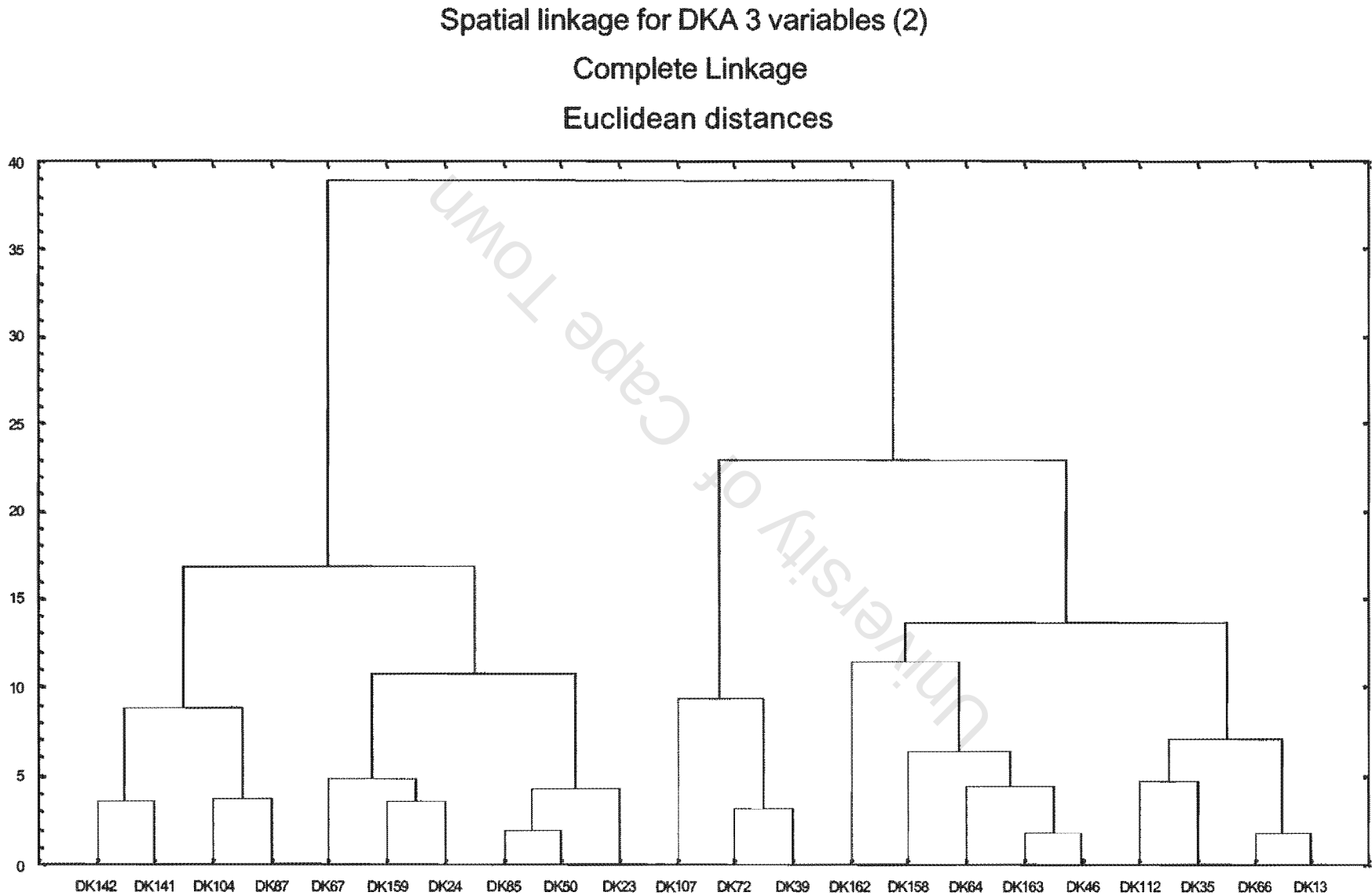


Figure 192: Cluster analysis of 3 variables (2) showing spatial relations of DKA prints (2)

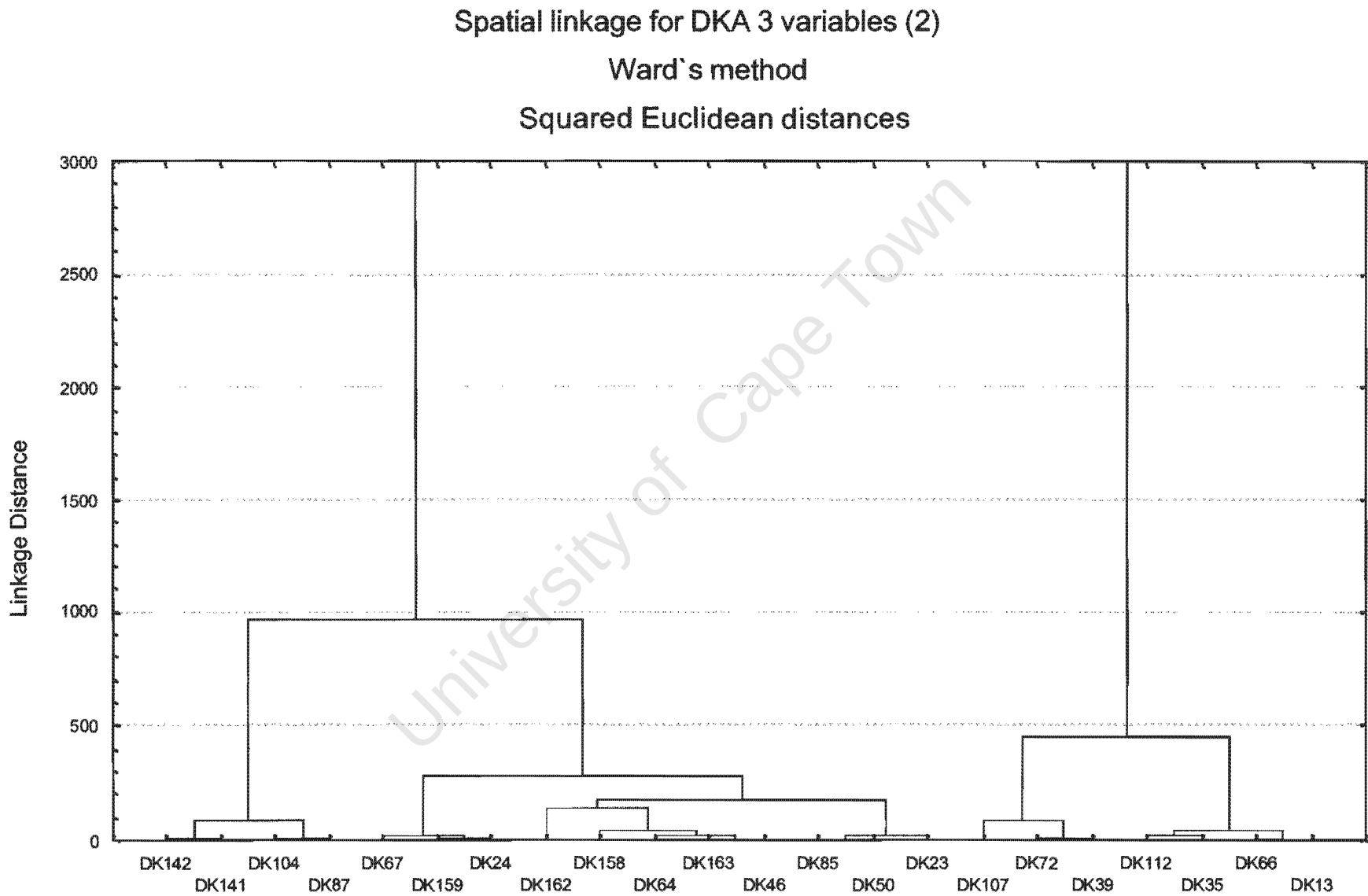


Figure 193: Cluster analysis of 3 variables (2) showing spatial relations of DKA prints
(3)

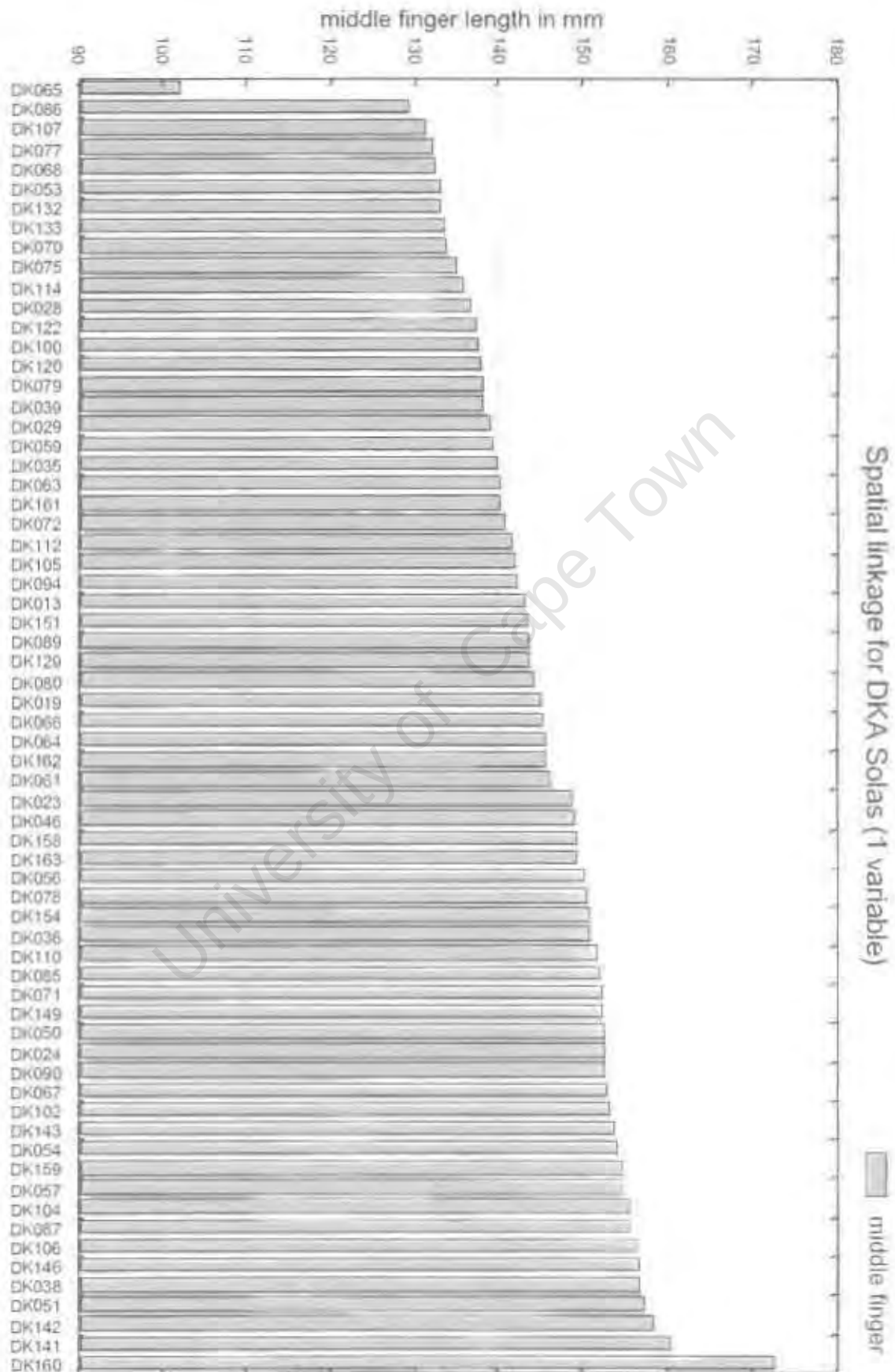


Figure 194: Bar-plot of middlefinger length for spatial proximity of DKA (SOLAS) handprints

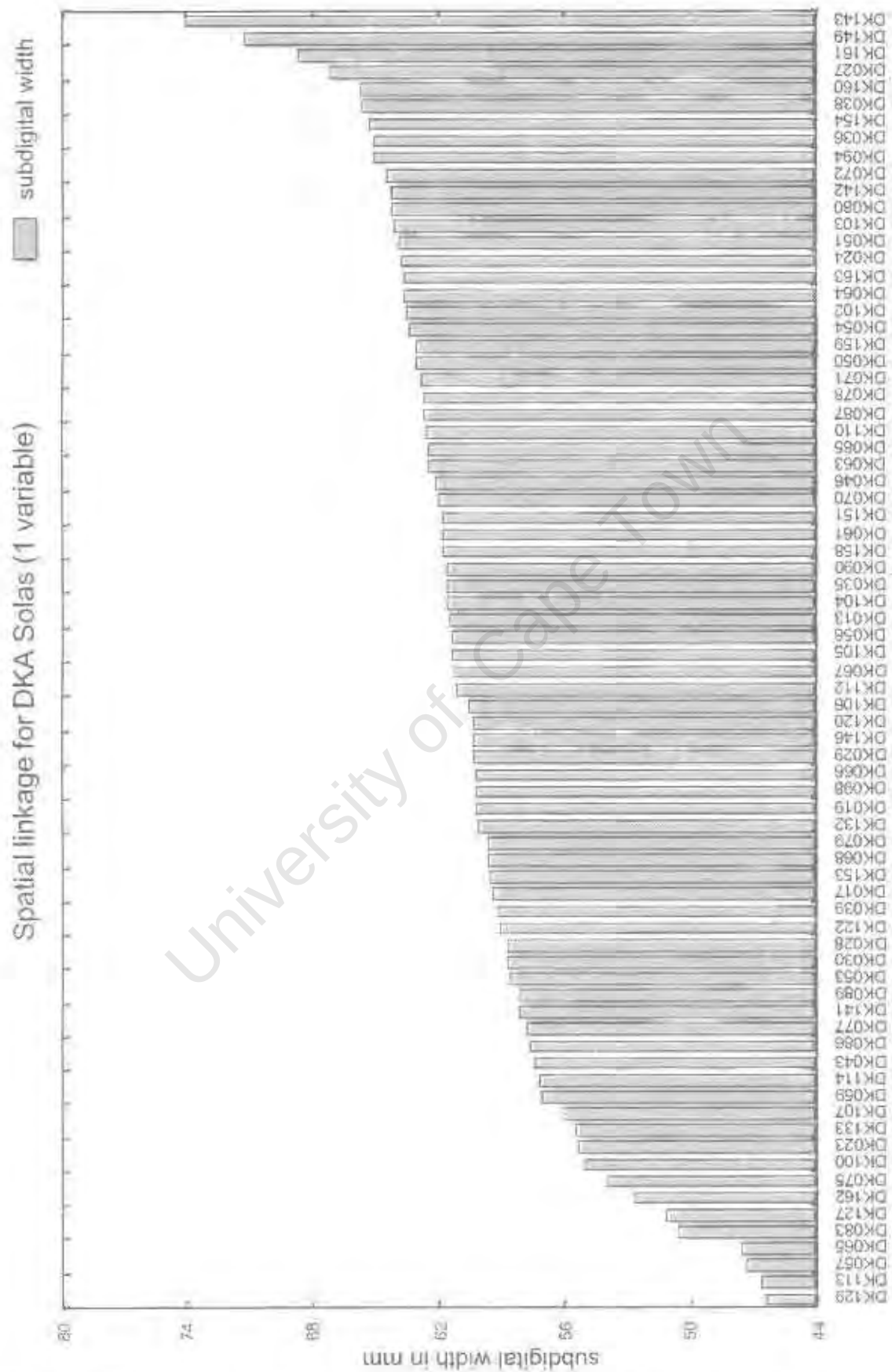


Figure 195: Bar-plot of subdigital width for spatial proximity of DKA (SOLAS) handprints

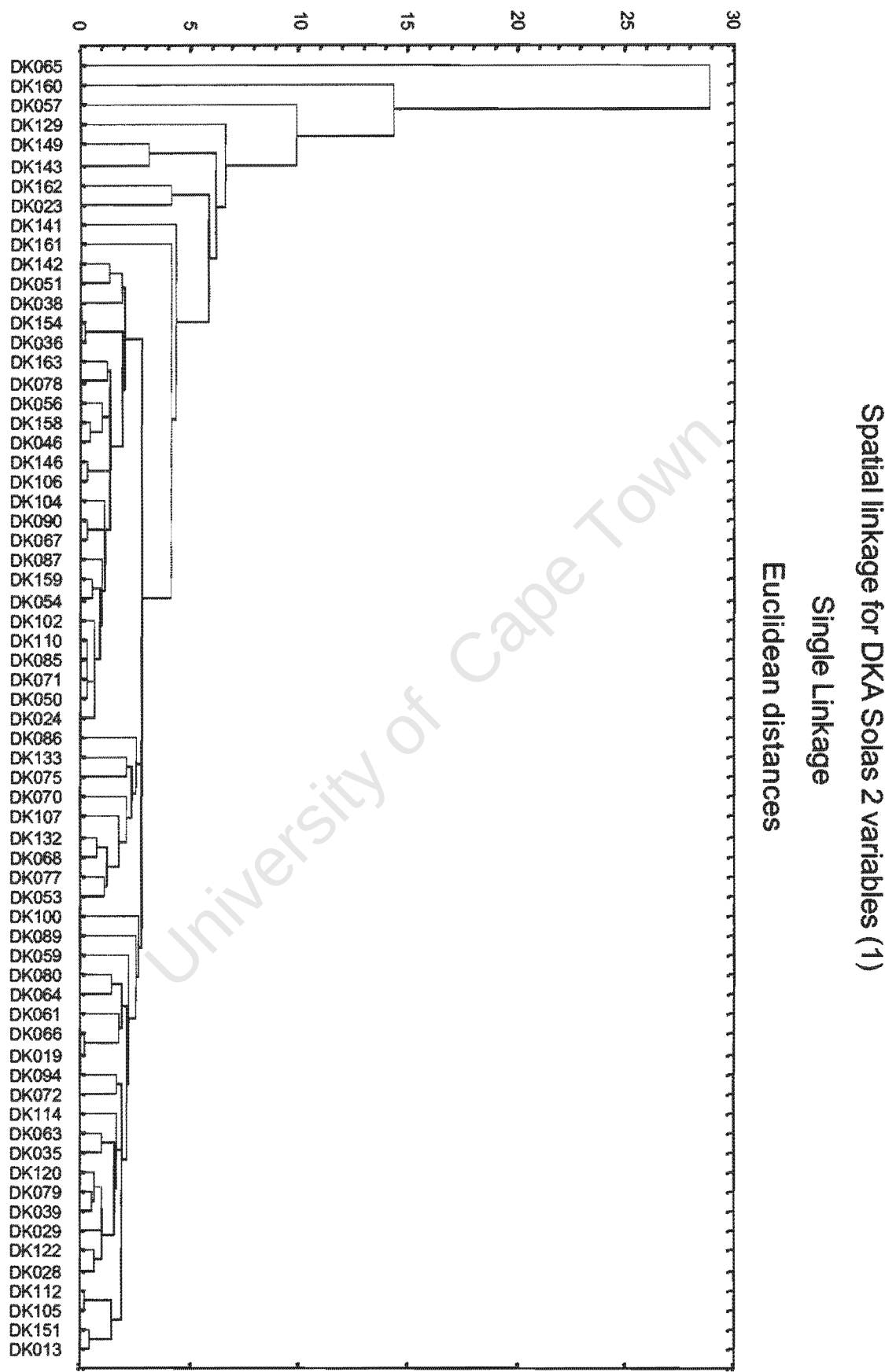


Figure 196: Cluster analysis of 2 variables (1) showing spatial relations of DKA (SOLAS) prints (1)

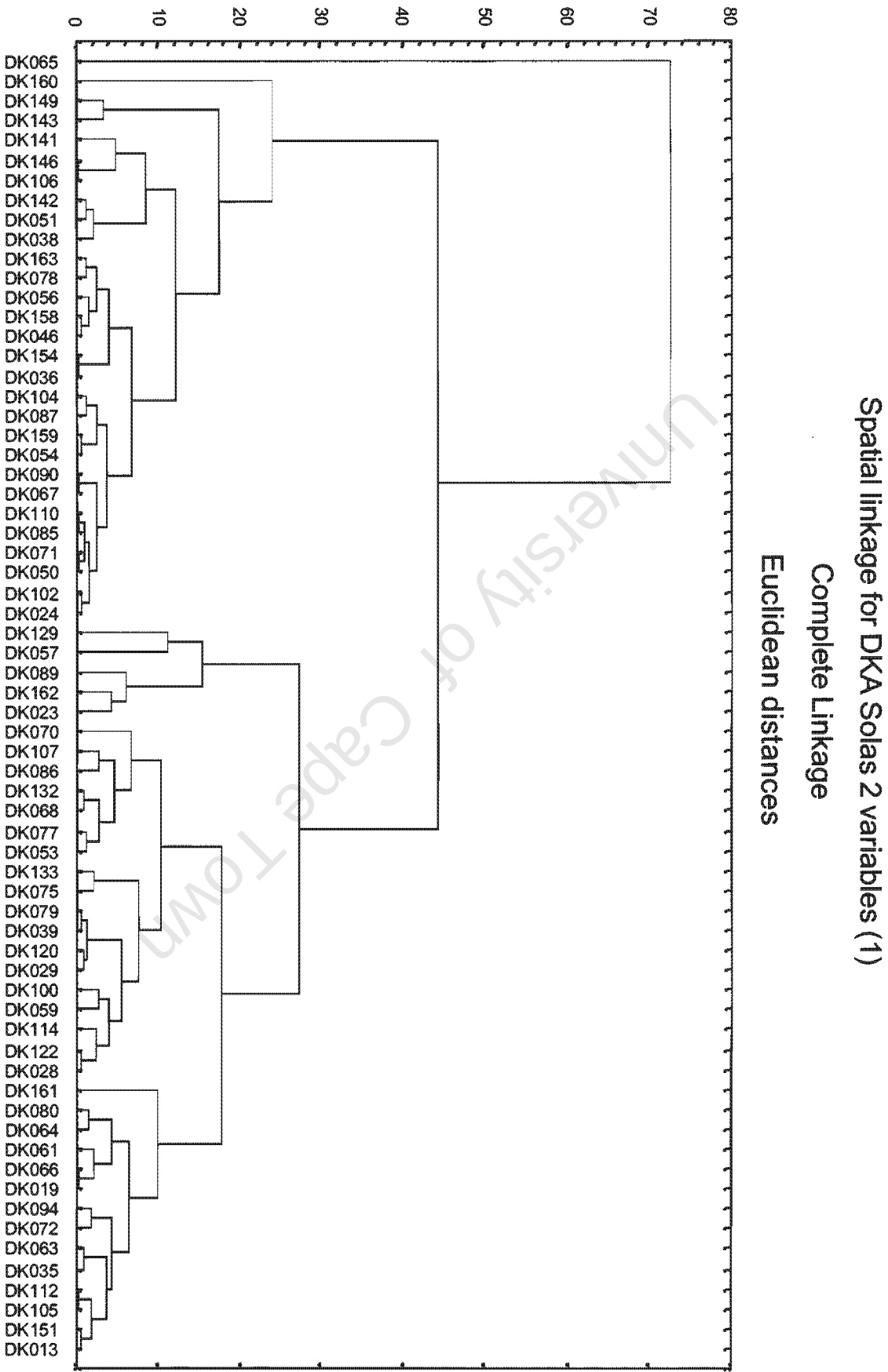


Figure 197: Cluster analysis of 2 variables (1) showing spatial relations of DKA (SOLAS) prints (2)

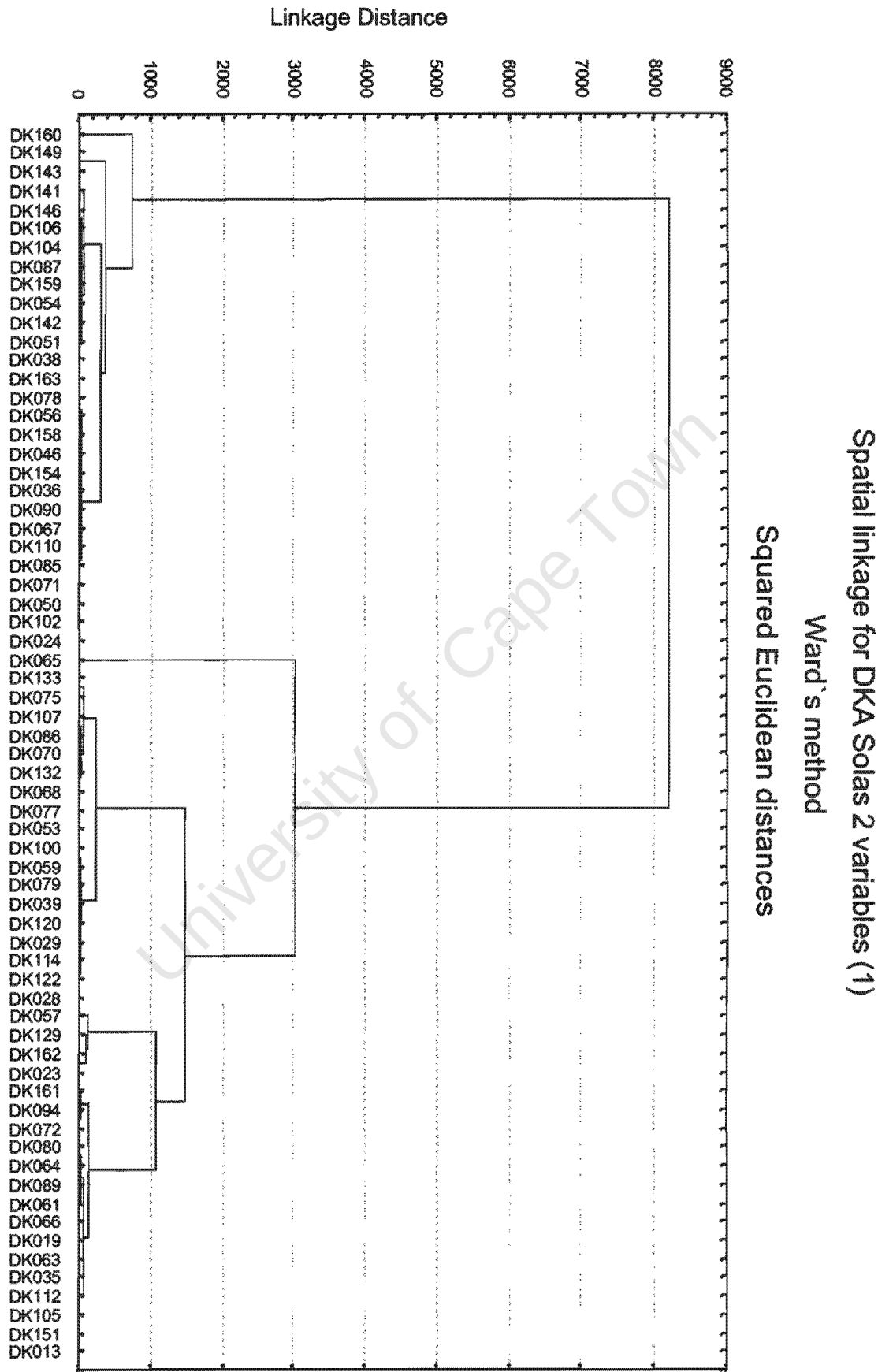
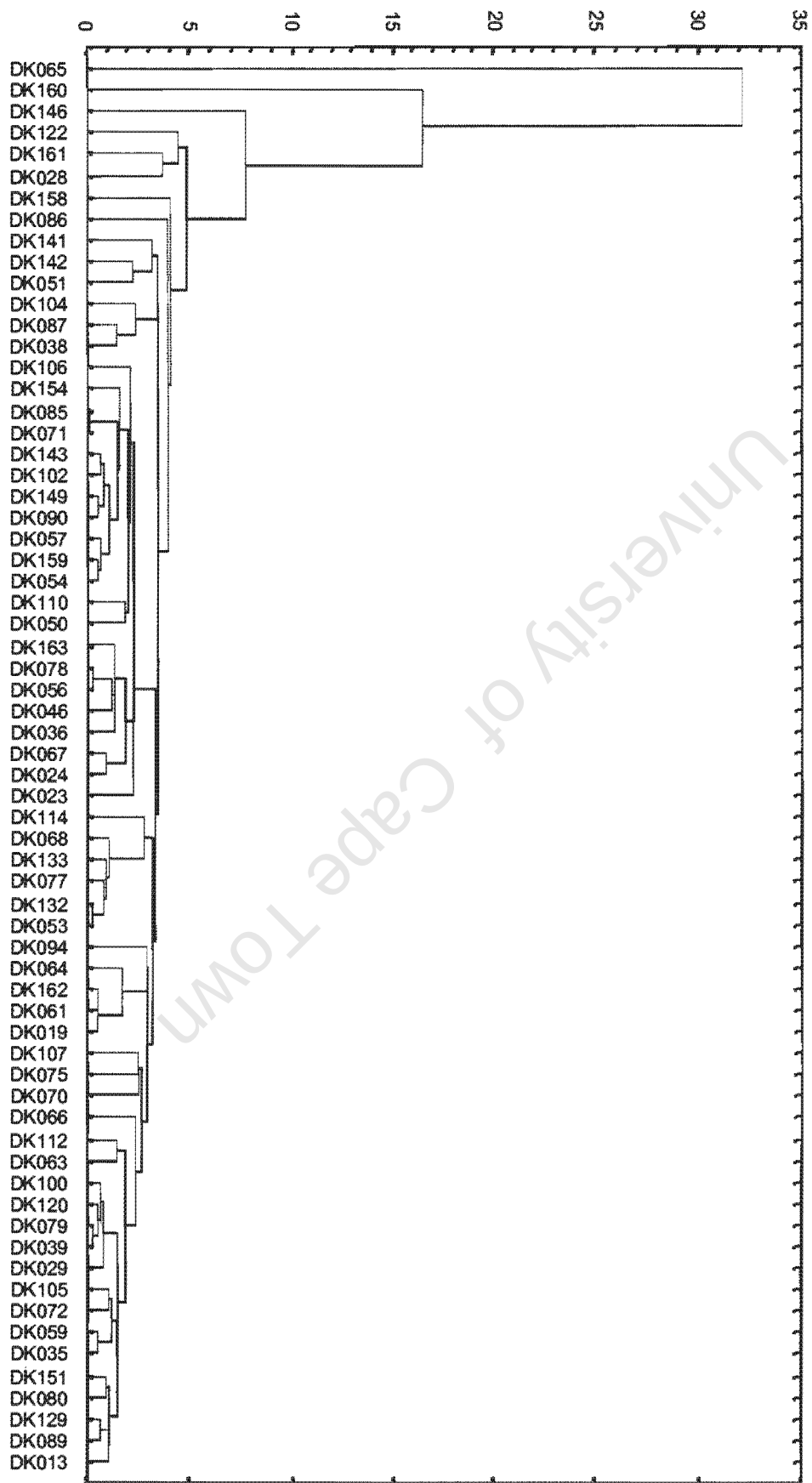


Figure 198: Cluster analysis of 2 variables (1) showing spatial relations of DKA (SOLAS) prints (3)



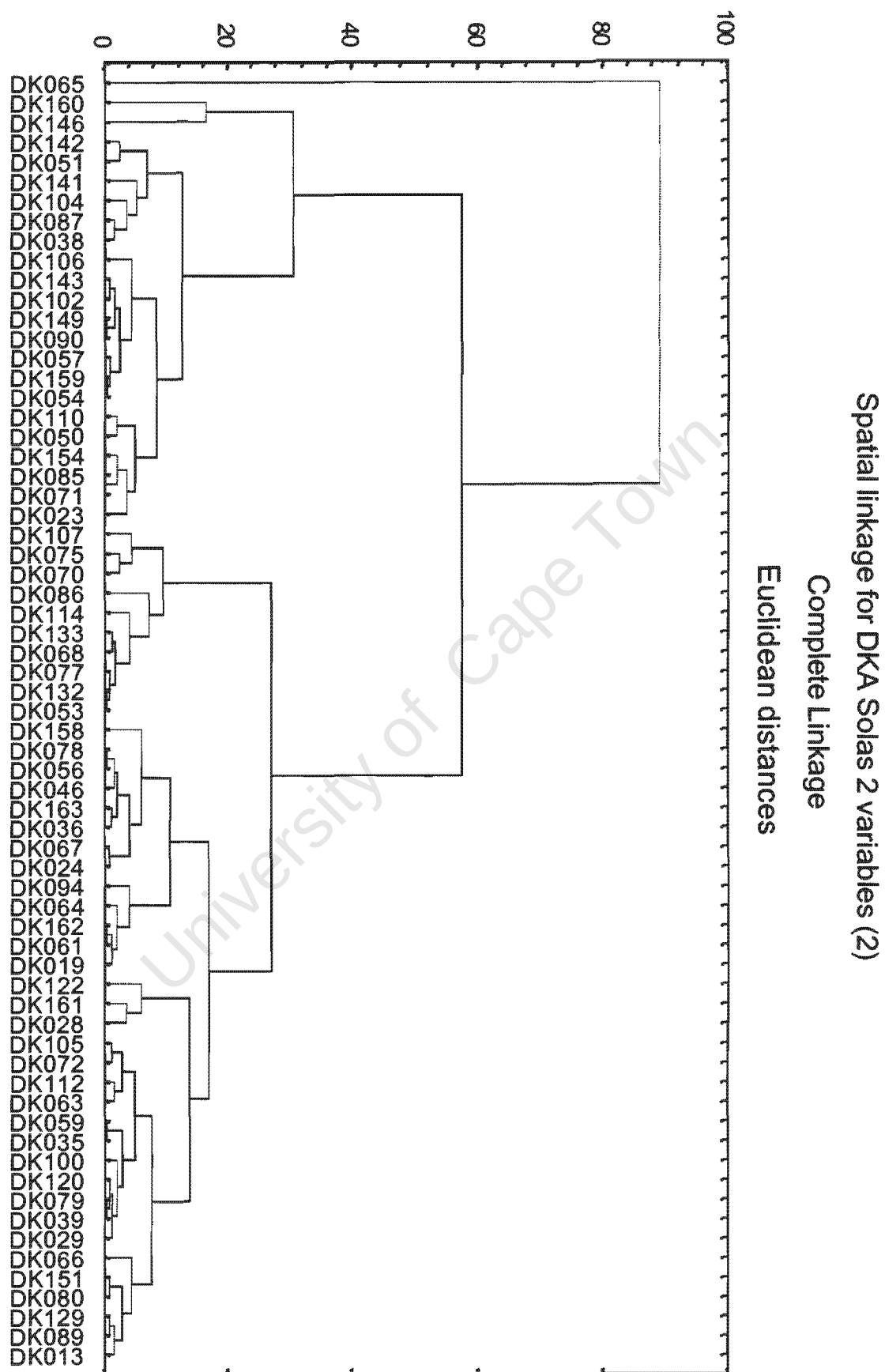


Figure 200: Cluster analysis of 2 variables (2) showing spatial relations of DKA (SOLAS) prints (2)

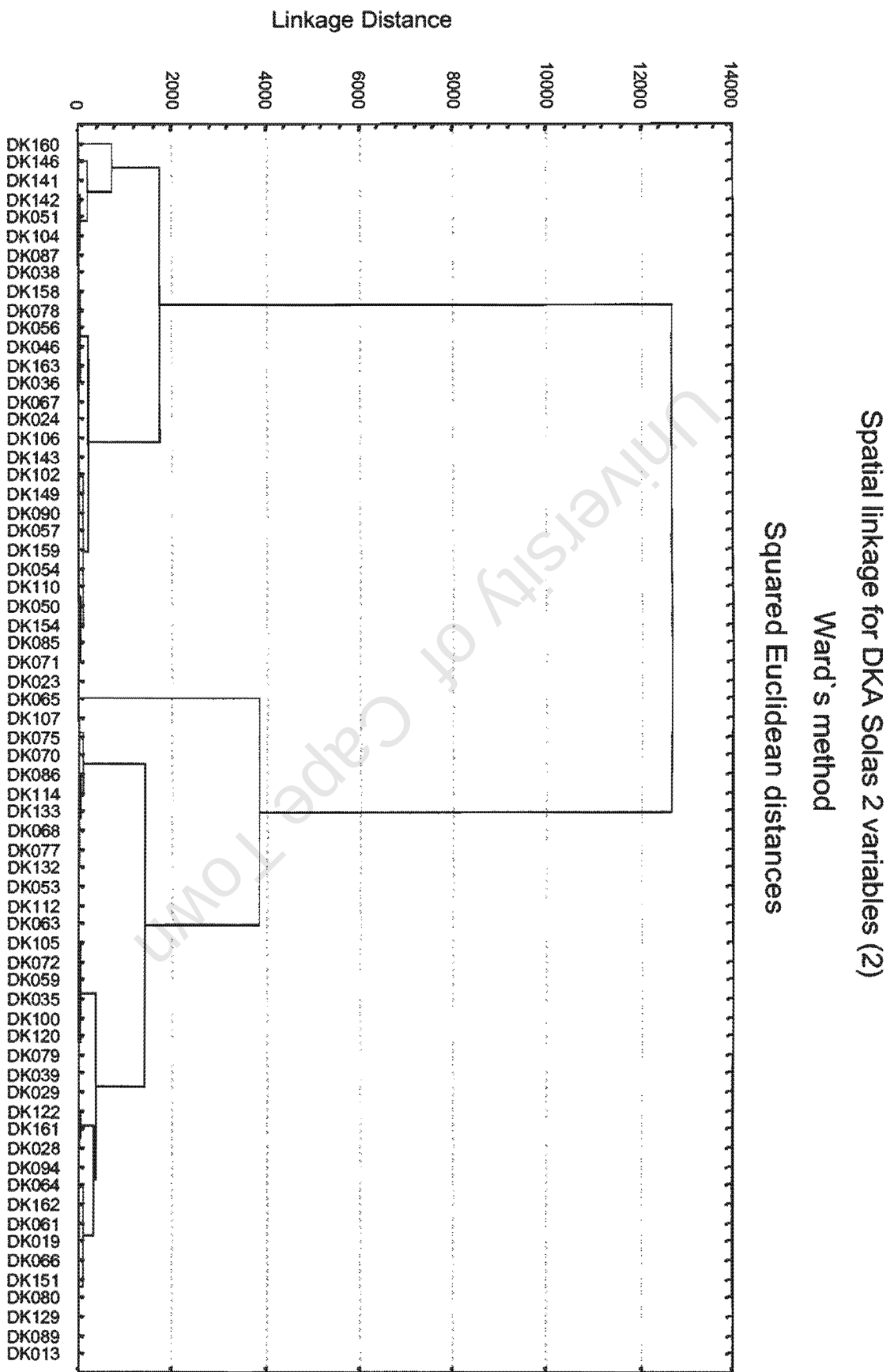


Figure 201: Cluster analysis of 2 variables (2) showing spatial relations of DKA (SOLAS) prints (3)

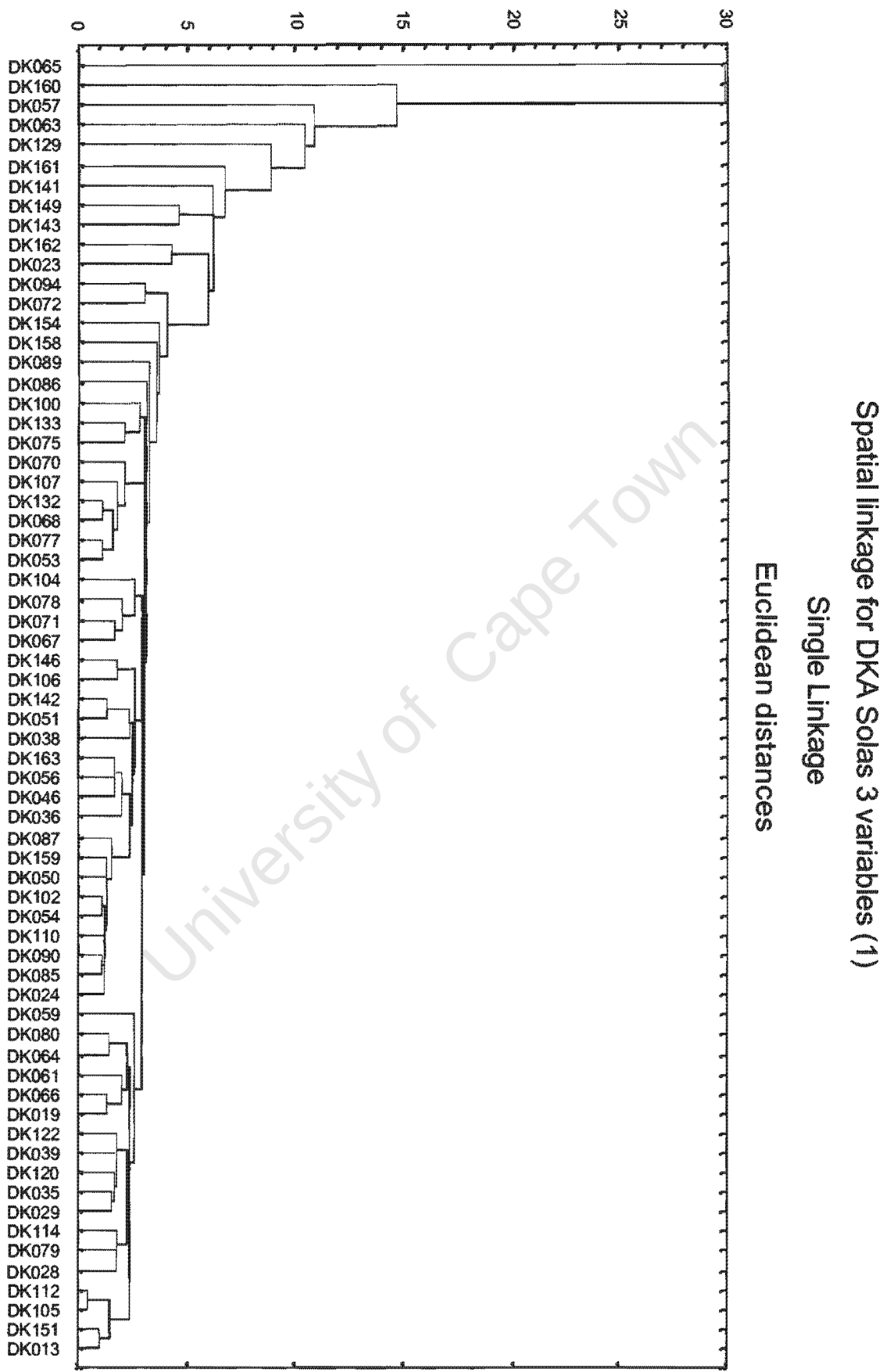


Figure 202: Cluster analysis of 3 variables (1) showing spatial relations of DKA (SOLAS) prints (1)

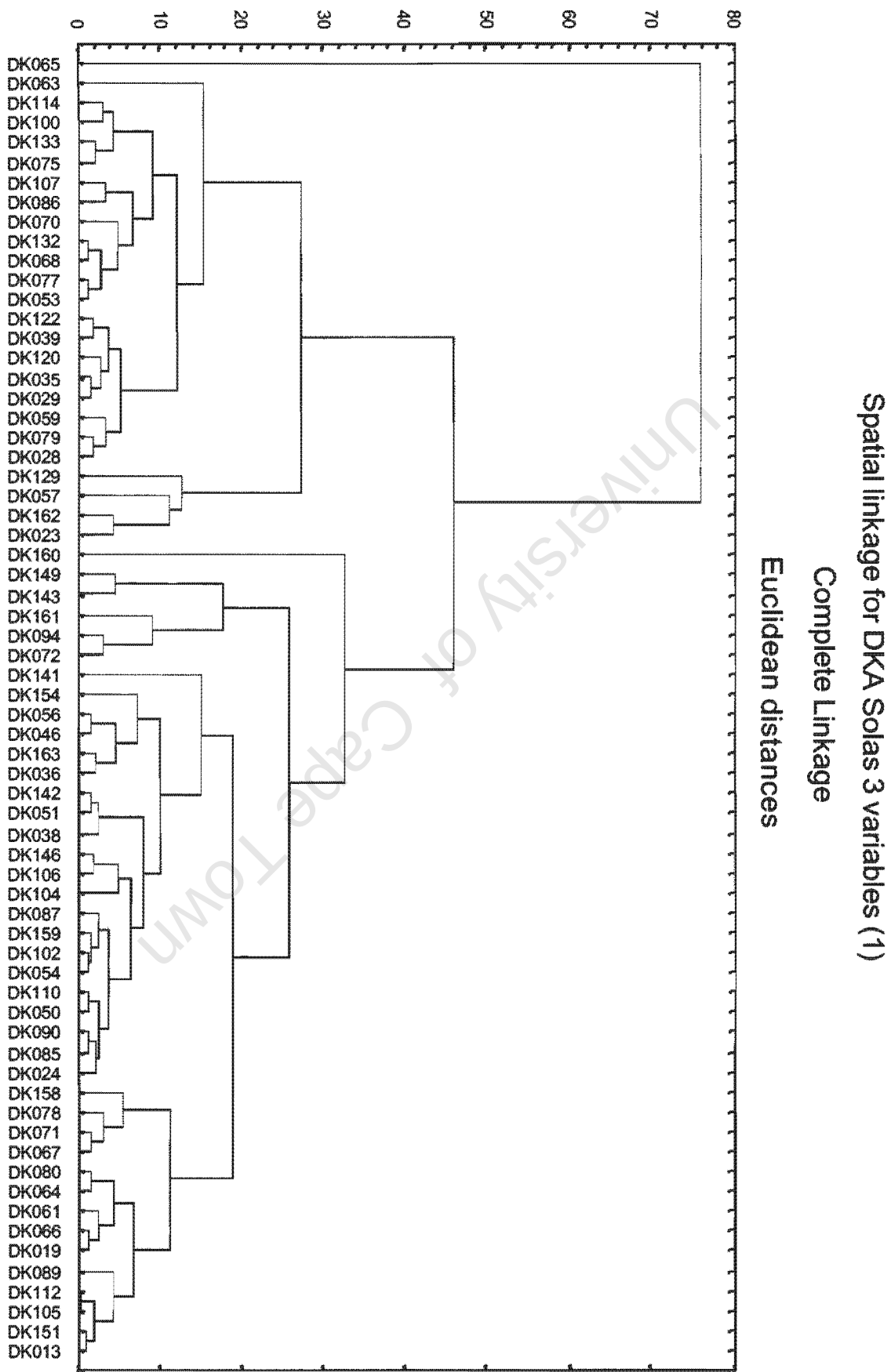


Figure 203: Cluster analysis of 3 variables (1) showing spatial relations of DKA (SOLAS) prints (2)

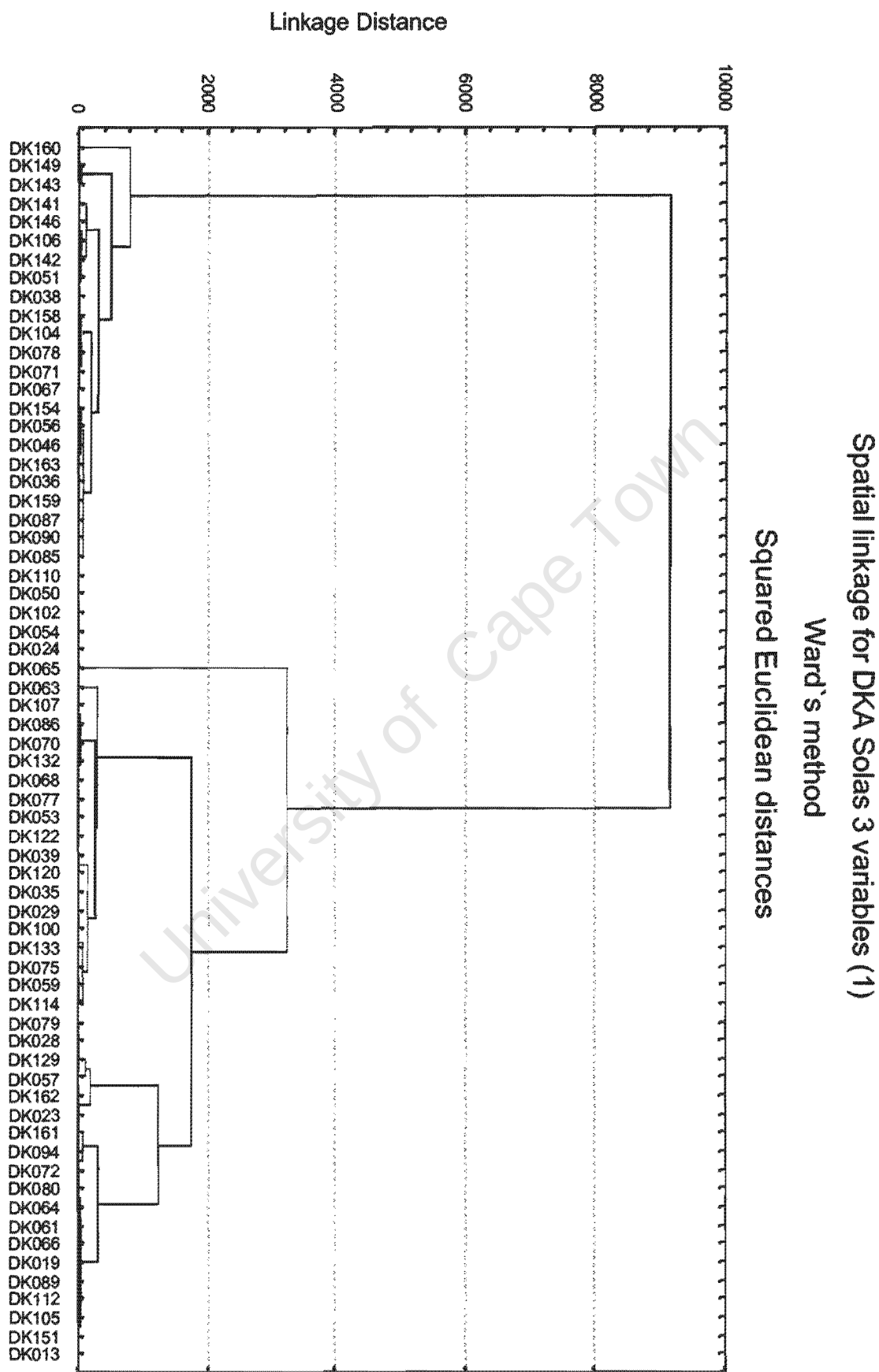


Figure 204: Cluster analysis of 3 variables (1) showing spatial relations of DKA (SOLAS) prints (3)

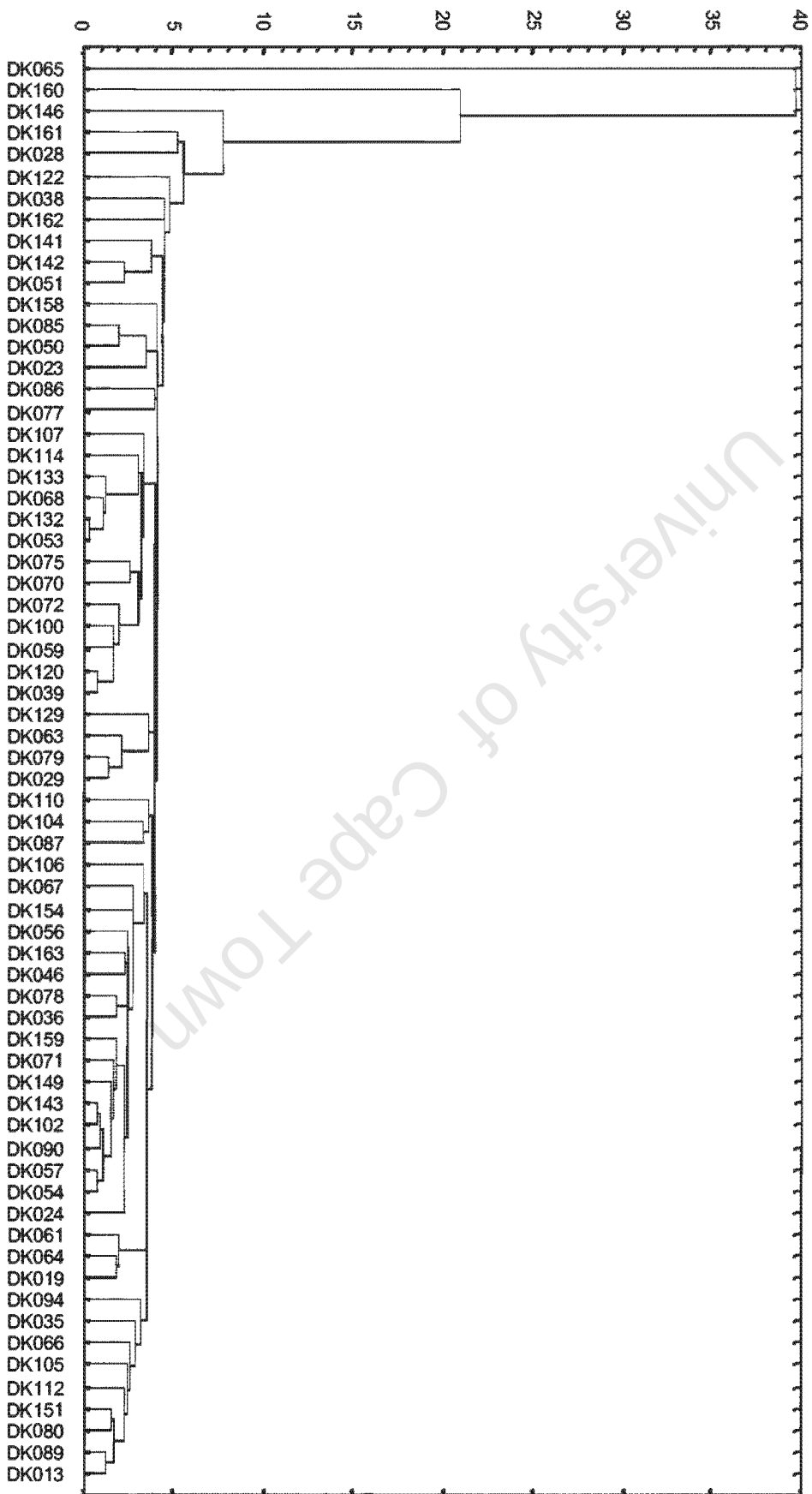


Figure 205: Cluster analysis of 3 variables (2) showing spatial relations of DKa (SOLAS) prints (1)

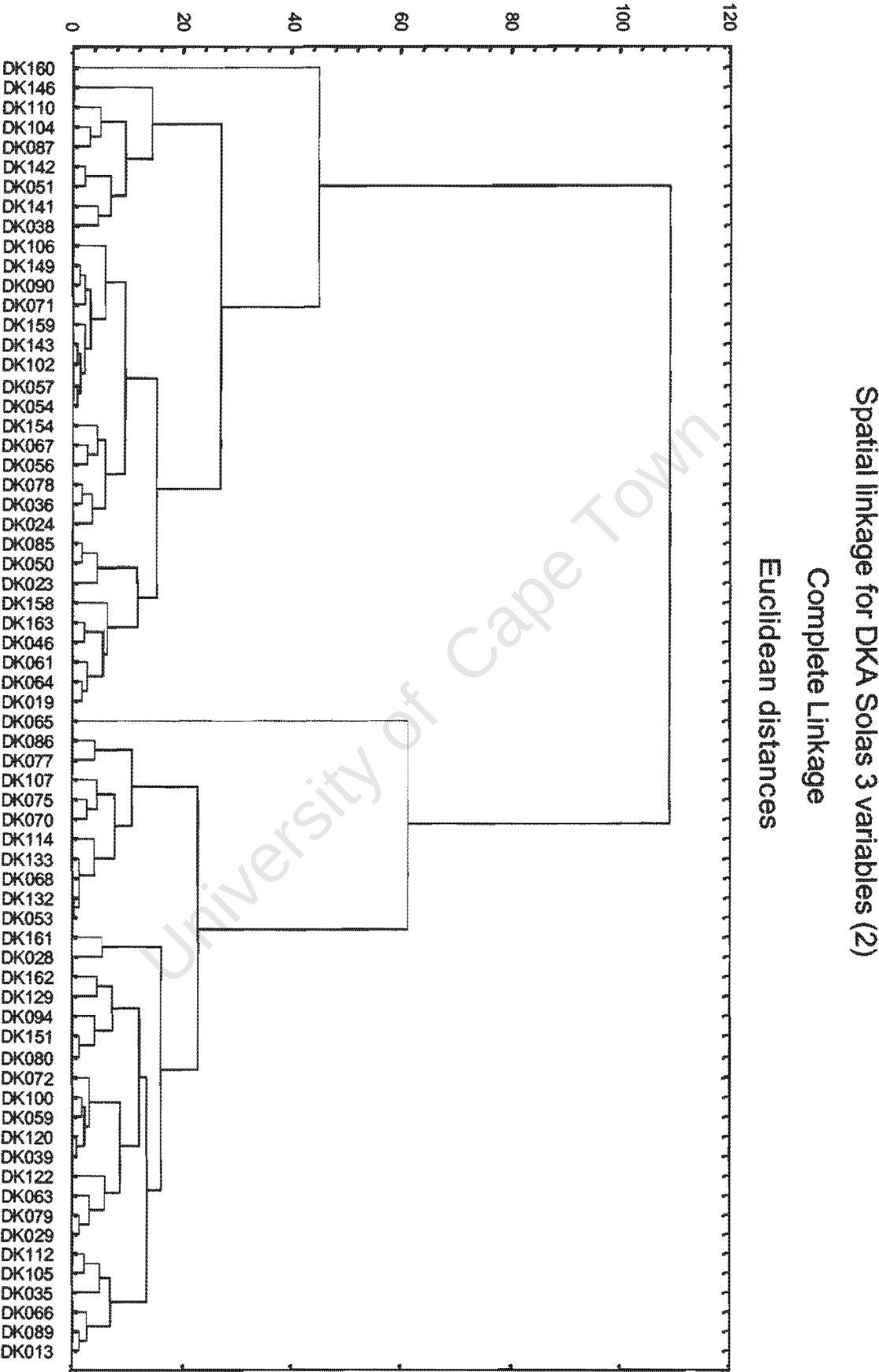
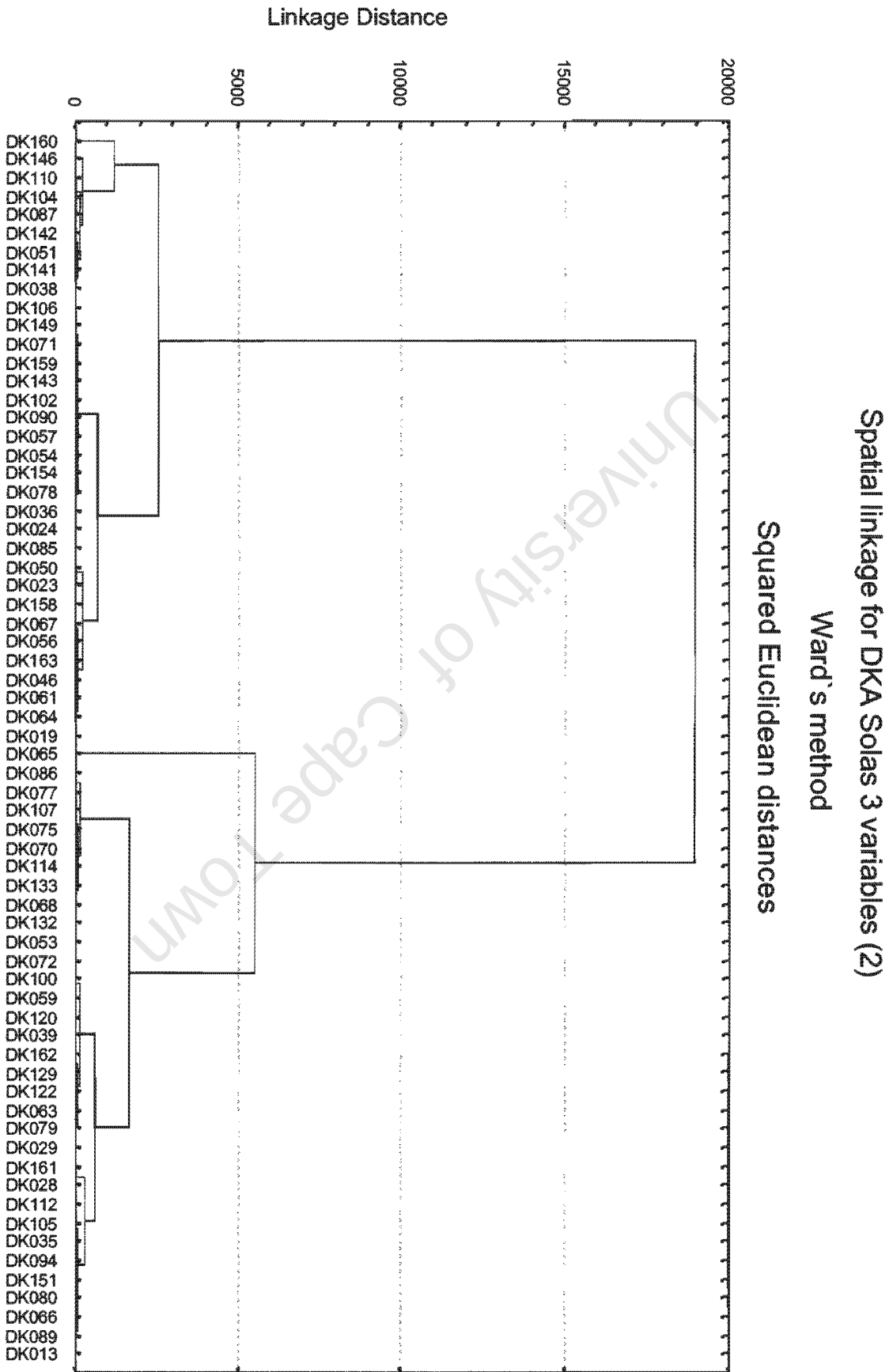


Figure 206: Cluster analysis of 3 variables (2) showing spatial relations of DKA (SOLAS) prints (2)

Figure 207: Cluster analysis of 3 variables (2) showing spatial relations of DKA (SOLAS) prints (3)



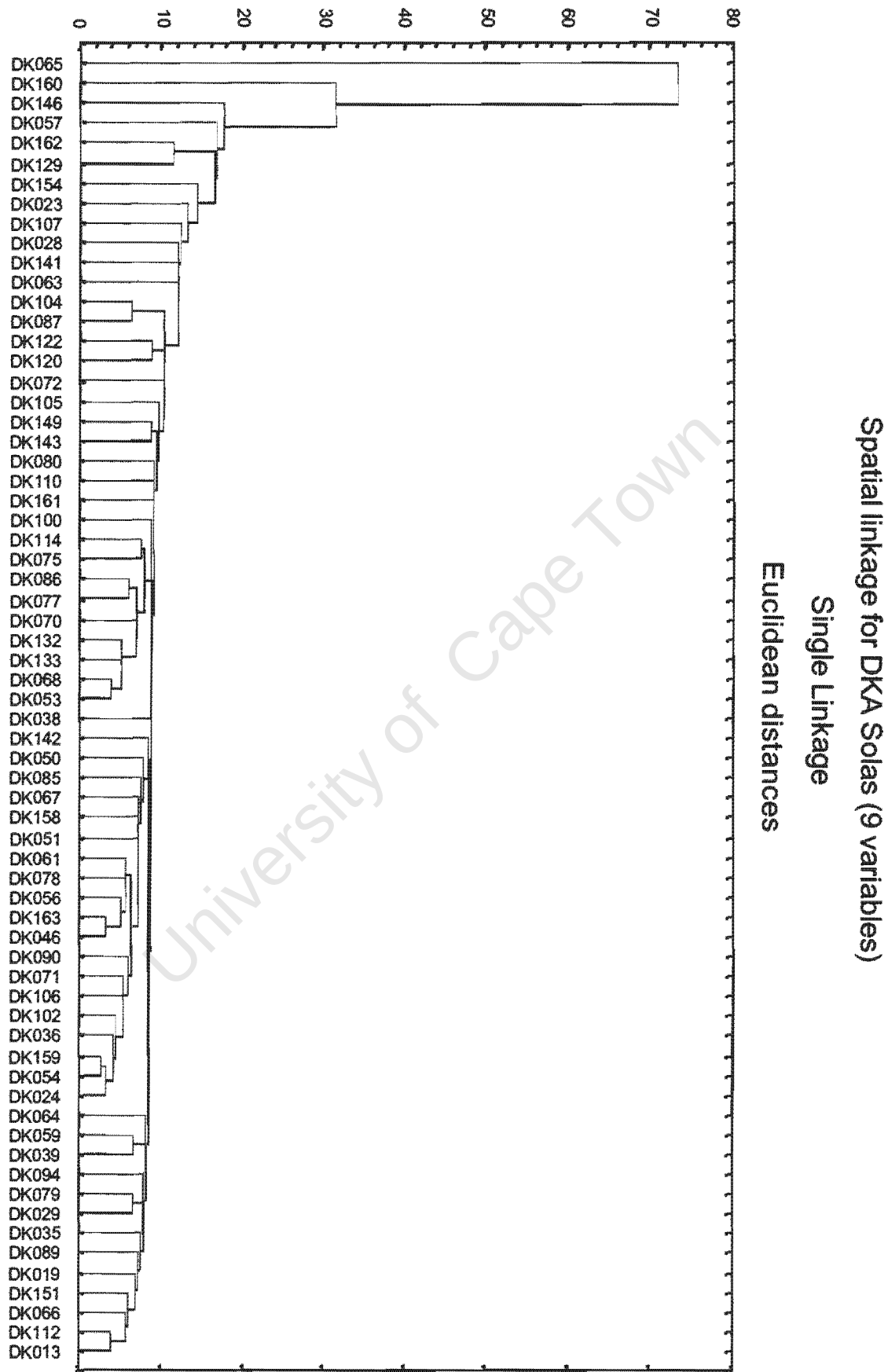


Figure 208: Cluster analysis of 9 variables showing spatial relations of DKA (SOLAS) prints (1)

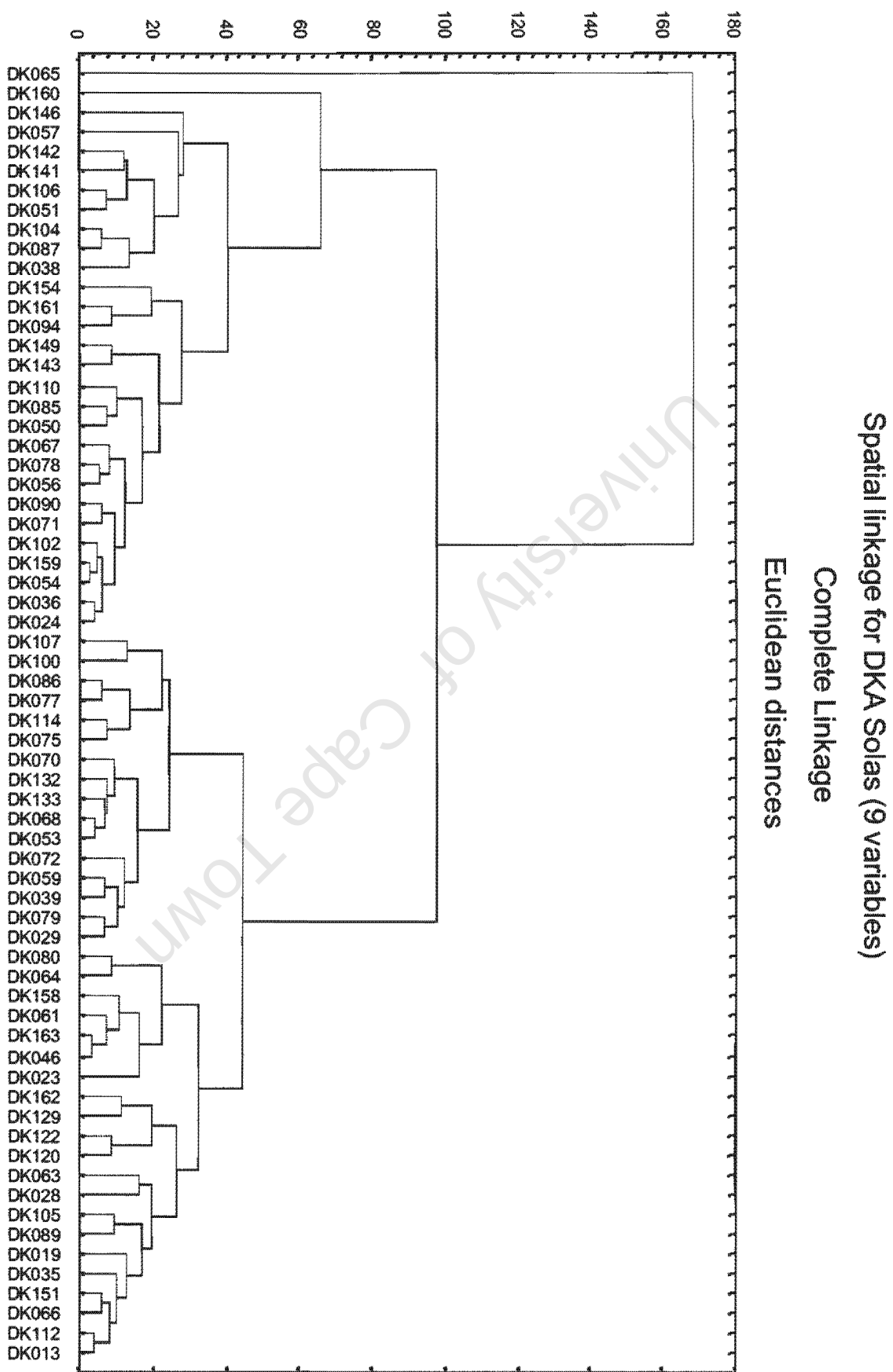


Figure 209: Cluster analysis of 9 variables showing spatial relations of DKA (SOLAS) prints (2)

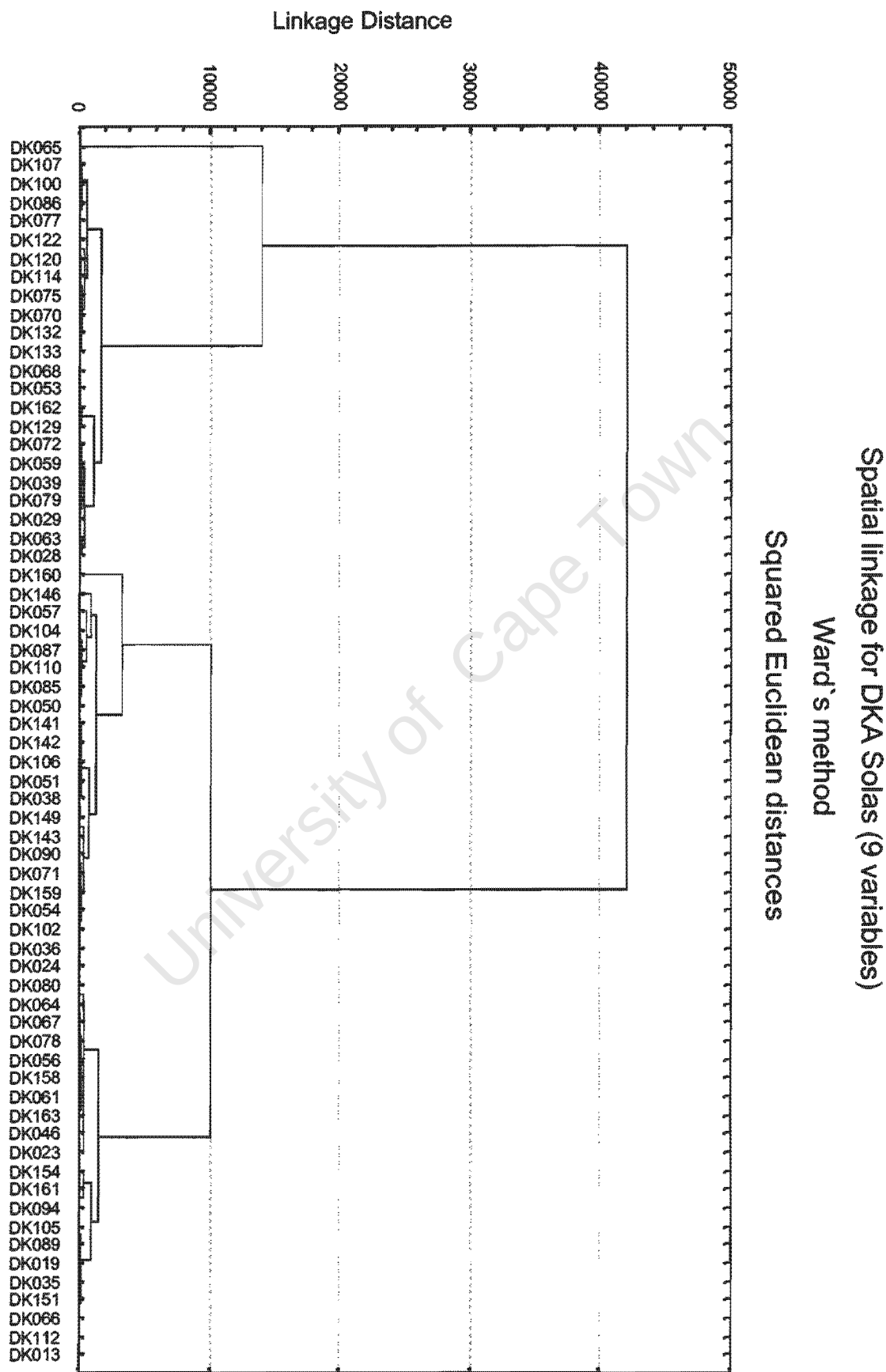


Figure 210: Cluster analysis of 9 variables showing spatial relations of DKA (SOLAS) prints (3)

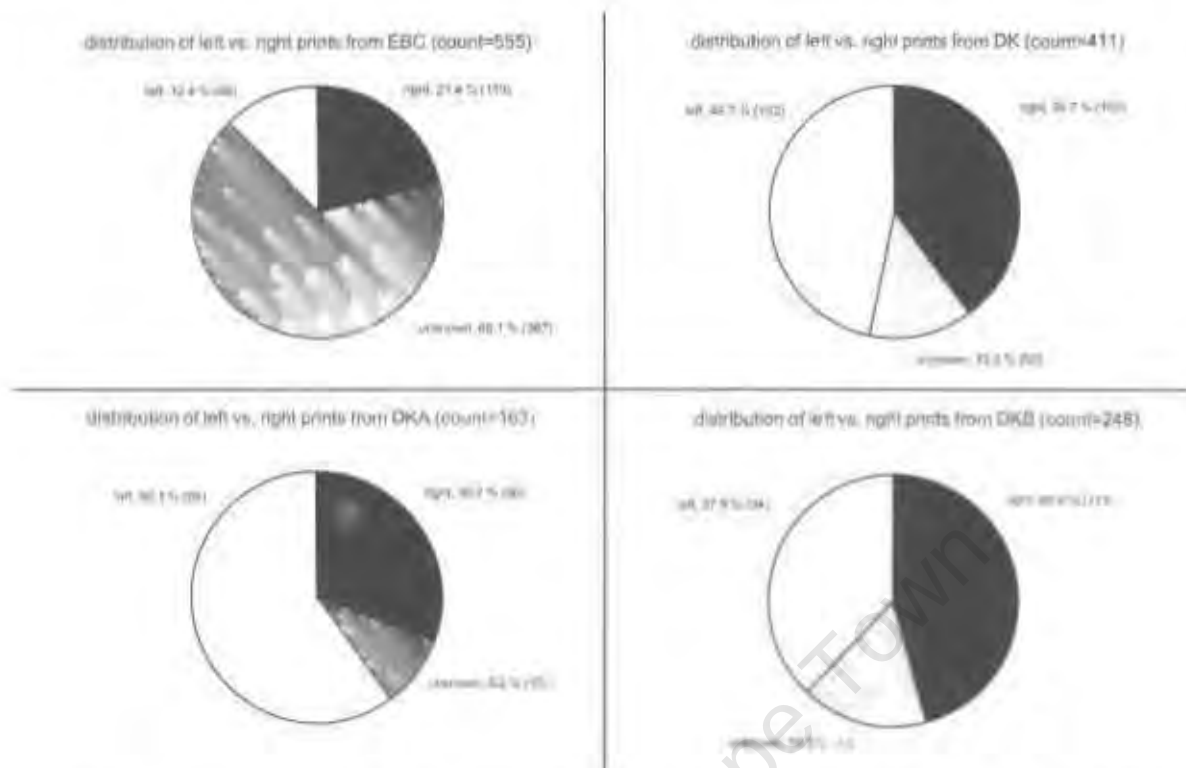


Figure 211: Percentages of left and right handprint frequencies in EBC, DK, DKA and DKB, respectively

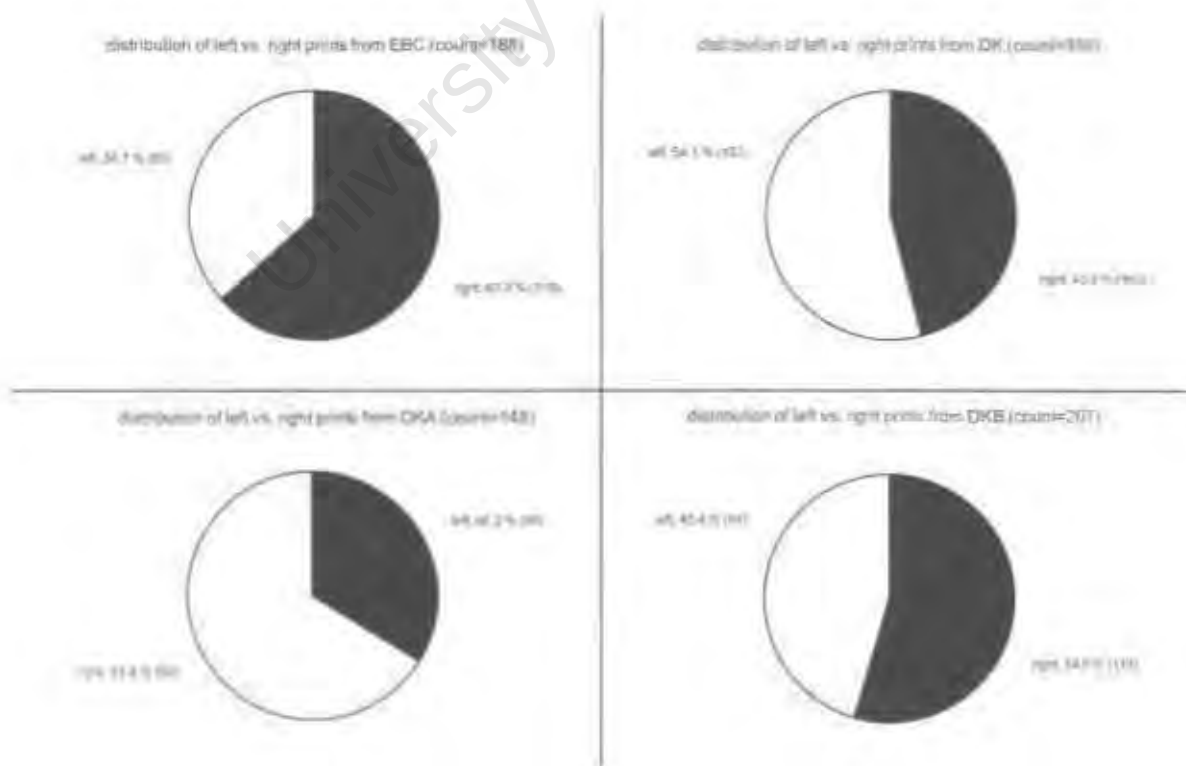


Figure 212: Percentages of left and right handprint frequencies in EBC, DK, DKA and DKB, respectively (without unknown prints)

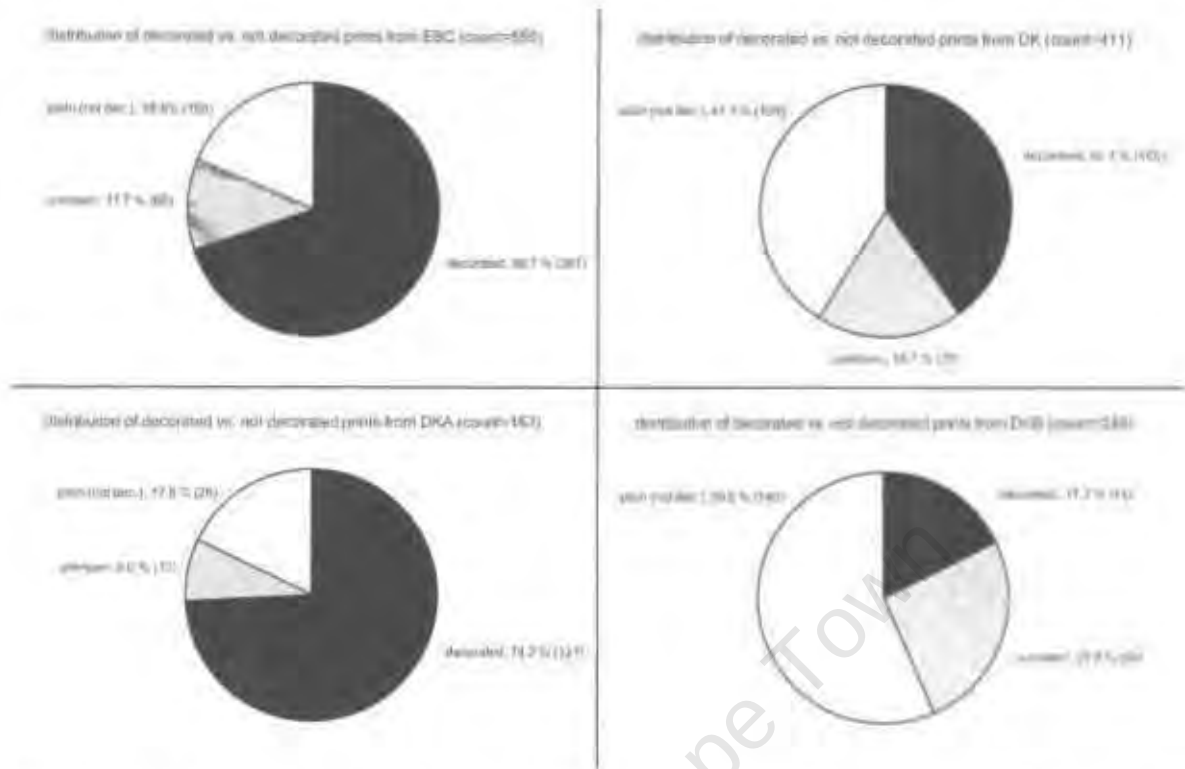


Figure 213: Percentages of decorated and plain (not decorated) handprint frequencies in EBC, DK, DKA and DKB, respectively

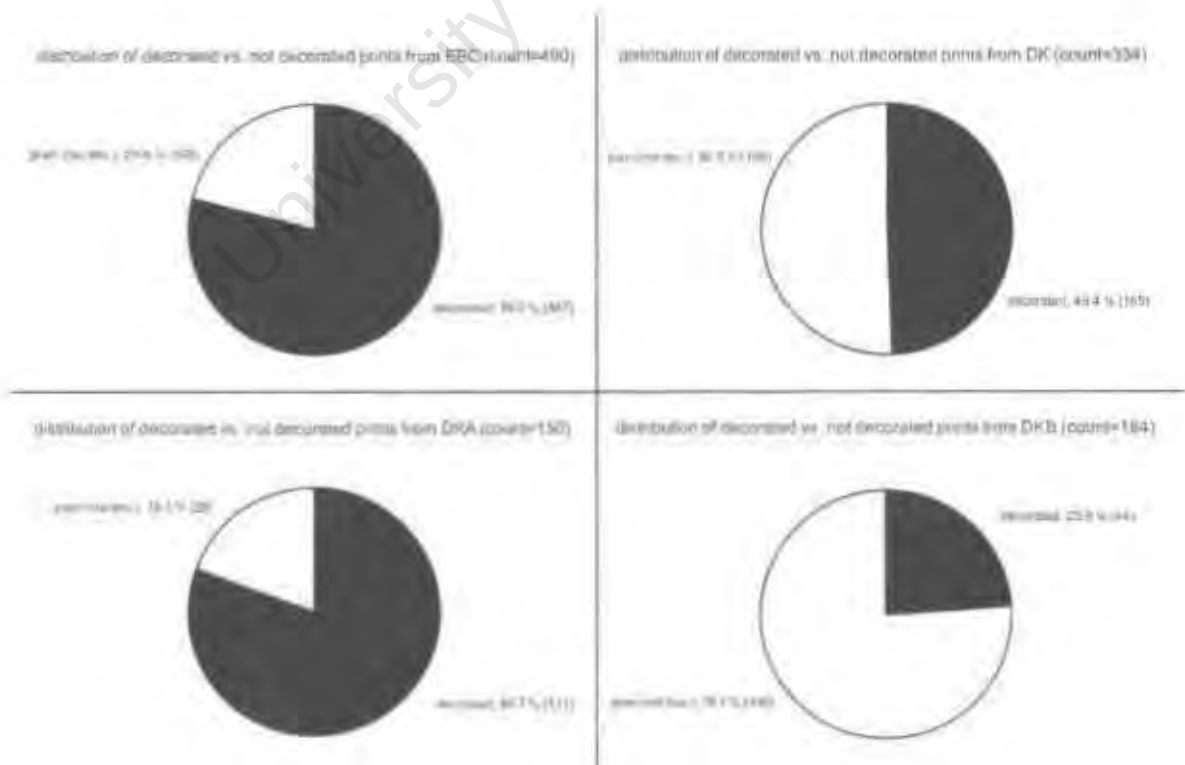


Figure 214: Percentages of decorated and plain (not decorated) handprint frequencies in EBC, DK, DKA and DKB, respectively (without unknown prints)

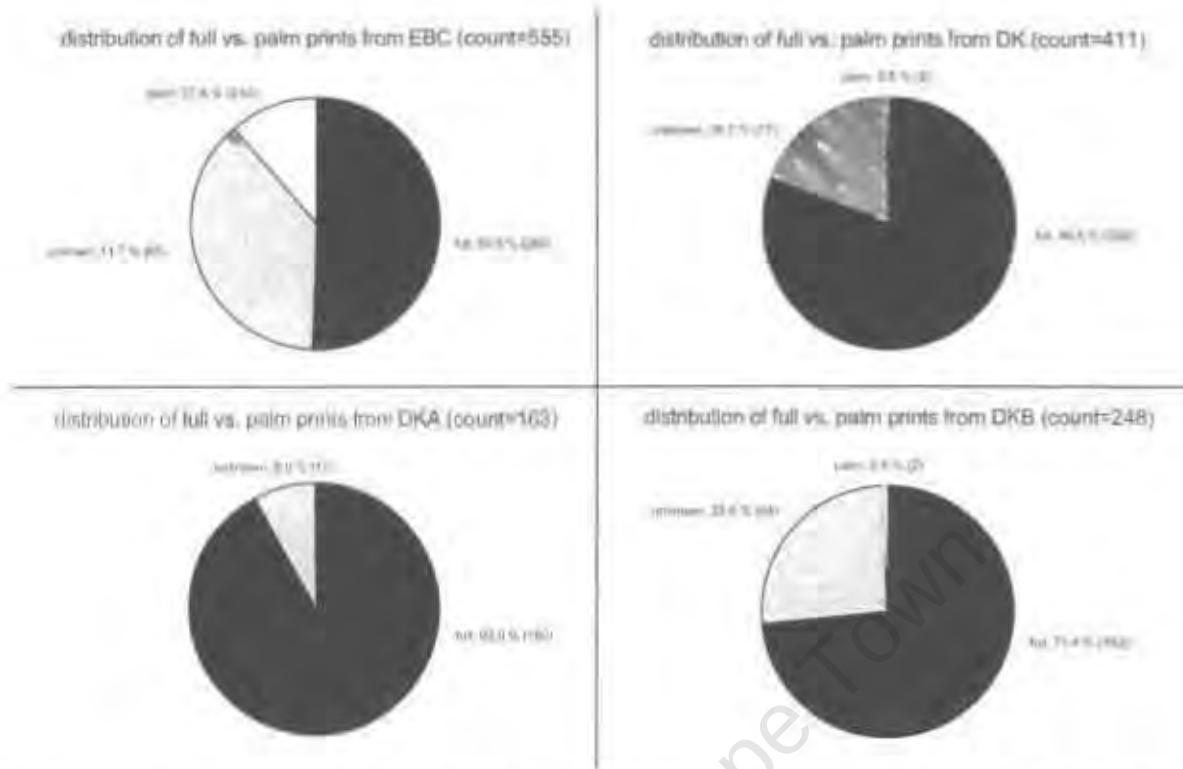


Figure 215: Percentages of palm and full (hand)print frequencies in EBC, DK, DKA and DKB, respectively

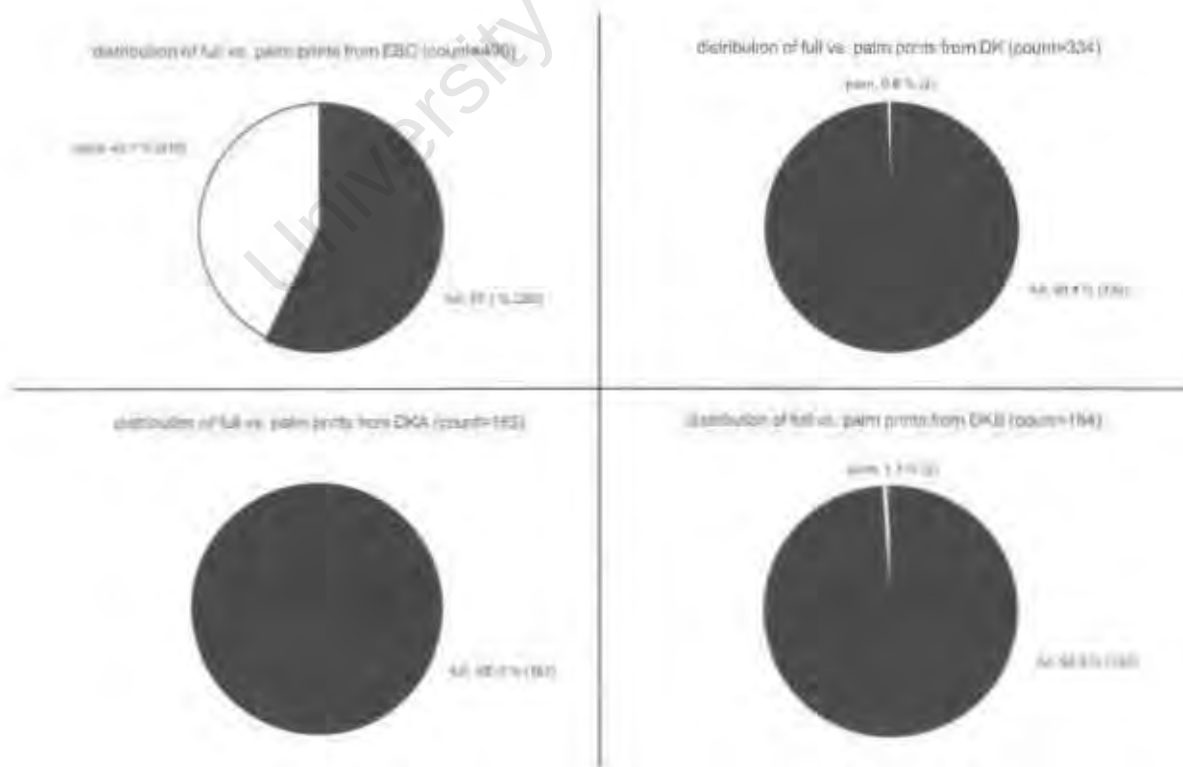


Figure 216: Percentages of palm and full (hand)print frequencies in EBC, DK, DKA and DKB, respectively (without unknown prints)

11.

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