NIST Special Publication 1151

Markup Instructions for Extended Friction Ridge Features

Will Chapman
Austin Hicklin
George Kiebuzinski
Peter Komarinski
John Mayer-Splain
Melissa Taylor
Rachel Wallner

http://dx.doi.org/10.6028/NIST.SP.1151

National Institute of Standards and Technology
U.S. Department of Commerce

NIST Special Publication 1151

Markup Instructions for Extended Friction Ridge Features

Melissa Taylor
Law Enforcement Standards Office
Office of Special Programs

Will Chapman
Austin Hicklin
George Kiebuzinski
John Mayer-Splain
Rachel Wallner
Noblis
Falls Church, VA

Peter Komarinski
Komarinski & Associates, LLC
Rotterdam, NY

http://dx.doi.org/10.6028/NIST.SP.1151

January 2013

U.S. Department of Commerce
Rebecca Blank, Acting Secretary

National Institute of Standards and Technology
Patrick D. Gallagher, Under Secretary of Commerce for Standards and Technology and Director

National Institute of Standards and Technology Special Publication 1151
Natl. Inst. Stand. Technol. Spec. Publ. 1151, 43 pages (January 2013)
CODEN: NSPUE2

Markup Instructions for Extended Friction Ridge Features

January 2013

Abstract

This document provides instructions for latent print examiners in marking friction ridge features to maximize consistency among examiners. This document builds upon the Extended Feature Set (EFS) defined in American National Standard for Information Systems: Data Format for the Interchange of Fingerprint, Facial & Other Biometric Information, American National Standards Institute/National Institute of Standards and Technology, Information Technology Laboratory (ANSI/NIST-ITL) 1-2011*. These instructions include examples and specific guidance for latent print examiners and minimize references to technical details of the file format.*

Three interrelated specifications have been designed to enable vendor-neutral latent automated friction ridge identification systems (AFIS) interoperability: the EFS Profile Specification*; the* Latent Interoperability Transmission Specification*; and this one, the* Markup Instructions for Extended Friction Ridge Features*. The three documents define data exchange specifications for latent print interoperability and are all based on the EFS features in the* ANSI/NIST-ITL *(2011) standard.*

Contents

1 Introduction

The Extended Feature Set (EFS) defined in *American National Standard for Information Systems: Data Format for the Interchange of Fingerprint, Facial & Other Biometric Information, American National Standards Institute/National Institute of Standards and Technology, Information Technology Laboratory 1-2011* (ANSI/NIST-ITL 2011)[1] is a quantifiable, repeatable, and clear method of characterizing the information content of a friction ridge image (fingerprint, palmprint, or plantar). This document provides instructions specifically for latent print examiners in marking EFS features to maximize consistency among examiners. This document may also be used by feature extraction and matcher algorithm developers as a basis for their expectations as to how examiners mark features.

EFS is specifically designed to be used for vendor-neutral Automated Friction ridge Identification System (AFIS) searches as well as for the interchange of latent print annotation among examiners as part of non-AFIS casework:

AFIS Searching

EFS is an interoperable AFIS interchange format for human-initiated searches, fully automated searches, data interchange among automated systems, and feedback to examiners from automated processing.

Interchange of Casework

EFS defines the information content of a single friction ridge impression as discerned by an examiner during analysis—or the information content and determination of a comparison of two friction ridge impressions as discerned by an examiner during comparison and evaluation—for archiving, interchanges with other examiners, validation and quality assurance processing, and quantitative analysis.

The *Markup Instructions for Extended Friction Ridge Features* are software implementation agnostic.

[1] In the unlikely event there is a difference or discrepancy between *ANSI/NIST-ITL* and the *Markup Instructions for Extended Friction Ridge Features*, *ANSI/NIST-ITL* takes precedence.

2 Latent Interoperability Specifications

Markup Instructions for Extended Friction Ridge Features is a companion document to the *Latent Interoperability Transmission Specification* (LITS) and the *EFS Profile Specification*, all three of which build upon *ANSI/NIST-ITL* (2011). The three documents define data exchange specifications for latent print interoperability:

- *Latent Interoperability Transmission Specification* is a system-level specification, parallel to and compatible with the Federal Bureau of Investigation (FBI) Criminal Justice Information Services (CJIS) *Electronic Biometric Transmission Specification* (*EBTS*) (FBI CJIS 2011), but focuses on the definition of vendor-neutral latent transactions to be exchanged among disparate cross-jurisdictional AFIS systems. LITS-conformant AFIS systems provide the examiner with a seamless search capability for all interoperable AFIS systems. Encoding EFS features for searching on the examiner's host AFIS creates a search record that may be sent to an AFIS operated by another jurisdiction with no or little additional markup.
- *EFS Profile Specification* defines sets of features that are to be used in latent friction ridge AFIS searches and that are designed to be interoperable among AFIS from different vendors to enable cross-jurisdictional searches that would not otherwise be practical.
- *Markup Instructions for Extended Friction Ridge Features* specifies a common set of instructions and data annotation guidelines for the markup of EFS features by latent print examiners.

3 Search Strategies and Profile Selection

EFS Profiles are sets of features to be used in latent friction ridge searches of automated friction ridge identification systems (AFIS). EFS Profiles are designed to be interoperable among AFIS systems from different vendors and to enable cross-jurisdictional searches that would not otherwise be practical. Multiple EFS Profiles are defined to allow for tradeoffs between examiner time and search accuracy; these profiles provide a range from image-only searches (requiring no examiner markup) through standard minutiae searches to profiles including skeletons or ridge counts (to maximize accuracy at the cost of additional examiner markup time). EFS also may be used to document latent friction ridge features documentation (e.g., for potential use in legal proceedings or exchange between examiners) and need not be for AFIS matching purposes. EFS Profiles are incorporated by reference by *ANSI/NIST-ITL* (2011).

EFS Profiles are grouped as follows:

Image-only

EFS Profile 0: Image-Only Profile requires no examiner markup. No examiner time is necessary for marking features, but accuracy may be lower than for feature-based searches. This corresponds to the FBI CJIS *EBTS* (2011) Latent Friction Ridge Image Search (LFIS) transaction.

Profiles for fundamental latent AFIS searches

EFS Profile 1: Minimal Markup Profile requires very limited examiner markup to improve the accuracy of image-only matching; it includes the Region of interest (ROI), Orientation, Pattern classification, Core(s), or Delta(s).

EFS Profile 2: Quick Minutiae Search Profile includes minutiae in addition to the features in EFS Profile 1: Minimal Markup Profile, includes the features common to all interoperable systems, and is used by the FBI CJIS *EBTS* (2011); this profile is compatible with Department of Defense *EBTS* (2011), Prüm (2008), and Interpol *INT-I* (2007) requirements because the *INCITS 378* (ANSI/INCITS 2004) features used by those standards can be losslessly translated to or from the features used in this profile.

The image is included with the features for both EFS Profile 1: Minimal Markup Profile and EFS Profile 2: Quick Minutiae Search Profile so that searches using these profiles can combine the image processing capabilities of the AFIS with feature-based search capabilities.

Additional profiles for maximized accuracy

Other EFS Profiles include features that can be used to increase search accuracy in systems that implement these optional profiles. These features require additional examiner time, but may optionally be used to maximize search accuracy (such as for critical cases or poor-quality latents). These features include ridge quality map, ridge flow map, center point of reference, distinctive features (e.g., scars), dots, incipient ridges, ridge counts, and skeletons. These profiles include EFS Profile 3: Detailed Markup Profile, EFS Profile 10: Skeleton Profile, and EFS Profile 11: Minutiae Ridge Count Profile. (For details of these profiles, see the *EFS Profile Specification*.) EFS Profile 2: Quick Minutiae Search Profile is a subset of EFS Profile 3: Detailed Markup Profile so that if a target AFIS does not implement the optional features, searches can still be conducted using EFS Profile 2: Quick Minutiae Search Profile.

Features used in special cases

Features that may be used in unusual circumstances include evidence of fraud (e.g., deliberate mutilation), possible lateral reversals (i.e., it is unclear if the print may be flipped left-for-right, such as in some prints on transparent tape), tonal inversion (black for white), or growth or shrinkage (e.g., deceased subjects with swollen or desiccated skin or comparison of adult and juvenile prints).

Features used for casework annotation

EFS Profile 90: Full Annotation Profile provides for annotation of casework, separate from the AFIS-specific profiles. In addition to the features included in the AFIS-specific profiles, this profile may optionally include any of the extended feature set fields, such as pores; creases; ridge edge features; latent substrate, matrix, or processing; analysis assessment (value); or comparison determinations. This version of the *Markup Instructions for Extended Friction Ridge Features* focuses on features that are used for AFIS searches and does not include the additional features used for casework annotation.

EFS Profile 0: Image-Only Profile and EFS Profile 2: Quick Minutiae Search Profile are designed to be common to, and available across, all interoperable systems that are conformant to the *EFS Profile Specification*. Additional optional EFS profiles allow for tradeoffs between examiner markup time and search accuracy, a valuable consideration for systems that can make effective use of the additional features; optional EFS profiles may be implemented by some, but not all, AFIS systems, so use of optional profiles will depend on the specific arrangements between AFIS owners and users, generally defined in a Memorandum of Understanding. EFS profiles are incorporated by reference by ANSI/NIST-ITL (2011) and are fully compatible with the FBI CJIS *EBTS* (2011).

The selection of an appropriate markup strategy allows the examiner to make effective use of the time necessary to mark features that are commensurate with the search accuracy needs for a specific case. Following the initial scanning or entry of the latent image, the examiner assesses the level of detail required for a successful search, based on the data content and quality as well as on the importance of the specific case at hand. The level of detail is used to select the appropriate search profile and its corresponding markup requirements. For example, image-only searches may be appropriate for low-priority cases that might not otherwise be searched or for backlog reduction. Some agencies may choose to use a “low-hanging-fruit” approach, in which they conduct initial searches using EFS Profile 0: Image-Only Profile or EFS Profile 1: Minimal Markup Profile but only review the first one or two candidates so that easy AFIS hits are made without taking time for examiner markup; if the initial search does not result in a hit, minutiae and possibly other features are marked for a standard minutiae-based search.

If the examiner determines that the latent needs to be searched against another AFIS outside the examiner’s immediate jurisdiction, any system that conforms to the *EFS Profile Specification* accepts searches using EFS Profile 0: Image-Only Profile or EFS Profile 2: Quick Minutiae Search Profile; alternatively (if supported by the interoperable AFIS), the encoding may be modified with additional features for an optional profile selected to maximize search accuracy against another AFIS.

Table 1 provides a cross reference of extended friction ridge features for which EFS Profiles in which they might appear.

Table 1: Extended Friction Ridge Features by EFS Profile

Feature	Field	Mnemonic*	1	2	3	10	11	Special Cases
Region of interest	9.300	ROI	X	X	X			
Orientation	9.301	ORT	X	X	X			
Finger, palm, plantar position	9.302	FPP	X	X	X			
Pattern classification	9.307	PAT	X	X	X			
Cores	9.320	COR	X	X	X			
(no cores present)	9.325	NCOR	X	X	X			
Deltas	9.321	DEL	X	X	X			
(no deltas present)	9.326	NDEL	X	X	X			
Minutiae	9.331	MIN		X	X			
(no minutiae present)	9.334	NMIN		X	X			
Evidence of fraud	9.354	EOF		X	X			
Ridge quality/confidence map	9.308	RQM			X			
Dots	9.340	DOT			X			
(no dots present)	9.346	NDOT			X			
Incipient ridges	9.341	INR			X			
(no incipient ridges present)	9.347	NINR			X			
Distinctive features	9.324	DIS			X			
Ridge flow map	9.310	RFM			X			
Center point of reference	9.323	CPR			X			
Core-delta ridge counts	9.322	CDR			X			
Skeletonized image	9.372	SIM				X		
Minutiae ridge counts	9.333	MRC					X	
Minutiae ridge count algorithm	9.332	MRA					X	
Possible lateral reversal	9.315	PLR						X
Tonal reversal	9.314	TRV						X
Possible growth or shrinkage	9.317	PGS						X

*The term “mnemonic,” rather than “abbreviation,” is used here to maintain consistency with the base standard.

4 Image-Only Searching

Image-only searches require no examiner markup. Image-only searches are conducted with an assumption that accuracy may be lower than for feature-based searches, but they require much less examiner time to prepare each search. The FBI CJIS *EBTS* (2011) Latent Friction Ridge Image Search transaction is an example of an image-only search.

An image appropriate for an image-only search has no obscuring background or multiple impressions and is upright[2] (visually appears to be within approximately ±15° of upright). Large clear impressions are well suited for image-only searches.

[2] This requirement stems from EFS Profile 0: Image-Only Profile having no Region of interest/ROI (field 9.300), which accommodates obscuring background or multiple impressions, nor Orientation/ORT (field 9.301), which accommodates non-upright or unknown orientation.

5 Features for Fundamental Latent AFIS Searches

5.1 Region of interest/ROI (field 9.300)

The region of interest (ROI) is a rectangle or polygon that bounds the area of the original image containing a single friction ridge impression and separates it from the background and any other friction ridge data present in the image. (See figure 1.) Using an ROI is strongly recommended when the overall image contains multiple impressions or when differentiating between the friction ridge detail and the background is difficult.

A region of interest (ROI) delineates a single continuous friction ridge impression. Mark the ROI to include all of the impression being evaluated, while excluding as much as possible of the background and other impressions. If in doubt, be inclusive.

All other features must be within the ROI, with the exception of the Center point of reference/CPR (field 9.323).

An ROI includes only one impression made by a single or contiguous portion of friction ridge skin. For example, an ROI may be limited to a single distal fingerprint or include multiple fingers as part of a single full palm impression but may not include impressions of different fingers that are not connected by a common interdigital impression. Simultaneous impressions or other images containing multiple impressions must mark each impression separately. In the case of overlapping fingerprints, the ROI may include superimposed impressions. There can be only one ROI for a given image.

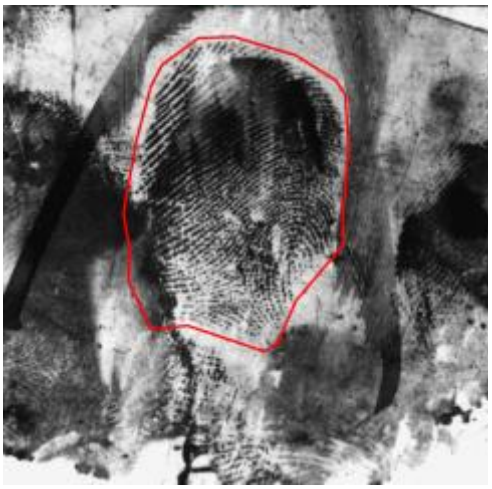

Figure 1: Region of interest.

5.2 Orientation/ORT (field 9.301)

Orientation indicates the direction towards the tips of the fingers. Indicate whether the orientation is upright, unknown, or a specific orientation.

Orientation (ORT) indicates the distal direction towards the tips of the fingers. (See figure 2.) There are three options for indicating orientation: upright, unknown, and specific orientation.

1. ***Upright*** indicates that the impression is upright ("tip up") within about ±15°. This is the default if not otherwise indicated.
2. ***Unknown*** indicates that the orientation cannot be determined.
3. ***Specific orientation*** indicates that the orientation can be determined and the impression is not upright. Specify the orientation. If the orientation is approximate, optional bounds of uncertainty may be indicated.

Although arbitrary rotation of the image is not recommended because of image degradation concerns, rotation of the image in multiples of 90° can be performed without image degradation and is acceptable.

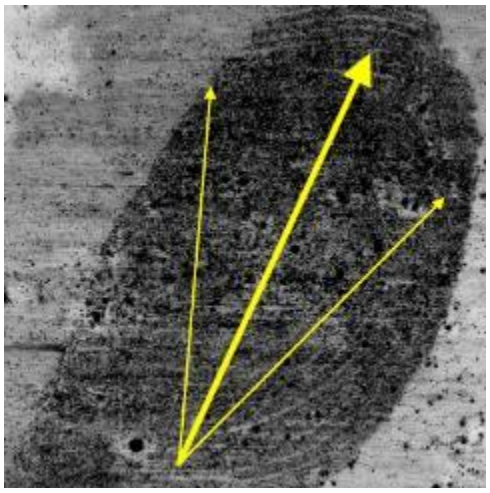

Figure 2: Orientation marked with ±20° uncertainty.

5.3 Finger/palm/plantar position/FPP (field 9.302)

The finger/palm/plantar position indicates the portion of friction ridge skin that created the impression. Note the position only if the source area of friction ridge skin can be determined definitively or limited to a set of positions.

Indicate the area of friction ridge skin that created the print, using the codes from table 2 (fingers, including tips or lower joints), table 3 (palms), or table 4 (plantar impressions).

If the source cannot be definitely determined, indicate any areas that could have been the source of the print. Note that there are different options when the source is unknown. If the physical source of the impression cannot be determined and may be a finger, palm, or plantar, use *unknown source* (18) (as shown in table 5); if some sources may be excluded, use one or more of the position codes *unknown finger* (0), *unknown palm* (20), *unknown sole* (60), or *unknown toe* (63).

These position codes are as defined in ANSI/NIST-ITL (2011), table 8, which specifies additional position codes that are not applicable for EFS markup, such as codes for four finger slap impressions.

Table 2: Position Codes for Fingers (including Tips and Lower Joints)

	Right	Left
Unknown finger	0	
Thumb	1	6
Index	2	7
Middle	3	8
Ring	4	9
Little	5	10
Extra digit	16	17

Table 3: Position Codes for Palms

	Right	Left
Unknown palm	20	
Full palm	21	23
Writer's palm	22	24
Lower palm	25	27
Upper palm	26	28
Other area of palm	29	30
Interdigital	31	34
Thenar	32	35
Hypothenar	33	36
Grasp	37	38
Carpal delta area	81	82
Full palm, including writer's palm	83	84

Table 4: Position Codes for Plantar Impressions

	Right	Left
Unknown sole	60	
Sole	61	62
Unknown toe	63	
Big toe	64	69
Second toe	65	70
Middle toe	66	71
Fourth toe	67	72
Little toe	68	73
Front/ball of foot	74	76
Back/heel of foot	75	77
Arch	78	79

Table 5: Position Code for Unknown Source

Unknown source (may be finger, palm, or plantar)	18

For subjects with extra fingers or thumbs, label the four fingers closest to the thumb with the index/middle/ring/little position codes, label the thumb closest to the fingers with the thumb position code, and label additional fingers with the extra finger position code for the appropriate hand. In the case of conjoined fingers, include the image of the entire conjoined finger by using the finger position closest to the thumb, and use the next finger position for the next fully separable finger. Use the EFS comment field (field 9.351) to describe specifics of the extra or conjoined fingers.

If the image/ROI contains multiple areas, label and mark each of those areas within the ROI with a rectangle or polygon delineating each of the areas.

Rectangles or polygons may overlap if appropriate. If the ROI contains only a single area, such area markup is unnecessary. If the image includes two or more segments of a finger (or substantial portions of two or more segments), mark the image with the finger number (0-10) and mark the individual segments with rectangles or polygons. (See figure 3.) If the image is of a palm (or foot), mark each of the palm areas present with the relevant position code and delineate with a rectangle or polygon. (See figure 4 and figure 5.) Note that the interdigital and hypothenar areas overlap at the base of the little finger.

Figure 3: Use of rectangles to mark multiple finger segments in a latent print with multiple segments.

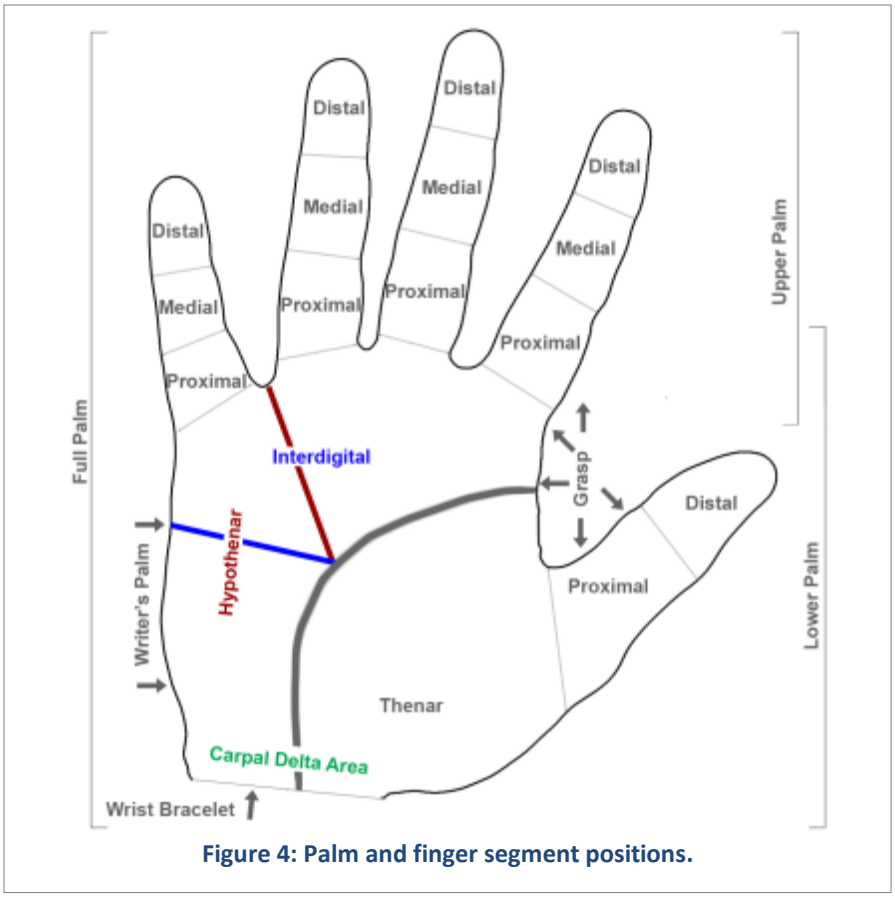

Figure 4: Palm and finger segment positions.

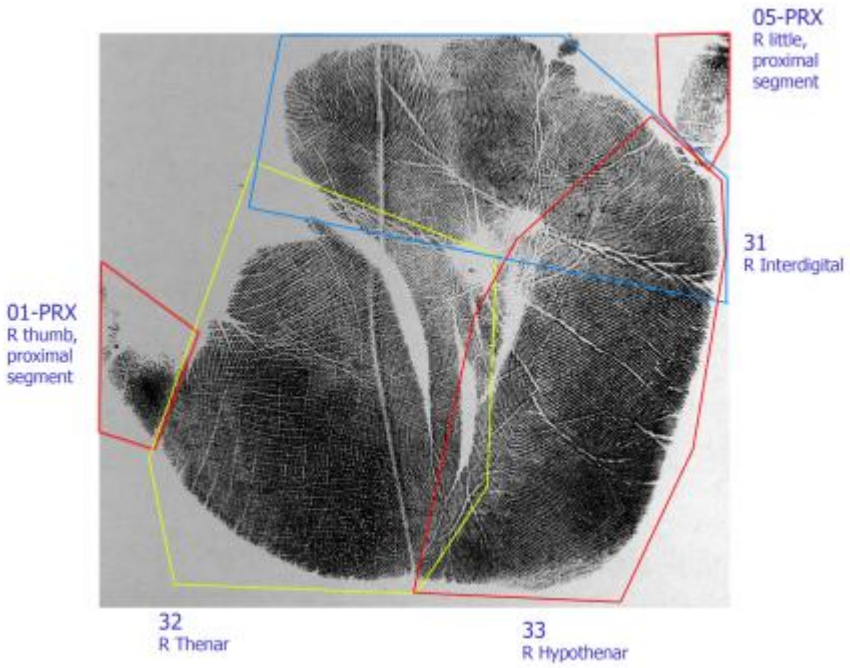

Figure 5: Use of polygons to mark multiple areas within a palm impression.

For fingerprints in which the impression does not contain the central area of the fingerprint (i.e., the core), use the code from table 6 to indicate the off-center position of the fingerprint image. (See figure 6 and figure 7.) Right or left side may apply to any segment of a finger (or thumb); "tip only" applies to the distal segment. Because only one area is present in figure 6, it is not necessary to mark the area with a polygon or rectangle.

Table 6: Off-Center Fingerprint Positions

Name	Code	Description
Tip	T	The plain or rolled extreme tip of the image
Right side	R	The right side of the finger or thumb
Left side	L	The left side of the finger or thumb

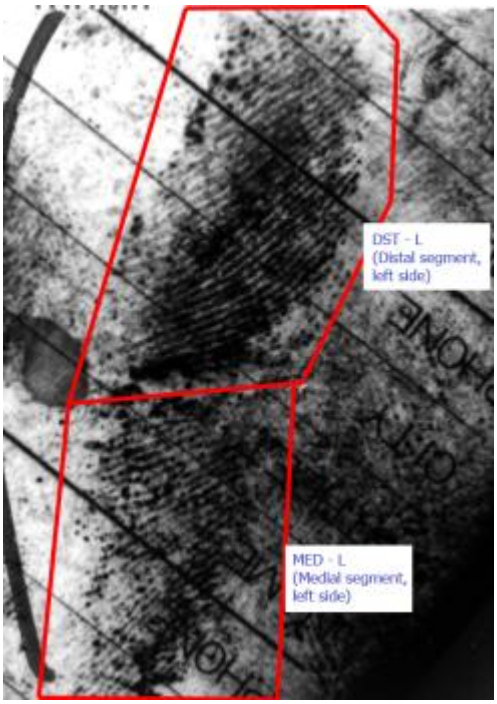

Figure 6: Off-center fingerprint showing left side of finger.

Figure 7: Off-center fingerprint showing extreme tip.

5.4 Pattern classification/PAT (field 9.307)

Pattern classification of fingerprints follows the Henry system. When the pattern classification is noted, take care to be inclusive of all possible pattern classes.

This field contains fingerprint classification information for the image. (See table 7.) This field does not apply to palms, lower joints, extreme tips, or plantar impressions.

Classification must be conservative: if the pattern is known precisely, indicate only a single pattern; however, if there is any doubt as to the precise classification, include all possible patterns. Figure 8 shows an example of ambiguous pattern classification; this latent print should have a pattern classification that includes BOTH right loop and double loop whorl (it is, in fact, a double loop whorl). If the pattern cannot be classified, but a pattern type can be definitively excluded, then indicate that by including all possible patterns. For example, if the image contains a delta, but the image cannot otherwise be classified, then exclude the plain arch.

Table 7: Pattern Classification Codes

	Pattern Classification	General Class	Subclass	Whorl Delta Relationship[3]
Arches	Arch, type not designated	AU		
	- Plain arch	AU	PA	
	- Tented arch	AU	TA	
Whorls	Whorl, type not designated	WU		
	- Plain whorl	WU	PW	I, O, or M
	- Central pocket loop	WU	CP	I, O, or M
	- Double loop	WU	DL	I, O, or M
	- Accidental whorl	WU	AW	I, O, or M
Loops	Right slant loop	RS		
	Left slant loop	LS		
Unable to print	Amputation	XX		
	Temporarily unable to print (e.g., bandaged)	UP		
Unable to classify	Unable to classify	UC		
	- Complete scar	SR		
	- Dissociated ridges/dysplasia	DR		

The field consists of three information items: general class, subclass, and whorl delta relationship.

1. ***General Class*** indicates the basic pattern classifications (arches, whorls, loops).
2. ***Subclass*** indicates the subcategories of the general class, which applies only to arches and whorls. Indicate this information item only if the subclass can be determined precisely or if specific subclasses can be excluded.
3. ***Whorl Delta Relationship*** may optionally be used by a human examiner or automated system to provide the relationship between the deltas in a whorl. Include this information item only for whorls if the subclass is known and only if the whorl delta

Figure 8: Example of ambiguous pattern classification for a latent print.

[3] I = Inner, O = Outer, M = Meeting

relationship can be determined precisely. Set this information item to I (Inner), O (Outer), or M (Meeting), following the Henry guidelines (detailed in *The Science of Fingerprints (SOF),* p. 60). The information item is *Inner* if the ridge emanating from the left delta passes three or more ridges above (inside) the right delta and is *Outer* if the ridge emanating from the left delta passes three or more ridges below (outside) the right delta; otherwise, it is *Meeting*.

Up to seven pattern classifications may be indicated (including subclasses).

Note Complete Scar (SR) and Dissociated Ridges/Dysplasia (DR) if the fingerprint cannot be classified. If the fingerprint can be classified and scar(s), dissociated ridges, and/or dysplasia are present, note the classification(s) in this field. Note the scar(s), dissociated ridges, and/or dysplasia by using Scars and other distinctive features/DIS (field 9.324). Use (if desired) Core-delta ridge counts/CDR (field 9.322) to further subcategorize pattern classification.

5.5 Cores/COR (field 9.320)

The core or cores of a fingerprint are defined for all pattern classifications other than plain arches. (See table 8.) Mark (if desired) cores on tented arches if an innermost recurving ridge is present. Plain or central pocket loop whorls will have only one core if the innermost recurving ridge is circular or two cores if elliptical. A whorl with only one core does not have a defined direction. For plain arches, a Center point of reference/CPR (field 9.323) may be marked instead of marking a core.

Cores are marked at the focus of the innermost recurving ridge. Mark the direction of the core in the direction of ridge flow.

Figure 9: Placement of the core at the focus of the innermost recurving ridgeline, with direction in the direction of ridge flow.

For palmprints, lower joints, or plantar impressions, define core-like patterns by using this field if such structures are present.

The location of a core is at the focus of the innermost recurving ridge: if the curve of the innermost continuous ridge is viewed as a section of a circle, the core is the center of that circle. Note that in EFS, the location of cores differs from that defined in *SOF* to accommodate AFIS interoperability. Figure 9 and figure 10 show examples of core locations. Use (if desired) an optional radius of uncertainty if the location is not known precisely. If the location cannot be determined because of poor clarity or ambiguity of the innermost recurving ridge, size the radius of uncertainty to include other possible locations of the core.

The direction of the core is the direction of ridge flow.

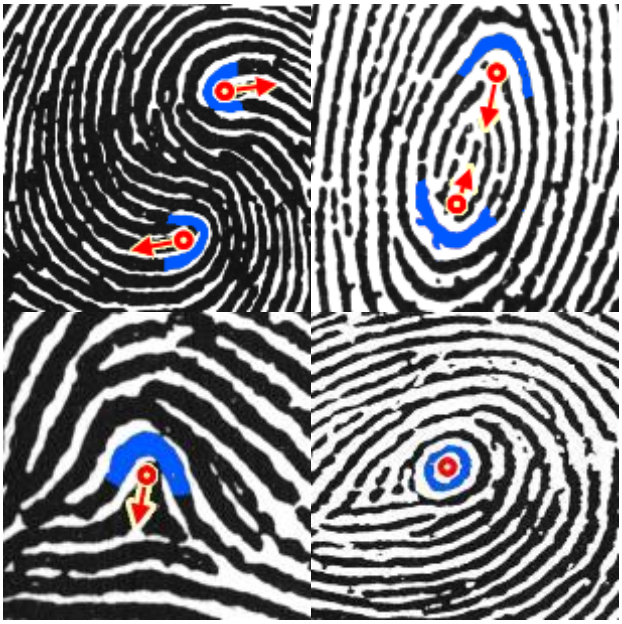

Figure 10: Examples of core locations for a double loop whorl, plain whorl, tented arch, and central pocket loop whorl.

If the core's direction cannot be accurately determined, a range of direction uncertainty may be indicated optionally.

In the special case that the core cannot be seen in the impression but a reasonable estimate of location can be made, it is permissible to mark the core in the approximate location with an appropriately large radius of uncertainty.

Table 8: Maximum Number of Cores and Deltas by Fingerprint Pattern Classification

Pattern Classification		Cores	Deltas
Arches	- Plain arch	0	0
	- Tented arch	0 or 1	0 or 1
Whorls	- Plain whorl	1 or 2	2
	- Central pocket loop	1 or 2	2
	- Double loop	2	2
	- Accidental whorl	Any number	Any number
Loops		1	1

If analysis determines that there are no cores present, that is to be indicated by using No cores present/NCOR (field 9.325).

5.6 Deltas/DEL (field 9.321)

Deltas are marked where the three directions of flow converge, with directions marked in each of the three directions of flow.

The delta or deltas of a fingerprint are defined for loops and whorls. Tented arches may optionally have deltas marked if such a structure is present. Accidental whorls may have any number of deltas. Mark interdigital and carpal deltas for palms, and mark (if desired) delta-like patterns for other areas of friction ridge skin.

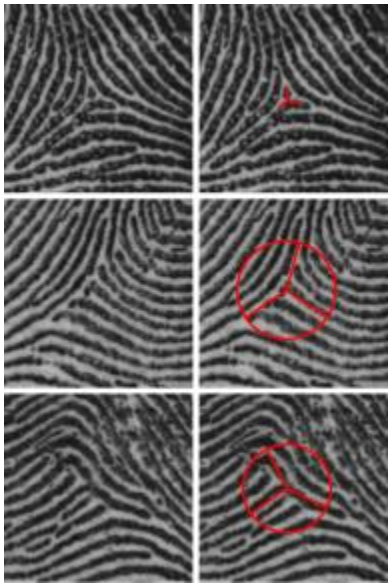

Figure 11: Examples of delta markup, with radii of uncertainty indicated when the delta structure is ambiguous.

The location of the delta is at the center of the delta structure, where the three directions of flow converge. Use an optional radius of uncertainty if the location cannot be determined precisely because of poor clarity or ambiguity of the delta structure. (See figure 11.)

Mark the three directions of the delta in the three directions of ridge flow. When orientation is known, mark the direction closest to upright first, proceeding counter-clockwise. If the directions cannot be determined accurately, define a range of direction uncertainty for each direction. (See figure 12.)

In the special case that the delta cannot be seen in the impression but a reasonable estimate of location can be made, mark the delta in the approximate location (if desired), with an appropriately large radius of uncertainty.

Figure 12: Palm with carpal delta and inter-digital deltas.

Indicate the type of delta when known, as defined in table 9.

If one or more deltas are present and the feature set is from a fingerprint, Pattern classification/PAT (field 9.307) should be defined. This does not mean that the classification has to be known definitively, but must at least be known to the extent of excluding plain arches.

If analysis determines that there are no deltas present, that is to be indicated by using No deltas present/NDEL (field 9.326).

Table 9: Delta Type

Code	Applies to	Name	Description
L	Finger	Left fingerprint delta	The delta to the left of the image for whorls or right loops—for accidental whorls with more than two deltas, this indicates the leftmost delta.
R	Finger	Right fingerprint delta	The delta to the right of the image for whorls or left loops—for accidental whorls with more than two deltas, this indicates the rightmost delta.
I00 I02..I05 I07..I10	Palm	Interdigital delta (with finger number)	The deltas at the base of the fingers in the interdigital areas—note the finger number if known; otherwise, set the number to "00". Thumbs do not have interdigital deltas. Figure 12 shows examples of I07 through I10.
C	Palm	Carpal delta	The delta at the base of the palm where the thenar and hypothenar meet. Figure 12 shows an example.
<empty>	Finger, palm, or foot	Other delta	Any other delta or delta-like structure in a friction ridge impression.

5.7 Minutiae/MIN (field 9.331)

Mark the type of minutiae if clearly identifiable as a bifurcation or ridge ending; otherwise, mark the type as unknown. The locations for bifurcations and ridge endings are equivalent: the placement of a bifurcation at the "Y" of the ridge with the theta angle running down the valley (see figure 13) is determined the same as for a ridge ending at the "Y" of the valley with the theta angle running up the ridge (see figure 15); there would be no difference in location if the image were tonally reversed (black for white). The ridge ending location corresponds with that used for the FBI's Integrated Automated Fingerprint Identification System (IAFIS) and Next Generation Identification (NGI), as well as the *INCITS 378*, (ANSI/INCITS 2004) definition, but differs from some legacy vendor-specific approaches.

Bifurcations are marked at the "Y" of the ridge, with the direction ("theta") running down the valley between the fork of the bifurcation.

Ridge endings or minutiae of unknown type are marked at the "Y" of the valley, with the direction running up the ridge.

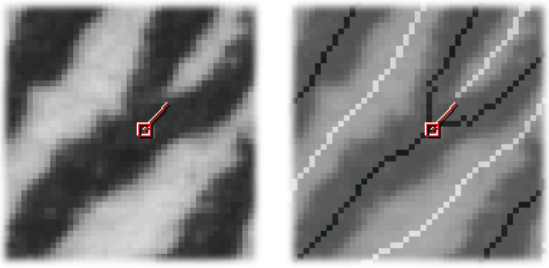

Figure 13: Minutia placement for a bifurcation.

Mark all minutiae in the impression, not omitting short ridges or minutiae near cores and deltas. If a receiving AFIS does not use such minutiae, it is

incumbent on that system to ignore them. See Dots/DOT (field 9.340) and incipient ridges/INR (field 9.341) for instructions on how and when to mark dots.

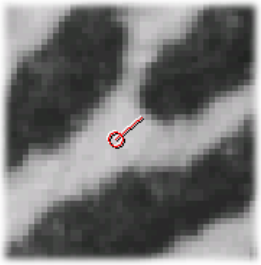

Figure 15: Minutia placement for a ridge ending.

The angle of a minutia may be more difficult than usual to determine when the direction of ridge flow is ambiguous, when the ridges are near the minutiae curve, or when the ridges come together at obtuse angles. In such cases, the angle of a bifurcation is determined by following each of the three ridges forming the bifurcation for a distance of about three ridge widths (1.93mm or 0.064"); the smallest of the three angles formed by the rays is bisected to indicate the minutiae direction. The angle of a ridge ending is determined equivalently, based on following the three valleys that form the ridge ending.

If the precise location for a ridge ending cannot be determined, mark a radius of uncertainty to include the area of possible locations. (See figure 14.) If the type is unknown, indicate the radius of uncertainty.

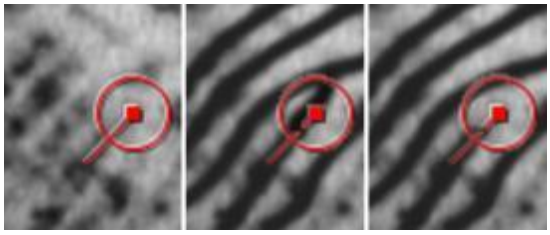

Figure 14: Minutia placement when type is unknown.

Because of the frequency with which minutiae appear to be ridge endings in one impression and bifurcation in another, even in clear images, it is recommended that the minutiae type be used as supporting evidence rather than as a basis for exclusion. Mark all complex minutiae types as combinations of bifurcation/endings; for example, mark a crossover or trifurcation as two bifurcations located closely together.

In many cases, distinguishing among dots, incipients, and ridge edge protrusions is a judgment call. There are two unusual minutiae shown in figure 16: a crossover (at left of the right image, marked in green as a distinctive feature) and a delta-shape minutia (near the core, marked in red with direction uncertainty range).

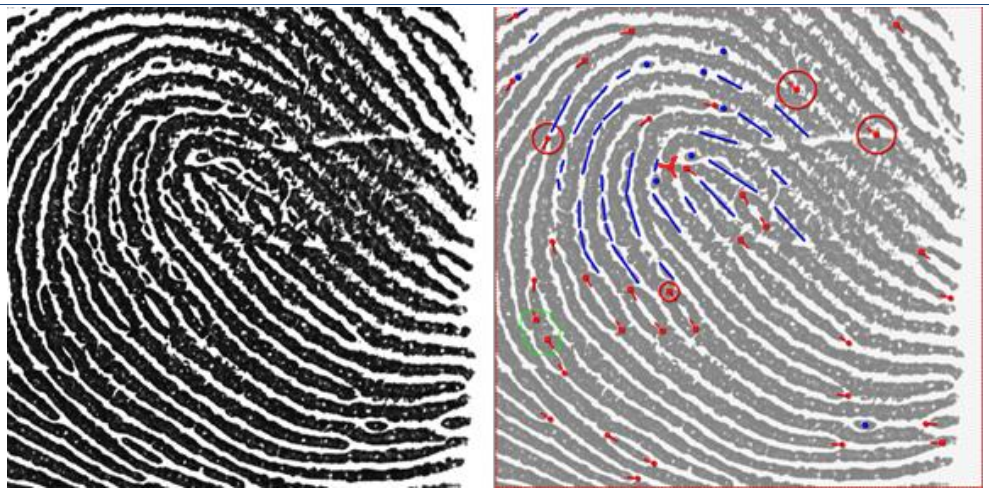

Figure 16: Example of original image and markup of dots (shown in blue) and incipients (shown with blue lines).

If analysis determines that there are no minutiae present, that is to be indicated by using No minutiae present/NMIN (field 9.334).

5.8 Evidence of fraud/EOF (field 9.354)

An examiner should always indicate whenever there is evidence that the image may be fraudulent, regardless of the EFS profile used. A comment must be included to explain what indications of fraud are present. There are four types of fraud: evasion, spoofing, forged evidence, and fabricated evidence.

Note evidence of fraud if there is any indication that the image may be fraudulent. The types of fraud include evasion, spoofing, forged evidence, and fabricated evidence.

1. ***Evasion*** includes actions that prevent/lessen the likelihood of matching, such as by degrading or obscuring physical characteristics or mutilating fingers. Examples are acid balding of fingers or use of a knife or laser to alter the fingerprints.
2. ***Spoofing*** includes purposefully attempting to be identified as a different person in a biometric system by modifying biological characteristics or using fabricated characteristics. Examples are using a rubber finger, gelatin fingerprint attached to a real finger, or image of a fingerprint to fool a biometric reader.
3. ***Forged evidence*** is forensic evidence that was fraudulently placed on the surface from which it was collected, using another mechanism or device than the natural contact with friction ridge skin. An example is using a rubber lifter to move a fingerprint from its actual source to another source.
4. ***Fabricated evidence*** is forensic evidence that never existed on the surface from which it was supposedly collected. An example is a crime scene examiner deceitfully mislabeling the source of images or lift cards.

6 Additional features used in latent AFIS searches

6.1 Ridge quality/confidence map/RQM (field 9.308)

Local friction ridge quality is an assessment of the clarity of each area within an image. The colors and categories are defined in figure 17. Because accurate and consistent markup of ridge quality is essential, follow the guidelines in this section as closely as possible.

Ridge quality can be generated by an automated process with human reviewed/editing, or it can be painted manually by a human examiner.

While automated systems and all examiners should ideally concur on ridge quality markup, in practice individual examiners are likely to disagree at times. An individual examiner may differ and create a different quality assessment that documents what that specific examiner sees in the print.

The ridge quality/confidence map is a standard color-coded means of indicating the clarity of the print. This is the means by which the recipient can determine whether the features marked at a given location are definitive or debatable.

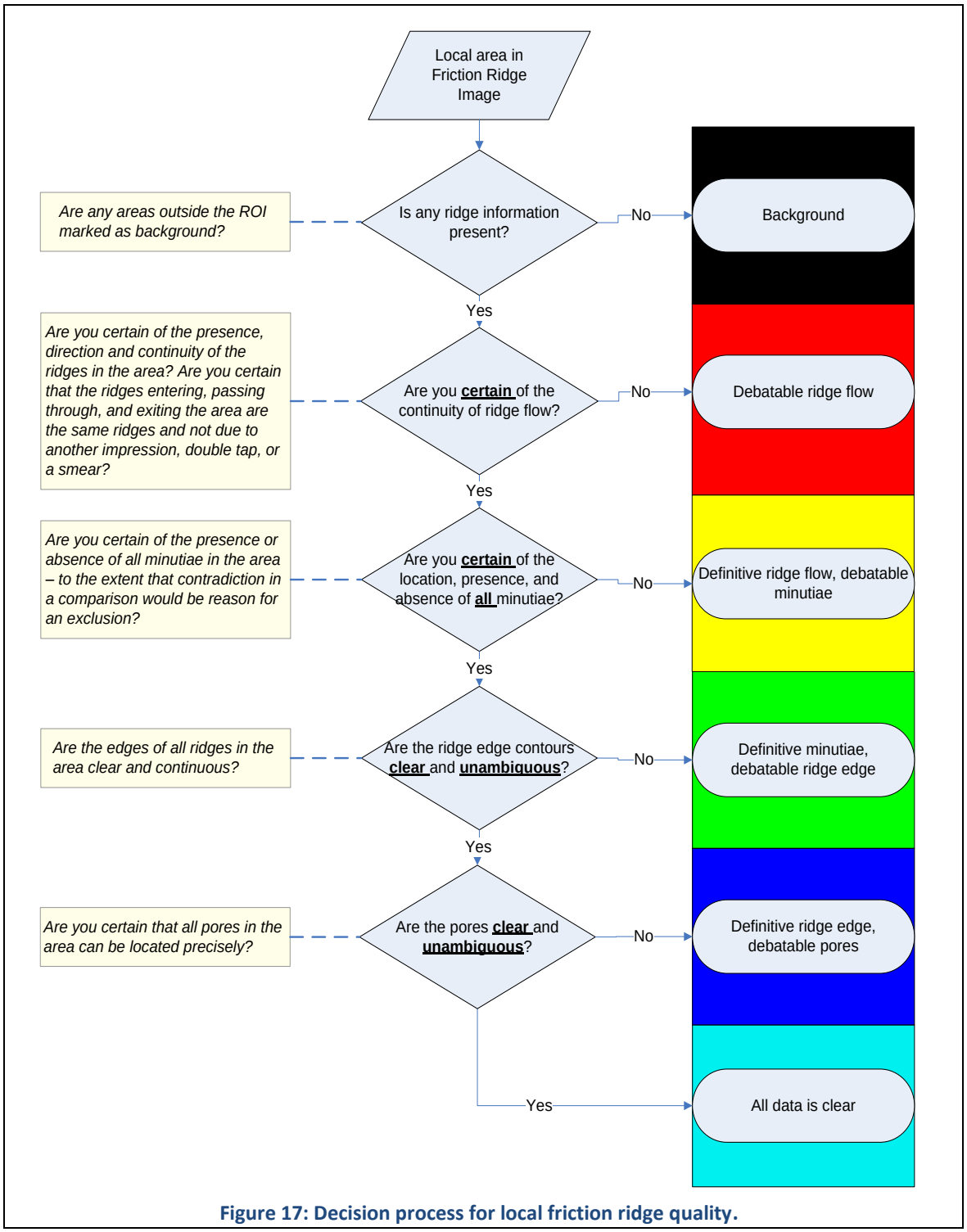

Figure 17: Decision process for local friction ridge quality.

Figure 18 shows examples of ridge quality markup. In a graphical interface in which the quality map is superimposed on the image, these colors are displayed as a semitransparent layer on the image. The images of ridge quality markup allow an examiner (or software program) reviewing the image a straightforward means of assessing the value and data content of the image: large Blue areas are excellent, Green areas are satisfactory, Yellow areas may potentially contain false or missed features, and Red areas are not of value. Automated tools that calculate overall and corresponding quality assessments that are based on the size and continuity of these areas are being developed.

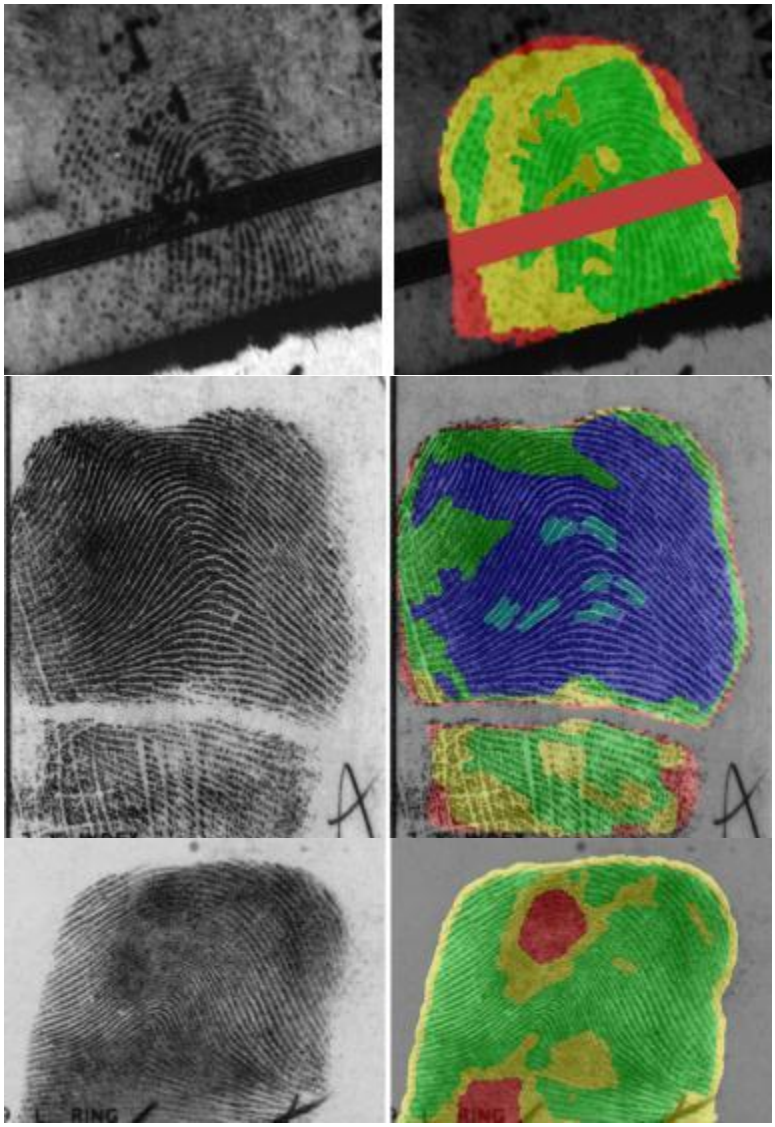

Figure 18: Ridge quality markup on latent and exemplar prints.

The ridge quality map is used to define the confidence in all other features. (See table 9.) In addition, when the quality map indicates a high-quality region in which features are not marked (such as an open field of ridges), that information can be used as "negative features" or definitive absence of features, which may be used as support for exclusion.

Table 9: Ridge Quality Map Values and Their Relation to Feature Confidence

			Ridge flow	Minutiae	Dots	Incipients	Ridge edge features	Pores
Black	0	Background	✗					
Red	1	Debatable ridge flow	?	✗				
Yellow	2	Definitive ridge flow, debatable minutiae	✔	?	✗			
Green	3	Definitive minutiae, debatable ridge edges	✔		?			✗
Blue	4	Definitive ridge edges, debatable pores	✔					?
Aqua	5	All features definitive	✔					

✔	Definitive and unambiguous	Presence, absence, and location are definitive. Contradictory presence or absence of definitive features in a comparison is cause for exclusion.
?	Debatable or ambiguous	Features may be marked, but presence, absence, and location are debatable. Corresponding/contradictory features in a comparison are supporting evidence for individualization/exclusion.
✗	Not discernible or unreliable	Features should not be marked and are ignored if present. No evidence for individualization or exclusion in a comparison exists.

Note particularly two critical distinctions:

- If the presence or absence of minutiae is definitive enough to be used for exclusion in future comparisons, mark the area Green or better; otherwise, mark the area Yellow.
- If the area was left as a single impression with continuity of ridge flow, mark the area Yellow or better; however, if a double tap, movement, or second impression resulted in discontinuous ridge flow, mark the separation between continuous areas with a region of Red.

The following sections provide examples and more detailed explanations of the levels of ridge quality. In each case, if there is doubt as to which level of ridge quality to assign, use the *lower* quality.

6.1.1 Black—Background

Background areas are any areas of the image that are not from the impression of interest. Any of the image outside of the ROI is by definition considered background, including extraneous impressions. When displayed by workstation software or in color-coded images, Black areas may be shown by lack of color, rather than Black per se. (See figure 18.)

6.1.2 Red—Debatable ridge flow

Red areas are those portions of images for which there is some (minimal) ridge information but for which the examiner (or software) has low or no confidence that the ridges in the area are continuous. Indicate those areas of the image that contain ridge data but that are of insufficient quality to use in comparison. These areas are of greatest importance for images with discontinuities, as discussed in the next section. (See figure 19.)

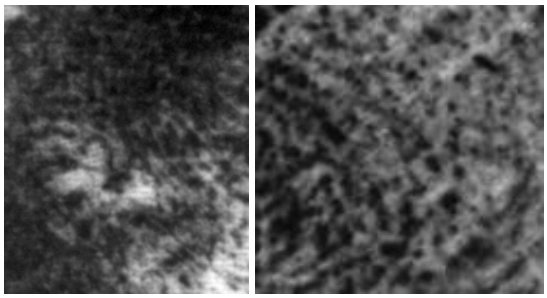

Figure 19: Examples of Red areas—debatable ridge flow.

6.1.3 Yellow—Definitive ridge flow, debatable minutiae

Yellow areas are those portions of images for which the examiner (or software) has confidence in the presence and direction of ridge flow, but the location and/or presence of minutiae are debatable.

Mark an area Yellow, instead of Green, to indicate that marked minutiae are low confidence and that areas without marked minutiae may have undetected minutiae.

Mark an area Yellow instead of Red, to indicate certainty that the area is from a continuous impression. Superimposed ridge detail from two impressions can be marked Yellow only if there is no doubt about the continuity of the ridge detail for the impression of interest. (See fFigure 20.)

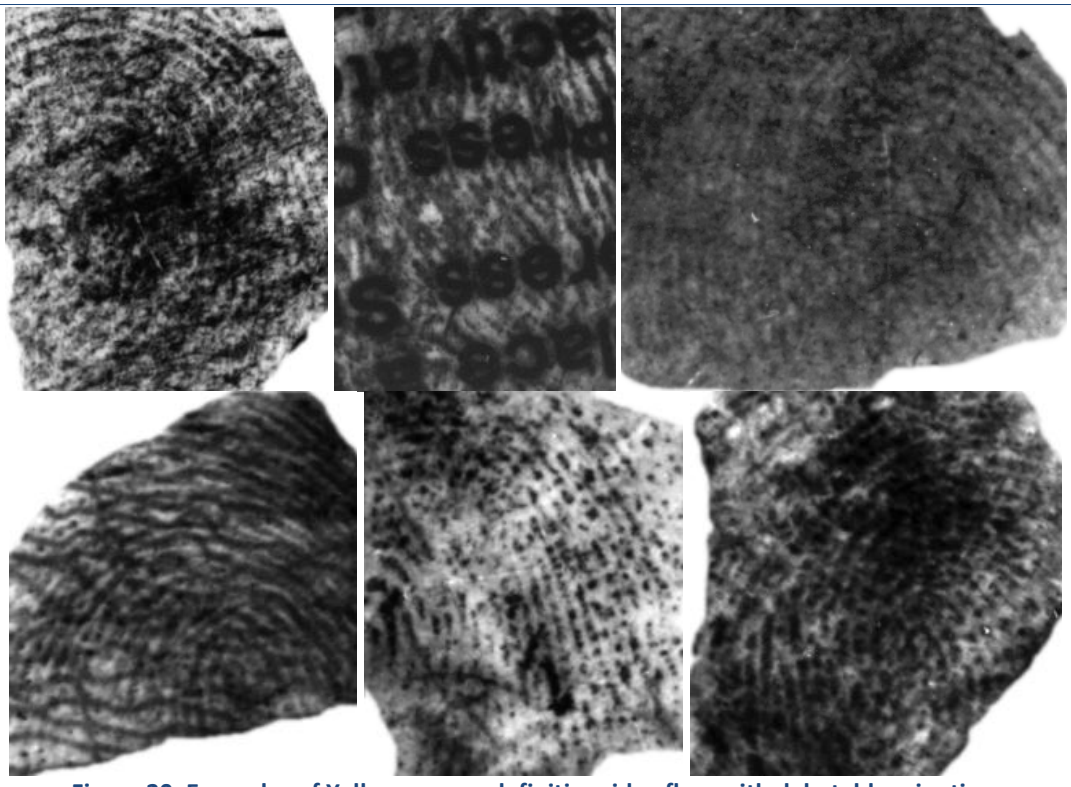

Figure 20: Examples of Yellow areas—definitive ridge flow with debatable minutiae.

6.1.4 Green—Definitive minutiae

Green areas are those portions of images in which there is no doubt that any and all minutiae can be accurately detected, but without clear ridge edges. By assessing an area as Green or better, the examiner (or software) is indicating that the likelihood of false or missed minutiae in the area is remote. Minutiae in Green areas may require limited interpretation. (See Figure 21.)

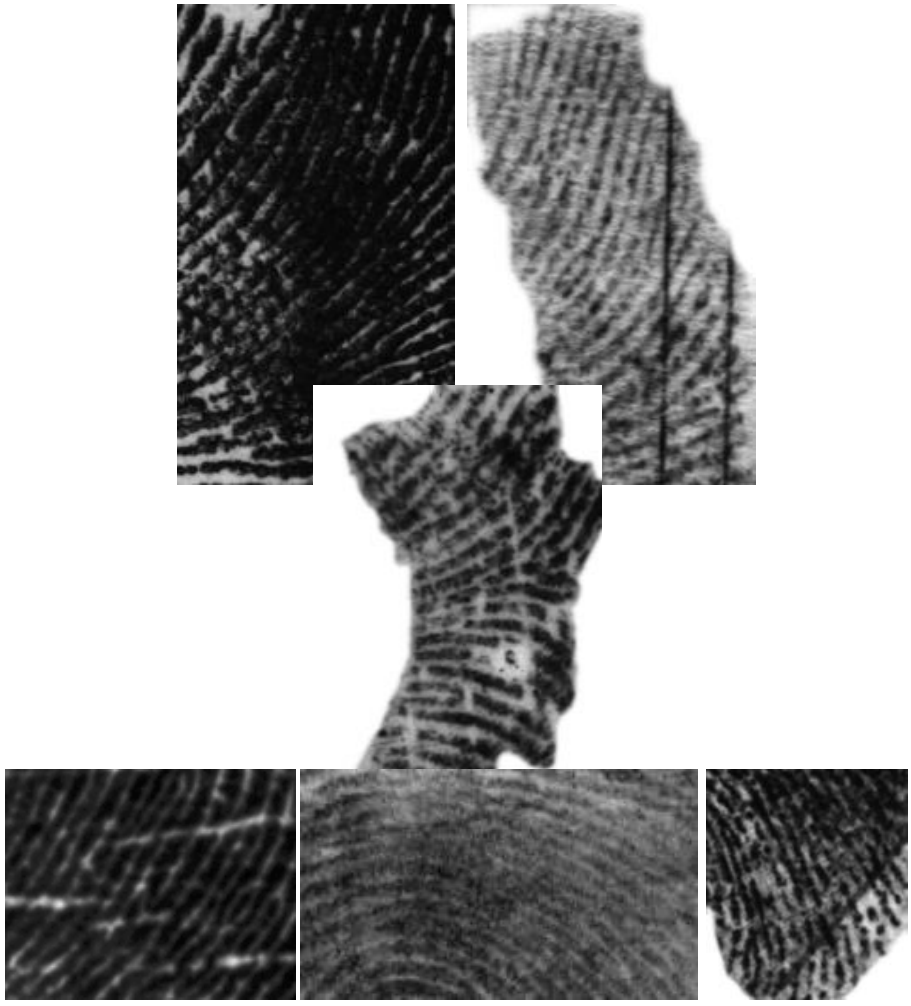

Figure 21: Examples of Green areas—definitive minutiae.

6.1.5 Blue—Definitive ridge edges, debatable pores

In Blue areas, all levels of ridge features other than the pores are not only visible or interpretable but obvious and unambiguous, including the shape and contours of ridge edges, and the shape and precise location of all minutiae, dots, and incipients. *Pores may be*

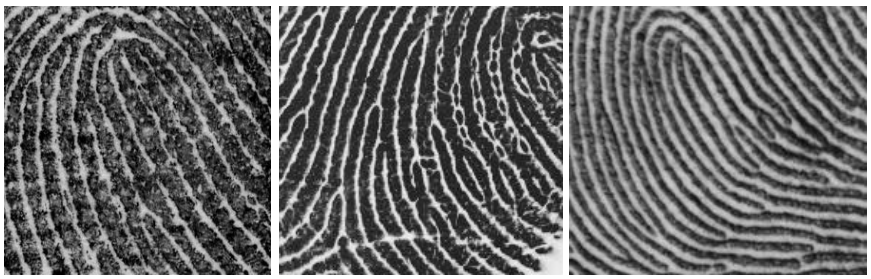

Figure 22: Examples of images with Blue quality—definitive ridge edges with debatable pores.

absent or debatable. Blue areas are common in well-captured exemplars, but much less frequent in latents. (See Figure 22; portions of the leftmost image are Aqua quality.)

6.1.6 Aqua—All features (ridge edges, minutiae, ridge flow, and pores) definitive

In the highest-quality areas, all levels of ridge features are not just visible or interpretable but obvious and unambiguous, including the shape and contours of ridge edges and the shape and precise location of all minutiae, dots, incipients, and pores. Mark Aqua only in the specific areas in which the *pores are obvious and unambiguous*. (See Figure 23.)

Figure 23: Example of print with Aqua quality—All features definitive.

6.1.7 Continuity of ridge flow

Careful marking of ridge quality is most important for images with extensive discontinuities. In an image, such as the one shown in figure 24, limit the analysis of the image to the contiguous areas of Yellow or better. The small separations of Red are critical because those define the problem areas that can cast doubt on comparison decisions. The image contains at least five impressions; impressions other than the one of interest are outside the ROI and, therefore, are considered background. If the multiple prints in this image need to be searched, mark and search each impression separately.

If there is any doubt that two portions of the image are not from a single impression (such as a double tap, smear, or second impression), separate those areas by Red areas.

For minor occlusions, such as printed text or lines, mark (if desired) the area Yellow if the occlusions are thin enough that it is clear which ridges on one side connect to specific ridges on the other side.

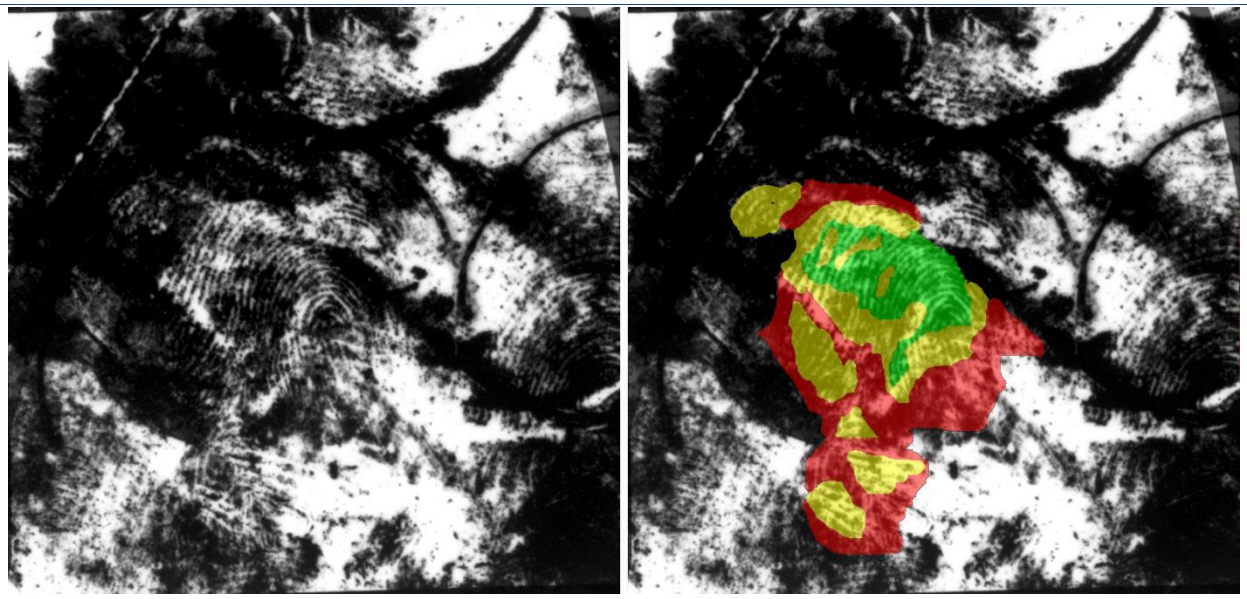

Figure 24: Latent image with multiple discontinuous areas.

6.2 Dots/DOT (field 9.340) and incipient ridges/INR (field 9.341)

A dot is an isolated single ridge unit (ridge that contains a single pore). Generally, the width of a dot is similar to the width of neighboring ridges, and the length of a dot approximates its width.

An incipient ridge is a thin ridge, substantially thinner than local ridge width. Incipient ridges generally do not contain pores. Incipients frequently appear as a series of separate segments.

Often the distinction between a dot, an incipient ridge, and a short ridge is unclear.

- If the feature is similar in width to the local ridge width and at least twice as long as it is wide, mark it as a standard ridge with a pair of ridge endings. If pores are visible, a standard ridge should have at least two pores.
- If the feature is similar in width to the local ridge width, but about as long as it is wide, mark it as a dot.
- If the feature is substantially thinner than local ridge width, mark it as an incipient ridge.

A dot is a very short ridge whose length approximates its width. A dot is marked at its center point.

An incipient is a thin ridge, substantially thinner than local ridge width. An incipient is marked with a line segment along its longest dimension.

If the distinction between a series of dots and an incipient ridge is unclear, it may be marked as one or the other.

Mark a dot at its center point. Mark an incipient ridge with a line segment along its longest dimension. If an incipient ridge is composed of a series of segments, do the following:

- Mark the series as a single line if the segments of the incipient are close together or the separations between segments are indistinct.
- Mark the series as separate incipient ridges if the segments are clearly separate (with distinct lines drawn for each).

If an unbroken incipient ridge curves, mark it as a series of adjoining line segments. In many cases, distinguishing among dots, incipients, and ridge edge protrusions (spurs) is a judgment call. (See figure 16.)

If analysis determines that there are no dots present, indicate that by using No dots present/NDOT (field 9.346). If analysis determines that there are no incipient ridges present, that is to be indicated by using No incipient ridges present/NINR (field 9.347).

6.3 Scars and other distinctive features/DIS (field 9.324)

Mark scars, dysplasia/dissociated ridges, warts, blisters, or other abnormalities that interfere with normal ridge flow as distinctive features. These features are physical aspects of the friction skin itself, not issues specific to the impression (such as smudging). Minor cuts (white lines) that do not affect ridge flow are not considered scars. (See figure 25.)

Scars or other physical abnormalities that interfere with normal ridge flow are marked as distinctive features.

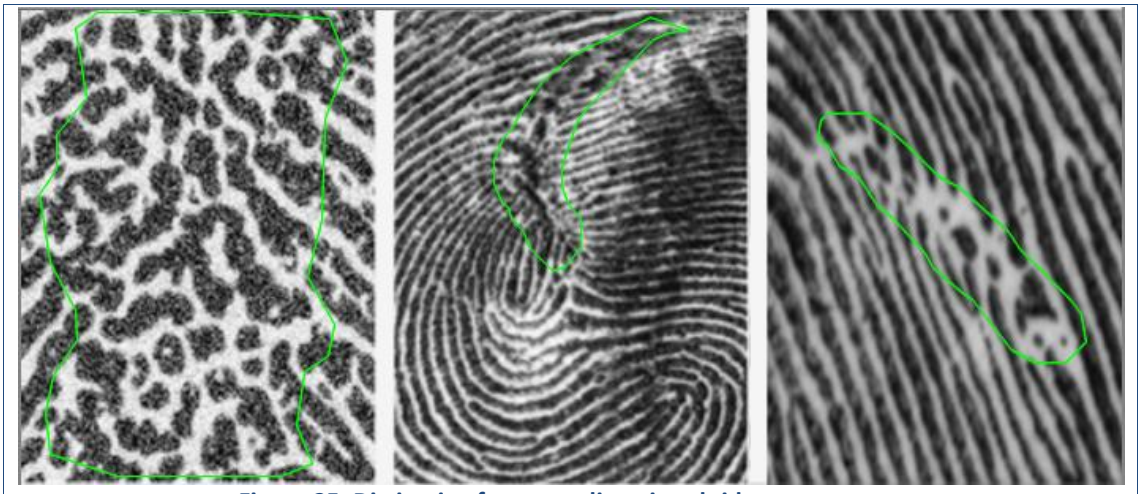

Figure 25: Distinctive features: dissociated ridges, scar, scar.

Enclose the relevant area with a polygon, with the appropriate code from table 10.

When recording the presence of unusual features in this field, mark as part of casework annotation.

Table 10: Types of Distinctive Features

	Code	Description
Physical abnormalities — must be marked	SCAR	Scar
	WART	Wart or blister
	DYSPLASIA	Dissociated ridges/dysplasia
Unusual features — may be marked optionally for casework annotation	MINGROUP	Unusual group or cluster of minutiae
	CORE	Unusually distinctive core area
	DELTA	Unusually distinctive delta area
	MINUTIA	Unusually shaped minutia
	CREASE	Unusually distinctive crease
	CLEAR	Large clear field of ridges; large clear area with no minutiae
	OTHERFEAT	Other unusual features not characterized elsewhere; details should be noted in comments

6.4 Ridge flow map/RFM (field 9.310)

Ridge flow refers to the directional arrangement of friction ridges and is most often used for pattern-level screening of fingerprints. Ridge flow provides more specific detail than pattern classification and can be used more effectively on partial fingerprints. It can be used by AFIS algorithms as an end matcher to refine the candidate list produced by the feature matchers.

The ridge flow map contains the direction of the ridges at various sampling points.

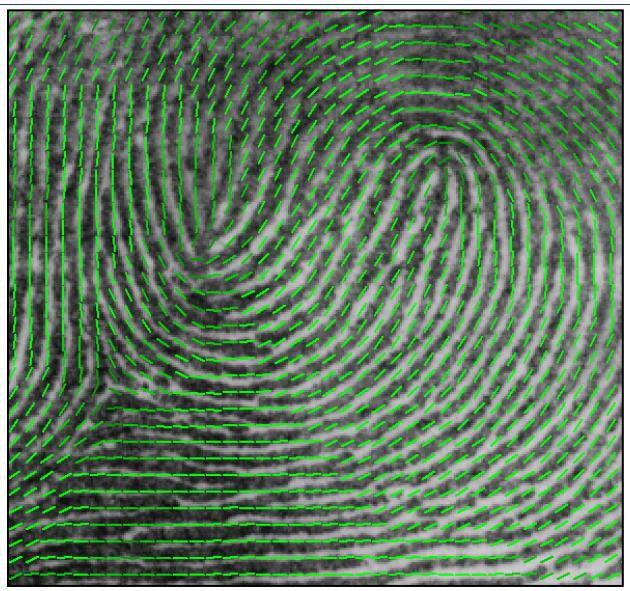

Figure 26: Ridge flow map.

Ridge flow map markup, as shown in figure 26, is typically started using automated tools to extract the flow directions from the image. This automated markup is then corrected by the examiner (if necessary) to correct inaccuracies in the automated flow map. A latent corresponding to the right half of this print would appear to be a left slant loop; ridge flow maps permit rapid automatic comparison of such partial prints, unlike traditional pattern classification.

6.5 Center point of reference/CPR (field 9.323)

This field contains the location of a center point of reference of a fingerprint, which is used to define how centered a fingerprint is, as a feature, for registration or orientation, and for quality measurements. Although the core may serve some of the same purposes, a center point of reference is defined for arches and provides a single center location for complex whorls, unlike cores. The center point of reference does not apply to palmprints.

For fingerprints, the center point of reference is the center of the distal pad of the finger.

For tips or lower joints, the lateral center (centerline of the finger) should be marked.

The center point of reference is the sole EFS feature that can be located outside of the ROI; as such, this allows the estimated center of the finger to be marked even for an extreme side or tip. The center point of reference must be within the bounds of the overall image itself.

The location of a center point of reference can be determined using different approaches. Use the uppermost point of the ridge with greatest curvature approach when practical; otherwise, use an estimate of the approximate center of the distal fingerprint pad, with a radius of uncertainty. For extreme tips, lower joints, or any cases where the center of the distal fingerprint pad cannot be estimated, indicate the lateral centerline of the finger. The workstation software provides a means to indicate which method to use.

Uppermost point of the ridge with greatest curvature

To precisely determine the center point of reference, use the uppermost point of the ridge with greatest curvature. For a fingerprint with a known or estimated orientation, determine the center point by finding the highest point of each ridge that is convex and pointing upward and measuring the curvature/peak angle by following the ridge 1.63mm (0.064in, about 3 ridge widths) in both directions from that point. The point with the minimum angle[4] (greatest curvature) is the center point of reference. (See figure 27.)

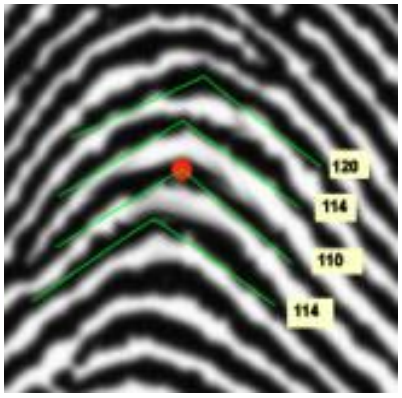

Figure 27: Uppermost point of the ridge with greatest curvature—measurements are angles, in degrees.

Estimate of the approximate center of the distal fingerprint pad

In this approach, estimate the center of the distal pad of the finger by measuring halfway vertically between the distal interphalangeal crease and the tip, and halfway horizontally across the finger. (See figure 28.) This is the center of the physical finger, not the center of the print as seen in the image.

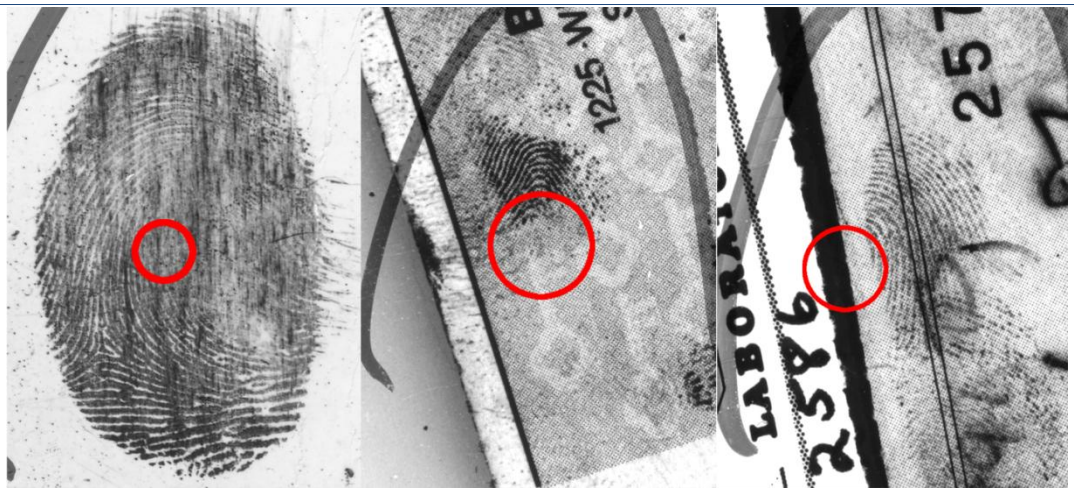

Figure 28: Examples of center point of reference based on an estimate of the approximate center of the finger.

Lateral centerline of the finger

For arches, tips, and lower joints, if the approximate centerline of the finger can be determined, mark the lateral (horizontal) center. The location is not meaningful in the other direction (longitudinally or along the finger). Lateral center is only meaningful if the orientation is known or can be estimated; the point marked is the center with respect to the orientation angle. (See figure 29.)

Figure 29: Lateral center example.

[4] This angle need not be an integer value.

6.6 Core-delta ridge counts/CDR (field 9.322)

This field contains the count of intervening ridges between each core and delta. Each ridge count can be set as an exact value, or minimum and maximum values can be specified. If the exact value is known, then that value should be put in both the minimum and maximum fields. (See figure 30. For details on ridge counting, see 6.8, Minutiae ridge counts/MRC (field 9.333) and Minutiae ridge count algorithm/MRA (field 9.332).)

For loops and whorls, note a count of intervening ridges between each core and delta. If the exact count cannot be determined, define a range or minimum.

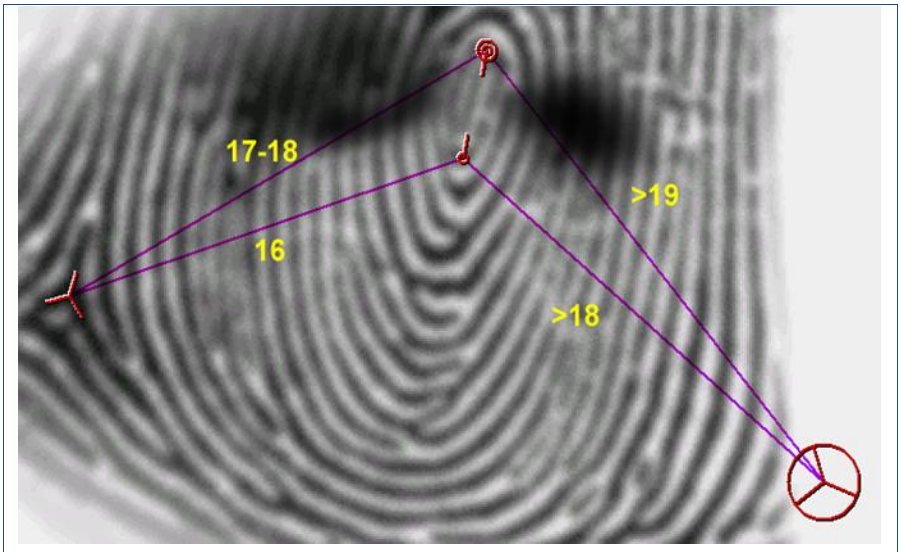

Figure 30: Core/delta ridge count example.

6.7 Skeletonized image/SIM (field 9.372)

The skeleton, also known as a ridge tracing, is a representation of the ridge structure of the print in which the thinned skeleton follows the midpoint of each ridge. Incipient ridges, dots, ridge discontinuities, and protrusions are not included in the skeleton. (See figure 31.)

When the skeleton is marked, use automated tools to extract an approximation of the skeleton to use as a starting point, or create the skeleton in its entirety. Then edit the skeleton to correct extractor errors and verify that the skeleton is consistent with minutiae markup and consistent with quality markup (if present).

The skeleton is a thinned representation of the ridge structure of the print.

Skeletons may be used optionally when searching some AFIS systems to increase accuracy, at the cost of additional examiner markup time.

- When a skeleton is used in combination with the ridge quality map, mark the skeleton as follows with respect to the ridge quality map:
    - In all areas marked “definitive minutiae” (Green) or better, the skeleton must be complete and unbroken, and the skeleton’s ridges stop only at ridge endings.

- In areas marked “debatable minutiae” (Yellow), the skeleton may be incomplete, and the skeleton’s ridges may stop at locations that do not correspond to ridge endings.
- Any areas of the print that cannot be represented in the skeleton must be marked “debatable minutiae” (Yellow) or worse.

- When a skeleton is used and the ridge quality map is not present, treat the skeleton as if the entire region of interest had been marked using the ridge quality map value of “debatable minutiae” (Yellow). The skeleton may be incomplete, and the skeleton’s ridges may stop at locations that do not correspond to ridge endings.

Skeletons are of value in AFIS matching because each ridge segment within the skeleton can be used to show the relationships of the minutiae and other features connected by that ridge, enabling a topological representation of the print.

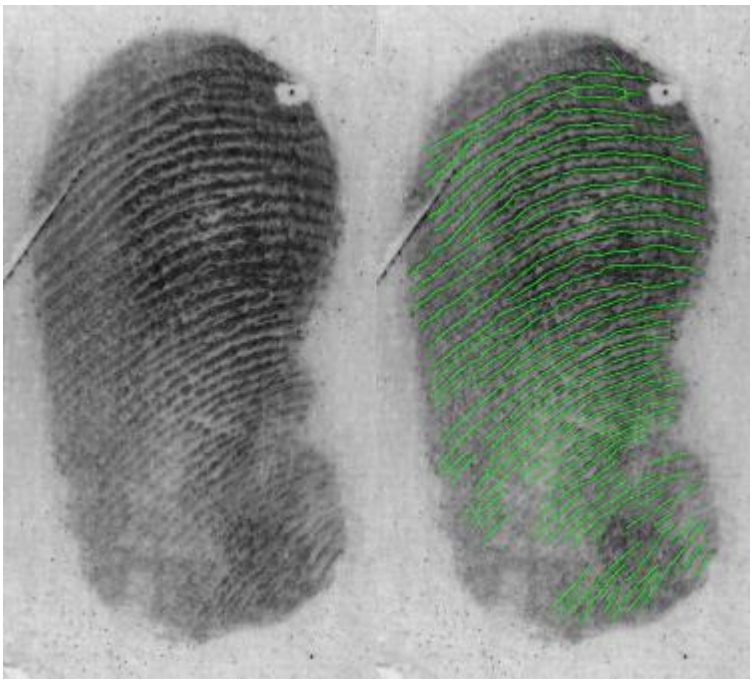

Figure 31: Skeleton marking.

6.8 Minutiae ridge counts/MRC (field 9.333) and Minutiae ridge count algorithm/MRA (field 9.332)

The ridge count is the number of ridges crossed or touched on a straight line between the minutia and each of its neighbors. The count begins at zero at the minutia and increases by one for each ridge crossed, not including the ridges that form either of the endpoint minutiae. For example, if one of the minutiae is a bifurcation and if the straight line passes through one of the ridge segments forming the bifurcation, the latter is not counted. (See Figure 32.)

Two algorithms calculate which neighbors should have ridge counts calculated, based on four or eight neighbors per minutia. (See ANSI/NIST-ITL (2011), table 44.) Set Minutiae ridge counts/MRC (field 9.333) and Minutiae ridge count algorithm/MRA (field 9.332) accordingly.

Ridge counts indicate the intervening number of ridges between minutiae.

Use ridge counts optionally when searching some AFIS systems to increase accuracy, at the cost of additional examiner markup time.

Because of the curving of ridges, the straight line between a minutia and its neighbor might cross a ridge twice (or more). Do not count the additional crossing unless the straight line first passes through at least the center of an adjacent valley. Do not count a ridge unless the straight line passes at least to the center of the ridge.

Specify the ridge count as unknown when it is not possible to estimate or determine the ridge count within plus-or-minus one ridge.

In addition, EFS ridge counts[5] do not have an upper bound.

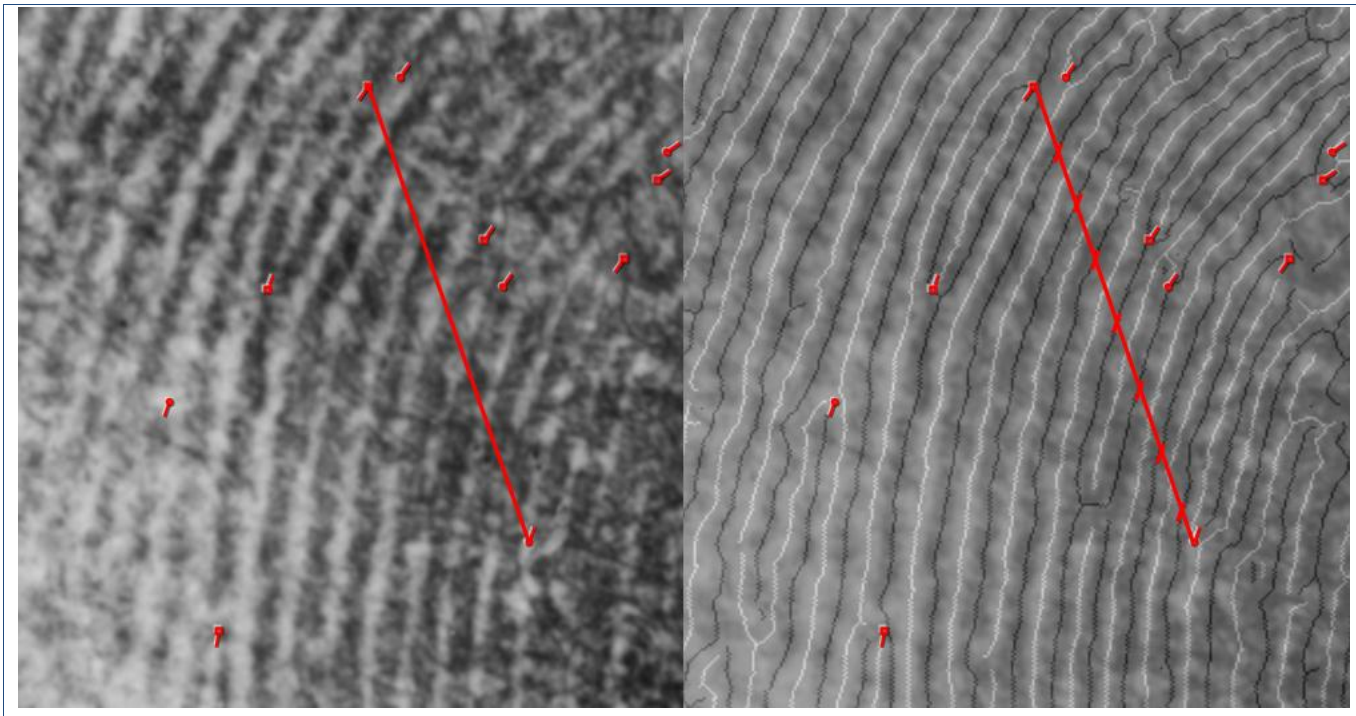

Figure 32: Minutiae ridge counts—The count of intervening ridges in this case is 7 and does not include the ridges that form either of the endpoint minutiae.

[5] EFS ridge counts differ from ridge counts used by IAFIS, which limits ridge counts to 13, in that the count is of the intervening ridges, not the intervening number + 1. NGI does not use ridge counts.

7 Features used in special cases

7.1 Possible lateral reversal/PLR (field 9.315)

If the impression is or may be laterally reversed (i.e., flipped left for right, such as in some prints on transparent tape), note the possible lateral reversal when the image is marked up.

Possible lateral reversal indicates if the impression is or may be flipped left for right.

When the workstation software creates AFIS transactions based on impressions that the examiner indicates are *known* to be laterally reversed, it is the job of the workstation software to build the resulting transaction with the image and features corrected (no longer laterally reversed).

When the workstation software creates AFIS transactions based on impressions that the examiner indicates *may possibly be* laterally reversed, it is the job of the workstation software to create two search transactions, one forward and one flipped, to avoid the complexity/potential confusion of commingling candidate matches for normal and flipped images in a single response. Each of the two transactions results in a separate latent search results transaction.

It is an implementation detail for latent print workstation software to provide the examiner with the ability to generate two search transactions, either manually or automatically. The field is used for the examiner to indicate to the workstation software that two mirror-image search transactions must be created, but the Possible lateral reversal/PLR field (field 9.315) is not included in the actual search transactions sent to an AFIS.

7.2 Tonal reversal/TRV (field 9.314)

Tonal reversal indicates if all or part of the image is reversed tonally (black for white).

Ridges in friction ridge images are generally represented as dark areas with valleys as light areas. This field indicates whether all or part of the image is reversed tonally (black for white). Options include Negative (ridges are light and valleys are dark throughout the image) or Partial (ridges are light and valleys are dark only in portions of the image). (See ANSI/NIST-ITL (2011), table 36.) Tonal inversion can occur for reasons, such as processing method, imaging method, or heavy pressure.

When this field is set, the image in the transaction is saved as it was originally received (i.e., tonally reversed): setting this field and reversing the image when saving results in inconsistent data. When this field is set, a software user interface may display the tonally corrected image but save the image as originally received with this field set.

7.3 Possible growth or shrinkage/PGS (field 9.317)

Possible growth or shrinkage indicates that the print may have changed size or scale because of growth, swelling, or desiccation.

In the unusual circumstance that the friction ridge impression is believed to have changed size or scale from potential comparisons, such as for deceased subjects with swollen or desiccated skin or for comparison of adult and juvenile prints, indicate such a change in Possible growth or shrinkage/PGS (field 9.317). In these cases, the size of ridges and distances between ridges change to a greater extent than would ordinarily be assumed in comparisons; this field acts as a flag to indicate that greater than ordinary dimensional variation should be expected in

performing subsequent comparisons. Options include Growth (impression is believed to be dimensionally larger than exemplars or other prints from the same subject), Shrinkage (impression is believed to be dimensionally smaller than exemplars or other prints from the same subject), or Both (may be either Growth or Shrinkage). (See ANSI/NIST-ITL (2011), table 38.)

8 Terminology

Bifurcation	The point at which one friction ridge divides into two friction ridges
Core-delta ridge counts	A count of intervening ridges between a core and a delta, applies only to loops and whorls
Creases and linear discontinuities	Major creases, or permanent flexion creases: the named creases that separate the joints of the fingers and divide the palm
	Minor creases, or cracks, cuts, and thin or nonpermanent scars: collectively called linear discontinuities
Distal segment	The segment of a finger or thumb farthest from the palm
Distinctive characteristic	An area containing unusually discriminating/unique characteristics that cannot be defined adequately using the other features, such as scars
Dot	A single ridge unit
Exemplar	An impression or image of friction ridge skin purposely collected with the knowledge of the subject, a non-latent friction ridge image
Finger/palm/plantar position	The portion of friction ridge skin that created the impression
Friction ridge skin	The skin found on the palms of the hands and soles of the feet
Incipient ridge	A friction ridge not fully developed that appears shorter and thinner in appearance than fully developed friction ridges
Lateral center	The center line of a finger (if it can be determined) for arches, tips, and lower joints
Local quality issues	One or more areas containing localized quality or transfer issues that indicate that the anatomical friction ridge features may not have been accurately represented in the image
Medial segment	The middle segment of a finger, not present in thumbs
Minutiae	Features marked on a latent print, generally used to refer to bifurcations and ridge endings
Minutiae ridge counts	The intervening number of ridges between minutiae
Orientation	The distal direction, towards the tips of the fingers
Pattern classification	The general shape or pattern of the impression
Plantar	The friction ridge skin on the feet (soles and toes)
Pores	Small openings in the friction ridge allowing for secretion of sweat
Profile (EFS Profile)	Sets of EFS features to be used in latent friction ridge (fingerprint, palmprint, or plantar) searches of AFIS systems from different vendors; different EFS Profiles allow for tradeoffs between examiner time and search accuracy
Protrusion	An abrupt increase in ridge width that is not long enough to be called a bifurcation (also known as a spur)
Proximal segment	The segment of the finger or thumb closest to the palm
Region of interest (ROI)	A single continuous friction ridge impression

Ridge edge features	Protrusions and indentations at the edges of ridges
Ridge ending	The termination point of a single, continuous ridge
Ridge flow	The arrangement and direction of adjacent friction ridges.
Ridge flow map	A representation of the direction of ridge flow at sampling points in a grid superimposed over a friction ridge image
Ridge quality	A means by which a user may determine whether all features are definitive or debatable
Ridge path	The path of a single ridge
Ridge segment	A section of a ridge that connects two minutiae so each ridge segment starts and stops either where the ridge intersects another ridge path segment (a bifurcation), ends (a ridge ending), or leaves the region of interest (also known as ridge path segment)
Skeleton	A thinned representation of the ridge structure of a friction skin image in which all pixels are white except for a thinned black skeleton following the midpoint of each ridge (also known as a ridge tracing or skeletonized image)

9 References

ANSI/INCITS (American National Standards Institute/InterNational Committee for Information Technology Standards). 2004. *INCITS 378-2004, Finger Minutiae Format for Data Interchange*. http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI+INCITS+378-2004.

ANSI/NIST-ITL (American National Standards Institute/National Institute of Standards and Technology, Information Technology Laboratory). 2011. *American National Standards Institute/National Institute of Standards and Technology, Information Technology Laboratory: Data Format for the Interchange of Fingerprint, Facial & Other Biometric Information,* 1-2011, NIST Special Publication 500-290. http://biometrics.nist.gov/cs_links/standard/AN_ANSI_1-2011_standard.pdf.

Department of Defense. 2011. *Department of Defense Electronic Biometric Transmission Specification*. Version 3.0, DIN: BIMA-STB-STD-11-001. http://www.biometrics.dod.mil/Files/Documents/Standards/DoD_EBTS_v3_0.pdf.

FBI CJIS (Federal Bureau of Investigation Criminal Justice Information Services Electronic). 2011. *Electronic Biometric Transmission Specification*, IAFIS-DOC-01078-9.3. https://www.fbibiospecs.org/docs/EBTS_v9_3_Final%2012_07_11_clean.pdf.

Federal Bureau of Investigation 1984. *The Science of Fingerprints*; Rev 12-84. Washington, DC: Federal Bureau of Investigation.

ICPO/INTERPOL AFIS (International Criminal Police Organization-International Police Automated Fingerprint Identification System Expert Group). 2011. *Data Format for the Interchange of Fingerprint, Facial & SMT Information*: *INTERPOL Implementation,* 1-2007, Version No. 5.03, May 24, 2011. https://www.interpol.int/Public/Forensic/fingerprints/RefDoc/ImplementationV5.pdf.

NIST-OLES (National Institute of Standards and Technology, Law Enforcement Standards Office). 2012. *Extended Feature Set Profile Specification*. http://www.nist.gov/itl/iad/ig/ansi_standard.cfm.

NIST-OLES (National Institute of Standards and Technology, Law Enforcement Standards Office). 2013. *Latent Interoperability Transmission Specification*. http://www.nist.gov/itl/iad/ig/ansi_standard.cfm.

Prüm. 2008. *Draft Council Decision on the Implementation of Decision 2008/…/JHA on the stepping up of cross-border cooperation, particularly in combating terrorism and cross-border crime*. http://register.consilium.europa.eu/pdf/en/08/st09/st09152-ad01.en08.pdf.

10 Acknowledgments

This document builds upon ANSI/NIST-ITL (2011); therefore text, tables, and figures (see table 11) are borrowed heavily from that document, as well as from the *EFS Profile Specification*.

Table 11: Tables and Figures Reproduced from *ANSI/NIST-ITL* (2011)

Markup Instructions	*ANSI/NIST-ITL*
Figure 2	Figure 28
Figure 4	Figure 3
Figure 5	Figure 30
Table 6	Table 31
Figure 6	Figure 31
Figure 7	Figure 31
Table 7	Table 32
table 8	Table 39
Figure 9	Figure 8
figure 10	Figure 9
figure 12	Figure 32
Table 9	Adapted from Table 40
figure 13	Figure 36
figure 15	Figure 37
figure	Figure 38
figure 17	Figure 27
table 9	Adapted from Table 103
table 10	Table 42
figure 27	Figure 34

The FBI's Universal Latent Workstation, a reference implementation of EFS, was used to create examples for this document, and text in the discussion of ridge counts is derived from its help documentation. The ridge quality map definitions used in EFS were derived from research conducted by the FBI Laboratory and Noblis.

The editors of this document are:

Melissa Taylor
Law Enforcement Standards Office
Office of Special Programs

Will Chapman
Austin Hicklin
George Kiebuzinski
John Mayer-Splain
Rachel Wallner
Noblis
Falls Church, VA

Peter Komarinski
Komarinski & Associates, LLC
Rotterdam, NY

Ellie Abrams
ESA Editorial and Training Services, Inc.
Burke, VA