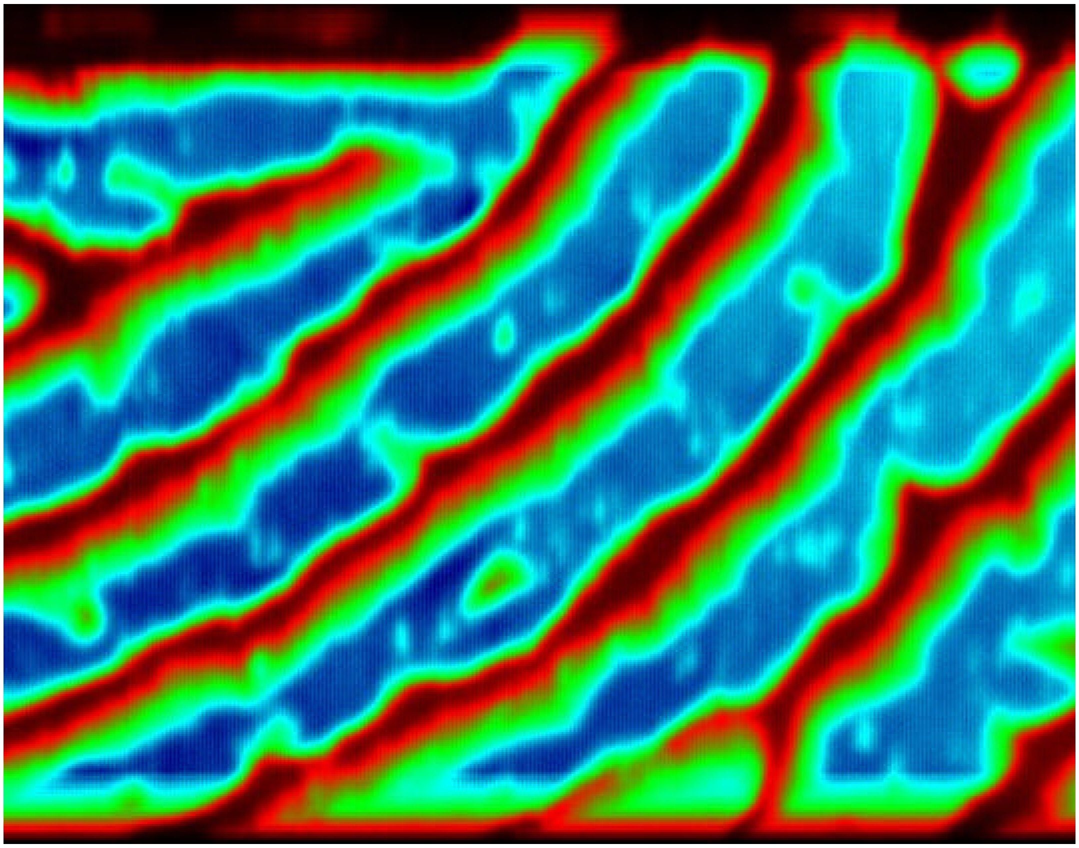
Do fingerprint ridges and characteristics within ridges change with pressure?



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1. SUMMARY

Fingerprint identification uses first level detail (overall pattern shape), second level detail (minutia) and third level detail (shape of the ridges themselves, plus the shape and location of pores). Edgeoscopy is one aspect of third level detail, which looks at the shape of the ridges.

In 1962, Salil Chatterjee proposed a system of seven categories into which the features on the sides of fingerprint ridges could be categorised. The purpose of this project is to examine the effect of pressure on the appearance of these features.

It was found that one feature (straight) was always consistent regardless of the pressure applied. The other features changed with increasing pressure usually to produce a straight ridge edge. The peak, angle and table features have the greatest chance of producing an end result other than straight and although the percentages are not high (i.e. below 10%) – the results are unpredictable.

Can and should unpredictable features be reliably used in the identification process?

All of the features (except for straight) have a likelihood of producing either 1 or 2 pores, with the pocket, table and peak features having the highest probability. Again, it is usually not possible to predict when and how many pores will be produced.

Knowledge of how much force or relative pressure was applied at the time of deposition would be therefore by of assistance when comparing the third level detail between two prints. Although finger impressions have an inherent variation, the amount of pressure applied can be approximated.

In general, a fingerprint produced by minimal pressure would have narrow, potentially blocky and broken ridges, the ridge edges would be distinct with many edge features visible and there may be creases evident. Another print produced with high pressure would have wider ridges which may be joining with the adjacent ridges, the ridges will be more even looking with smooth edges and minimal or no creases visible. The pores will also appear smaller.

The amount of pressure applied to a finger will affect the ridge edge features as specified by Salil Chatterjee. Changes in the edge features can also be affected by other variables such as surface variations and latent composition. This project aims to provide a greater understanding into the changes due to differing amounts of force.

In general…

With an increase in pressure:

? Ridges get broader
? Subsidiary ridges may appear
? Tapering ridges may become longer
? Features vary towards straight in most cases
? Feature forms may appear to vary form pore openings either in the middle or either side
? Fine creases will tend to disappear
? Ridge detail may appear to become reversed

Other comments:

? Minimal perspiration, moisture and other factors may reduce the visibility of the features
? Excessive perspiration or other moisture will tend to swamp the features causing a reduction in the visibility of the features

Comparison and identification:

? Comparison of third level detail uses the same criteria for comparison – type, orientation, relative position and intervening features in sequence.
? Features may be recognisable as being the same if placed at similar pressures
? A difference in pressure between the known and questioned prints may be apparent due to the variation in the appearance of the features, ridges, and other observable factors. This is consistent and acceptable so long as the feature varies in a manner that would be expected should the pressure have been that difference on deposition.
? Relative pore locations should be consistent
? Pores and other third level detail will not always be consistently visible throughout a latent or known impression.

2. INTRODUCTION

2.1 General

The skin on the underside of the fingers and thumbs, palms and soles of the feet differs from the skin on the rest of the body as it has no hair, is thicker and is corrugated. This skin is referred to as friction ridge skin. It is known that all areas of friction ridge skin are unique and never repeated either on that finger, person or on any other person. When an area of friction ridge skin touches a surface, an impression is left which may later be identified to the person who left it. Fingerprints are one of the most frequently obtained and important pieces of evidence used for identification purposes. Detectable third level detail (the shape of the ridge edge plus the shape and location of pores) contributes to the identification process. This project examines one aspect of third level detail known as Edgeoscopy.

2.2 Aim

The aim of this project is to evaluate the effect of differing amounts of pressure on the shape of ridge edge characteristics and to ascertain whether it has any affect on the identification process.

2.3 BACKGROUND

2.3.1 General

Fingerprints are recognised to have three levels of detail.

First level – is the overall pattern type – i.e. Whorl or arch. It gives the examiner a gross means of narrowing down the search – it is a class characteristic and can not be used on its own to individualise. Some fingerprints due to lack of clarity may only have this overall level of detail.

Second level detail – is the flow of the friction ridges (incorporating the coarse ridge variation – ie: minutiae) and when compared has the power to individualise a fingerprint. The minutia must be of the same type, appear in the same sequence and be in the same relative location and any apparent differences be explainable. Again, due to lack of clarity, some prints may have second level detail but have no finer detail.

Third level detail - Is the shape of the ridge edge and relative pore locations and shapes. Potentially this level of detail can assist in the identification process especially if only a small amount of the print is visible. Although the concept to use third level detail in the identification process is valid, it is not widely practiced for several reasons:

- The required level of detail is often not visible and can be obscured by over development of a latent print or too much pressure/ movement applied in producing the impression.
- The time required to make a comparison using third level detail is often not available
- Examining third level detail may require the use of other tools
- Difficulty locating the pores
- Training
- If an area of print has insufficient minutia to make an identification, it may be difficult to locate that area on an inked print, even if the third level detail is available.

In a study where people were fingerprinted carefully, only 20% of the inked impressions had useable third level detail. In the same study, after chemically treating latents on paper, less than 50% of the impressions had useable detail. (Moenssens, 1970).

Third level detail identification is a broad term for several areas of study:

1. Ridgeology , a term coined by David Ashbaugh in his book 'Quantitative – qualitative friction ridge analysis' is the study of the pores, ridges, creases, scars and incipient ridges. This book produced in 1999 has promoted the examination of third level detail.

2. Poroscopy: Dr Edmond Locard developed the study of poroscopy in 1912, in Lyons France. He used the size and shape of pores and their relative location in inked and latent fingerprints to assist in the identification process. Pores vary in size between 88 – 220 micra and as with all forms of third level detail, poroscopy is always used in concert with first and second level detail. Locard found that it was possible to have up to 1500 pores in a fingerprint, whereas there may only be between 80 and 150 minutia in the same print. In 1912 Locard identified two men by using pores in conjunction with conventional fingerprint methods. Although he did not need to, he located more than 2000 pores of similarity in a palmar impression left by one of the men to prove that the field of poroscopy was valid.

3. Edgeoscopy is the study of the shape of the ridge edges and it is the focus of this project.

Salil Chatterjee published an article titled 'Edgeoscopy' in the September 1962 edition of 'Identification'. He believed that the characteristics on the side of fingerprint ridges are persistent and unique and could be of benefit in the identification process. Ridge edge features are formed from the differential growth factors on the ridge edge or the affect on the ridge edge of a pore which is nearby.

Chatterjee proposed a system of 7 categories into which he believed the majority of ridge edge characteristics could be classified. The definitions as taken from the article:

1) Straight – the edge is straight

2) Convex – the edge is convex shaped

3) Peak – the edge is protruding with the base wider than the pointed top

4) Table – edge is protruding with the base narrow and a broad flat top

5) Pocket – When the edge looks like a pocket with a sweat pore having one side open

6) Concave – the edge is concave, generally joining two other edge characteristics

7) Angle – Edge is like an angle joining two other edge characteristics

8) Infinite – any characteristics other than those mentioned above

The definitions are obviously very broad and not well defined. This can lead to inconsistencies, as the classification of the features is subjective. Also, two adjacent features may affect the classification – i.e. two adjacent table features may produce a pocket in between these features. A more defined classification system may produce fewer inconsistencies.

Theoretically, every millimeter of ridge could contain around 10 ridge units and 20 edge characteristics, but due to the flexibility of the skin and substrate, usually only the largest of the characteristics are visible (Chatterjee, 1962). The formations must be in the same order and the same distance apart to help form individualization – the same requirements for identification by 2nd level detail.

In the article, Chatterjee states that the appearance of ridge edge features may vary due to the inking procedure or the amount of pressure applied to the finger but that the differences can be explained so that if the conditions were the same, the features would appear similar. He goes on to say that the use of excess pressure distorts the finer characteristics but the "striking characteristics retain their general form in most cases" (p. 11 Identification). Further, "the striking characteristics and other characteristics in their relative positions will suffice for establishing identity when the Galton details are very few in number" (Chatterjee 1962). Chatterjee recommended the use of the ridges at the base of the fingers as they are broader and the edge characteristics appear more clearly. He also suggested that using different amounts of pressure and ink in taking the suspects impressions could assist when comparing the features in the identification process.

2.3.2 Deposition Pressure.

The clarity of a fingerprint impression determines the amount of detail that is able to be used at a first, second or third level examination. There are many factors, which affect the clarity of the print, and deposition pressure is an important consideration.

Deposition pressure refers to the amount of vertical weight placed on the fingerprint ridges. The amount of pressure used to deposit a fingerprint impression depends on many factors. These can include the surface being manipulated, the number of fingers on the item, presence of the palm when gripping, number of adjacent fingers used to assist the process, weight of the object and purpose of the contact – i.e. Glancing touch, picking up item etc.

The function of the hands and feet is associated with grip and manipulation of items. To achieve manipulation, the hands are constructed in such a manner that they apply force through the skeletal structure and achieve grip with friction ridge skin. Because of the structure of the fingers, the actual pressure applied to the friction ridges varies across the surface of the finger. Deposition pressure is proportional to the force compressing the friction ridges between the bone and other structures of the finger and the surface. Other forces that may effect latent deposition are lateral and rotational movement of the finger on the surface. Other factors that influence deposition pressure include weight of the object, surface shape variation and the skins ability to grip.

The fingers of a person hanging from a window ledge would have a greater force being applied as opposed to somebody picking up a pen. In addition, if an item such as a glass were being picked up, there would be more force on the thumb as compared to the remaining four fingers, which would be sharing a comparable weight. The surface and shape of the object, amount of perspiration and any injuries would also have an affect.

The amount of deposition pressure is visible in a developed latent or inked fingerprint by the flattening or broadening of the ridges. A light touch shows only the top of the friction ridges – the impression is light, the furrows appear wider and third level detail is minimal or non existent. A medium touch flattens the ridges more and is ideal for third level detail and clarity. A heavy touch flattens the ridges more, clarity is reduced and third level detail is minimal due to filling in by the development medium. With extreme pressure, only first level detail may be visible. A medium amount of pressure (between two and seven kilograms) is ideal when comparing fingerprints.

Depending on how the print was deposited, the centre of the print may have a higher level of deposition pressure than the edges, so a combination of the above situations may occur.

If a fingerprint with high deposition pressure is developed, the fingerprint ridges are pressed onto the surface so much that the latent material is pushed to the edges of the ridge, giving the impression of empty hollow ridges after development. In a lighter impression, the development may occur on the higher ridges, but not in the valleys or lower tapering ridge endings. This may look very different to an impression with a higher amount of pressure. It is very difficult to deposit two prints with exactly the same amount of pressure, even if the circumstances are the same.

Pressure distortion refers to the amount of horizontal pressure on a fingerprint - this would appear as a sideways sliding or smudging.

2.4 Fingerprint Theory

Knowledge of the structure of friction ridge skin and the factors affecting the growth and development of friction ridge skin is essential in understanding why fingerprints - including third level detail - are unique.

2.4.1 Structure of Friction ridge skin.

Friction ridge skin is divided into two main layers - the inner dermis layer and the outer epidermis - where the surface ridge formations are located.

The dermis is between 15 and 40 times thicker than the epidermis and it constitutes between 15 and 20% of a mans total body weight .The dermis is constructed to resist tearing and pressure, but it is flexible enough to allow joint movement and localised areas of stretching. It is also able to regenerate itself when damaged.

The dermis is a matrix of loose connective tissue made of collagen, reticulin and elastin in a base substance. Nerves, blood vessels and lymphatics cross this matrix and items from the epidermis such as eccrine sweat glands and apocrine glands penetrate it. The dermis provides several functions – it provides the epidermis with nutrients and interacts with it during embryogenesis, repair and remodeling. It also provides a dense protective barrier from injury and enables ion exchange.

The single layer of cells next to the dermis is known as the basal layer and this is the lowest layer of the epidermis. It is separated from the dermis by a membrane called the basal lamina, which permits the passing of nutrients into the epidermis and waste to be removed through the dermis. The epithelium of the basal layer is continually producing new cells by the process of mitosis. The new cells are a roughly rectangular shape and as newly generated cells force them out the older cells start a migration towards the surface

It takes about a month for the cells to complete the migration to the surface on the volar areas. Cells at the centre of friction ridges are produced at a higher rate than those at the side of under a ridge.

Above the basal layer is the spinous layer, followed by the granular layer, the hyalin layer and the outer horny layer. As the cells migrate to the surface, they lose the active microorganisms and accept greater amounts of keratin (a protein which has water resistant properties) and as a result, the cells become harder. In this process, the cells become squashed and are attached firmly together with desmosome (a cement like substance). These flatter cells form the top 20 layers of dead cells in the skins surface. This outer layer sheds at approximately 1300cells/cm2/hr through abrasion or break down of the desmosome.

The surface of the dermis is covered by blunt peg like formations known as dermal papillae. The papillae are formed in double rows and they supply oxygen and nutrients to the epidermis and they also remove waste. They also contain nerve endings, which allow the sense of touch on the dermal surface. Dermal papillae fill in spaces at the base of the epidermis - with the dermal surface showing a negative shape of the bottom of the epidermis. The path of an epidermal ridge can be worked out by following the double rows of dermal papillae. The structure of the outer layer of the epidermis is a direct result of the cells migrating from the same shaped top layer of the dermis. Injury or disease that penetrates to the dermal papillae can cause permanent damage to the basal layer and as a result new cells may not be able to be produced. The surrounding cells compensate - but this will produce a deformation, which is visible on the skins surface as a scar – a permanent change to the skins appearance.

2.4.2 How fingerprints Develop

From the moment of conception, there is constant cell division and growth. 27 days after conception, the four limb buds have formed and by day 40 the fingers and toes are webbed, but distinct. The skin begins forming at around 50 days and at 36 weeks the integumentary system is fully functional and the friction ridges have completely formed. It is thought that the critical period of fingerprint development is between 11 and 17 weeks (Babler 1991)

Between 10 and 12 weeks there is a large increase in the amount of basal layer cells being produced. This causes stress and movement along the dermis/ epidermis border. At this time, 11 volar pads (swelling of mesenchymal tissue) are formed on the hands and feet, which add to the stress of the border layers. The volar pads grow quickly between 6 and 10 weeks - they initially start as rounded areas, but change shape and position as the digits separate and grow longer. The digits can soon be moved individually and the thenar flexion crease, distal and proximal transverse creases and interdigital flexion creases appear. Studies by Popich and Smith (1977) indicate that these creases are formed as a result of the movement of the digits, while Kimura and Kitagawa (1986) believe that the creases and volar pads develop at the same time.

The interdigital and palmar volar pads start to regress at 10 weeks, with the digital pads regressing after 12 weeks and this corresponds with the development of friction ridges. The changing topology of the volar pads is recognized to create stress in the forming skin, producing differences in the formation of the overall pattern flow. The number of ridges increases to keep up with the swelling of the skin, with new ridges formed between, or next to existing ridges. Any formations after the initial ridge formation are visible as minutia.

At this stage, the epidermis is a smooth, thin layer and the ridges begin as small penetrations in the basal layer. These develop into shallow primary ridges, which project into the top layer of the dermis. Hale (1951) believes that the primary ridge is genetically controlled. Stresses from changing rates of growth and the alignment and fusion of the ridge units establish the primary ridges. The epidermis produces what Ashbaugh (1999) refers to as ‘ridge units’ – an area which encompasses a sweat gland penetrating into the dermis and a pore opening on the surface. He believes that the ridge units are joined together to form the friction ridges. Due to genetic and physical influences the ridge units are subjected to in the formation of friction ridges, the paths of the ridges are unique to that area of friction ridge skin. The ridge units are subjected to many factors when they are growing, and then they are subjected to further factors when they are fusing with another ridge unit - so they vary in shape, size and whether and how they fuse to each other – forming unique ridge formation.

The primary ridges develop quickly – both in width and penetration into the dermis. To keep up with the overall growth of the hand and increase in the area of the volar surface, new ridges are formed between the existing primary ridges, or on the surface of them forming minutia. This development causes the development of minutia at the epidermis-dermis border. Bifurcations develop from ridges separating from other established ridges. A branch begins as a swelling on a primary ridge, and as the surface expands, the branch fills out and expands, forming another ridge. This process occurs early in the overall ridge formation process. Islands develop between existing primary ridges. Shorter islands may have only 1 ridge unit and develop later in the process. Islands, which do not properly develop before the process ends, form what we call incipient ridges. All ridge formations are affected, and affect the ridge formations around them.

At around 15 weeks, the basal layer can not support any more and the primary ridges are unable to continue their dermal penetration – so they stop developing. At around 15 weeks, secondary ridges begin to develop between the primary ridges and this continues until the depth of dermal penetration is roughly the same as the primary ridges. Secondary ridges cause the separation of surface ridges, which is represented by a valley.

Interstitial ridges result from late formed primary ridges, which had not yet developed eccrine glands before the development of the ridges ceased.

By 17 weeks, the epidermal ridges become visible on the surface. For the next 5 weeks, the secondary ridges continue to develop and the final arrangement of the secondary and primary ridges will not be complete until the fourth or fifth month of fetal development.

2.4.3 Ridge Formation

There have been numerous studies looking at various aspects of fingerprint growth – trying to ascertain why fingerprints are unique.

Many studies have found that friction ridges follow the path of the greatest topographical change, forming around and between the volar pads. If a volar pad is high, the friction ridges will go around the pattern - forming a whorl formation. If the volar pad is flat, the pattern will tend to be an arch, while a medium pad will form a loop pattern. It is thought that fingerprint pattern formation is determined when the friction ridges start developing and the timing of the rise and fall of the volar pads. Most people have similar pattern types and crease formations as the volar pads develop in similar locations at similar times.

Other studies have found the shape of the volar pads is genetic with similar fingerprint patterns passing from parents to children. Twins develop in the same environment and studies have found that overall, fingerprint patterns are similar- with the differences being caused by external stressors and pressure.

Diseases and genetic aberrations affect the development of volar pads and the resulting patterns. People sharing the same affliction often have similar fingerprint patterns. For example, people with Downs's syndrome often have low count loops in the fingers, a higher carpel delta and possibly a simian crease (a single crease where 'typical' fetuses have a top and middle crease).

Kollman believes the stresses and compressions in the developing skin affect the ridge alignment. L.S. Penrose and P. O'Hara (1973) furthered this idea by hypothesizing that ridges develop at right angles to the forces acting on the volar pads. Karen Bonnevie (1924) studied the relationship between the pattern configuration and height of the volar pads and the thickness of the epidermis. William Babler (1991) believed that the timing of the primary ridge formation affected the pattern - early ridge formation produced a whorl formation, later formations produced an arch pattern, and intermediate formed a loop. Babler (1981) also found that the width of the volar pad had a greater impact on the ridge development than the height of the pads. Yoku Misumi and Toshi Akiyoshi (1991) studied the presence of a polypeptide hormone – the epidermal growth factor (EGF) and biofeedback systems. They believe that the EGF hormone is responsible for the start of the basal cell growth, which produces the primary ridges.

Bonnevie (1924) found that the distribution of nerves influenced the centre of the ridge pattern development. Blechschmidt found that vascular patterns also had an affect. Hirsch and Schweichel (1973) found a link between the location of vessel-nerve pairs and primary ridges, and the resultant dermal ridge layout. Dell and Munger (1986) found that overlapping dermatomes have a role in ridge differentiation.

In a study by De Wilde, it was suggested that the layout of the ridges was predetermined by the 6th week after conception – before the volar pads had started to rise and before the separation of the fingers and location of the creases.

Several studies have found a relationship between the length of the phlanges and the number of ridges (Ashbaugh 1999) and Babler (1991) extended this by suggesting that the length of bones in the fingers (not widths) had a direct effect on the distance between the primary ridges. The length of the distal phlange had a relationship to the pattern type, with whorl patterns occurring on shorter phlanges.

Due to the differential development of the ridges, the topography of the skins surface is uneven. The ridges are comprised of a collection of ridge units that are roughly aligned with non-uniform heights, each ridge unit consisting of a number of dermal papillae with an eccrine pore duct opening between them. As the applied force increases, the actual amount of these structures that contact the surface increases and the ridge units become compressed resulting in a varying contact area and shape.

This has a marked affect on the appearance of the ridges themselves as well as the third level detail when the skin is pressed onto a surface. A raised area of skin will touch the surface and compress before the lower areas and will continue to do so with increasing amounts of pressure.

It is thought that more pronounced dermal papillae produce an elevated area of friction ridge skin. Studies have found that there are approximately 4 dermal papillae surrounding each pore. If one of these papillae is larger, producing a higher area around one side of the pore, this area may start to enclose and fill in before the other areas. Similarly, the dermal papillae will affect the height of the primary ridges, forming higher areas, which will have a greater compression at the same level of pressure.

It is clear that many factors potentially affect the development of the fingerprints on the growing embryo. This causes the fingerprint ridges to develop in a unique way enabling the identification of fingerprints and the study of third level detail.

3. MATERIALS AND METHODS

3.1 Materials

A donor places their finger on a Perspex prism, the surface of which is horizontal and parallel to the bench. The Perspex is triangular shaped and sits in a framework so that the top face is exposed on which to place the finger, a second face is covered with black cardboard and hidden in the framework and the remaining face is above a camera lens. A polilight beam is directed into the prism through the same face as the camera faces to enable the fingerprint ridges to be highlighted and visible when looking through the camera.

The application of the light illuminates the face of the prism that the subject's fingers will contact and also the black cardboard. In the absence of any finger contact, total internal reflection takes place on the finger contact surface making the black cardboard visible. On the placement of a finger, the moisture on the surface of the finger having a different refractive index to air enables refraction to occur, thereby making the finger visible where contact has occurred. This process relies on sufficient moisture being on the skin surface to allow the refraction to occur, and therefore becomes a variable and limitation of the process and project.

The camera used is a Basler Vision Technologies A202K and is situated on an aluminum framework so that the camera lens is under the Perspex. The distance from the Perspex can be varied as can the angle of the camera. The frame grabber takes between 15 - 20 frames per second and is linked to a computer. A Nikon 28-70mm lens in conjunction with three PK stepping rings is attached to the camera.

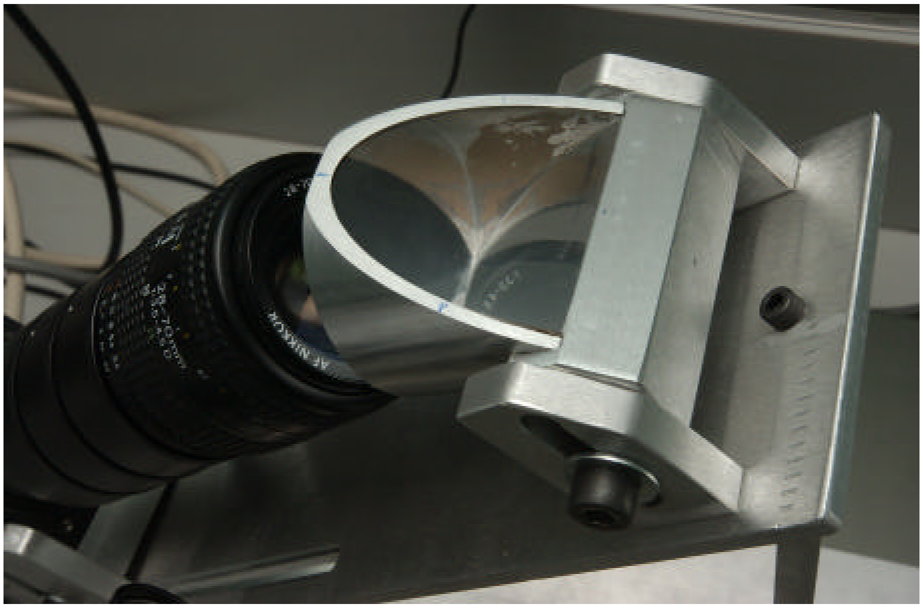


Photo 1 Camera and prism setup

The framework has been specifically made for the camera/ prism setup, which rests on a set of A @ D, HP20K scales which logs weights from .1 gram to 21 kilograms. The scales are connected to the computer so that (theoretically) a weight is taken every time a frame is grabbed.

Photo 2 Equipment setup on the scales.

V++ version 4.0.6.209 by Digital Optics Ltd is used to coordinate the acquiring of images and querying the scales for weights. This is achieved through scripting within V++ in conjunction with a dialog box written in Microsoft Visual Basic 6. A series of macros means that the weights and frames are interrelated and the data can be viewed on the computer screen as shown below.

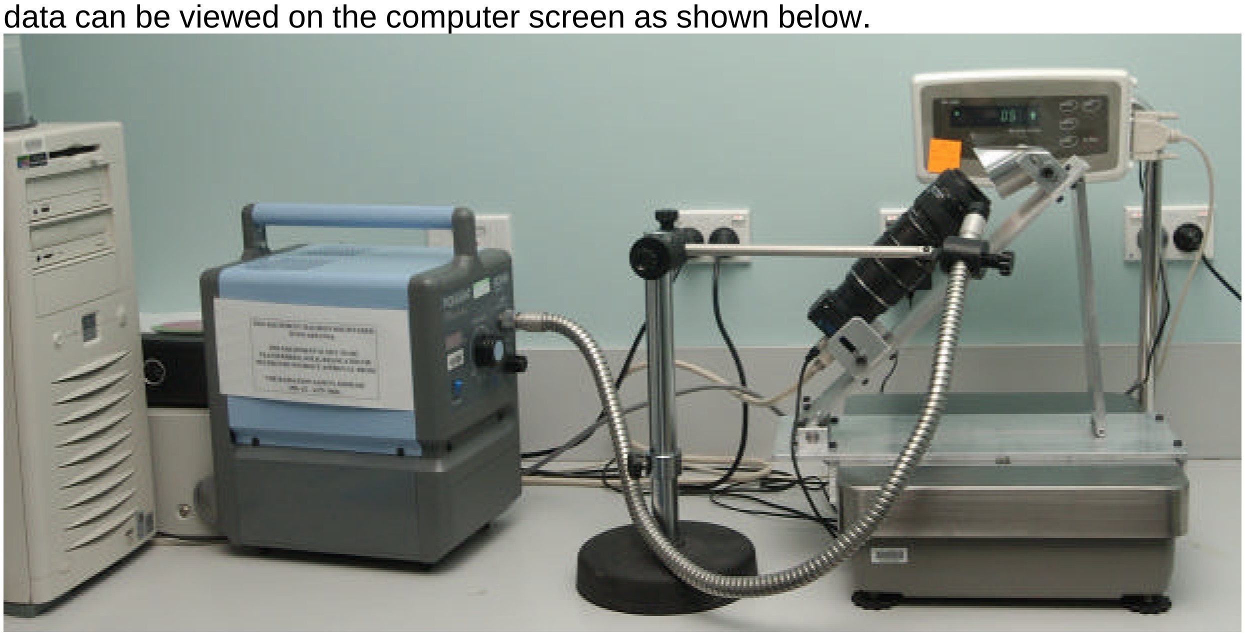


Photo 3 Overall setup showing polilight, scales and camera.

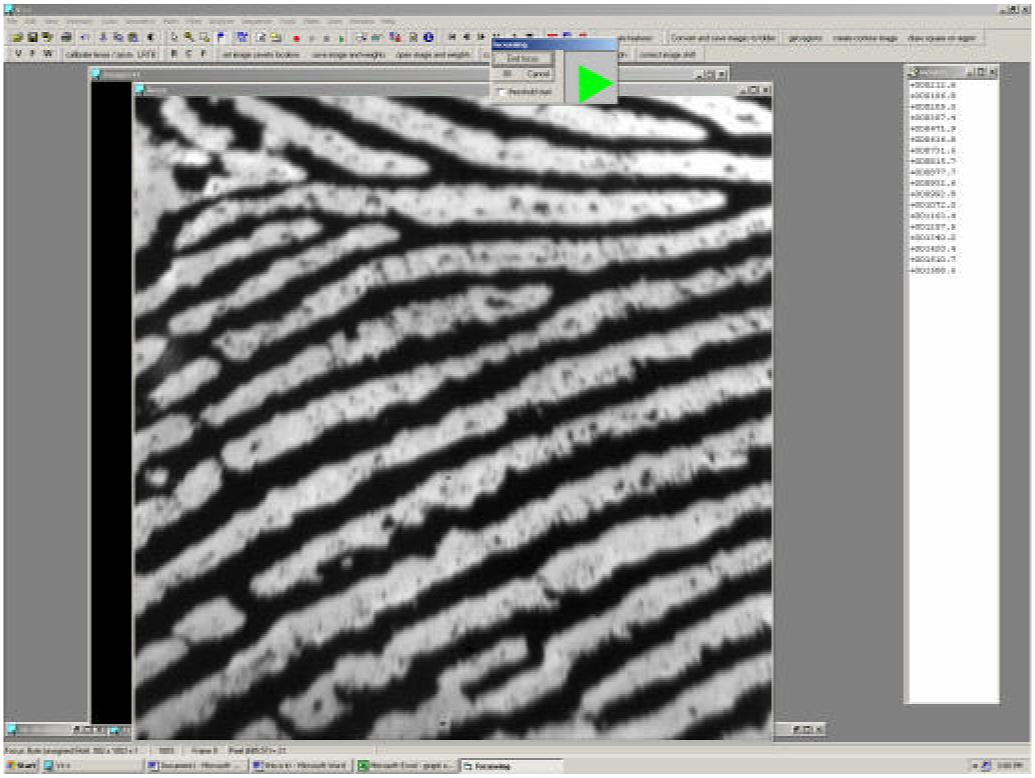


Photo 4 V++ screen.

This picture shows the image of the finger in the center, the weights being logged on the right hand side of the screen and the panel in the middle from which the operator controls the capture of the data.

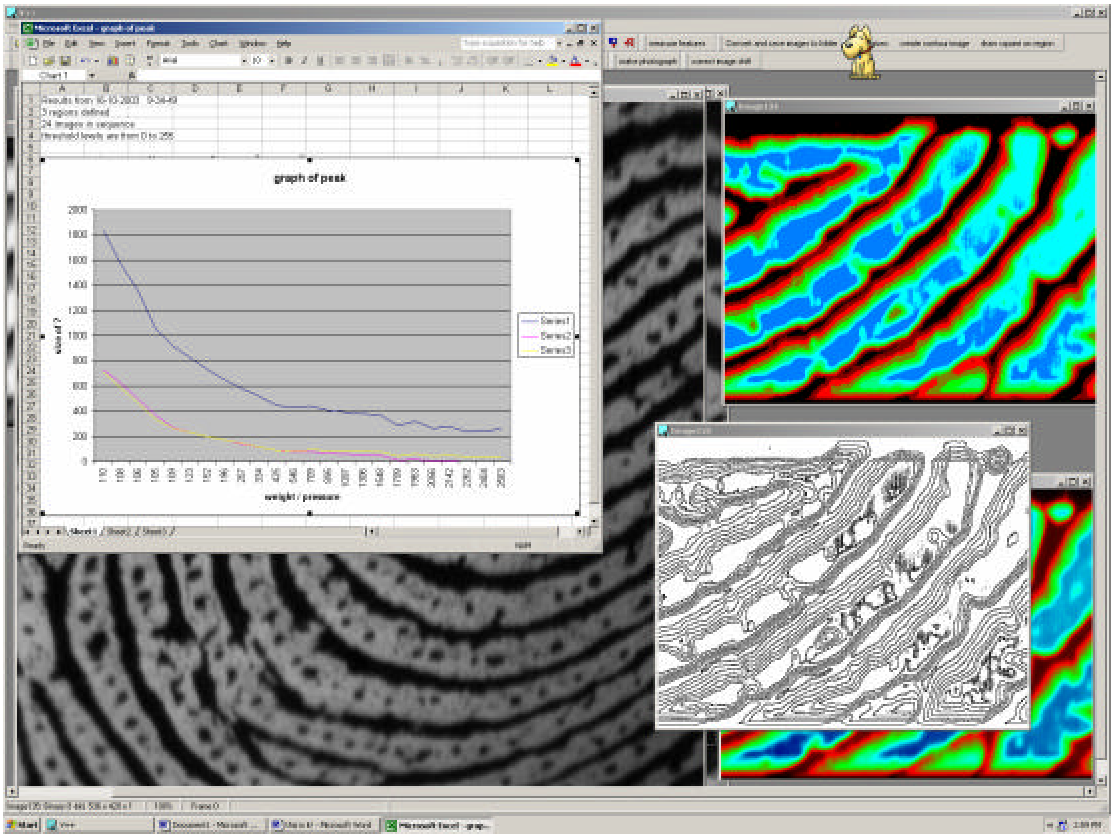


Photo 5 V++ screen.

This picture shows the basic fingerprint image in the background and different ways to present this information in the foreground.

3.2 Method.

Five people were chosen from my peers to obtain a spectrum of ages and hand sizes.

Donor 1 – Male 40 small build, medium fingers
Donor 2 – Female 30 small build long fingers
Donor 3 – Female 20 small build small fingers
Donor 4 – Male 20 small build small fingers
Donor 5 – Female 40 small build medium fingers

Two fingerprint impressions were taken at random from each candidate. The candidate would initially practice using the prism by placing increasing amounts of pressure on their finger with minimal sideways movement. The donor would lift their finger so it was just off the prism and the frame grabber would begin recording images from this point until maximum pressure was reached on the finger (according to the donor).

Photo 6 Equipment setup. Candidate on the right is placing his finger on the prism.

An image would be selected which had minimal pressure, but with the majority of the finger visible. This would be the base image from which the comparisons would be made. From this image two Chatterjee characteristics would be selected for each finger impression. The characteristics were chosen as proposed by Chatterjee (1962) in his article ‘Edgeoscopy’ – the most striking characteristics that were present in the image.

These images would be flagged on the computer and in a hand drawn diagram. The characteristics were monitored over the set of images with increasing pressure. Any changes were noted such as the shape of the feature, if a pore resulted, any intermediate changes of the feature as well as overall observations of the print.

The following results were obtained

(Total of 26 results for each type of characteristic).

CHARACTERISTIC	END SHAPE	PORES FORMED	CONSISTENCY
Straight	100% Straight		Consistent
Convex	24 end up straight 2 end up convex 13 straight by ½ way frame 11straight after ½ way frame	9 have 1 pore 1 has 2 pores	Inconsistent NB. 1 goes thru several changes before final classification
Peak	22 end up straight 1 ends convex 1 ends as a peak 1 ends as an 'other' – like a whale tail	14 have 1 pore - 5 before 10th frame - 5 after 10th frame 1 has 2 pores	Inconsistent
Table	24 end up straight 1 slightly table 1 slightly convex	21 have 1 pore - 11 before 10 - 10 after 10th frame 7 have 2 pores	Good
Pocket	100% end up straight	25 have 1 pore - 14 by 10th frame - 6 after 10th frame 1 has 2 pores	Good
Concave	19 end up straight 3 end as angle 1 ends as concave	8 end up with 1 pore - 5 before 10 - 3 after 10 1 has 2 pores	Inconsistent
Angle	24 end up straight 1 angle 1 peak	14 have 1 pore - 8 before 10 - 5 after 10 2 have 2 pores	Inconsistent

Table 1 Results of initial experiments – 26 replications were used for each feature.

From these experiments it was found that four of the Chatterjee characteristics required further study, as the results were inconsistent. Further experiments using different people were undertaken concentrating on these features.

The following results were obtained from these subsequent experiments, concentrating on the concave, peak, angle and convex features (note that a total of 25 characteristics were used for each type of characteristic):

Characteristic	End shape	Number of pores formed
Concave	20 straight 4 concave 1 angle	12 pores (1 characteristic formed two pores)
Peak	17 flat 5 larger peaks 3 small peak	16 pores (2 characteristics formed two pores)
Angle	22 flat 3 angle	16 pores (2 characteristic formed two pores)
Convex	21 flat 3 convex 1 angle	9 pores

Table 2 Results of subsequent experiments

From the above results, hypotheses were made for each characteristic.

Straight: Of the ridge characteristics which were initially straight 100% of them would remain straight with maximum pressure. No pores would be produced.
Convex: 88% would be straight 10% would be convex 2% would be angle 35% would have 1 pore 2% would have 2 pores
Concave: 82% would be straight 10% would be concave 8% would be an angle 39% would have 1 pore 4% would have 2 pores
Angle: 90% would be straight 8% would be an angle 2% would be a peak 58% would have with 1 pore 8% would have 2 pores
Pocket: 100% would be straight 90% would have 1 pore 3% would have 2 pores
Table: 92% would be straight 4% would be a table 4% would be convex 80% would have 1 pore 28% would have 2 pores
Peak: 78% would be straight 12% would be a large peak 6% would be a smaller peak 2% would be convex 2% would be miscellaneous 58% would have 1 pore 6% would have 2 pores

Table 3 Overall results

The pores are an integral part of the ridge unit structure and it is to be expected that pores will occur and contribute to the shape of the features observed. Whether or not a pore can be observed in each case may depend on the type of feature being studied the three-dimensional structure of the feature and other normal deposition factors. Whilst the table above details the results, there may be pores present that for the above reasons have not been observable.

5.1 Underlying factors of consideration.

It should be noted that there are several factors which may have affected the results and these should be taken into consideration when assessing the results of this project.

After the fingerprint impressions were obtained from the donors, a frame where the majority of the print was visible on the screen was chosen to begin the observations. This has the potential to affect the overall results as features are constantly changing. The features can vary considerably between frames (i.e. one feature can change from a pocket to a straight in one frame) and this should be taken into consideration when looking at the project.

The person pressing their fingers on the prism would tell the operator when they believed maximum pressure was obtained on their finger, at which stage the operator would stop recording the images. The maximum pressure may therefore vary between people and even between prints of the same person and there is a small lag until the operator stops recording.

In the majority of prints, it was always relatively easy to find certain characteristics - such as straight, pockets, concave and convex. It was usually more difficult to find the peak, table and angle features. For the purpose of this study, characteristics were chosen that although would have fit into say, the angle category more easily than any other – it was not a ‘typical’ specimen – but a certain number of features were required to be examined. There is also some subjectivity in choosing the features. The features as described by Chatterjee in his article are broad which allows most features to fit into the 7 categories. However it was found that choosing a certain example of a feature would give a certain result. Some concave impressions are unto 4 times the size of a standard concave feature – and when I picked the larger features – several pores could eventuate which is different from the expected result. Potentially some of the characteristics could be broken down into sub categories, which would produce more standard results. This would require further study.

Another point, which should be noted, is that the scale weight and the frame, which it is linked to, are not perfectly aligned. To establish this fact, increasing amounts of water were put in a beaker and the frame grabber was operated to see how long the system took to stabilize. The amount of water started at 315 grams and went to 3.7 kilos.

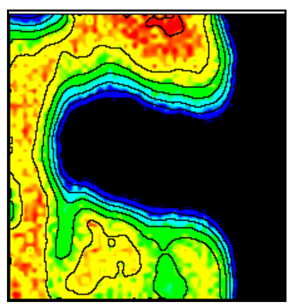
It was found that there was a delay in the scales of several seconds. The accuracy of the system was more questionable at lower weights – it was approximate at less than 2 kilograms. The time taken to stabilize regardless of the weight is constant. The rate increase in measured weight is 4 times the actual rate. That is, when the weight is increased (ie. larger amounts of water), you get to the final weight faster. The weights were not greatly used in the project, as the results were not easily adapted to normal work situations. The pressure applied can be judged relative to other prints from the same source but to measure the actual pressure applied by examining a latent print from an examiners point of view would be extremely difficult and unreliable). This will be discussed later.

5.2 Discussion of features

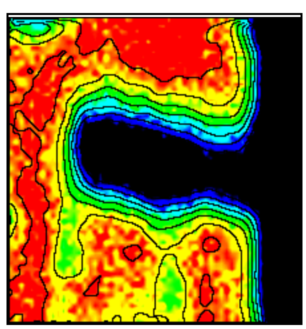
Each of the features as identified by Salil Chatterjee will be discussed individually.

5.2.1 Pocket

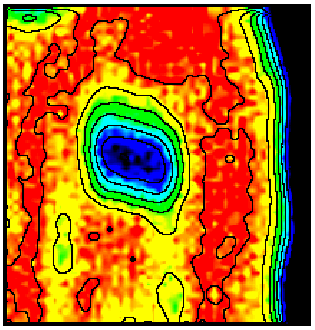
The Pocket feature is one of the most common features visible in (most) of the fingerprints. They are easily visible and fairly consistent in appearance (although occasionally there were quite wide pockets which could produce several pores). Pockets appear to be a pore open to the surface at low pressures, but with increasing pressure, the surface of the pore closes together resulting in an enclosed pore and a straight ridge. Occasionally (approximately 3% of the time) 2 pores would result – either on top of each other or side by side. In around 10 % of cases the opening would simply infill with no pore being visible with the technology that was being used. However, in the majority of cases, 1 pore resulted with a straight ridge edge and this was one of the most predictable of all of the features. In some instances, a convex pattern may have been an intermediate feature – but not for extended periods of time and never at times of maximum pressure. However, the majority of the time, the top of the pocket simply joins together and then builds up around itself.



Minimum pressure



With more pressure the top of the pocket has started to build in.

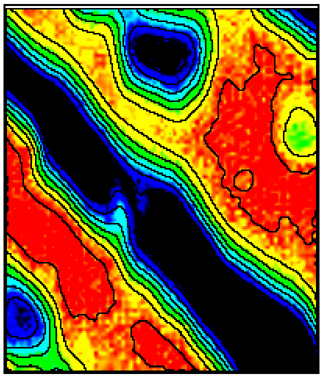


At maximum pressure, the top of the pocket has completely joined producing an enclosed pore in the centre. With increasing pressure the ridge builds around the pore and the pore appears smaller.

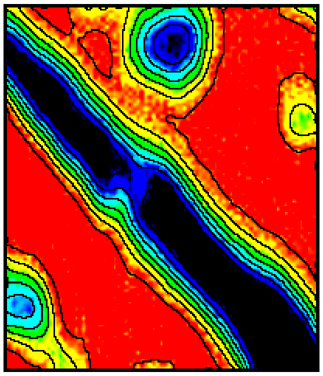
Photo7 Pocket with increasing pressure

5.2.2 Straight.

In all of the experiments undertaken, a ridge area which is straight with minimal pressure will be straight with increasing pressure. The area builds up and may have slight unevenness, but at all times would be classified as a straight feature. This feature was easy to find on all of the prints, which were examined. This is the only feature which was completely predictable in its results.



Straight feature at minimum pressure.



Straight feature at maximum pressure

Photo 8 – Straight feature with increasing pressure.

5.2.3 Table.

Overall, the table feature was harder to find than many others. A feature, which was higher than its surrounds more often fit into the convex category – there is only a small window between the hump of a convex and the higher, formed peak into which a table would fit. Tables were often found in conjunction with pockets – forming one side of the pocket. At maximum pressure, all of the tables ended with a straight classification. In the majority of cases, 1 pore resulted, however in nearly a third of the cases, two pores resulted. In the photos below, it can be seen how this could happen. A convex classification may arise as an intermediate form of the table – but this was rare and did not persist long.

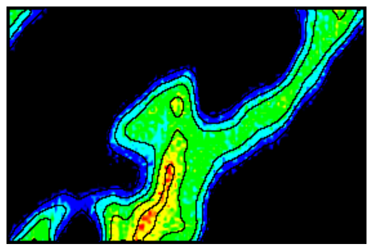
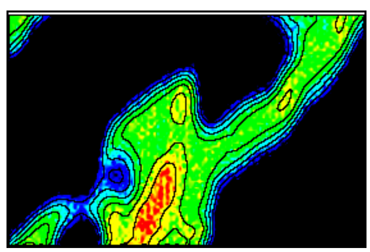
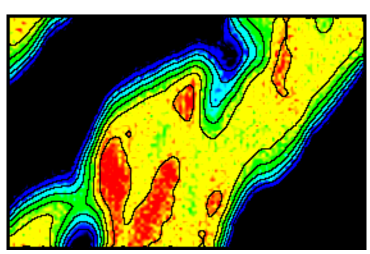


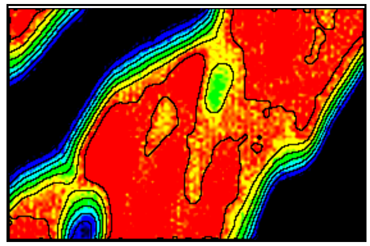
Table at lowest pressure



With slightly more pressure, the table is infilling on left side – a pore may have eventuated on the left in some cases.



No pore on the left, but the table is starting to infill on the right.

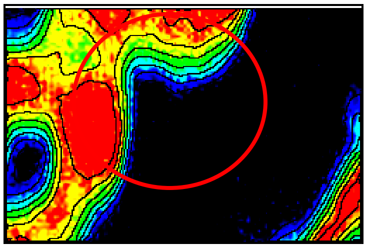


… Resulting in a pore on the right hand side at mid and maximum pressure.

Photo 9 – Table feature with increasing pressure.

5.2.4 ANGLE

The Angle feature was one of the hardest features to locate in most of the impressions which were examined. Most of the indentations into the ridge were pockets or concaves – it was difficult to find the straight lines which an 'angle' requires. Angles were one of the least predictable features – possibly because there was no clear distinction between concaves and angles which may have skewed the results. Most of the angles ended flat on the surface, however angles and peaks were observed when medium and maximum pressure were applied. Peaks had the lowest frequency of forming a pore – in only around half of the cases, but in several instances, 2 pores resulted. It should be bared in mind that an angle may be an intermediate form of a concave or maybe a pocket (however this was not often seen)



Angle feature at low pressure

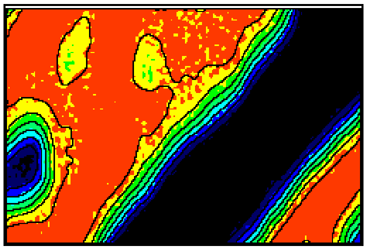
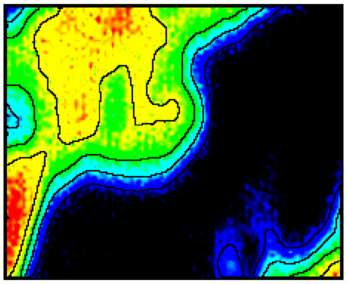


Table feature at maximum pressure

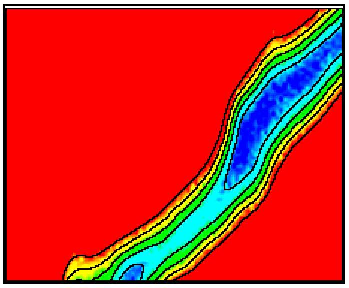
Photo 10 – Angle feature with increasing pressure.

5.2.5 CONVEX

Convex features were one of the easiest to find. With increasing pressure the sides of the feature slowly filled in producing a straight ridge most of the time. Around a third of the convex features ended up forming a pore – usually to one side of the feature as it infilled – very rarely did 2 pores form. Strangely, an angle was formed at maximum pressure in one example. A convex may be an intermediate form of a peak or table in some instances.



Convex feature at low pressure

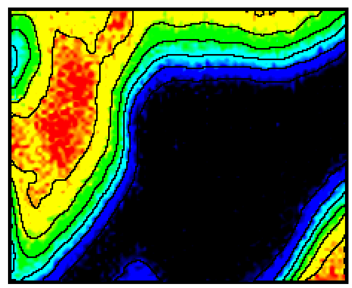


Convex feature at maximum pressure.

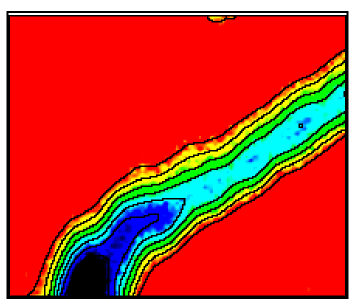
Photo 10 – Convex feature with increasing pressure.

5.2.6 CONCAVE

Concave features were again fairly common and the majority of the time resulted in a straight ridge at maximum pressure. These features formed both one and two pores roughly at roughly the same frequency as the convex features. There were some inconsistencies at maximum pressure with concave and angle features resulting instead of the usual straight edge. Again, the concave feature may be an intermediate form of a pocket or angle.



Concave feature at minimum pressure

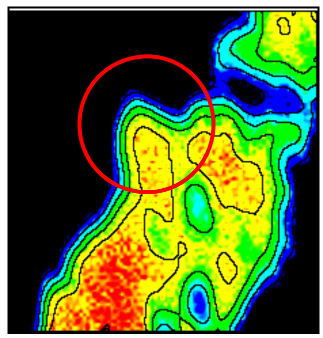


Concave feature at maximum pressure

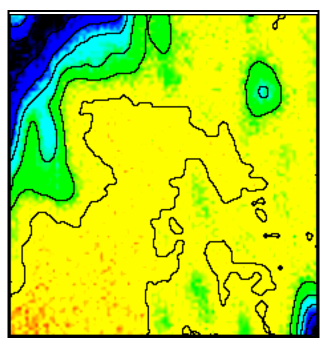
Photo 12 – Concave feature with increasing pressure

5.2.7 Peak:

The peak feature was the most difficult feature to locate in the majority of the prints that were examined. The feature has to be fairly pronounced before it becomes a peak rather than a convex or table. Out of all of the features, it was the most inconsistent feature to predict at maximum pressure – forming a straight ridge only around 78% of the time. Often (15%) a peak would still remain, although a convex also resulted, as did a feature that looked like a whales tail – which would be placed in the 'infinite' category. Peaks also had one of the lowest frequencies of producing a pore. Prints which appeared blocky and disjointed had a higher frequency of peak features.



Peak feature at minimum pressure



Peak feature at maximum pressure

Photo 13 Peak feature with increasing pressure

Overall, to some extent the features can be predicted to produce certain results at different pressures. Most of the features ended up straight – and this is a big indicator in determining the pressure of an unknown print. From the experiments, it was not possible to guarantee how a certain feature would appear at maximum or medium pressure levels; however they always fell into certain confidence levels. Indicators of relative pressure between the two impressions being compared and then the ridge details would be considered in conjunction with this.

5.3 Other Characteristics

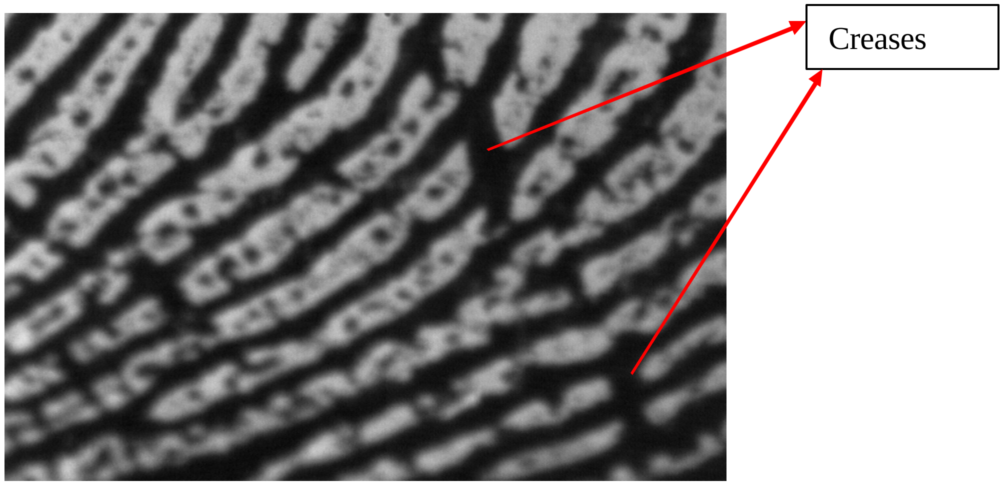
It is not just the edge characteristics, which change with differing amounts of pressure. The technology being used made it easy to observe what occurred to other features in the fingerprints. These features may provide an indication of the amount of pressure being applied to the finger.

5.3.1 Scars and Creases

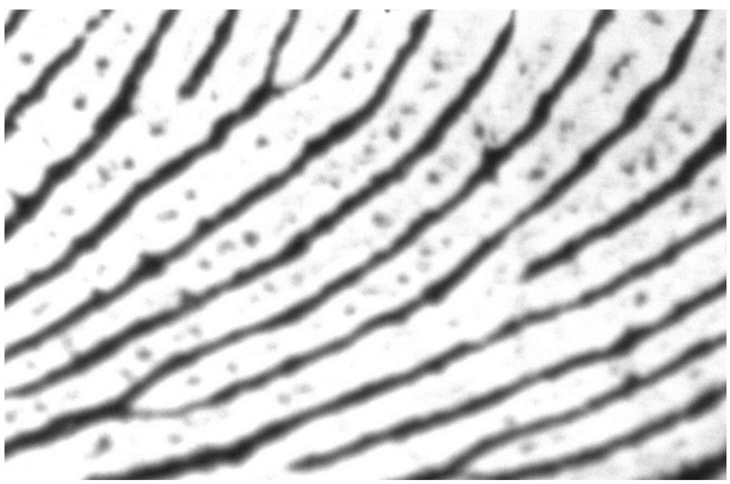
Some fingerprint impressions had fairly obvious breaks in the ridges which appeared to have been caused by a cut (superficial epidermis damage) as they were fairly well aligned. With minimal pressure the breaks were present – however with even the slightest pressure (ie. Frame 2 and 3) to maximum pressure, the ridges joined with no evidence of the break.

In another circumstance, a twenty year old female had a distinctive scar – the ridges were very broken and distinctive. With increasing pressure the ridges built and infilled, forming pores in the large gaps in the center of the ridges. Even at maximum pressure these breaks in the ridges were still visible.

Some fingerprint impressions (especially a 30 year old female) had a substantial number of creases visible over the finger (indeed the whole hand) and the skin appeared dry and creased. At minimal pressure the creases were very obvious – but by frame 9 the majority of the creases were gone. At maximum pressure, some of the creases in the ridges were still visible. The appearance of these fingerprint impressions appeared very blocky and disjointed, probably due to the dry skin (even though sebaceous deposits were also used to improve the impression). By the 12th frame, the overall impression was very different – the ridges were complete and more like a ‘usual’ ridge – very different from the initial images.



Low pressure. Note the creases and disjointed appearance of the ridge.



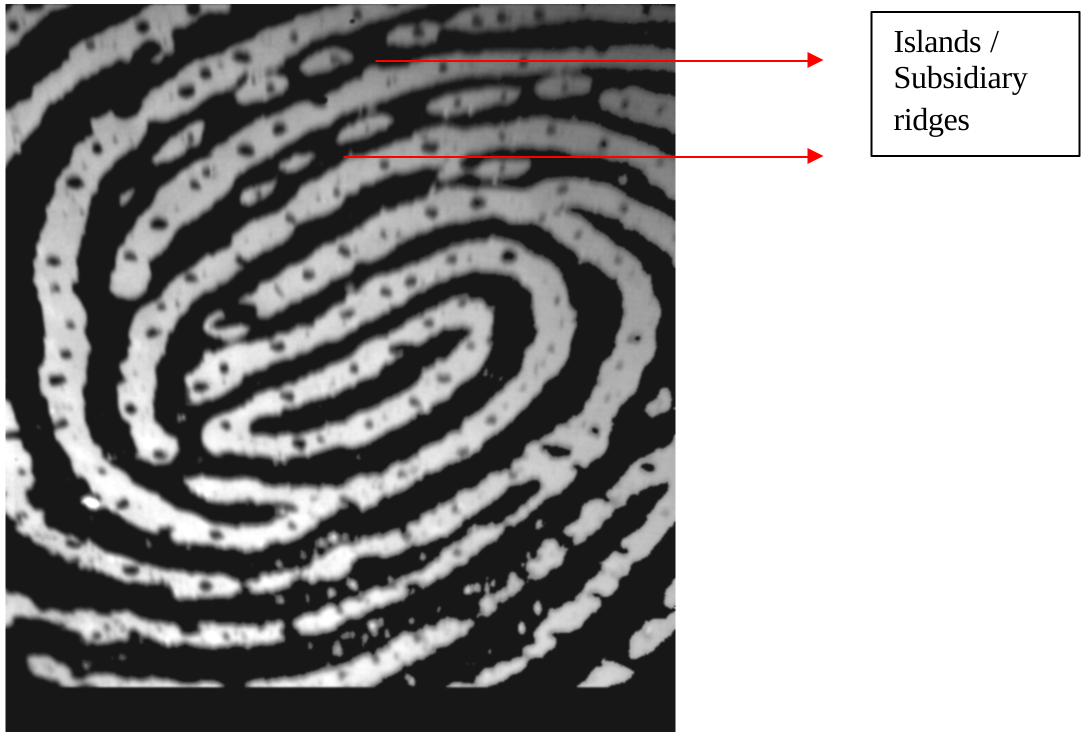
High pressure. Note that the creases are not as visible (some puckering remains).

Photo 14 – Creases with increasing amounts of pressure

5.3.2 Subsidiary Ridges

Younger males from this donor pool were more likely to have subsidiary ridges. Incipient ridges which were visible at minimal pressure became thicker with increasing pressure and often joined with the nearby ridges.

In several instances, subsidiary ridges were not visible until around the 4th frame and they became thicker with increasing pressure – although they never became as thick as those subsidiaries which were visible originally. Subsidiary ridges which appear as broken islands from the earliest frames are joined to the standard ridges by the 6th frame.



Low pressure.

At higher pressure the islands have joined to each other and in some instances to the adjacent ridges.

Photo 15 Subsidiary ridges with increasing amounts of pressure.

5.3.3 Sweat

Prints from donors which are either sweaty to begin with or become so under the heat of the polilight have a distinctive appearance.

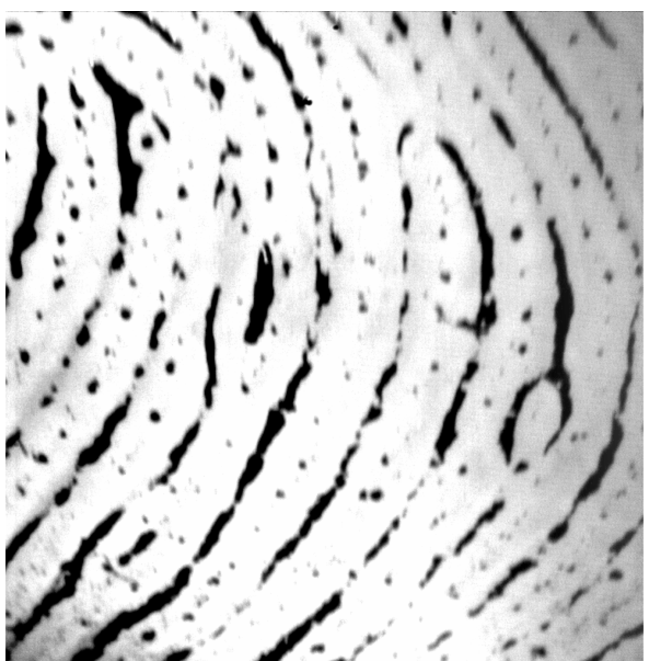
The sweat appears very brightly reflective in colour – the ridges look fatter and the valleys and any ridge formations infill quickly (even with minimal pressure) so that everything looks even and glassy. Islands and subsidiaries join quickly. The smaller pores are less obvious. With a sweaty print – it would be difficult to compare any but the most obvious of the edge features – and even then it would be questionable how accurate the results would be. The pores may be the best option in these instances.

Low pressure – finger is already slightly sweaty. Note that even at this pressure the features are not as obvious as would be expected on a non sweaty print.

High pressure – only the largest of the edge features are obvious – most of the detail has been obliterated.

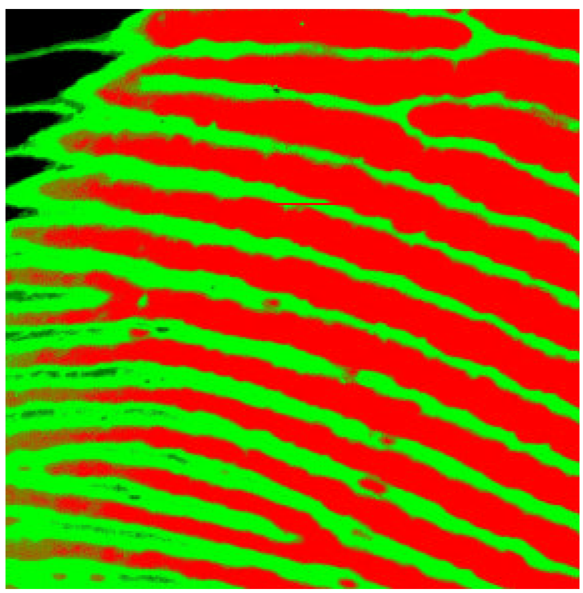
Photo 16 Sweaty prints with increasing pressure.

Print that was not sweaty (even appears dry) at low pressure – note the print is blocky and uneven.



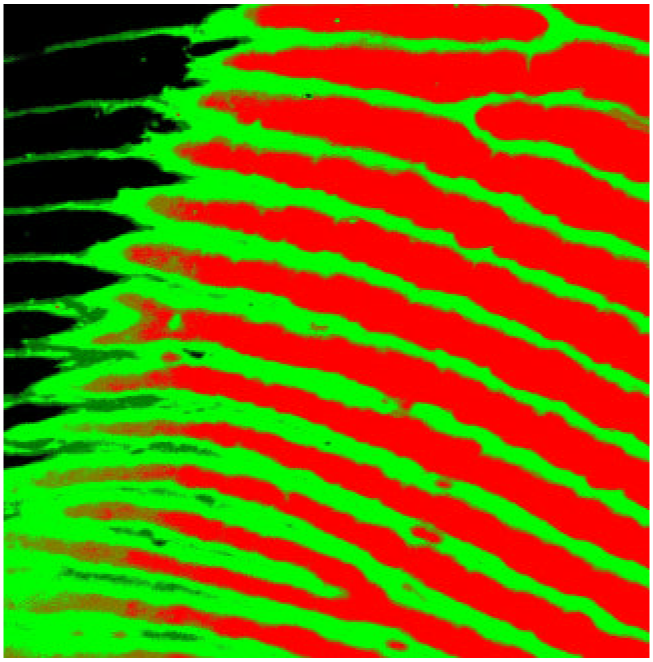
Same impression at high pressure – note that the ridges and subsidiaries are joining together and only the largest features are visible.

Photo 17 – Non sweaty print which becomes sweaty with increased pressure. An experiment was undertaken to try and emulate excessive sweat or blood. Some detergent was placed on the surface of the prism and a finger was dragged across the prism surface. Colour was later added to the images. Of interest in these images is the reversal of ridges. In the images, the thick red lines are the ridges and the green lines on the right are the valleys. After the finger moves across the surface, the excessive 'sweat' in the valleys remains on the surface – almost appearing as a ridge - producing a reversal of the ridges. Interestingly a bifurcation is visible in the 4th image after the finger has passed that point. A reason for this is that the green liquid is forced between the ridges where the finger contact exists – as the finger moves away from the surface; the green appears to bead possibly due to surface tension, and gather about the ridge. It is left in the path of the ridge, leaving a very wide spaced valley (black), which has the appearance of a ridge due to its width.



Red Ridges
Green valleys

The finger is moving from left to right.



Green – ridge reversal of the valleys

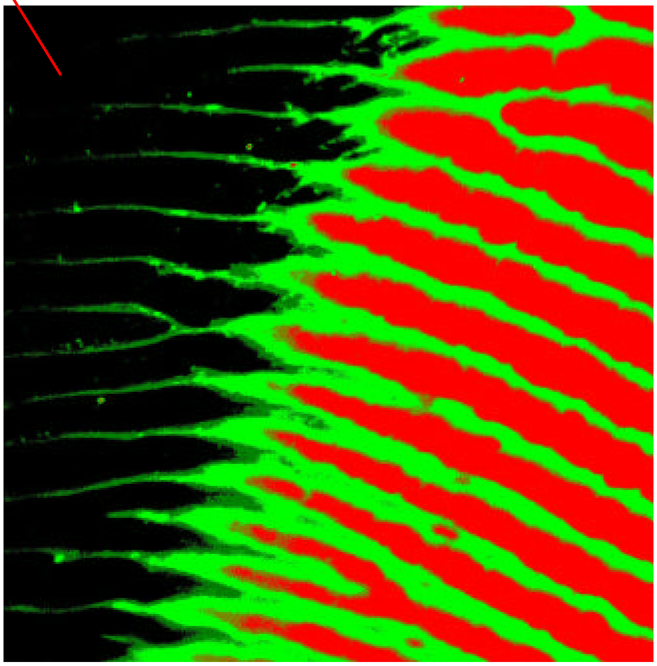
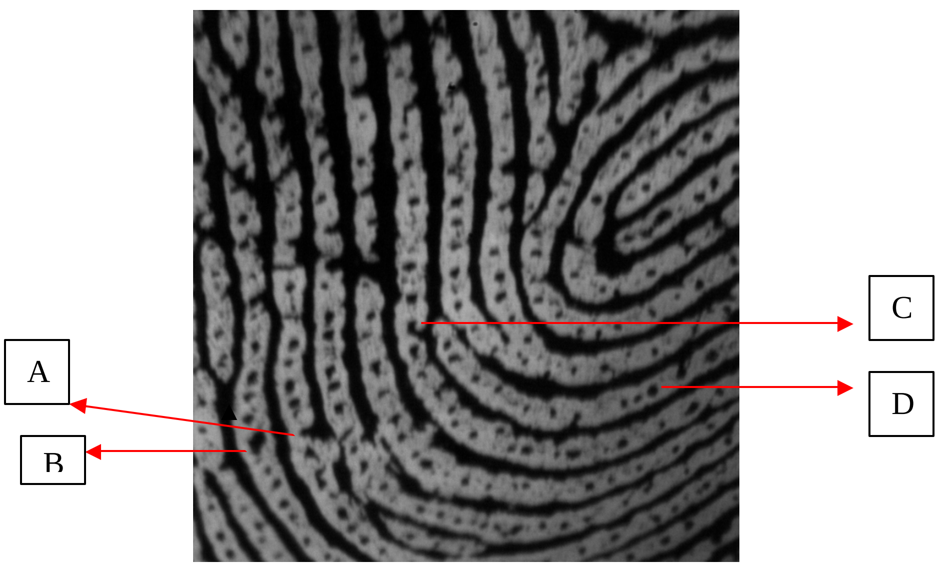


Photo 18 – Print emulating excessive sweat with sideways movement

5.3.4 Pores

The location of pores appears constant with increasing pressure, although the pores appear to change shape, with many pores appearing smaller at higher pressure levels. (It should be noted that the fingerprint samples were taken at one time, not over a period of time). The flexible skin of the fingerprint ridge builds around the pores which may change the appearance – say from an open pore to an enclosed pore (A, C below). Enclosed pores also change shape as the ridge builds in around it (B, D below). If one edge of a pore is higher – possibly due to higher dermal papillae, this section may start filling in before the others – changing the appearance. Potentially with increasing pressure, deeper portions of the conical shaped sweat pores may contact, with the skin moving in around the pore, changing its appearance.



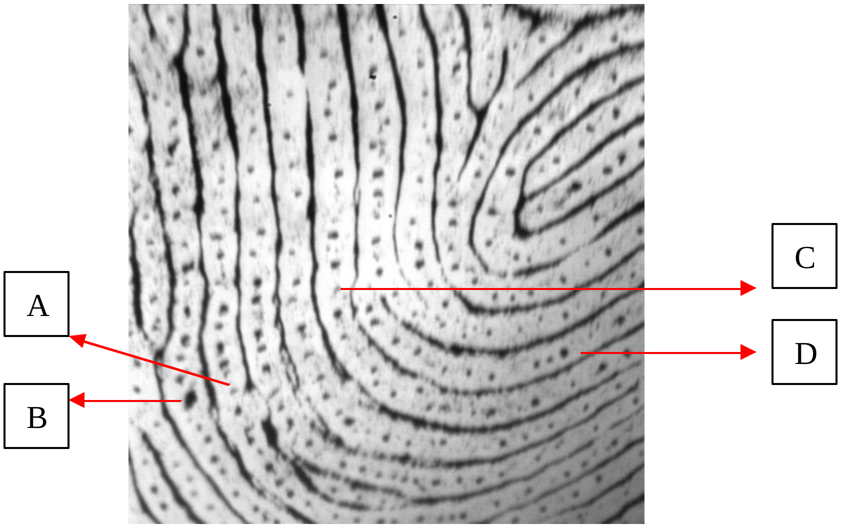


Photo 19 – Pores with increasing pressure

The size of the pores appears to decrease with increasing pressure. Below is a graph of 14 pores randomly chosen from a fingerprint. Pore size was compared against the weight being applied to the finger at that time. It can be seen that the decrease in size is fairly uniform among all of the pores with the exception of the initial application of pressure where some pores have a sharp decrease in size.

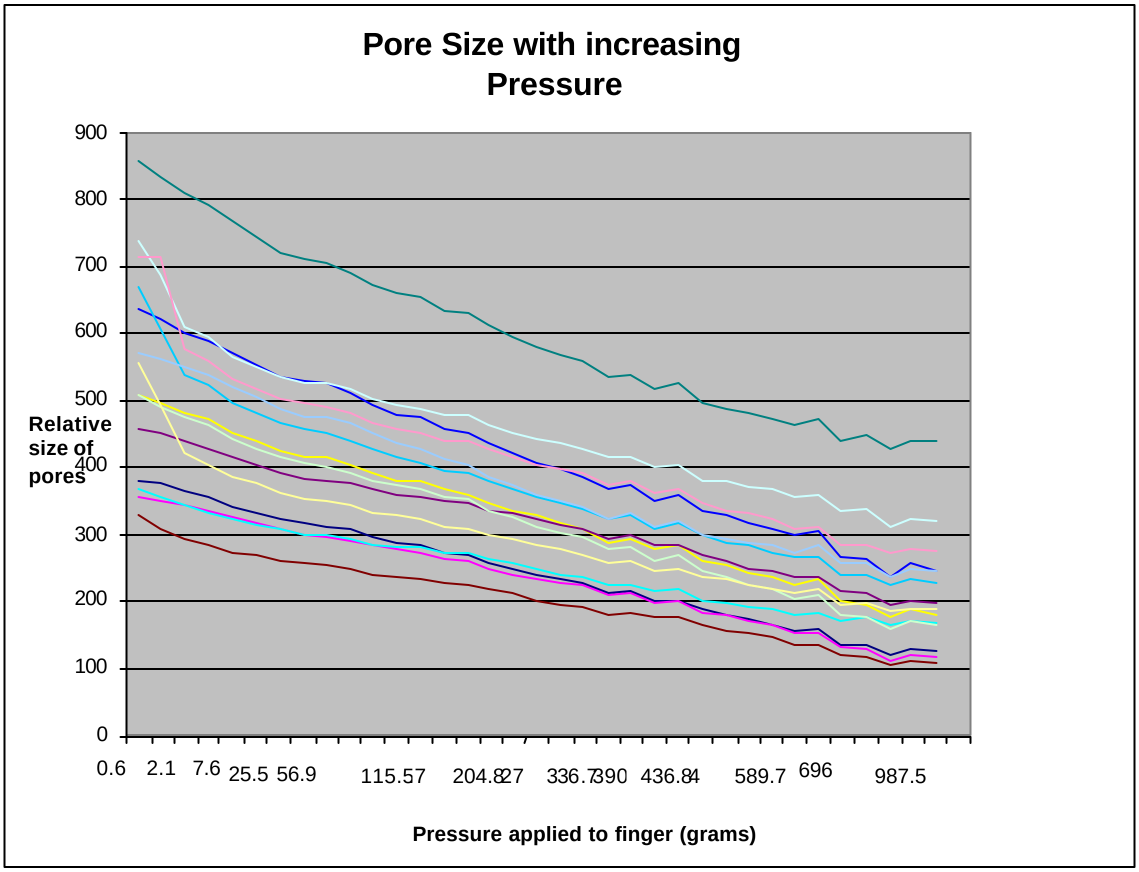
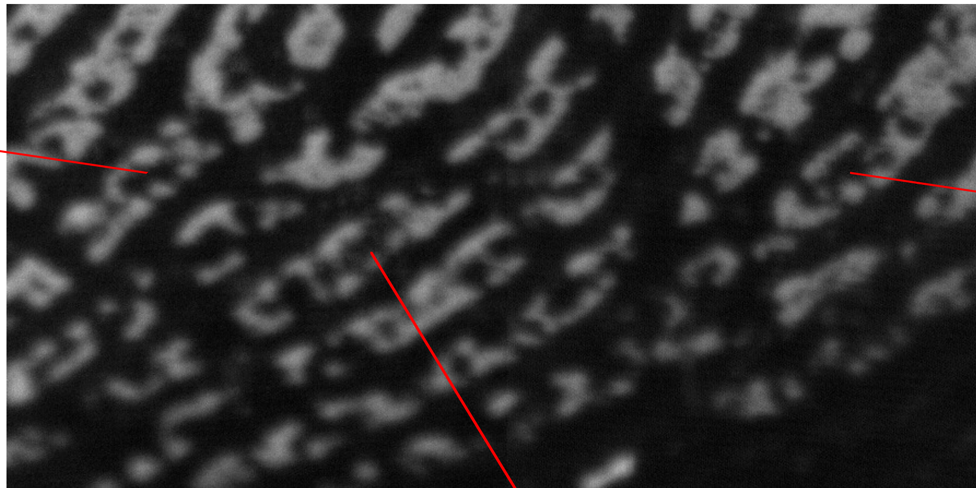


Figure 1 Pore size with increasing pressure

In some fingers, pores were joined, indicating long depressions in the ridges. These long areas of pores often seemed to be more prevalent in dry fingers. With only minimal pressure, the areas of joined pores started to separate forming distinct pores. With maximum pressure although the pores were largely distinct, there are occasionally areas of small indistinct pores.



Minimum pressure.

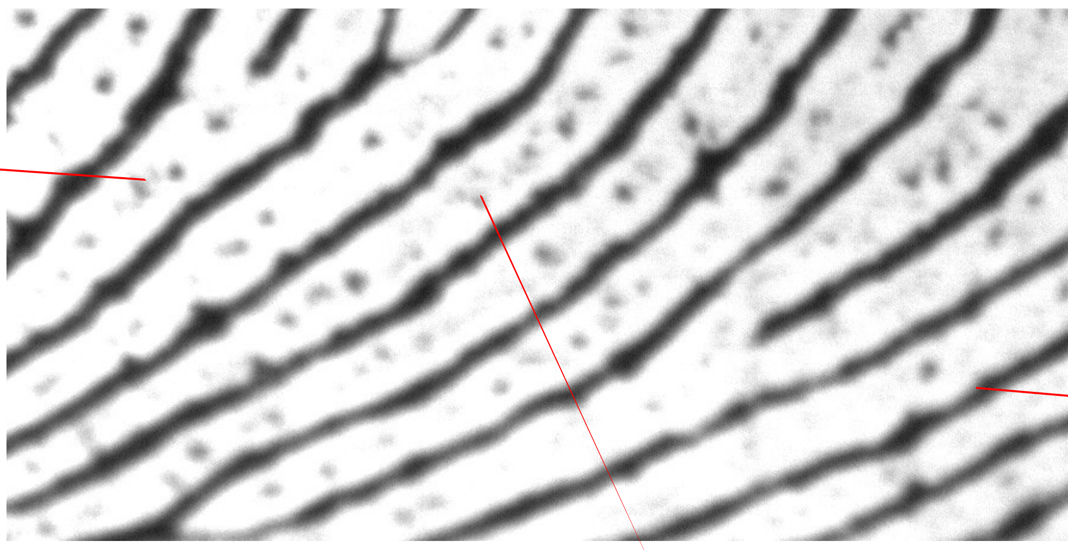


Photo 20 Joined areas of pores with increasing pressure

Characteristic size was plotted against pressure and it was found that the size of these features also decreased. However, as the majority of features are not enclosed and significantly change shape (ie. A convex feature usually ends as a straight line) these results can not be relied upon. A visual examination is of more value

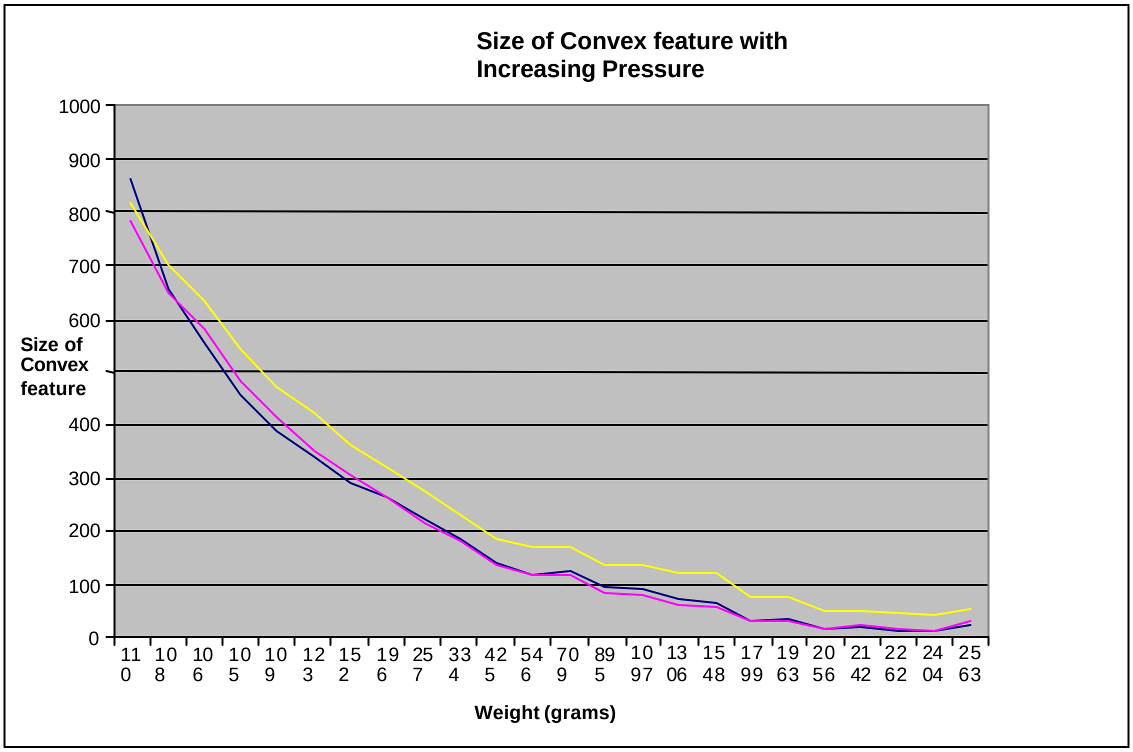
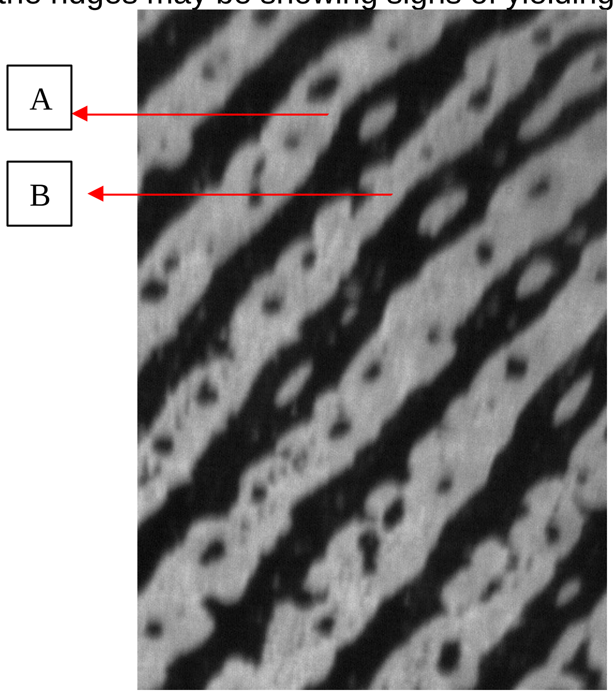


Figure 2 Size of convex feature with increasing pressure

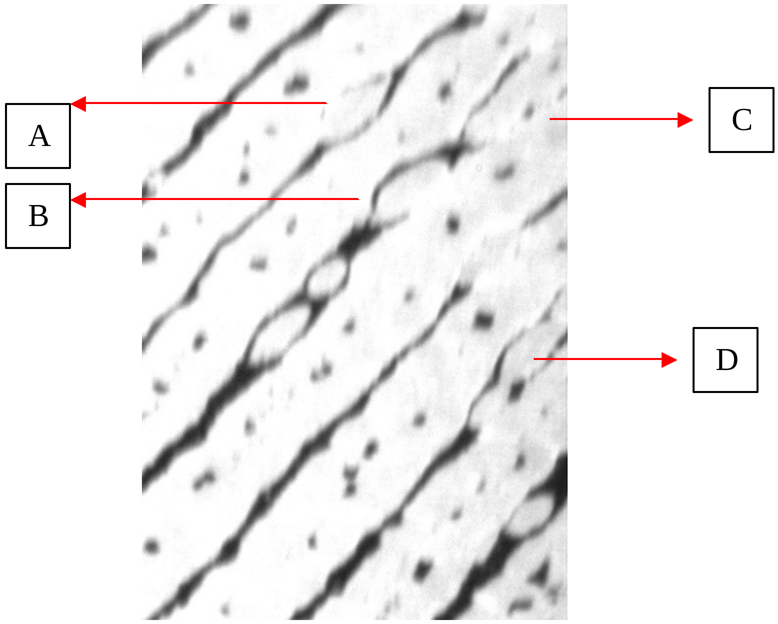
5.3.5 Islands

Islands were a relatively common feature in the impressions examined. At low pressure some prints had small islands which, with increasing pressure became larger and often joined with other islands or the ridges themselves. In other instances, islands only became visible after pressure had been applied to the finger. These islands were never as large or obvious at maximum pressure as compared to islands which were visible at low pressure. The majority of islands had little ridge definition, although pores were sometimes seen. Chatterjee features other than straight were not often found.

There is a dynamic balance between the islands and the nearby ridges with the ridges forming around the islands so at maximum pressure there was minimal vacant space. It could be interpreted from this that if an island was not visible at low pressure, the ridges may be showing signs of yielding around it.



Low Pressure (596 grams). The ridges can be seen yielding to the islands (A, B).



At high pressure (3216 grams) the ridges have continued to move around the islands (A, B). The islands appear to have joined to the adjacent ridge (C), and other islands.

Photo 21 Islands with increasing pressure

5.3.6 Shapes on adjacent items

When looking at the fingerprint images, it was often seen that ridges tended to compensate/move around each other. This was seen on two levels. On the larger scale, ridges moved around islands and subsidiary ridges – especially in impressions with higher pressure. This could be a visible reminder that the primary ridges form first on the finger, and subsidiary ridges and secondary ridges form afterwards, filling in every available space on the finger.

On a smaller scale, a peak may be on a ridge opposite a ridge with an angle. At higher pressures, the two formations looked to move around each other. This may be a smaller scale version of the forces acting on ridge formation.

On the image below the marked areas:

A – The adjoining ridges are moving in concert around – down to ridge edges moving around each other.

B – Note the very fine level at which the ridges are compensating around each other

C – Ridges at a larger scale

D - Larger scale again

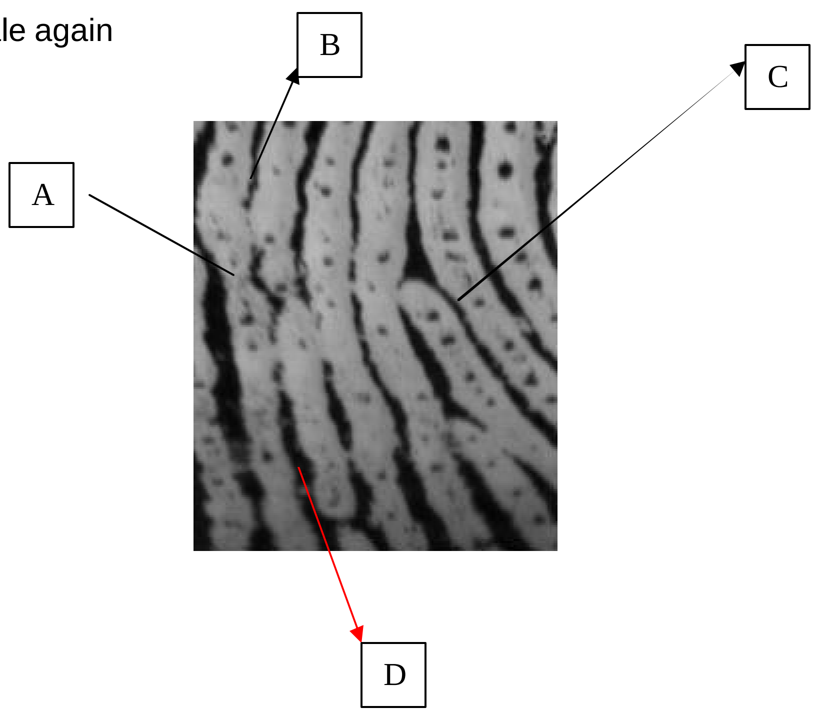
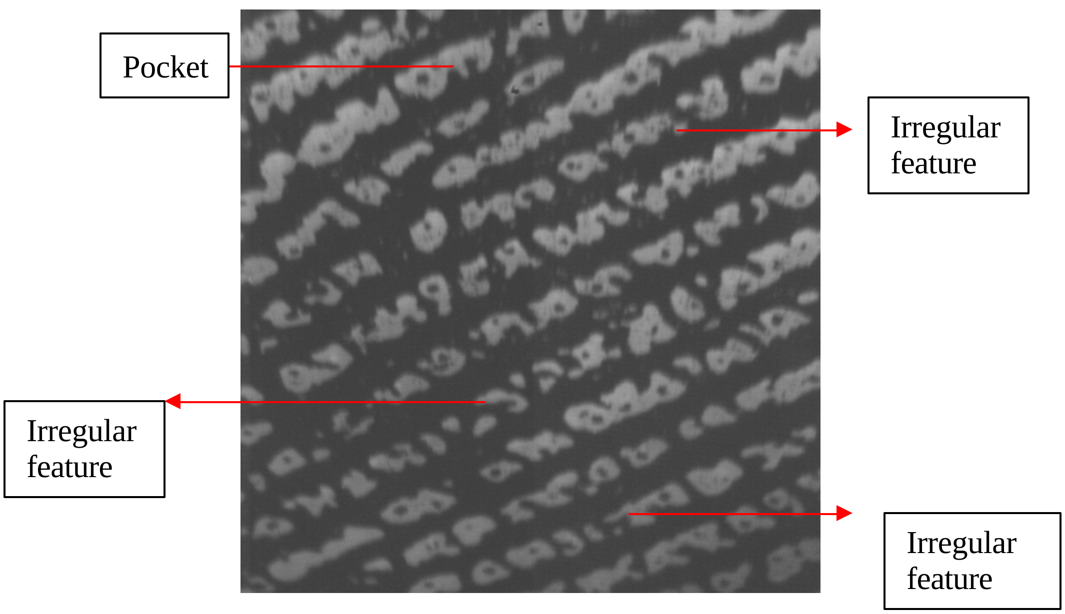


Photo 22 Shapes on adjacent items

5.3.7 Different areas of the palms and fingers.

Chatterjee recommended using the area at the base of the pattern as the ridges are broader and the edge characteristics appear more clearly. Following on from this, it was decided to examine impressions from several different areas of the fingers and palms.

Areas of the palm were examined. In all instances the palmar impressions appeared blocky, disjointed and irregular looking, even after sebaceous deposits were applied to the area. With maximum pressure there was very little difference – the impression still appeared blocky and had irregular edge shapes. Many of the Chatterjee characteristics used on fingers were obvious on the palms – however there were other features which did not easily fit into these categories.

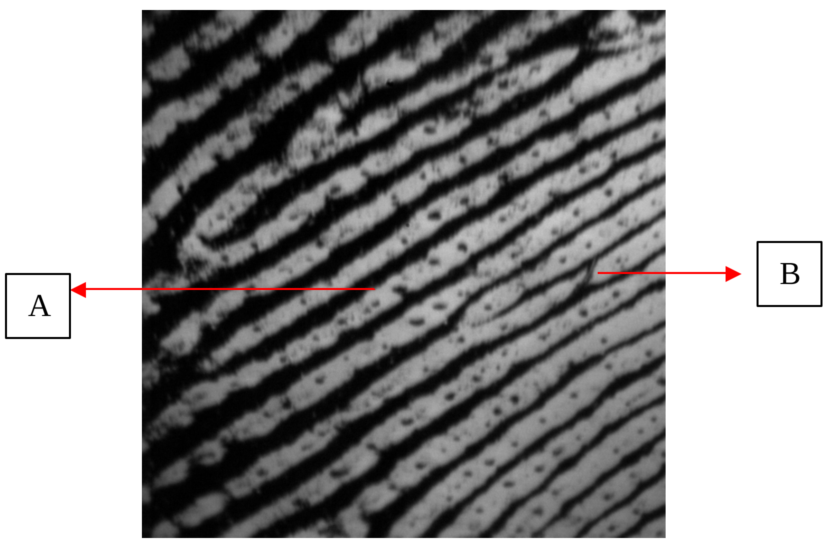


Photograph 55: Hypothena area of the palm - medium pressure (1786 grams). There was very little difference between different pressure levels.

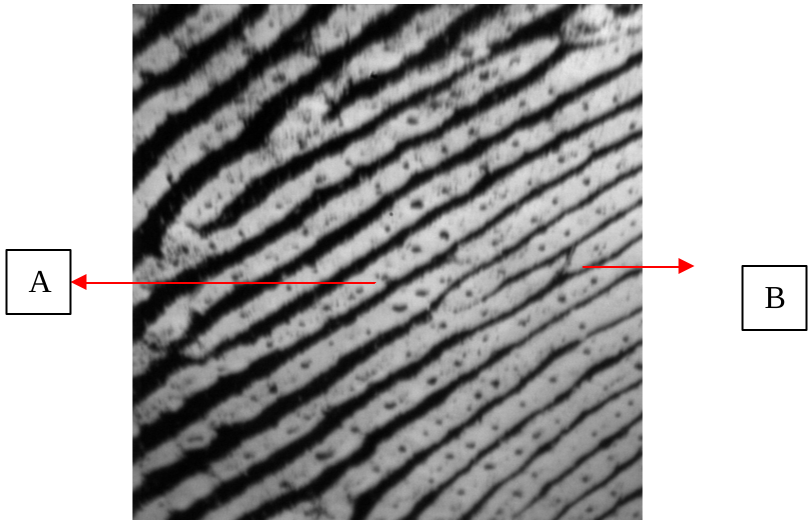
It would be reasonable to assume that, the structure of the palm is different to the finger and the area of contact for a palm will generally be larger, so, the force on the skin is not concentrated on one point (as in a finger tip because of the bone). The area that the force is distributed over is larger, so the effect of the increased force will be less on a palm than a finger for a given area of skin.

Impressions at the base of the finger were compared against areas around the core and tips of the finger. After initial comparison, the majority of impressions examined were the middle of a fingerprint, with tips and base of pattern used occasionally.

It was found that areas at the tip of the finger had minimal ridge definition which made locating features more difficult. There was not a lot of difference between light and heavy pressure which may mean that this area may be more reliable when comparing ridge details in prints with differing amounts of pressure. If the impressions below were compared using standard criteria, it would be expected that the features would change a lot more than they do. The open pore would usually become closed with minimal pressure and the ridge break would usually significantly change shape and close together. Potentially, the area being examined was higher than the fingerprint bone – so there may be less pressure being applied to the skin.



Area at the tip of the finger minimum pressure (223 grams). Note the ridges are largely regular. An open pore (A), and ridge break (B) are labeled.

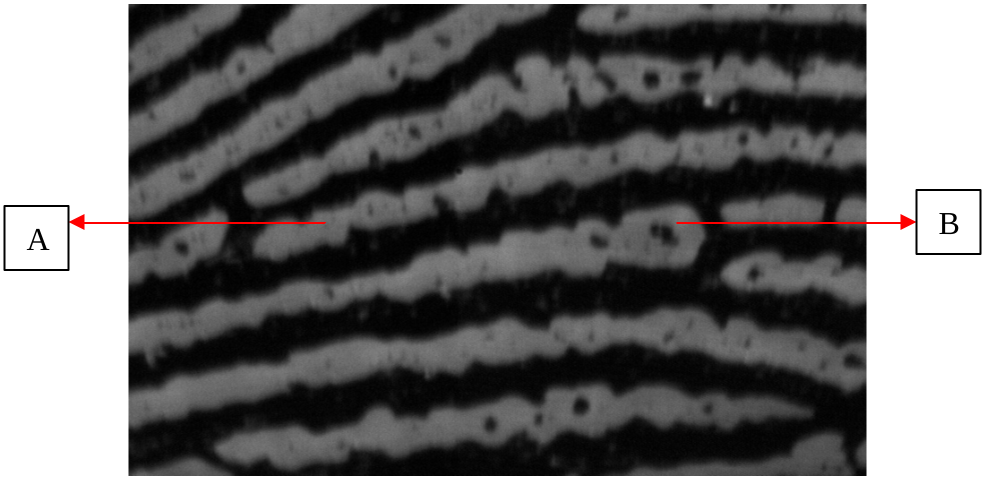


Maximum pressure (3116 grams). The open pore (A) remains slightly open and the ridge break (B) has not changed significantly.

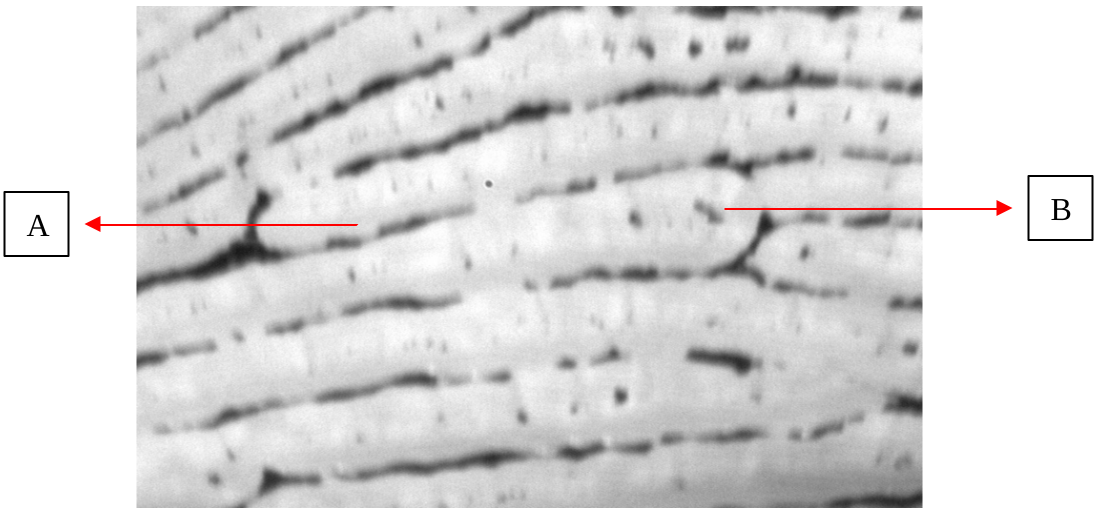
Photo 24 – Area at the tip of the finger with increasing pressure.

The area below the pattern certainly had more ridge definition as opposed to the tip of the fingers. At maximum pressure, the area at the base of the finger often tended to be more undulating – but in most instances, the ridge edge was not defined enough to be easily classified as anything but straight. In some impressions, pores were less prevalent in this area – but again, this depended on the person, as it tended to be widespread over the whole pattern.

There was often more variation between people as opposed to the actual area (centre of the pattern or base of the pattern), which was used.



Minimum pressure (75 grams). A convex feature (A) and a large group of pores (B) are labeled.



Maximum pressure 5214 grams. Note that (A) is still slightly rounded. The pores (B) appear smaller, but are still obvious.

Photo 25 – Area at the base of the pattern with increasing pressure

Overall, if the tip of the finger is used, there is less ridge definition which may make locating features more difficult; however the features do not change appearance as much – which may be of advantage in the comparison process. Areas at the centre of the pattern and base of the pattern are not noticeably different – they tend to vary more between people rather than area of the pattern itself. Palms have a more blocky, disjointed appearance which again do not change as much as finger impressions. This again, may be of advantage in the comparison process.

5.4 Sideways pressure.

The project concentrated on downwards pressure – however, most prints are deposited with some form of sideways movement or slippage. The equipment being used made it easy to record these sorts of movement – although it is difficult to replicate or quantify how much sideways movement occurred.

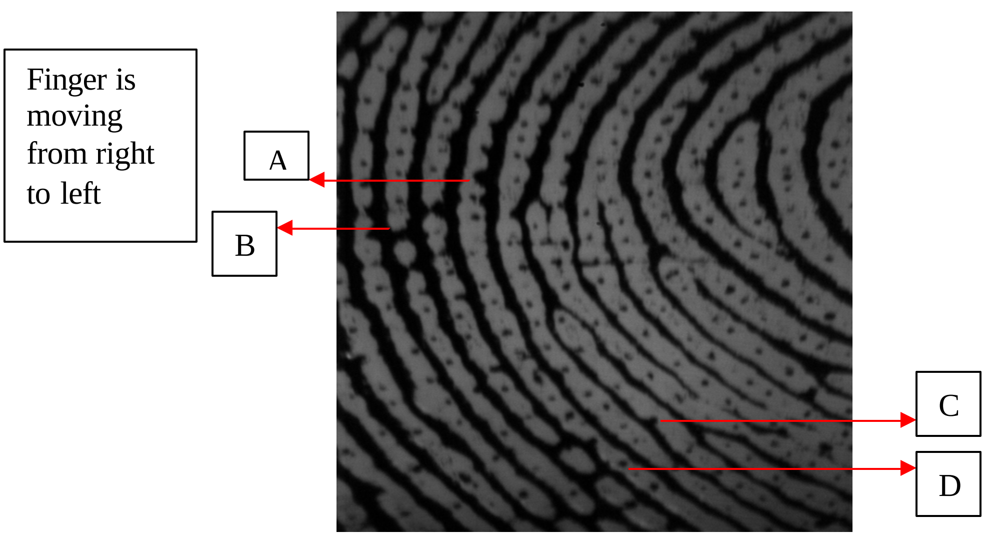
The images below show 4 frames taken of a finger sliding from right to left ideally with similar amounts of vertical pressure. It can be seen that horizontal pressure affects the appearance of both the ridges and features themselves. The flexibility of the skin can easily account for this and there is the potential for further research into this area.

(A) shows a pore which is open in the first and third images, but is closed on the second.

(B) shows a ridge which is broken – however the next image (with more pressure on that area) shows a complete ridge (B).

(C) shows a pore which is open in the first two images but closes in the third image.

(D) was of interest as the ridge shows a lot of edge variation in the first image, yet is smoother in the second. The third and fourth images depict a ridge which is a lot narrower and uneven.



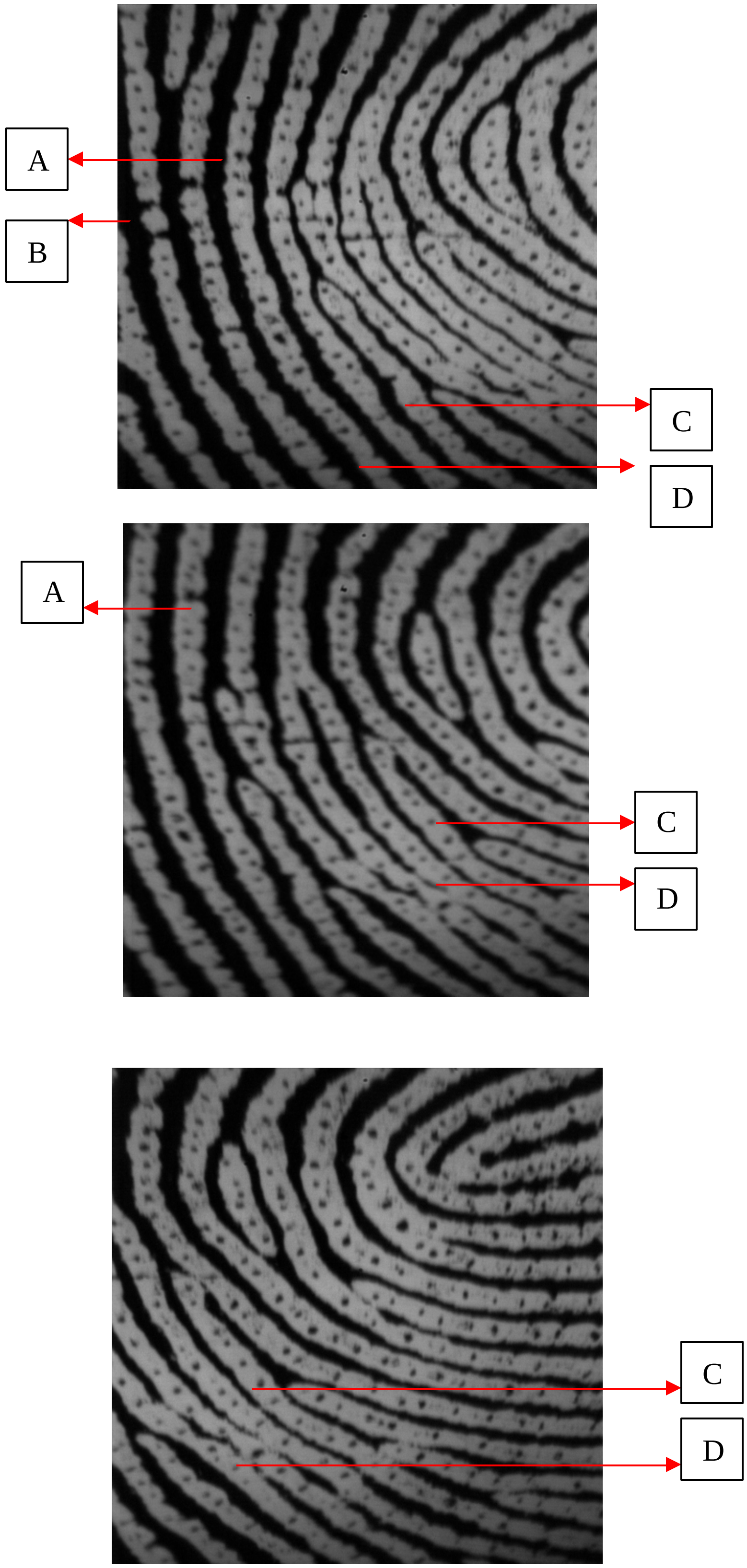
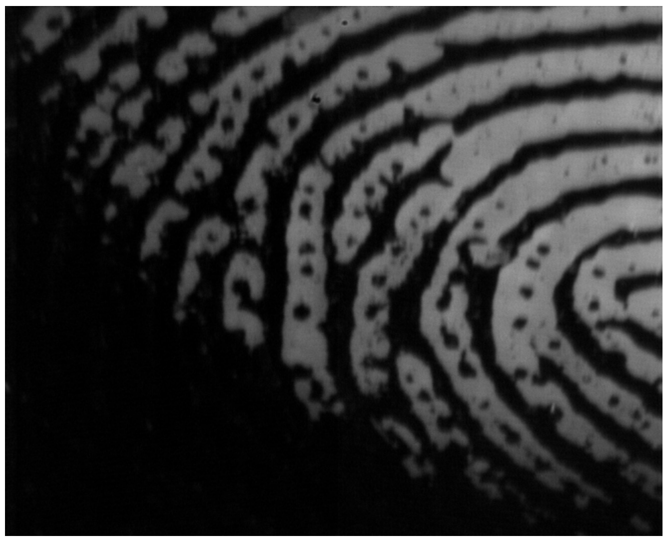


Photo 26 – Series of four photos showing sideways movement/slippage.

5.5 Rolling pressure

The following images are of a finger which has been rolled – as in on a fingerprint form. There is less sideways force on a rolling finger as opposed to the fingerprint sliding as was pictured in the images above   The right side of the finger was placed down first with increasing pressure over a larger area as the finger is rolled. With greater pressure in the subsequent images, the pores are infilling and ridges are filling out – much as would be expected from the studies undertaken on vertical deposition pressure.

Finger is moving from right to left



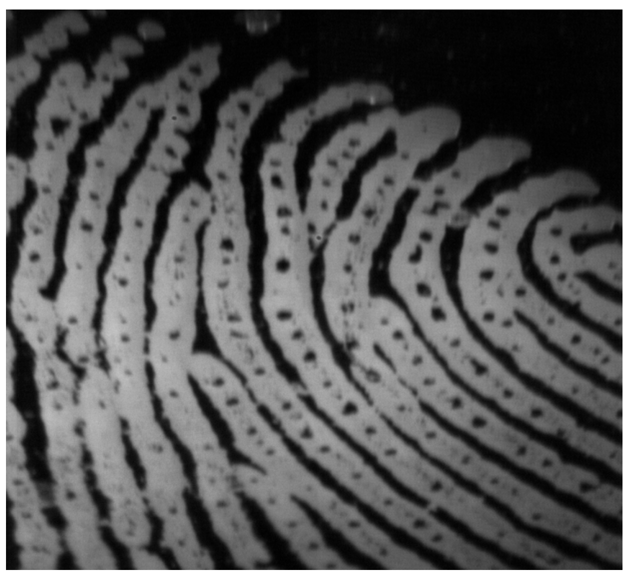


Photo 27 Series of photos showing rolling movement on the finger

5.6 Deposition Pressure

One of the aims of the project was to get some idea of pressure that was used to deposit a print, so that it could be compared to another print or latent to determine whether the edge features could be used reliably. This was very difficult to quantify and could be the focus of further study. Pressure is a measure of force over a given area. If the area of friction ridge skin contact remained constant, the pressure change would be relatively simple to calculate. With an increase in force applied the friction ridges expand in a non-linear manner, increasing the area of contact. Therefore, the increase in pressure is not directly proportional to the increase in applied force and the actual pressure change is not as great and probably not as significant a factor as force itself.

However, a visual comparison could be made between prints of high and low pressure, which could be used to determine the relative pressure.

Blocky prints, prints with many thin creases and highly featured ridge outline are likely to have been produced with lower pressure. The ridges are relatively narrow as compared to the valleys. Subsidiary ridges and islands, which are distinct and not joined to neighboring ridges may also indicate lower pressure.

Ridges with minimal topography, fatter, glossier looking ridges and fatter ridges as opposed to narrower valleys may indicate higher pressure. Islands and mess in the valleys may have joined to adjacent ridges, and ridges which may be joining with each other indicate a higher likelihood of greater pressure.

Overall, the prints were compared to see what would be the optimal amount of pressure which would be applied to obtain the greatest amount of clear ridge detail. Medium levels of pressure would be ideal – however, to quantify this would again be irrelevant. Some prints required a weight of only 108 grams before the majority of the ridges lost definition and became straight, while other prints required pressures up to 1840 grams before the majority of ridges became straight. Sex of the donor and size of the finger did not seem to affect the result. Sweaty fingers lost definition a lot earlier – so care should be taken to avoid this situation.

6 Future Directions.

During the experimentation stage, several ideas were discussed which may be of interest if further work was to be undertaken but due to time constraints was not carried out for this project.

? A thumbscrew attachment on the prism, which would provide a downward pressure which would be measurable. This would minimize the amount of sideways movement which we invariably would have gotten with this project. This would give provide a quantifiable way to compare differing amounts of pressure. Whether this information would be useful in daily practice is questionable.

? In combination with the above, establish how much pressure is applied by any given finger doing a particular task – i.e. picking up a glass. This would be difficult to achieve for several reasons. The amount of pressure applied by the thumb would be very different to the amount of pressure being applied by the opposing three fingers holding a cup. The size of the fingers, surface of the glass, weight of the item, personal idiosyncrasies, sore finger etc would all affect the results. However, this information may be useful if you could then compare the amount of pressure used to pick up a knife as compared to stabbing somebody. Potentially the amount of force used for this activity could be assessed.

? The above information may also enable the fingerprint examiner to have a rough indication of the pressure distortion visible on a lift card rather than the purely descriptive accounts that we currently have. The usefulness is questionable.

? Compare the affect of lateral pressure (sliding and rolling motion) on the ridge features.

? Different surfaces – does the affect of pressure on ridges differ when the surface is rough, plastic, glass, metal etc?

? Does the age of the donor / size of the fingers / sex of the donor have an effect on the overall print? Or is there a difference in the effect of pressure on the edge features?

? Does the amount of sweat on a finger affect the edge features and their usefulness in the comparison process?

? Is there a differentiation between different ages or sexes with the amount of pressure needed to cause the prints to be useable – ie. An upper and lower level of pressure?

- More study would be required to further assess the weight being applied to the finger and the resulting effects. As mentioned in section 5.6 there are many inconsistencies in the results which would be interesting to explore further.

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