

University of Debrecen

Faculty of Science and Technology

Institute of Earth Sciences



**Identifying Prospective Areas for the Chatree
Epithermal Gold Region from Airborne Magnetic
Data Using Advanced Analyzing Techniques, with
Interpretative Correlation**

TDK paper

Supervisor
Dr. Tamás Buday
Senior Lecturer

Author
Kanoknapat Pinkaew
BSc in Earth Sciences

TDK paper completion date: 29 november 2024

Debrecen, 2024

Abstract

The Chatree Epithermal Gold Region is recognized as one of Thailand's most important gold prospects, part of which comprises the Akara Gold Mine. To support resource identification and development of the area, Akara Resources Public Company Limited, the mine's operator, has conducted extensive exploration, including airborne magnetic surveys. This study explores the use of magnetic data to enhance the efficiency and accuracy of identifying potential gold deposit zones by integrating automated and manual interpretation methods, aiming to improve exploration practices and provide a practical framework for resource-efficient mineral exploration.

This study aims to identify potential gold prospects in the Chatree Region using the Central of Exploration (CET) Grid Analysis. This method is specifically developed for detecting structurally complex zones, suggestive of epithermal gold deposits. To enhance the visibility of near-surface features and amplify the magnetic signal clarity of the Reduced to the Pole (RTP) magnetic grid, Downward Continuation (DWC) and Automatic Gain Correction (AGC) were applied. The CET Grid Analysis then generated two heat maps, including Contact Occurrence Density (COD) and Orientation Entropy (OE). These heat maps revealed six major and seven minor potential gold prospect zones. Subsequently, geological correlations and lineament interpretations were performed by integrating several filtered magnetic data with established geological knowledge of the region. This integrated approach offers a comprehensive framework for understanding the structural controls of gold mineralization, providing a valuable tool for future exploration in the Chatree Region and serving as the foundation for future studies, encouraging the application of similar integrated methods in other mineral exploration regions.

Statement of Originality

I hereby declare that this bachelor's thesis, titled "*Identifying Prospective Areas for the Chatree Epithermal Gold Region from Airborne Magnetic Data Using Advanced Analyzing Techniques, with Interpretative Correlation*" is the result of my own work. I affirm that I have not plagiarized any material, either in print or electronic form. All sources used have been acknowledged and cited appropriately.

This version of my thesis is submitted exclusively for consideration in the National Scientific Student Conference (OTDK), the National Scientific Student Conference of Higher Education (OFKD), and the 2024 Autumn Student Scientific Conference and has not been previously submitted for any degree or diploma or publication elsewhere.

Signed

Kanoknapat Pinkaew

Date:

Announcement

I would like to express my sincere gratitude to my thesis supervisor, Dr. Tamás Buday, for his invaluable guidance throughout my thesis journey, from initial conceptualization to the final presentation. I am also deeply grateful to Dr. Richard William McIntosh for his insightful recommendations regarding structural geology and geological mapping, which significantly shaped the direction and quality of my research. Their advice and support were instrumental in shaping the direction and quality of my research.

I extend my sincere thanks to the Earth Sciences in Geology Specialization program for providing me with a strong foundation in geology and geophysics, which has been instrumental in this research. The knowledge and skills I gained during my studies at the University of Debrecen, made possible by the generous support of the Hungarian Government through the Stipendium Hungaricum Scholarship, have been invaluable.

I am indebted to Luke Giordanelli, the manager of the academic program, and his team at Seequent, a subsidiary of Bentley System for their generous provision of a 2-week free trial and a 1-month academic license for Oasis Montaj. This software was crucial in conducting my analysis, and I would not finish this study without their kind contributions.

I would like to express my heartfelt thanks to Akara Public Company Limited for granting me access to their airborne magnetic data and providing additional valuable information. I am particularly grateful to Pitch Atayos, Juksana Udomphatthanakul, Rangsiman Jantho, and the entire employee whether geologists and other duties within the Exploration Department of the company for their warm hospitality and support during my internship and studying this thesis. Their guidance and encouragement were invaluable. I am especially thankful to Surachat Munsamai for allowing me to have an access of unpublished documents and Pitch Atayos for his dedication for helping me in navigating complex document collections.

Finally, I would like to express my gratitude for my own perseverance, patience, and motivation throughout this challenging journey. This experience has not only deepened my knowledge but has also fostered personal growth, making me a more resilient and determined individual.

List of Contents

Abstract	ii
Statement of Originality	iii
Announcement	iv
List of Contents	v
List of Figures	vii
Glossary of Terms	viii
List of Abbreviations	ix
Chapter 1 Introduction	1
Chapter 2 Literature Review	2
2.1 <i>Magnetic Surveys for Gold Exploration</i>	2
2.2 <i>Aeromagnetic Surveys</i>	3
2.3 <i>Magnetic Data Processing</i>	4
2.4 <i>Correlation—Magnetic Surveys and Geology</i>	5
2.5 <i>Regional Geological Setting</i>	5
2.6 <i>Local Geological Setting</i>	7
2.7 <i>Gold Mineralization and Magmatic-Hydrothermal Processes</i>	9
2.8 <i>Gold Mineralization and Structural Controls</i>	10
Chapter 3 Methodologies	13
3.1 <i>Introduction to the Study Area</i>	13
3.2 <i>Introduction to the Utilized Aeromagnetic Data</i>	13
3.3 <i>Introduction to the Software and Plugin</i>	14
3.4 <i>Data Processing and Analysis Workflow</i>	15
3.4.1 Reduced to the Pole (RTP)	15
3.4.2 Downward Continuation (DWC)	15
3.4.3 Automatic Gain Correction or Automatic Gain Control (AGC)	15
3.4.4 The Central of Exploration (CET) Grid Analysis	15
3.5 <i>Operational Workflow</i>	19
3.5.1 Automated Analysis	20
3.5.2 Manual Analysis	21
Chapter 4 Results and Discussion	24
4.1 <i>Results of the Automated Approach</i>	24
4.2 <i>Prospect Zone Classification</i>	25

4.3	<i>Geology and Lineament Interpretation</i>	26
4.3.1	Wang Phrong Prospect Zone (WPPZ)	26
4.3.2	Wang Hin Prospect Zone (WHPZ)	26
4.3.3	Chatree Prospect Zone (CPZ)	28
4.3.4	Wang San Prospect Zone (WSPZ)	29
4.3.5	Tha Kham Prospect Zone (TKPZ)	29
4.3.6	Thap Khlo Prospect Zone (TKHPZ)	29
4.3.7	Chon Daen Prospect Zone (CDPZ)	30
4.3.8	Wang Sai Phun Prospect Zone (WSPPZ)	32
4.3.9	Sap Poep Prospect Zone (SPPZ)	32
4.3.10	Ban Dong Suea Lueang Prospect Zone (BDSLPZ)	33
4.3.11	Khlong Huai Na Prospect Zone (KHNPZ)	33
4.3.12	Thai Thung Prospect Zone (TTPZ)	34
4.3.13	Lat Khae Prospect Zone (LKPZ)	35
Chapter 5 Conclusion		36
Bibliography		38
Appendix A		42
Appendix B		46
Appendix C		50

List of Figures

Figure 2.1 Magnetic field strength variations with orientation and location	3
Figure 2.2 Regional geology and Chatree Deposit location	6
Figure 2.3 Chatree Region location within LFB and LPN volcanic belt	7
Figure 2.4 Geological map of the Chatree Region by Akara Resources	8
Figure 2.5 Geological map of the Chatree Region by John Crossing	9
Figure 2.6 Hill's airborne magnetic interpretation of Chatree Region structures	11
Figure 2.7 Hill's lineament interpretation in the Chatree Deposit area	12
Figure 3.1 Satellite images of the study area and mine location	13
Figure 3.2 Fourier analysis of symmetrical and asymmetrical objects	16
Figure 3.3 Intersection points and orientation angles	18
Figure 3.4 Workflow of methodologies and associated parameters	19
Figure 3.5 Flowchart of parameter selection for DWC, AGC, and CET Grid Analysis	20
Figure 3.6 Flowchart of geological correlation and lineament interpretation	23
Figure 4.1 The comparison highlights the automated approach results	24
Figure 4.2 COD and OE heat maps with prospect zones	25
Figure 4.3 Lineament interpretation of WPPZ and WHPZ on RTP grid	27
Figure 4.4 Lineament interpretation of CPZ and WSPZ on RTP grid	28
Figure 4.5 Lineament interpretation of THKPZ and TKPZ on RTP grid	30
Figure 4.6 Lineament interpretation of CDPZ on RTP grid	31
Figure 4.7 Lineament interpretation of WSPPZ and SPPZ on RTP grid	32
Figure 4.8 Lineament interpretation of BDSLPZ and KHNPZ on RTP grid	34
Figure 4.9 Lineament interpretation of TTPZ and LKPZ on RTP grid	34
Appendix 1A Maps showing TMI, RTP, DWC, and AGC images	43
Appendix 2A Maps showing results of Standard Deviation, Phase Symmetry, and Amplitude Thresholding	44
Appendix 3A Maps showing results of Skeletonization, Skeleton to Vector, COD, and OE	45
Appendix 1B Filtered magnetic images: RTP, DWC→AGC, RTP→1VD and RTP→2VD	47
Appendix 2B Filtered magnetic images: RTP→AGC, RTP→1VD and RTP→2VD, RTP→2VD→AGC	48
Appendix 3B Filtered magnetic images: RTP→UPC-100, RTP→UPC-250, RTP→TDR→AGC Cut-off low and RTP→TDR→AGC Cut-off high	49

Glossary of Terms

Bicubic spline algorithm	An interpolating method using cubic polynomials in two dimensions to generate a grid
First vertical derivative	A filter that calculates the rate of change of a field in the vertical direction, providing the amplification of shallow subsurface features
Frequency domain	A type of data representation visualized in form of signal
Gain	The amplification of signal strength applied to a signal
Geomagnetic secular variation	Slow and continuous changes in the Earth's magnetic field over time
Lineament	Any linear features reflecting geological structures
Magnetic domain	A region where the magnetization is uniformly aligned in a specific direction
Micro levelling	A magnetic database pre-processing step to remove short-wavelength inconsistencies in magnetic survey data that generally occur along flight line gradients
Non-maximal suppression	A processing step to thin detected edges by retaining only local maxima
Polynomial leveling	A magnetic database pre-processing step to correct persist mis-ties in magnetic data after tie line leveling by fitting polynomial function into the data to make the data more consistent
Profile	A cross-sectional view or a plot showing variation of magnetic field intensity along a line
Second vertical derivative	A filter that calculates the rate of change of the first derivative, emphasizing rapid changes in the field
Spatial domain	A representation of data visualized in form of image space, represented by a unit of pixel or cell
Tie line leveling	A magnetic database pre-processing step to correct the intersection points between tie lines and transverse lines to observe the difference (mis-ties)
Tilt derivative	A filter that calculates the arctangent of the ratio of the vertical derivative to the total horizontal derivative, resulting in the suppression of strong anomalies and the amplification of weak anomalies
Upward continuation	A filter that calculates the anomaly as though the measurements were taken farther to the subsurface than they actually were

List of Abbreviations

1VD	Fist Vertical Derivative
2VD	Second Vertical Derivative
AADC	Aeromagnetic Automatic Digital Compensator
AGC	Automatic Gain Correction
BDSLPHZ	Ban Dong Suea Lueang Prospect Zone
BSPFZ	Bueng Sam Phan Fault Zone
CDFZ	Chon Daen Fault Zone
CDPZ	Chon Daen Prospect Zone
CET Grid Analysis	Central of Exploration Grid Analysis
CFZ	Chatree Fault Zone
COD	Contact Occurrence Density
CPZ	Chatree Prospect Zone
Cut-off high	High amplitude signals were removed from a grid
Cut-off low	Low amplitude signals were removed from a grid
DMR	Department of Mineral Resources
DWC	Downward Continuation
IGRF	International Geomagnetic Reference Field
KDFZ	Khao Din Fault Zone
KHNPZ	Khlong Huai Na Prospect Zone
LFB	Loei Fold Belt
LKPZ	Lat Khae Prospect Zone
NMS	Non-Maximal Suppression
OE	Orientation Entropy
RTP	Reduced to the Pole
SFB	Sukhothai Fold Belt
SPPZ	Sap Poep Prospect Zone
TDR	Tilt Derivative
TKCDF	Thap Khlo-Chon Daen Fault
TKHPZ	Thap Khlo Prospect Zone
TKPZ	Tha Kham Prospect Zone
TMI	Total Magnetic Intensity
TTPZ	Thai Thung Prospect Zone
UTM	Universal Transverse Mercator
UWC	Upward Continuation
WGS84	World Geodetic System 1984
WHFZ	Wang Hin Fault Zone
WHPZ	Wang Hin Prospect Zone
WPPZ	Wang Phrong Prospect Zone
WSPPZ	Wang Sai Phun Prospect Zone
WSPZ	Wang San Prospect Zone

Chapter 1 Introduction

The Chatree Region, also known as The Chatree Epithermal Low-Sulphidation Gold-Silver Region (Cumming et al., 2008), is one the most important gold prospects located in central Thailand. The area serves as the foundation of a gold-silver mine, currently operating in the name of 'Akara Gold Mine' (formally Chatree Gold Mine), wholly owned by Akara Resources Public Company Limited, a subsidiary of Kingsgate Consolidated Limited. The company has been employing numerous types of mineral exploration methods for identifying gold mineralization prospect areas, including geophysical greenfield surveys such as airborne magnetic surveys, radiometric surveys, and resistivity methods (Kingsgate Consolidated NL, 2004).

Among these exploration methods, my thesis focuses solely on magnetic data, due to the fact that magnetic surveys have been widely used in mineral exploration to identify geological features, such as lineaments, which are often associated with gold mineralization. During my internship at the company in the summers of 2022 and 2023, I noticed that the company's aeromagnetic data was primarily interpreted manually by geologists. While manual interpretation provides valuable geological insights, it is also subject to several limitations, such as time-consuming when analyzing large, high-resolution datasets, human bias, and subtle features that are unnoticed.

This raised concerns about the limitations and motivated me to explore automated techniques that can enhance the efficiency of gold prospect zone identification after the internship. Consequently, automated approaches, such as the Central of Exploration (CET) Grid Analysis and other filters in Oasis Montaj software were introduced in this study. Yet, simply automation processes are not enough. The results must be refined and validated through manual interpretation to ensure geological accuracy and relevance. By combining automated identification with manual analysis, it merges the efficiency of machine-based approaches with interpretive accuracy of human expertise, reflecting a collaborative approach in real-world exploration practices.

The objectives of this study are to identify potential gold prospect zones by analyzing the structural complexities of the Chatree Region's magnetic data using automated methods. Each identified zone is then subjected to detailed lineament analysis, combining automated detection with manual refinement to reconstruct geological structures accurately. Finally, the study examines the relationship between magnetic anomalies and geological features, providing a framework for future exploration initiatives in the region.

This study holds both theoretical and practical relevance for mineral exploration. From a theoretical perspective, it contributes the enhancement of exploration techniques by integrating automated and manual methods. Additionally, this emphasizes how the combined analysis of geophysical and geological data enhances the understanding of subsurface structural structures. By demonstrating the integrated use of these methods, this study provides a clear workflow and a case study that is applicable to other regions with comparable geological settings.

Practically, by employing automated screening to narrow down potential targets and then using manual interpretation of geological-geophysical correlations for refinement, this study effectively increases the efficiency and cost-effectiveness of mineral exploration, prioritizing the most promising zones. This approach allows for more informed decisions, more accurately target gold-bearing areas, and more effective resource allocations, particularly in areas with complex geological settings, as exemplified by the study area.

Chapter 2 Literature Review

2.1 Magnetic Surveys for Gold Exploration

Magnetic surveying plays an important role in gold exploration. The surveys rely on the ability of a rock body to create a magnetic anomaly by altering the Earth's magnetic field locally (Mussett & Khan, 2000). Considering gold exploration, magnetic data is primarily used for identifying lineaments which serve as conduits for the emplacement of hydrothermal fluid along the crustal cracks, or determining volcanic or magmatic activities that might be the host for gold deposits. Several factors must be considered in magnetic surveys for mineral exploration, including magnetic properties, remanent magnetization, location's latitude, source's shape, and orientation (Mussett & Khan, 2000). Each factor will be discussed at the following context.

Magnetic properties can be categorized into four types based on the alignment of atomic magnetization directions within magnetic domains (Mussett & Khan, 2000; Reynolds, 2011). From strongest to weakest, these types of magnetism are ferromagnetism, ferrimagnetism, paramagnetism, and diamagnetism (Reynolds, 2011).

Remanent magnetization refers to how magnetic domains aligned with the Earth's magnetic field at the time of their formation, a phenomenon known as primary remanence. Here, if the remanent magnetic domains align in the opposite direction to the Earth's current magnetic field, this results in a negative anomaly in the survey. Additionally, these magnetic domains can experience changes in orientation due to subsequent alterations, which result in secondary remanence (Mussett & Khan, 2000), leading to the alteration of magnetic responses.

Location's latitude includes the distribution of the magnetic strength across regions associated with magnetic inclination and declination. The magnetic declination plays a crucial role, with the strongest field occurring near the poles and the weakest near the equator (Mussett & Khan, 2000; Reynolds, 2011), because the Earth's magnetic field intersects with the surface vertically at the south and north Pole, and parallelly at the equator. The magnetic inclination, on the other hand, does not directly affect the magnetic strength, but alters the real position of rock bodies because the magnetic north pole is not aligned with the geographic north (see Figure 2.1).

Shape of the source can be identified by magnetic field strength distribution. Magnetic strength of a body can be determined by the rise of the value from a direction and the fall of the value to the other opposite direction on line profile. The larger extend with low gradient indicates a large magnetic body, while the smaller extend with high gradient indicates a small magnetic body. This will not be discussed any further, and sheet-like shape, which can be used to determine lineaments will be heavily focused on.

Orientation of the source involves the vectorized direction of the Earth's magnetic field, this giving the vertical direction at the north pole, inclined direction at the mid latitude, and the parallel horizontal direction at the equator. Consequently, the measured magnetic field at the north pole is independent from strike, while the mid latitude might incline into one direction: either north or south depending on the south or north situating. Finally, the equator is strongly dependent from strike, since the magnetic field align parallelly, resulting in less or no N-S trending orientation bodies detected (see Figure 2.1) (Mussett & Khan, 2000). Consequently, any lineaments appear in the equator are barely visible, and some filters are recommended to apply for amplifying the magnetic amplitude.

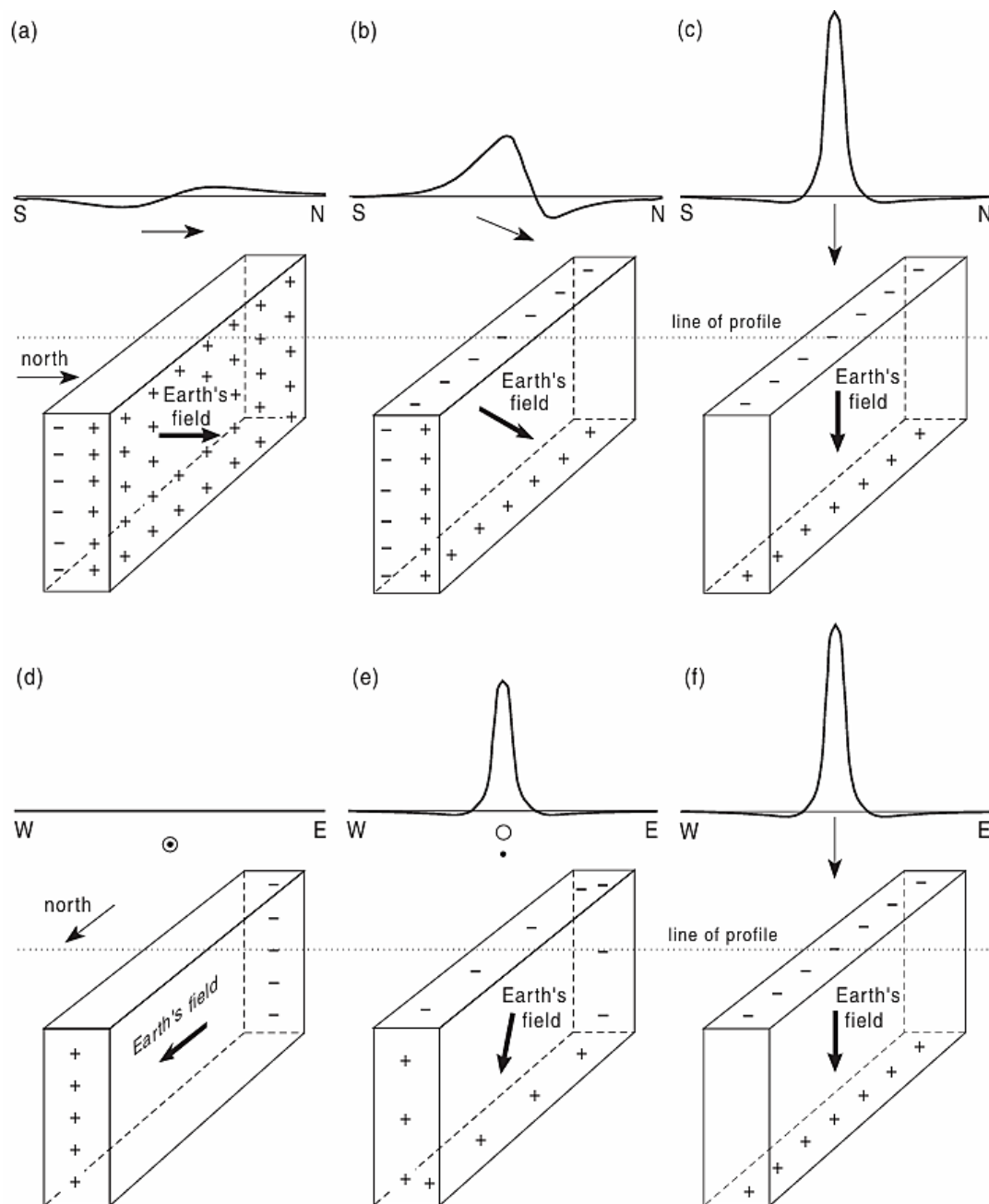


Figure 2.1 The magnetic field strength detected in the survey depends on the rock body's orientation and location. (a) and (d) show a lineament at the equator with E-W and N-S orientations, displaying weak or no field strength. (b) and (e) depict a lineament in the northern latitude with E-W and N-S orientations, showing inclined and weak field strength. (c) and (f) illustrate a lineament at the North Pole, where both orientations display strong and symmetrical field strength (Mussett & Khan, 2000).

2.2 Aeromagnetic Surveys

Aeromagnetic or airborne magnetic surveys are one of the widely used method for mineral exploration. The method is carried out from the air, which able to cover extensive and inaccessible area. The surveys conduct along parallel lines with equal spacing, namely survey or transverse lines, which are crossed cut by tie lines or control lines that having lower frequency line spacing in purpose for error checking (Reeves, 2005).

It is considered to be a cheap and fast method which helps reducing time variations in the Earth's magnetic field variations, particularly in geomagnetic secular variations. However, since the method takes place on a high altitude above the ground, fine details and near-surface geological feature may produce weaker magnetic signals, making it difficult to detect accurately (Mussett & Khan, 2000; Telford et al., 1990).

An aircraft is used for data acquiring, which may have a single or multiple magnetometers attached with it. The magnetometers are mounted whether on from the aircraft's tail known as the stringers, or the front of the aircraft's nose or tail known as the booms, or towed behind the aircraft on a long cable known as the birds. These installed locations are done in purpose to reduce the effect of the aircraft (Reynolds, 2011).

Considering magnetometers, there were two types of magnetometers utilized in the Akara Resources 2004 aeromagnetic survey, including a fluxgate magnetometer and alkali vapor magnetometer (UTS Geophysics Pty. Ltd., 2004), which will be discussed here. A brief explanation of each type is concluded from Mussett & Khan, (2000), Reynolds (2011), and Telford et al. (1990) can be evaluated at the following context.

Fluxgate magnetometers measure the magnetic field component aligned with the magnetometer's axis. They use two parallel ferromagnetic cores wound with coils in opposite directions, creating alternating magnetic fields that cancel each other out unless an external field, like Earth's, disrupts the balance. This disturbance induces a current, indicating the Earth's magnetic field strength along the sensor's axis. These devices are sensitive to orientation changes and requiring precise alignment for accurate readings.

Alkali vapor magnetometers, also known as optically pumped magnetometer or optical absorption magnetometer, measure the total magnetic field strength, and is usually used in aeromagnetic surveys since the surveys require high accuracy and sensitivity. In the device, electrons in an alkali vapor, such as rubidium or cesium, are excited to metastable energy states through optical pumping using circularly polarized light, resulting in transparent vapor. When there's a change in the Earth's magnetic field, the transparency of the vapor changes, which can then determine the field strength.

2.3 Magnetic Data Processing

The raw data gathered from surveys is not immediately applicable due to various disturbances and fluctuations in the Earth's magnetic field, as well as inconsistencies of the surveys. As a result, data corrections are required. Magnetic data processing generally consists of three key stages: pre-processing, gridding, and filtering. Pre-processing involves making adjustments to the database, gridding involves generating a grid by interpolating and gridding the data produced during the pre-processing stage.

Finally, filtering is optionally applied to the grid in order to refine and enhance the data quality or accuracy. As when a grid is acquired, it may require further processing, particularly to correct for the effects of Earth's magnetic field inclination and declination, poorly defined structural trends, or inadequate resolution. Therefore, numerous filters for the enhancements are available to use. However, in this study, only three filters, including Reduced to the Pole (RTP), Downward Continuation (DWC), and Automatic Gain Correction or Automatic Gain Control (AGC) will be discussed further in the Methodology Section.

2.4 Correlation—Magnetic Surveys and Geology

The variations in magnetic strength can reveal several geological features including possible rock types, magnetic mineral content, geological structures such as buried intrusions, faults, or fractures. Therefore, understanding geological features can enhance the identification of potential mineralization impacts. By accurately interpreting subsurface geological structures, we can better predict areas of interest for mineral exploration and assess their potential for valuable deposits. Consequently, the subsequent sections will be discussed on a detailed evaluation of the geological conditions and features of the study area. This includes regional and local geological setting and gold mineralization associated with magmatic-hydrothermal processes and structural control.

2.5 Regional Geological Setting

The Chatree Region is situated within N-S trending of the Loei Fold Belt (LFB), positioning between the Loei and Nan Sutures, next to the Sukhothai Fold Belt (SFB) to the west (see Figure 2.3), and both fold belts separate the Indochina and Shang Thai or Sibumasu to the east and west subsequently (Charusiri et al., 2002; Diemar, 1999). The formation and the age are controversial and different on each paper, therefore only tectonic theory from Charusiri et al. (2002) will be evaluated in the latter context. However, the term “Shan Thai” in the study will be replaced by “Sibumasu” given by Metcalfe (1984), because of the inadequate coverage of the region that it was meant to describe (Metcalfe, 2011).

The fold belt was initially formed by the subduction of the Paleotethys Oceanic Plate under the Indochina Terrane, which is later followed by the closure of the ocean between the Sibumasu and the Indochina Terrane, forming the Nakhon Thai Volcanic Arcs on the Indochina Terrane. Due to the roll-back process, this resulted in the local rifting of the Nakhon Thai Block away from the Indochina Terrane. However, as the Indochina Terrane moved towards the Sibumasu Terrane in the same direction as the Nakhon Thai Block rifted away, leading to the collision of the volcanic island arc block and the terrace, resulting in Au-Cu-Fe deposits. Simultaneously, three collision events were taking place around the same period of time, including the subduction of the Nakhon Thai Block under the Indochina Terrane, the subduction of the Lampang Chaing Rai block (a volcanic island arc resulted by the subduction of the Paleotethys Oceanic Plate under the Sibumasu Terrane) under the Sibumasu Terrane, and the closure of the Paleotethys Ocean as the two volcanics arcs collided, which leading to the formation of the LFB and SFB subsequently (see Figure 2.3).

The LFB extends from northern Laos, through Leoi Province, with its central portion located in Phetchabun Province, and its southeastern terminus in Sra Kaeo Province (Salam, 2013). Intasopa (1993) as cited in Salam (2013) suggested that subduction-related magmatism related to the formation of the LFB can be categorized into three main periods: Devonian to Early Carboniferous, Middle Triassic, and Tertiary. The magmatism started from the northern part and ended at the southeastern part respectively.

While precious minerals are found throughout the belt, but gold and other key deposits are concentrated in the central part of the LFB (Salam, 2013). The volcanic rocks along the belts are varied ranging from basaltic to rhyolitic compositions (see Figure 2.2). Highlighting in the Chatree Region area, the volcanic rocks consist predominantly of tuff and agglomerate rhyolite to andesite, and are associated with shallow intrusive rocks such as microgabbro, microdiorite, quartz-diorite, granodiorite, and granite. Additionally, in some areas limestone deposits can be observed indicating shallow marine intrusions (Corbett, 2004b; Jungyusuk & Khositant, 1992; Khositant, 2008).

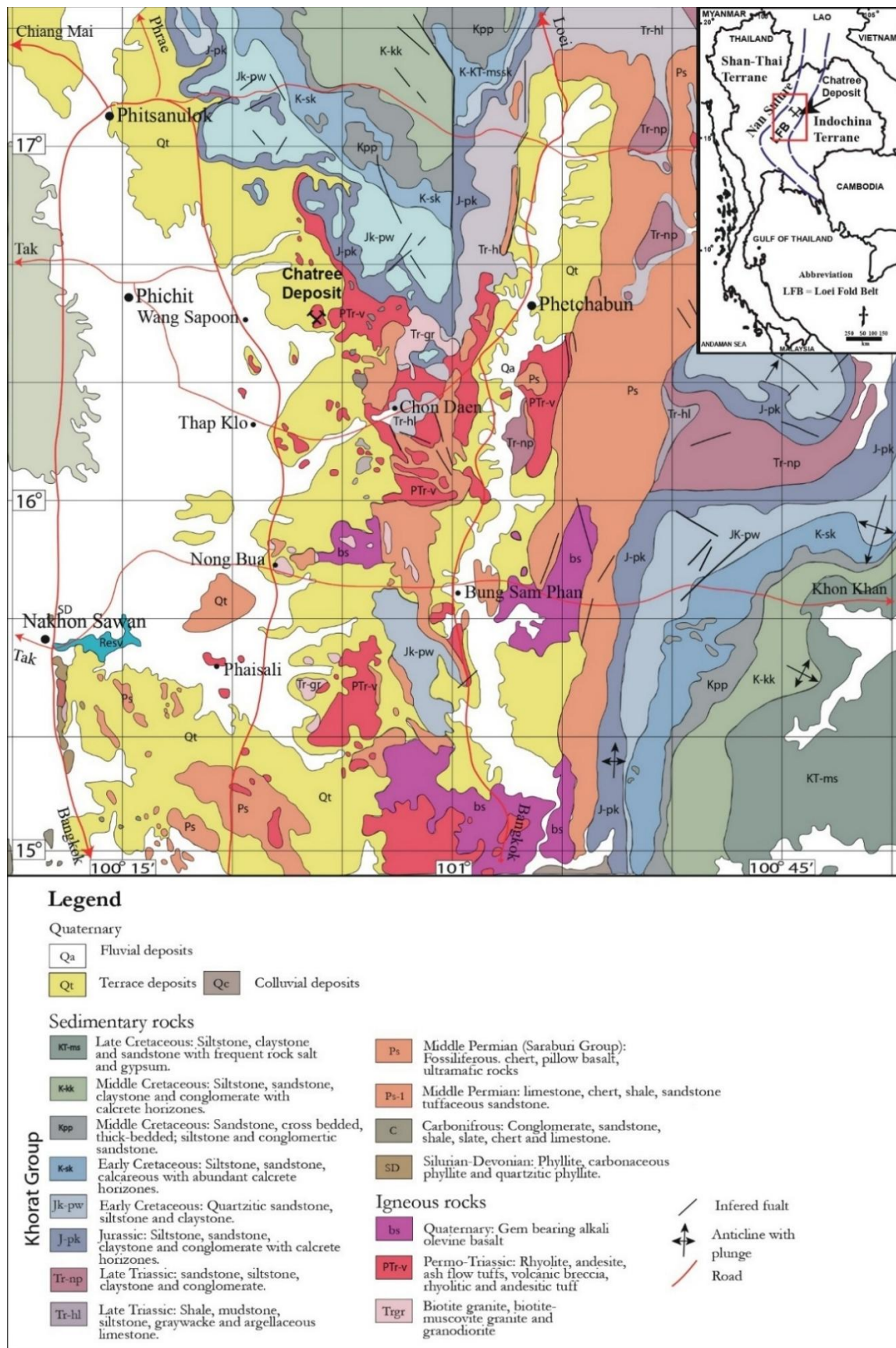


Figure 2.2 Regional geology in the middle part of LFB with the approximate location of Chatree Deposit (Map provided by Salam, (2013) which originally from DMR (1999))

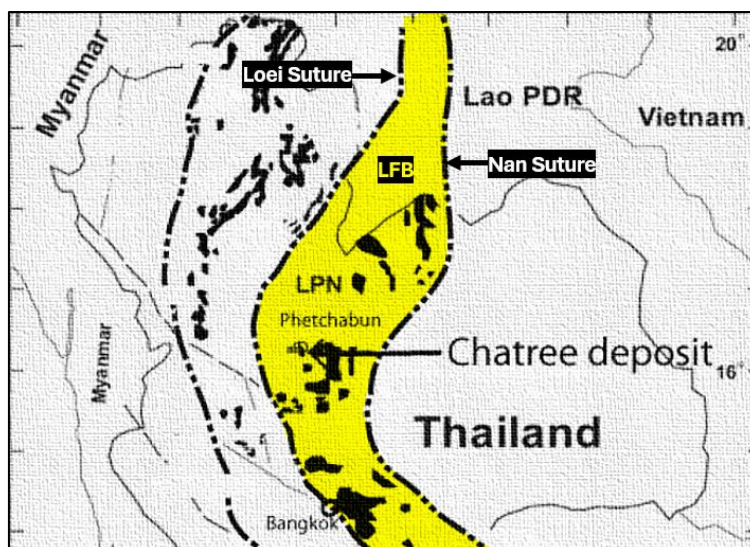


Figure 2.3 Approximate location of Chatree Region situated in the middle part of the LFB (highlighted by yellow). The NTFB is the belt next the LFB to the west (not highlighted) (Modified from Tangwattananukul et al. (2014), that was originally modified from Charusiri et al. (2002) & Cumming et al. (2008)

2.6 Local Geological Setting

Regarding the local geological setting, the structural and lithological features will be examined using two distinct geological maps, one created by Akara Resources Public Company Limited (2009) which mapped by the Akara's geologists, and the other one by John Crossing (2004, 2005, 2006) a consultant previously associated with the company. These maps can be found in Figure 2.4 and Figure 2.5 respectively. Each map offers slightly different interpretations of the geological features, such as the distribution of rocks, rock lithologies, lithological boundaries, and lineaments, with Crossing's map combines the analysis from field observations with Hill (2004a, 2004b) airborne magnetic interpretation, and Akara's map is based on more comprehensive field observations and focuses solely on interpreting the presence of outcrops (P. Atayos, personal communication, 2024a). Therefore, these two maps will be used simultaneously since the Akara's map providing more detailed view of lithology due to more comprehensive mapping, and Crossing's map reveals more structural correlation of the surface and subsurface geology, which collectively contributing a thorough understanding of the study area's geology.

The Chatree Region is located on the eastern edge of the Tertiary Chao Phraya Basin (Diemar, 1999). This area lies within the central LFB, formed predominantly during the Late Triassic period (Charusiri et al., 2002; Jungyusuk & Khositantont, 1992; Salam, 2013). The paleogeological setting of the study area is characterized by a series of stratovolcanoes in a shallow marine setting that scattered along the vicinity of continental margin. The volcanoes initially produced rocks which had basaltic-andesitic composition as the preceding volcanic rock, followed by successive andesitic and rhyolitic eruptions. Subsequently, more felsic intrusions including microdiorite, diorite, granodiorite, microgranite, and granite appeared, with diorite as the most prominent intrusion (Crossing, 2004, 2005, 2006). However, in the Akara's map, the felsic rock lithologies are limited to diorite, granodiorite, syenite and granite (Akara Resources Public Company Limited, 2009).

Considering volcanic sediments, the seaward side was dominated by submarine mass-flow deposits triggered by eruption-related seismic activity. While on the landward side, the volcanic sediments interdigitated with terrigenous sediments. The volcanism produced both lava flows

and pyroclastics, which can be classified into two main types based on the proximity to the volcanic centers, including proximal and distal volcanoclastics. The proximal volcanoclastics (deposited near volcanic centers) consist of rhyolitic to andesitic lava flows, autobreccias, submarine lithic (lapilli) tuffs, crystal tuffs, and ash fall tuffs. While the distal volcanoclastics (deposited far away from the volcanic centers) include finer grained volcanic clastic sediments including epiclastic siltstones, shales, and tuffaceous mudstones (Corbett, 2004b; Crossing, 2004, 2005, 2006).

Other types of sediments may include limestones, floodplain sediments, and Cretaceous-Permian sediments. Limestones developed in areas that were not severely influenced by the volcanic activities or developed between periods of increased activities as they can be observed relatively far away from volcanic centers and interbedded with volcanic deposits (Crossing, 2004, 2005, 2006). Floodplain deposits, on the other hand, were found on the eastern part of the study area, which is characterized by low-lying areas with hilly areas and the Khorat Plateau located nearby, resulting in the proneness to flooding. The alluvial sediments are derived from the hilly regions and predominantly from the Khorat Plateau (Crossing, 2004). All the deposits overlie the Cretaceous-Permian sediments, which include siltstones, shales, chert, and the Eastern limestone (Akara Resources Public Company Limited, 2009; Cumming et al., 2008).

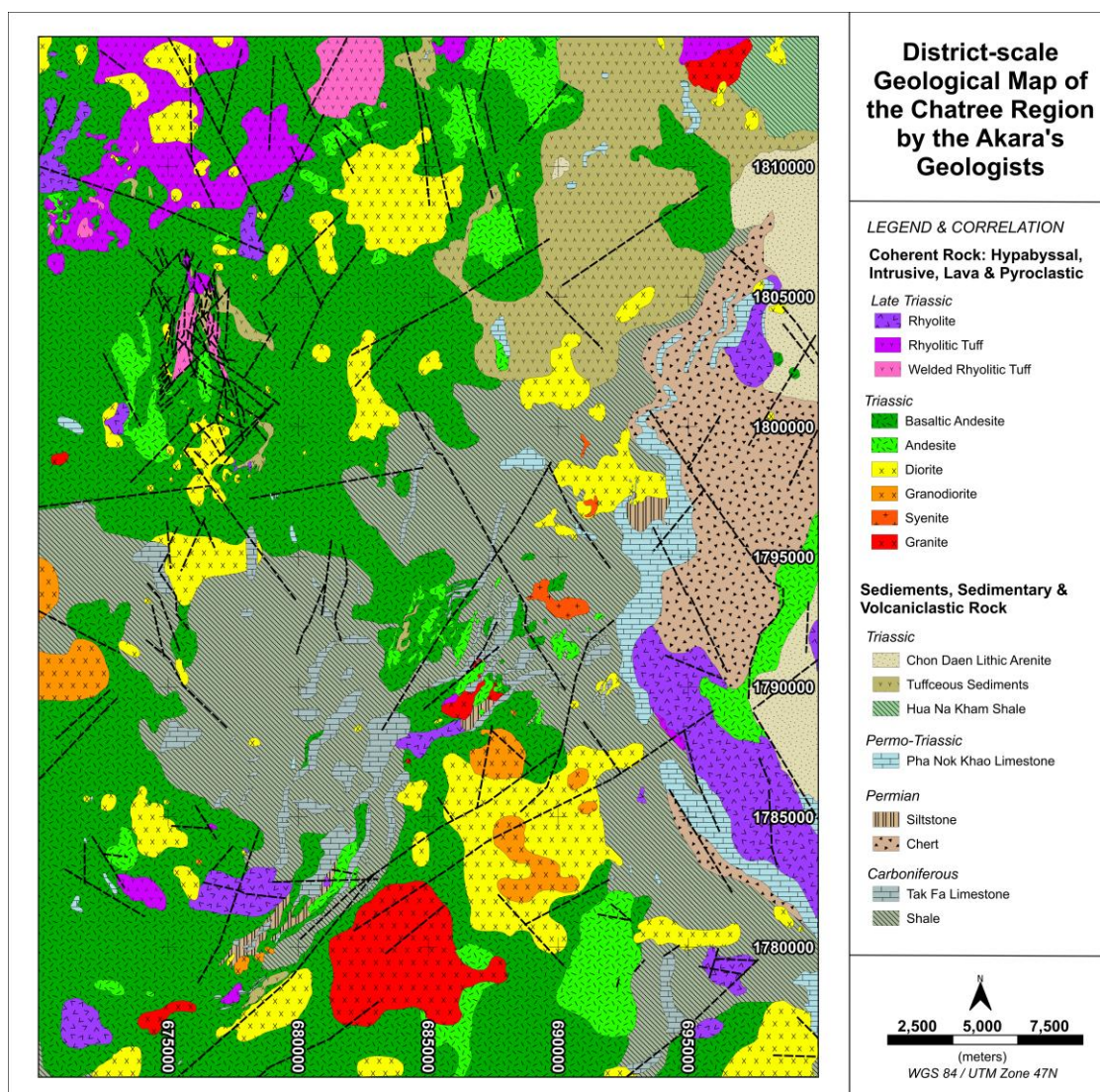


Figure 2.4 The geological map of the Chatree Region Mapped by the Akara's geologists (Modified from Akara Resources Public Company Limited, 2009)

Identifying Prospective Areas for the Chatree Epithermal Gold Region from Airborne Magnetic Data Using Advanced Analyzing Techniques, with Interpretative Correlation

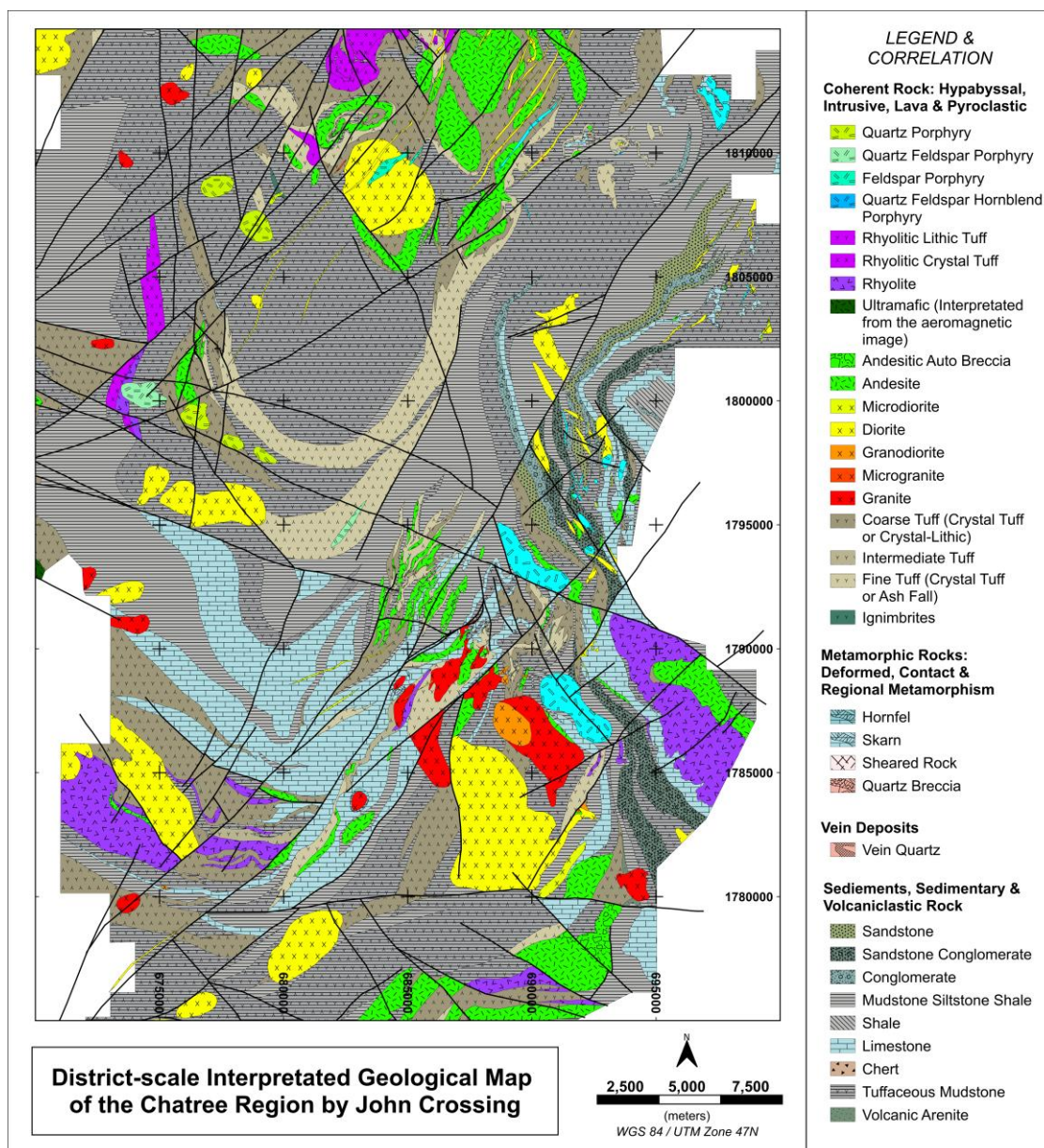


Figure 2.5 Geological map of the Chatree Region Mapped by John Crossing (Modified from Crossing, 2006)

2.7 Gold Mineralization and Magmatic-Hydrothermal Processes

Considering an overview scale of gold deposit types present in the Chatree Region, there are three main types including epithermal low-sulfidation Au-Ag (shallow epithermal and deep epithermal), porphyry Cu-Mo, and skarn Au-Ag (Corbett, 2004a). While in the Akara Gold Mine area, where several more detailed studies have been conducted sophisticatedly, more variations of low-sulfidation style can be observed and classified (Corbett, 2005) which will not be discussed in this study.

Epithermal low-sulphidation (shallow-type) also known as epithermal quartz Au-Ag, is characterized by hydrothermal fluids originating from an intrusive source, migrating to the uppermost crustal levels under the significant influence of structural controls, then getting mixed with meteoric waters that have different composition and significantly lower in temperature compared to the fluids (Corbett & Leach, 1998). Consequently, due to the rapid cooling and dilution of the fluid, this results in high Au grades in the Chatree Region (Corbett, 2004a).

Identifying Prospective Areas for the Chatree Epithermal Gold Region from Airborne Magnetic Data Using Advanced Analyzing Techniques, with Interpretative Correlation

Epithermal low-sulphidation (deep-type) also known as epithermal sulphide Au-Cu is similar to the shallow type, besides the mixing of hydrothermal fluids with meteoric water occur at a deeper crustal level. As a result, the Au grade measured in this deposit type is generally lower than the shallow type (Corbett, 2005). However, this style is prone to supergene enrichment where acidic water caused by the weathering of sulphide minerals mobilizes gold and deposit to another place, leading to localized high anomaly of Au grade in that location (Corbett, 2004a, 2005).

Porphyry Cu-Au style deposits form in volcanic or plutonic arcs within subduction zones triggered by faults developing in the vicinity of arc zones. Cooling of intrusions at shallow levels causes the surrounding rocks to be altered, creating zones of alterations (Corbett & Leach, 1998). These alteration zones exhibit varying magnetic response. Considering potassic alteration, this type of alteration involves construction of magnetite (or pyrrhotite) will exhibit high magnetic response. On the other hand, propylitic, argillic and phyllic involves deconstruction of the magnetic, resulting in low magnetic response. Additionally, on the carapace and the margin of intrusive bodies, magmatic fluids are then exsolved, forming stockwork to sheeted quartz. Despite the fact that Au grades are considered to be low in this style, they may increase if the formation involves groundwater mixing (Corbett, 2004a, 2004b; Corbett & Leach, 1998).

Skarn Au-Ag deposits are directly associated with porphyry style as this style occurs when calcareous rocks, such as limestone come, in contact with plutonic bodies. This contact metamorphism creates alteration zones of skarn (and sometimes hornfels) surrounding the plutonic bodies resembling a halo (Corbett & Leach, 1998). Skarn deposits can be identified by the juxtaposition of low- and high-magnetic anomalies, reflecting the magnetic contrast between skarn and porphyry bodies (Hill, 2004a, 2004b).

2.8 Gold Mineralization and Structural Controls

In this section, the majority of structural interpretations are derived from Hill's (2004a, 2004b) Akara airborne magnetic interpretation, supplemented by Crossing's (2004, 2005, 2006) structural interpretation that based on both field observations and airborne magnetic image and structural interpretations specific to the Chatree Deposit area drawn from (Corbett, 2004a, 2004b, 2005). Together, these sources will be analyzed and discussed collectively in this section to provide a comprehensive overview of the regional structural framework. It is crucial to note that certain terminologies and structure names have been modified to align with the study's context and protect the company's proprietary information.

According to the Hill's (2004b) Akara aeromagnetic image interpretation, there are two major structural zones of the N-S and NE-SW orientation controlling major intrusions and key geological structures in proximity to the Akara Gold Mine (see Figure 2.6). The principal N-S lineaments include the Chatree Fault Zone (CFZ), Wang Hin Fault Zone (WHFZ), Khao Din Fault Zone (KDFZ), Bueng Sam Phan Fault Zone (BSPFZ), and Chon Daen Fault Zone (CDFZ). Four of these fault zones are transected by a younger major NE-SW dextral strike-slip fault known as the Thap Khlo-Chon Daen Fault (TKCDF), which separates the N-S fault zones and major intrusions. As a result, the reconstruction of the regional structure suggests that the CFZ was once continuous with the KDFZ, and the WHFZ was also once part of the same fault zone as the CDFZ, while the BSPFZ is interpreted as an isolated fault. Additionally, these N-S fault zones are seen as they triggered several intrusions as seen in Figure 2.6.

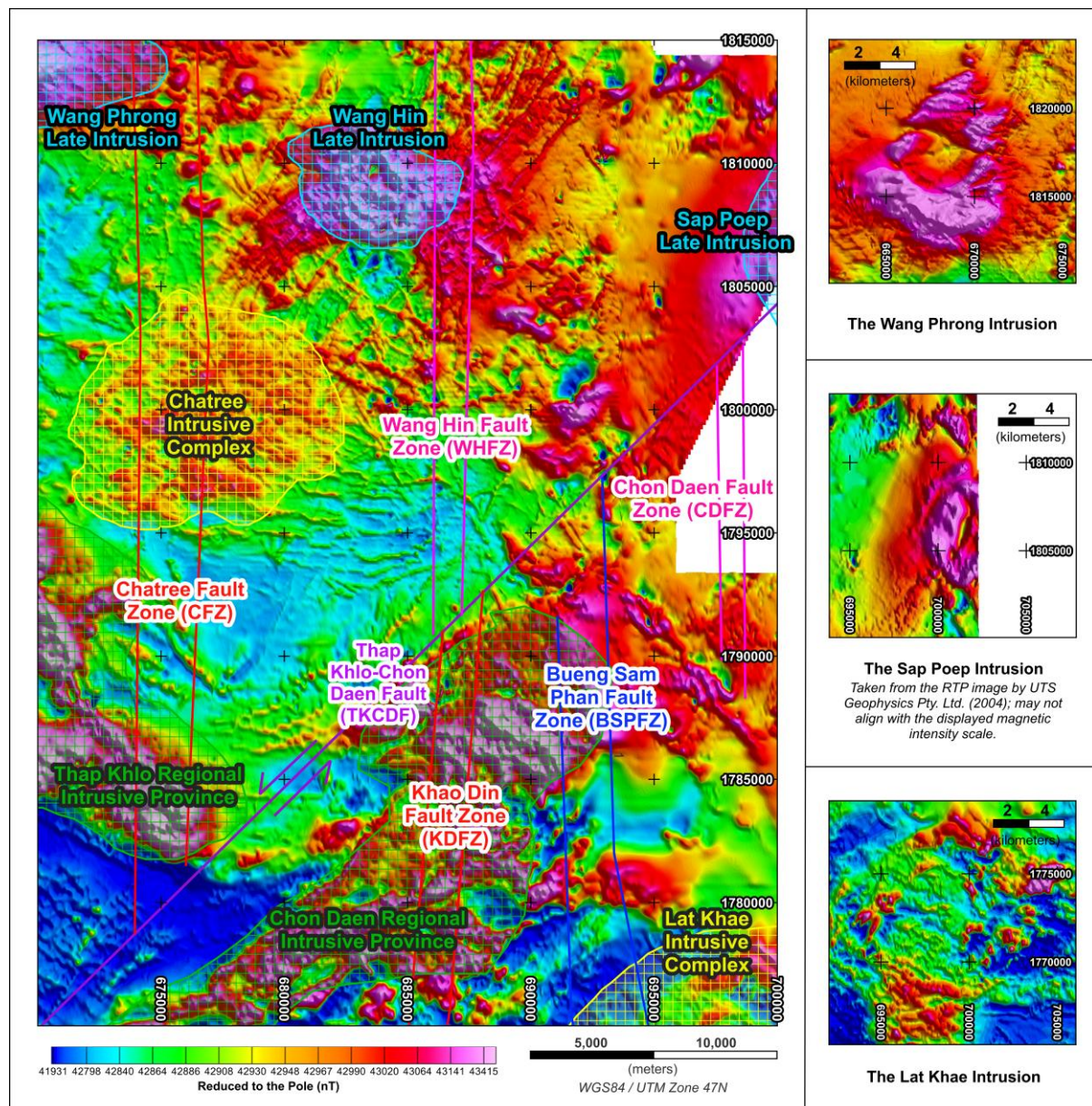


Figure 2.6 Hill's airborne magnetic interpretation of major structures in the Chatree Region showing the major fault, fault zones, and intrusion zones. The three images on the right show magnetic features of three intrusions that are not visible in the extent of the study area (Modified from Hill, 2004b).

The Wang Phrong, Wang Hin, and Sap Poep intrusions are interpreted to have formed simultaneously, as suggested by their magnetic signatures, characterized by prominent high magnetic anomalies surrounding a central low magnetic anomaly (see Figure 2.6). These intrusions are believed to have occurred near the end of tectonism and are thus classified as late intrusions. Similarly, the Chatree and Lat Khae intrusions exhibit comparable magnetic patterns, with a mix of dispersed high and low anomalies (see Figure 2.6).

Furthermore, the NE-SW and SE-NW trends of high magnetic anomalies in the central southern and eastern regions, respectively, can be reconstructed as part of a regional intrusive province. This province, which includes the Thap Khlo and Chon Daen intrusive complexes, appears to have undergone intense magmatic activity and was juxtaposed by the TKCDF (see Figure 2.6).

One of the most obvious magnetic lineaments is the NE-SW trend in the Wang Hin intrusion area. The lineaments are interpreted to be dioritic dyke swamp on Crossing's (2004) mapping (See Figure 2.5), which might be associated with refracted shear zone upon being dragged by

the N-S trending WHFZ or related with the dilatational linkage between the CDFZ and WHFZ (Hill, 2004b). The dykes are all unaltered, post-mineralization and obliterating the structures they intruded, indicating their occurring towards the end of the tectonic event (Crossing, 2004).

In the Chatree Deposit area, five main orientations can be observed including N-S, NE-SW, NWW-SEE and NNW-SSE (See Figure 2.8). The N-S trend is interpreted to be associated with a local horst-graben structure formed by orthogonal extension observed in resistivity surveys, which then get cross-cut by the conjunction of younger NE-SW, NWW-SEE, and NNW-SSE strike slip fault systems (Corbett, 2004b; Hill, 2004b). The orthogonal extension is then cut crossed by conjunction of NE-SW, NWW-SEE and NNW-SSE strike-slip faults systems (Corbett, 2004a), resulting in the development of steep normal faults so called listric normal faults, which highly contributing ore shootings along the fault planes. Additionally, meteoric water may percolate along the fault planes and then mix with hydrothermal fluid, resulting in the typical characteristics of the Chatree Deposits, epithermal low-sulphidation, with a considerably high Au grade (Corbett, 2004b, 2005; Cumming et al., 2008).

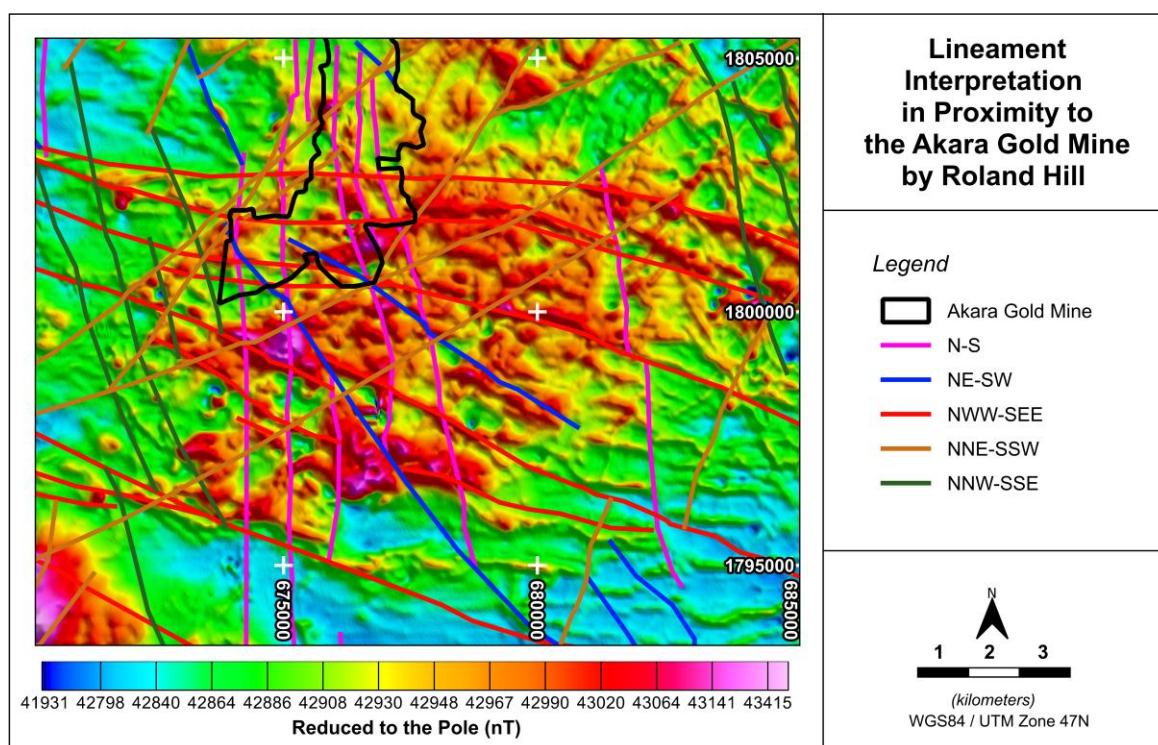


Figure 2.7 Hill's interpretation of lineament distribution in proximity to the Akara Gold Mine from aeromagnetic image (Modified from Hill, 2004b).Khao

In addition to the aforementioned lineaments, other areas also exhibit varied orientations with NE-SW and NW-SE variants (such as NNE-SSW, NEE-SWW, etc.,) as mapped by Akara Resources Public Company Limited (2009) and Crossing (2006). Furthermore, in areas with the absence of visible lineaments, varied magnetic responses can be observed.

Therefore, according to Crossing's field observations, gold mineralization in the Chatree Region typically shows a persistent spatial association with structures particularly in N-S, E-W and NE-SW directions with structural intersections of NE-SW and N-S trends (Crossing, 2004). While alterations can also be observed in the vicinity of andesite or rhyolitic volcanic piles as well as the other felsic intrusions (Crossing, 2005).

Chapter 3 Methodologies

3.1 Introduction to the Study Area

The study area is located in the northern central region of Thailand. It spans the areas near the borders of three central provinces: southeastern Phitsanulok, western Phichit, and primarily the eastern part of Phetchabun (see Figure 3.1). The terrain is predominantly flat, with the Phetchabun Mountains located to the east. Scattered mountains can also be found throughout the area. Several types of gold deposits can be observed in the exploration area, including epithermal low-sulphidation, porphyry, and skarn (Corbett, 2004a, 2004b).

While the Chatree Region contains a range of gold deposit styles, this study focuses particularly on identifying prospective areas for epithermal gold deposits. The significant structural control of epithermal systems explains the focus on them, as gold mineralization in this deposit style is primarily associated with faults, fractures, and other lineaments. For this study, the CET Grid Analysis was employed due to its suitability for identifying these structural features. This method may pose limited applicability to other deposit styles. Therefore, targeting epithermal deposit style provides a practical and geologically relevant context for its application

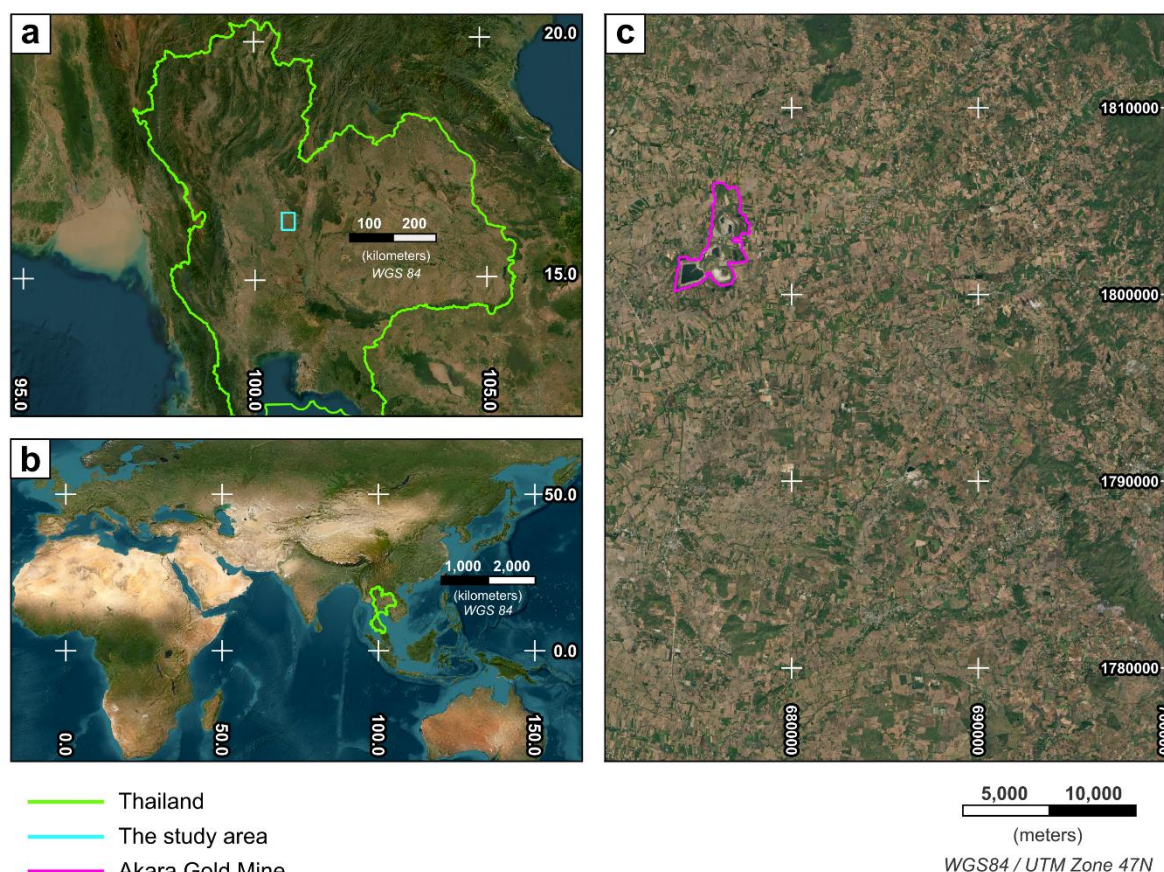


Figure 3.1 Satellite images of the study area: the mine highlighted in a pink polygon (c), the study area's approximate location within Central and Northern Thailand (a), and Thailand's position on the world map (b).

3.2 Introduction to the Utilized Aeromagnetic Data

This study focuses on detailed airborne magnetic data collected over the Chatree Region operated by UTS Geophysics (UTS Geophysics Pty. Ltd., 2004), which originally had

approaches for detailed airborne magnetic, radiometric and digital terrain survey. The data were acquired on 22 April to 7 June 2004. The flight was flown at a nominal flight height of 60 meters above ground level, with traverse lines spaced 200 meters apart and tie lines spaced 2000 meters apart. Survey data positioning and flight line navigation was derived using real-time differential GPS Novatel 3951R. The coordinate used in the flight the WGS84 coordinate system with UTM North Zone 47 projection type.

The aircraft used for this survey was a Cessna 210 fixed wing survey aircraft with tail mounted stinger. The interference caused by the aircraft was removed by RMS Aeromagnetic Automatic Digital Compensator (AADC II). The magnetometers used in the survey include Scintrex Cesium Vapour CS-2 total field magnetometer as a scalar total field magnetometer, with sensitivity of 0.001 nT and operating range of 15,000 nT to 100,000 nT. The other magnetometer is Develco Fluxgate Magnetometer, a three-component magnetometer, with sensitivity of 0.1 nT and operating range of -100,000 nT to 100,000 nT. Scintrex Envimag was used as the base station magnetometer with sensitivity of 0.1 nT and operating range of 20,000 nT to 90,000 nT.

The study focuses on an area of 30 km x 50 km, approximately in the eastern middle part of the whole surveyed area. It spans the areas near the borders of three central provinces: southeastern Phitsanulok in a section of Noen Maprang District, western Phichit in Thap Klo and Wang Sai Phun Districts, and primarily the eastern part of Phetchabun in Chon Daen and Wang Pong Districts. The area was chosen due to overlapping with the current exploration plan.

The diurnal base was checked for noises, then the filtered diurnal base was subtracted or added to the raw total magnetic intensity (TMI) data. Following that, any noises or spikes in the TMI were removed manually and applying the International Geomagnetic Reference Field (IGRF) 2000 correction. The data then were corrected by tie-line, polynomial, and micro leveling. Finally, the TMI value was grided using a bicubic spline algorithm, and applied the Reduced to the Pole (RTP) filter for correcting declination and inclination.

In this study, the RTP grid, in ER-Mapper format, directly derived from the company is used for analyzing by several methods, will be explained comprehensively in Chapter 3 Methodologies. The grid was analyzed using solely Oasis Montaj version 2023.2 (20231121.28) and all maps were made using QGIS 3.34.10.

3.3 Introduction to the Software and Plugin

The software used in this study includes Oasis Montaj version 2023.2 (20231121.28) for analyzing aeromagnetic data and generating geophysical-related maps, while QGIS 3.34.10 was employed for creating all of the maps presented in this project. Oasis Montaj is widely recognized for processing, integrating, visualizing, and analyzing geophysical and geochemical data, offering advanced 2D and 3D visualizations. It is commonly utilized in industries such as mineral and energy exploration, environmental monitoring, UXO detection, civil engineering, government, and academia (Seequent, 2023a). In contrast, QGIS efficiently handles geospatial data such as vector, raster, and tabular formats, with a variety of advanced tools for producing high-quality maps (QGIS Project Steering Committee [PSC], 2024). It is extensively used across industries like IT, higher education, environmental services, government, and oil & energy. Both software were used in tandem, as QGIS lacks advanced geophysical processing capabilities, while Oasis Montaj does not offer comprehensive mapping tools (Enlyft, 2024).

The plugin and filters used in this study include RTP, DWC and AGC, and the CET Grid Analysis. The CET Grid Analysis was developed by Holden et al. (2008, 2010, 2012). The method involves a lineament detection algorithm that combines texture analysis, contrast-

invariant ridge detection, line segment vectorization, and structural complexity heat mapping using spatial line analysis techniques to identify potential prospective areas for gold deposits based on structural complexities. It has been widely adopted in various studies to identify gold potential prospects, including Elkhateeb & Abdellatif (2018), Assran et al. (2019), Uwiduhaye et al. (2021), Soulaïmani et al. (2022) and Ogah & Abubakar (2024). The widespread adoption highlights the CET Grid Analysis's effectiveness as a highly suitable tool for identifying structurally controlled mineralization, particularly in gold exploration.

3.4 Data Processing and Analysis Workflow

3.4.1 Reduced to the Pole (RTP)

RTP was applied to the grid after finishing preprocessing steps as the TMI grid is generated as the RTP filter addresses complexities arising from variations in latitude, body orientation, and the difference between magnetic north and geographic north (Mussett & Khan, 2000; Telford et al., 1990).

3.4.2 Downward Continuation (DWC)

The filter involves mathematically calculating the anomaly as the measurements were taken closer to the subsurface than they actually were, aligning with the characteristics of epithermal deposits. The only one required parameter is *continuation distance*, representing the height for the simulated lowering of the measurement. This filter works by compressing wavelengths and amplifying amplitudes, resulting in the enhancement of nearer subsurface features (Reynolds, 2011).

3.4.3 Automatic Gain Correction or Automatic Gain Control (AGC)

AGC was developed by Rajagopalan & Milligan (1994). It works by adjusting the amplitude of the field strength across the grid, by amplifying weaker signals while attenuating stronger ones. The algorithm works by initially calculating the local gain by moving window, while recording the maximum gain of each window. The size of the window can be specified in the parameter called *filter size*. Once the algorithm runs processes the entire grid, all the signal strength are adjusted based on the record maximum gain values. Additionally, there is another parameter called *maximum gain correction* which controls the adjustment to prevent over-amplification or over-diminution, resulting in a balanced signal where weak magnetic signals become clearer and the strong signals retain their relative strength (Seequent, 2024).

3.4.4 The Central of Exploration (CET) Grid Analysis

This section briefly describes the CET Grid Analysis methodology employed in this study. For a more comprehensive explanation including theoretical background and implementation details, see the developers' original publications (Holden et al., 2008, 2010, 2012).

I Standard Deviation

The method serves as texture analysis, enhancing magnetic variations. It analyzed the variability of pixel intensity values over a specified local window (Holden et al., 2012), defined by the *window size* parameter, which given in the unit of cells. Discontinuities will stand out from the background signal. Values approaching 0 indicate little variation, which have values near the mean value. Larger values indicate high variation from the mean value.

This can be explained mathematically as shown in the Equation 1 (Seequent, 2023b): for a window containing N cells, whose mean value of all the interpolated data points

within the window is μ , the standard deviation measuring the deviation of the interpolated values σ of the interpolated value of a particular cell values x_i is given by:

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \mu)^2} \quad (1)$$

II Phase Symmetry

Phase Symmetry is originally developed by Kovesi (1997). It is a texture ridge detection that employing a contrast invariant detection technique to locate laterally continuous ridge features (Holden et al., 2012). This technique utilizes local phase symmetry to determine whether the symmetry of frequency components corresponds to the periodicity of their spatial frequency in the frequency domain (Seequent, 2023b), effectively identifying line-like structures regardless of intensity variations (Holden et al., 2012).

When analyzing symmetry in the frequency domain, the points of symmetry representing linear features in their Fourier components are located at either maxima or minima, indicating the most symmetric points in their cycle (Holden et al., 2010, 2012), as illustrated in Figure 2a. In the contrary, for images of non-linear features, the points of symmetry do not align with maxima or minima, as shown in Figure 2b.

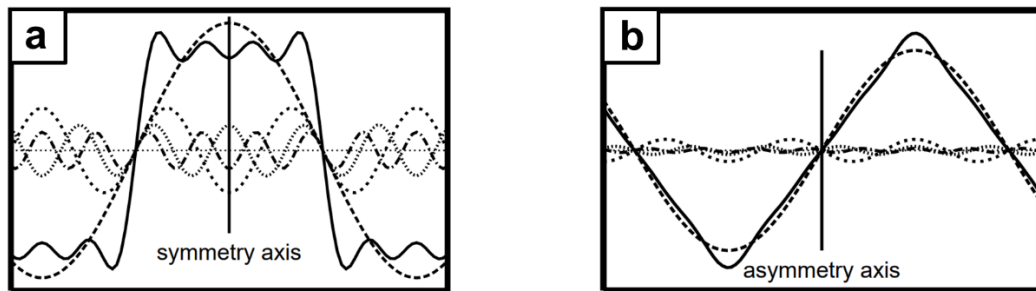


Figure 3.2 Fourier analysis results of a symmetrical object (a), and an asymmetrical object (b) (Kovesi, 1997)

In order to utilize Phase Symmetry, five parameters must be taken into account, including *smallest filter wavelength*, *number of filter scales*, *polarity of interest*, *orientation* and *robustness*. *Smallest filter wavelength* is a parameter indicating the smallest cells at which to start filtering. It works simultaneously with *number of filter scales* which determines the total number of scales used in the filtering process. *Polarity of interest* indicates the interest type of magnetic response (anomalies) of the grid, whatever positive, negative or both responses. Similar to *orientation*, which defines the interest orientations of the symmetry that prefer to detect, this can be whether north-south, east-west, or all orientations. Finally, *robustness* controls the sensitivity of the phase symmetry detection (Seequent, 2023b).

In the output for phase symmetry, numerical values representing the degree of symmetry are generated. However, the symmetry measure output is sometimes not evenly distributed between 0 and 1, which means it does not range from no symmetry to perfect symmetry. Therefore, converting color images to grayscale is recommended to perform (Seequent, 2023b), because each color channel is weighted and combined to calculate a single intensity value.

III Amplitude Thresholding

This process is the first step of line segment vectorization, which thresholds the output of Phase Symmetry to generate a binary grid (Holden et al., 2012), that involves the use of two distinct techniques, including Amplitude Thresholding and Non-Maximal Suppression (NMS).

NMS is employed to detect local maxima of the detected symmetry values. Local maxima represent the values that are higher than the values of their neighboring points. Apart from identifying local maxima, neighboring points that are lower in amplitude are suppressed (Seequent, 2023b).

Following that, Amplitude Thresholding is performed. The algorithm involves setting a threshold value to filter out features below a certain amplitude, identifying regions of high amplitude value (Seequent, 2023b). The output grid is generated as a binary grid (Holden et al., 2012) remaining only two values: local maxima and non-local maxima.

There are two parameters determining Amplitude Thresholding: *output ridge width* and *threshold value*. Output ridge width specifies the width of the detected features in the output (Seequent, 2023b), and threshold value acts as a Cut-off point, where cells with values above the threshold are classified as object of interest, while those below are considered irrelevant features.

IV Skeletonization

Skeletonization is the second step of line segment vectorization. The process involves iteratively eroding away the boundary cells of each foreground object unit until it is reduced to a single-cell width representation, referred to as a skeletal structure (Holden et al., 2012). Skeletonization involves only one parameter: *line length* which specifies the minimum acceptable length for line segments in the grid (Seequent, 2023b).

V Skeleton to Vector

Skeleton to Vector is the last step of line segment vectorization. The process converts skeletal structures to vectorized forms that accurately represent them. The structure is inspected to determine if it deviates from its corresponding line by more than a defined tolerance (Holden et al., 2012). This specified tolerance is the only parameter governing Skeleton to Vector which is *line deviation*.

VI Contact Occurrence Density (COD)

COD identifies areas of concentrated structural contacts, such as crossings, junctions, bifurcations, and changes in orientation. These interaction points represent zones of stress accumulation contributing to deformation and providing conduits for hydrothermal fluids (Holden et al., 2012). It works by determining if vectorized line segments intersect or meet at an angle greater than specified thresholds, with three key parameters taken into account for creating a COD heatmap: *proximity value*, *angle deviation*, and *contact voting influence*.

Proximity value represents a criterion for determining whether a projected intersection point (structural contact point), which is a point where two vectorized line segments would intersect if extended indefinitely, is close enough for the line segments to be considered as candidates within a given cell distance from either or both of the line segments. The two cases describing the quantification of a structural contact point are depicted in Figure 3.3. Following the identification of a candidate, the remaining candidates with similar orientation are eliminated due to the lack of significant structural changes (Holden et al., 2010, 2012).

Angle deviation parameter denotes the minimum angle deviation between two intersecting projected lines to be considered as a structural contact. In Figure 3.3, the valid intersection on the left-hand side shows a specified angle deviation of α degrees, indicating if any line segments intersect at an angle greater than α , a candidate point is created (Holden et al., 2010, 2012).

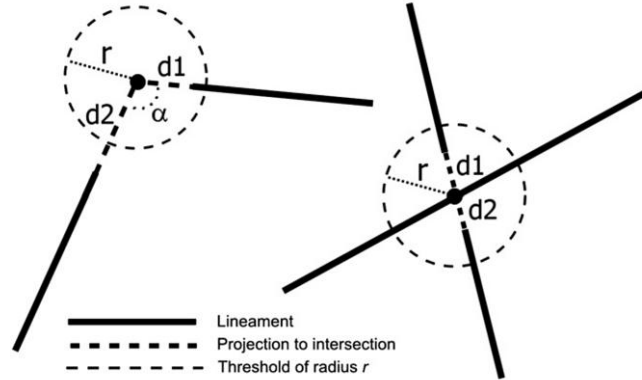


Figure 3.3 Two example cases are qualified valid intersection points, marked by a dotted circle representing the proximity radius, with an orientation angle of α degrees (Holden et al., 2012).

Contact voting influence is a parameter that determines the extent of influence around each structural contact point within a certain radius around it. After candidates are chosen, each point casts a vote represented by a Gaussian function $G_i(x, y, \sigma)$ as illustrated in Equation 2 (Holden et al., 2012). A COD heat map is then generated by accumulating all Gaussian contributions from each structural contact point, which determined by Equation 3 (Holden et al., 2012).

$$G_i(x, y, \sigma) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-x_0)^2}{2\sigma^2} + \frac{(y-y_0)^2}{2\sigma^2}} \quad (2)$$

$$H_{(x,y)} = \sum_{i=1}^n G_i(x, y, \sigma) \quad (3)$$

VII Orientation Entropy (OE)

OE works by measuring the level of randomness in the distribution of orientations within a specified window size. Two parameters are considered when generating an OE heat map: *entropy bins* and *window size*.

Entropy bins categorize the orientations of vectorized line segments into specific intervals within a 180-degree range. Following bin categorization, the entropy E is calculated for each cell by measuring the randomness of vectorized line segment orientations within a given window. This is determined by the number of different bins present in that defined window and the *window size* parameter controls the size of the window (Holden et al., 2012).

$$E = - \sum_{i=1}^n p_i \log p_i \quad (4)$$

Mathematically, the calculation of entropy E is performed using Equation 4 (Holden et al., 2012), where n represents bin intervals and p_i represents a proportion relative to the total number of line segments analyzed in the orientation histogram of n bins. the proportion of line segments within bin, similar to the process used in generating the COD heat map (Holden et al., 2010).

3.5 Operational Workflow

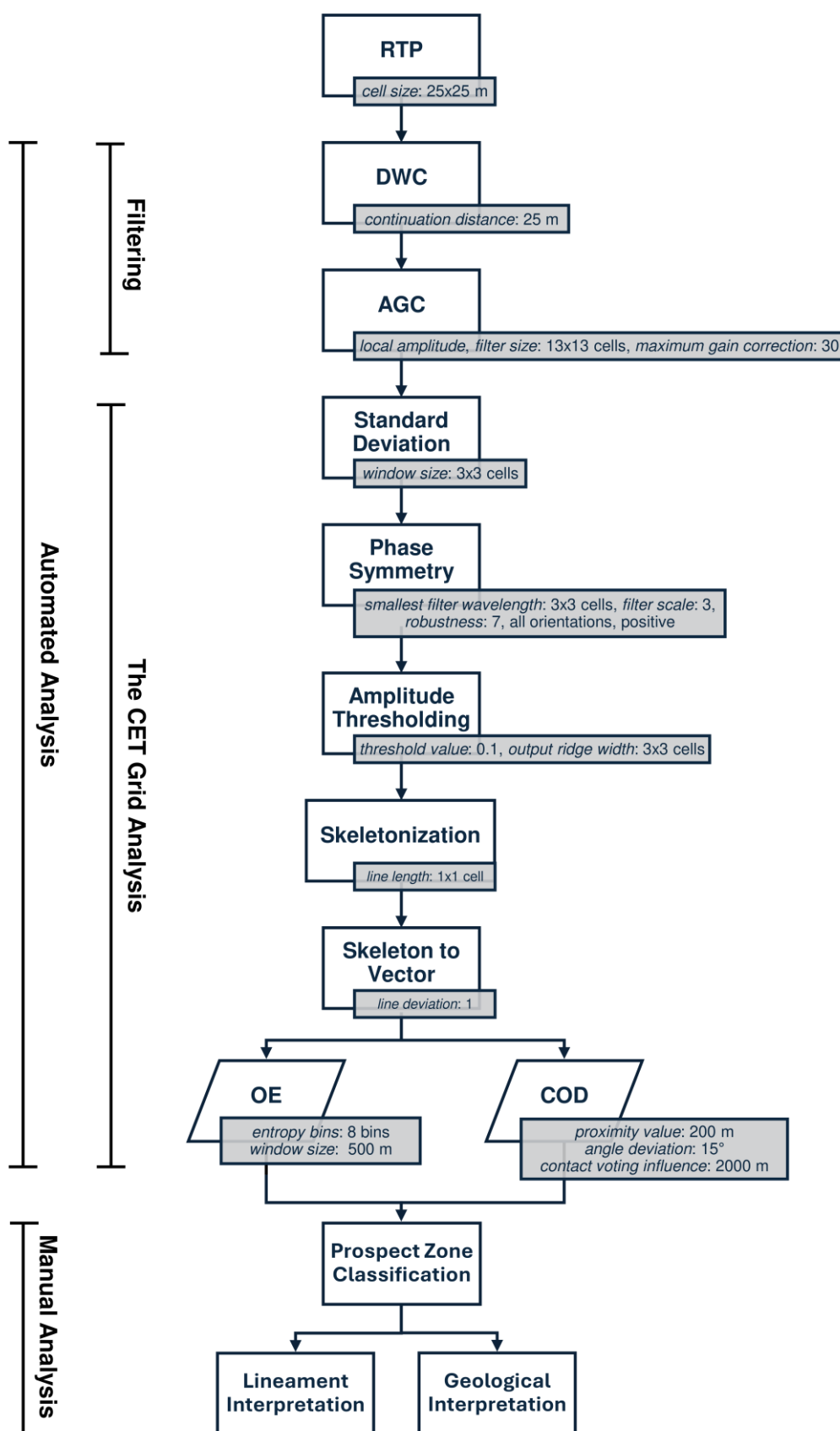


Figure 3.4 The workflow of methodologies used in this study and associated parameters.

3.5.1 Automated Analysis

The operational workflow is presented in Figure 3.4. The process begins with the RTP Grid, followed by the application of previously discussed filtering and analysis techniques, and concludes with the interpretations, which are discussed in a later section.

The employed parameters were subjected to evaluate the chosen parameters resulted in grids with acceptable noise levels and effectively captured prominent lineaments. This was necessary because the RTP grid in the study area exhibits highly complex structures and variations in magnetic strength (see Appendix 1A [b] for the RTP image). The final parameter values were determined through these experiments, with the flowchart in Figure 3.5 providing details on the parameter selection process.

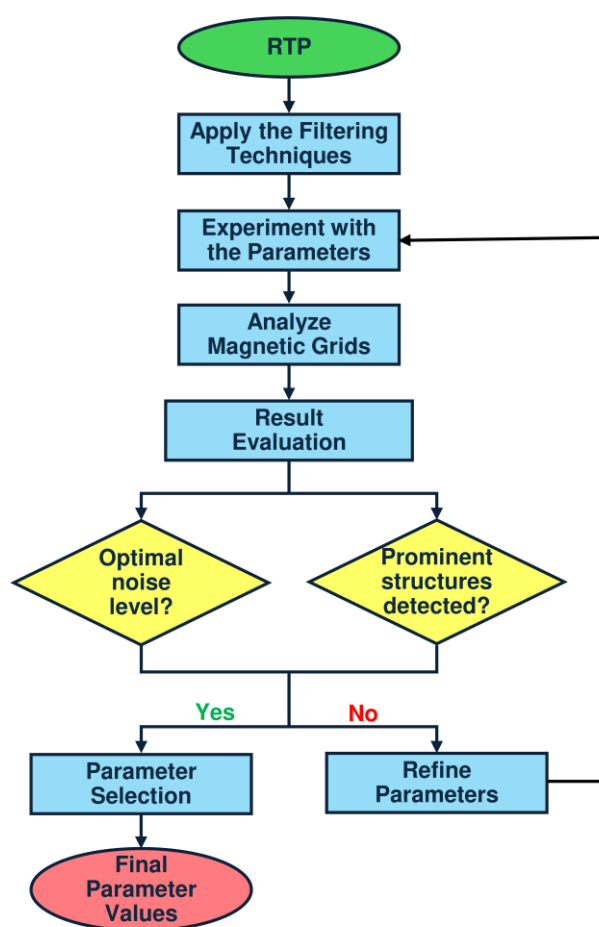


Figure 3.5 The flowchart of the parameter selection for DWC, AGC, and the CET Grid Analysis.

The selection of parameters for the COD and OE heat maps benefited from personal communications with geologists at Akara. These parameters included the *proximal value* and *voting influence* for COD, and the *window size* and *entropy bin* for OE heat map generation. The *proximal value*, *voting influence*, and *window size* were chosen due to the uncertainty of the gold deposit extents and inter-deposit distances (Sangsrichan, personal communication, 2024). The entropy bin value was set to 8 to match the company's use of eight cardinal directions in geological mapping (P. Atayos, personal communication, 2024b). The selected parameters yielded a balanced heat map that effectively captured both significant features and broader trends while avoiding excessive localization, which can obscure regional patterns, and overgeneralization, which can dilute local details.

3.5.2 Manual Analysis

Following the CET Grid Analysis, the OE and COD heat maps were generated. Both heat maps provided similar results (see Appendix 3A [c] and [d]), therefore they were used simultaneously and interchangeably. The COD and OE heat maps were then subjected to prospect zone classification, classifying into potential levels ranging from very low, low, medium, high, to very high based on their gradient values. Consequently, only areas with potential levels of "high" or "very high" were considered as prospect zones. These prospect zones were subsequently analyzed to comprehensively interpret lineaments and geological correlations.

The geological interpretations were derived through a combination of known detailed regional geological knowledge and two primary geological maps, one created by Akara's geologists and another by John Crossing (see Figures 2.4 and 2.5, respectively), where the Crossing's map supplemented by explanations from Crossing's studies (2004, 2005, 2006). Additionally, certain interpretations are based on the Hill's (2004b) Akara's airborne magnetic interpretation. This report provides critical information about anomalous magnetic features that were adequately explored in previous geological mapping reports and may not be directly observable at the surface.

In the context of lineament interpretation, even though automated methods are common in lineament detection, but there are various considerations that explain why lineament interpretation is more appropriate for the 'Manual Analysis' section. Automated image processing techniques for lineament detection, such as the well-known Canny Edge Detection (Canny, 1986), Sobel and Prewitt Filters (Prewitt, 1970; Sobel & Feldman, 2015), and Hough Transform (Duda & Hart, 1972; Hough, 1962), along with other lineament detection methods developed in recent studies (Aghaee et al., 2021; Cascone et al., 2017; Masoud & Koike, 2011; Middleton et al., 2015) and even techniques like CET Grid Analysis (Holden et al., 2008, 2010, 2012), all rely heavily on color gradient contrasts in aeromagnetic data.

While these techniques have proven effective in other regions, but they may encounter significant challenges in the Chatree Region, a region of volcanic arc setting characterized by extensive volcanism and intrusive magmatism. Consequently, many faults and structural lineaments have been buried, magnetically altered, or disrupted by these processes. The lineaments in this region appear fragmented, segmented, or diffuse, lacking the continuity of clear, linear features. To effectively reconstruct the geometry and continuity of lineaments in the Chatree Region, an integrated approach is required. This involves utilizing automated analysis for initial prospect identification followed by manual interpretation to refine and reconstruct features that may be obscured or disrupted.

The lineament interpretation was enhanced by utilizing multiple filtered magnetic grids, as relying solely on the RTP grid can be challenging due to the difficulty in identifying obscured lineaments. To ensure accurate and reliable lineament interpretation, this study incorporated multiple filtered magnetic grids, including

- **Total Magnetic Intensity followed by Reduced to the Pole (TMI → RTP)** (see Appendix 1B [a]) provides the accurate position of magnetic anomalies, eliminating positional distortion. Basically, it is the RTP image that serves as the default initial grid for analysis in this study. It is mentioned here again to emphasize its role as an integral component of the lineament interpretation process.
- **Reduced to the Pole followed by Downward Continuation and then Automatic Gain Control (RTP → DWC-25 → AGC)** (see Appendix 1B [b]) provides the visibility of lineaments that located closer to the surface 25 meters. This filtered

magnetic image highlights both weak and strong lineaments, ensuring a balanced visualization of all features.

- **Total Magnetic Intensity followed by First Vertical Derivative (TMI → 1VD)** (see Appendix 1B [c]) provides the enhancement of linear features with sharp gradients in the TMI data. It may highlight subtle or weaker features better than the RTP approach due to the lack of pre-correction by RTP. However, it can be replaced by RTP since it gives less accurate anomaly positions. It is primarily used to examine the presence of lineaments from different perspectives.
- **Total Magnetic Intensity followed by Second Vertical Derivative (TMI → 2VD)** (see Appendix 1B [d]) is a second-order derivative of the TMI → 1VD. It emphasizes high-frequency features from the first derivative, making it particularly effective for detecting detailed, small-scale structures. It is ideal for identifying subtle or closely spaced lineaments.
- **Reduced to the Pole followed by Automatic Gain Control (RTP → AGC)** (see Appendix 2B [a]) provides enhanced visualization of both weak and strong lineaments, ensuring a balanced representation of all features.
- **Reduced to the Pole followed by First Vertical Derivative (RTP → 1VD)** (see Appendix 2B [b]) result is similar to TMI → 1VD, but with some anomalies shifted due to the application of RTP. This ensures geologically accurate positions of lineaments and structures.
- **Reduced to the Pole followed by Second Vertical Derivative (RTP → 2VD)** (see Appendix 2B [c]) is the second-order derivative of RTP → 1VD. The results are similar to TMI → 2VD but reflect the positional corrections introduced by RTP.
- **Reduced to the Pole followed by Second Vertical Derivative and then Automatic Gain Control (RTP → 2VD → AGC)** (see Appendix 2B [d]) provides a detailed and consistent visualization of both weak and prominent lineaments, enhancing the features derived from RTP → 2VD.
- **Reduced to the Pole followed by Upward Continuation by 100 meters (RTP → UWC-100)** (see Appendix 3B [b]) provides the enhancement of larger-scale, deeper lineaments at a depth of 100 meters below the actual measurement.
- **Reduced to the Pole followed by Tilt Derivative, then Automatic Gain Control with High-Amplitude Cut-off (RTP → TDR → AGC → Cut-off High)** (see Appendix 3B [c]) provides an image which focuses on low-amplitude features only. The image was only refined by suppressing strong lineaments using the TDR. This is then followed by AGC to balance the visualization of both weak and strong lineaments, while the high-amplitude Cut-off emphasizes low amplitude features.
- **Reduced to the Pole followed by Tilt Derivative, then Automatic Gain Control with Low-Amplitude Cut-off (RTP → TDR → AGC → Cut-off Low)** (see Appendix 3B [d]) provides the opposite effect of RTP → TDR → AGC → Cut-off High. This method highlights only strong-amplitude features with the enhancement effects of AGC and the TDR.

For a comprehensive understanding of the geological correlation and lineament interpretation procedures employed in this study, the detailed methodologies underlying this approach are thoroughly outlined in the flowchart presented in Figure 3.6.

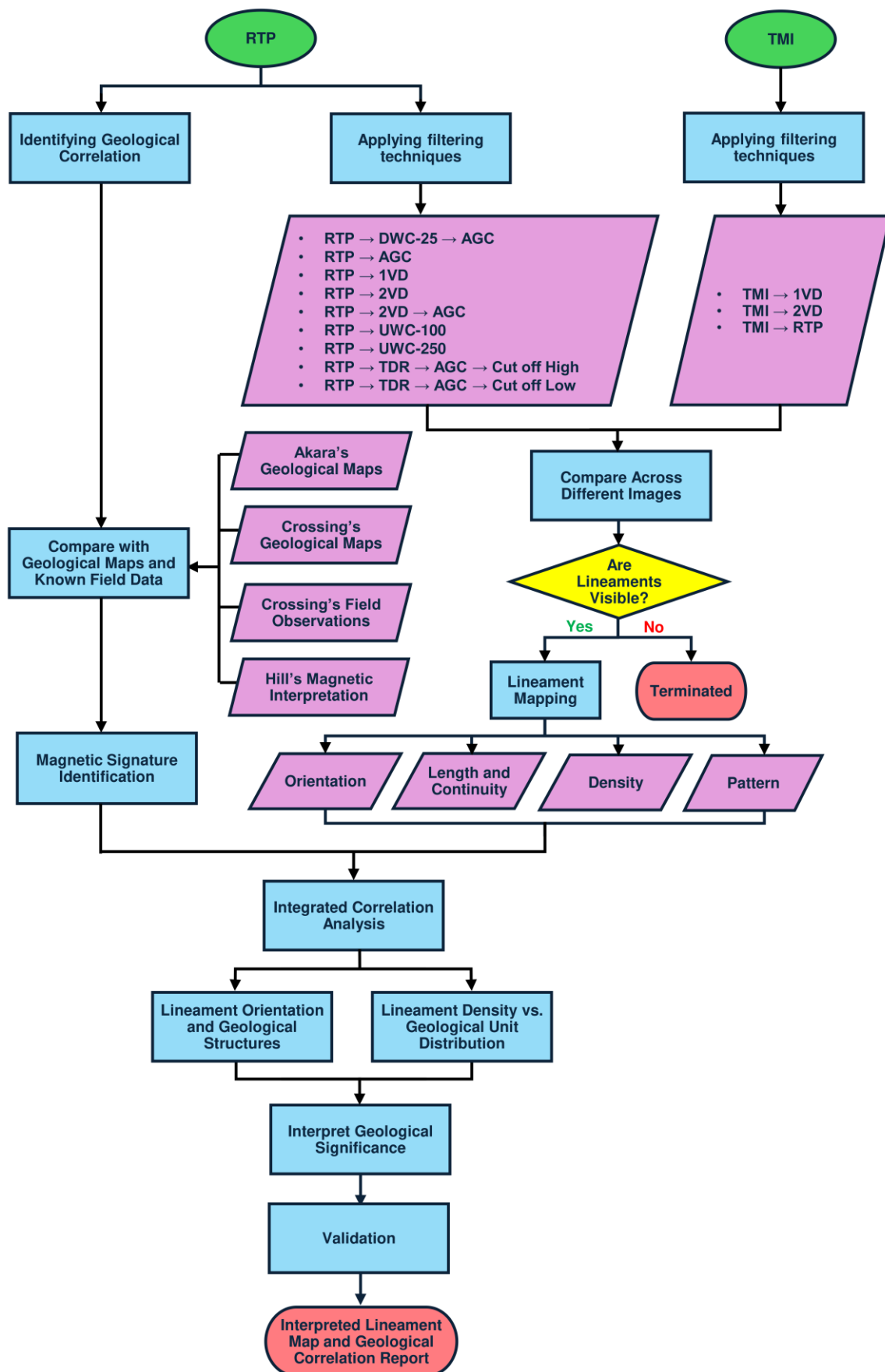


Figure 3.6 The flowchart of the geological correlation and lineament interpretation procedures

Chapter 4 Results and Discussion

4.1 Results of the Automated Approach

The results of the RTP grid filtering process are presented in Figure 4.1, with the proximity of the Akara Gold Mine are solely visualized for better visualization. Full grids of RTP, DWC, and AGC are available in Appendix 1A [b], [c], and [d], respectively. It can be observed that after applying DWC, the lineaments became more visible as the measurement was simulated to be taken 25 meters lower, resulting in capturing near-surface features more efficiently. The filtered grid not only highlighted prominent lineaments but also revealed previously obscured transverse lineaments. Through extensive experiments, a value of 25 meters was found to be optimal, as it enhanced feature visibility while minimizing the introduction of artificial noise.

Subsequently, AGC adjusted the amplitude variations of the grid. Weaker lineaments were enhanced to exhibit relatively strong amplitudes, comparable to other high-amplitude lineaments in the grid, while original strong-amplitude features retained their signal strength. The magnetic response values are now referred to as 'relative amplitude' to accurately reflect the fact that they have been adjusted by the AGC and no longer represent the original total magnetic intensity. This filter is particularly crucial in the Chatree Region, where many observed lineaments exhibit relatively weak amplitudes and the CET Grid Analysis is inherently dependent on the gradient contrast of cell values (Holden et al., 2012).

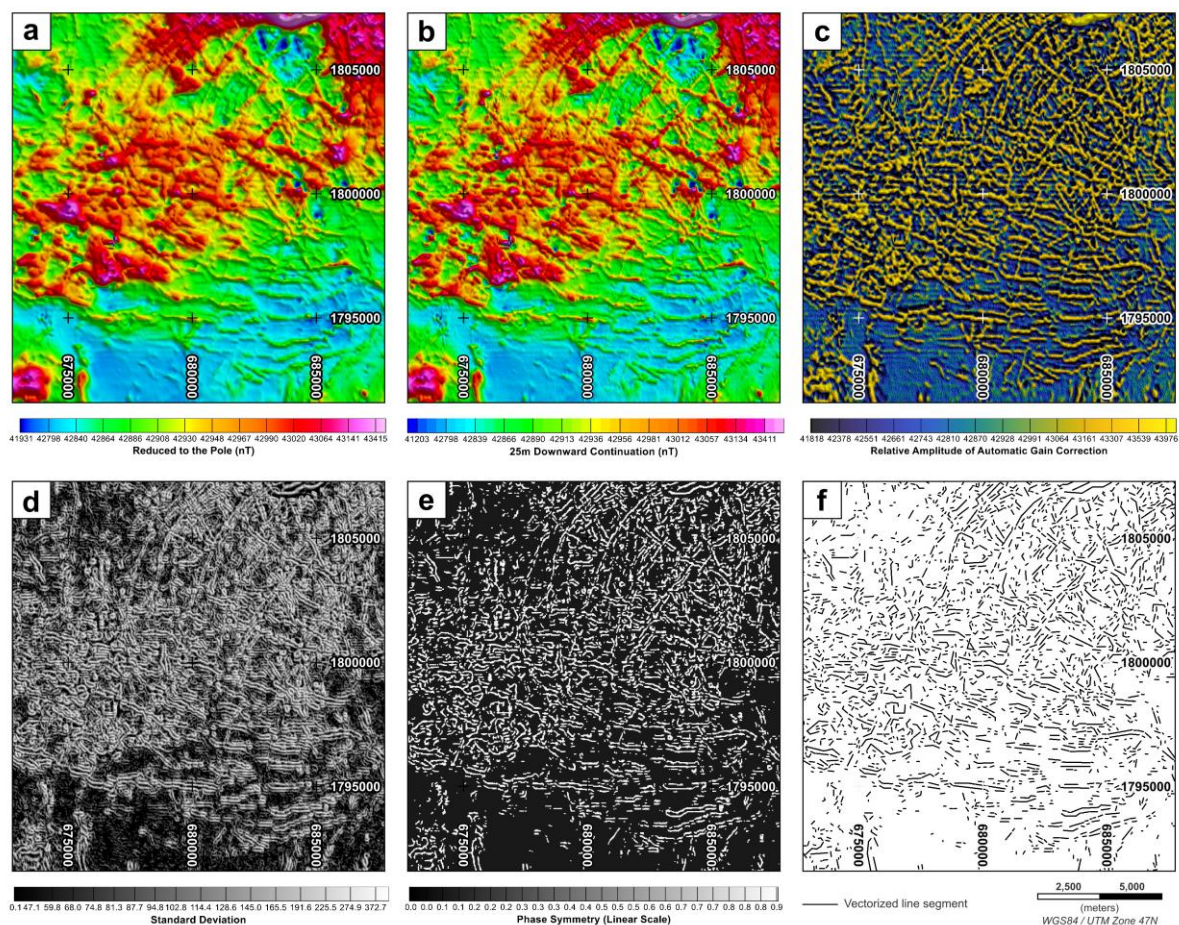


Figure 4.1 The comparison focuses on the area near the Akara Gold Mine, highlighting the RTP grid (a) and subsequent filtering steps, including DWC (b), AGC (c), texture analysis using Standard Deviation (d), contrast-invariant texture ridge detection with Phase Symmetry (e), and line segment vectorization in the final step, Skeleton to Vector (f).

Identifying Prospective Areas for the Chatree Epithermal Gold Region from Airborne Magnetic Data Using Advanced Analyzing Techniques, with Interpretative Correlation

Following AGC, the CET Grid Analysis was applied. The result from applying Standard Deviation (see full version in Appendix 2A [a]) enhanced magnetic variations derived from the AGC. Subsequently, a contrast-invariant texture ridge detection analysis, Phase Symmetry (see full version in Appendix 2A [b]), detected linear structures from the previous step and converted them into a binary grid using Amplitude Thresholding (see full version in Appendix 2A [c]).

The binary grid was then thinned and skeletonized during Skeletonization (see full version in Appendix 3A [a]) and subsequently converted into a vectorized form by fitting the skeletal structure through Skeleton to Vector (see full version in Appendix 3A [b]). Simplified results of the CET Grid Analysis are presented in Figure 4.1 (images d, e, and f). Ultimately, the results derived from the CET Grid Analysis produced the COD and OE heat maps (see Appendix 3A [c] and [d], respectively), which represent potential gold deposit areas.

4.2 Prospect Zone Classification

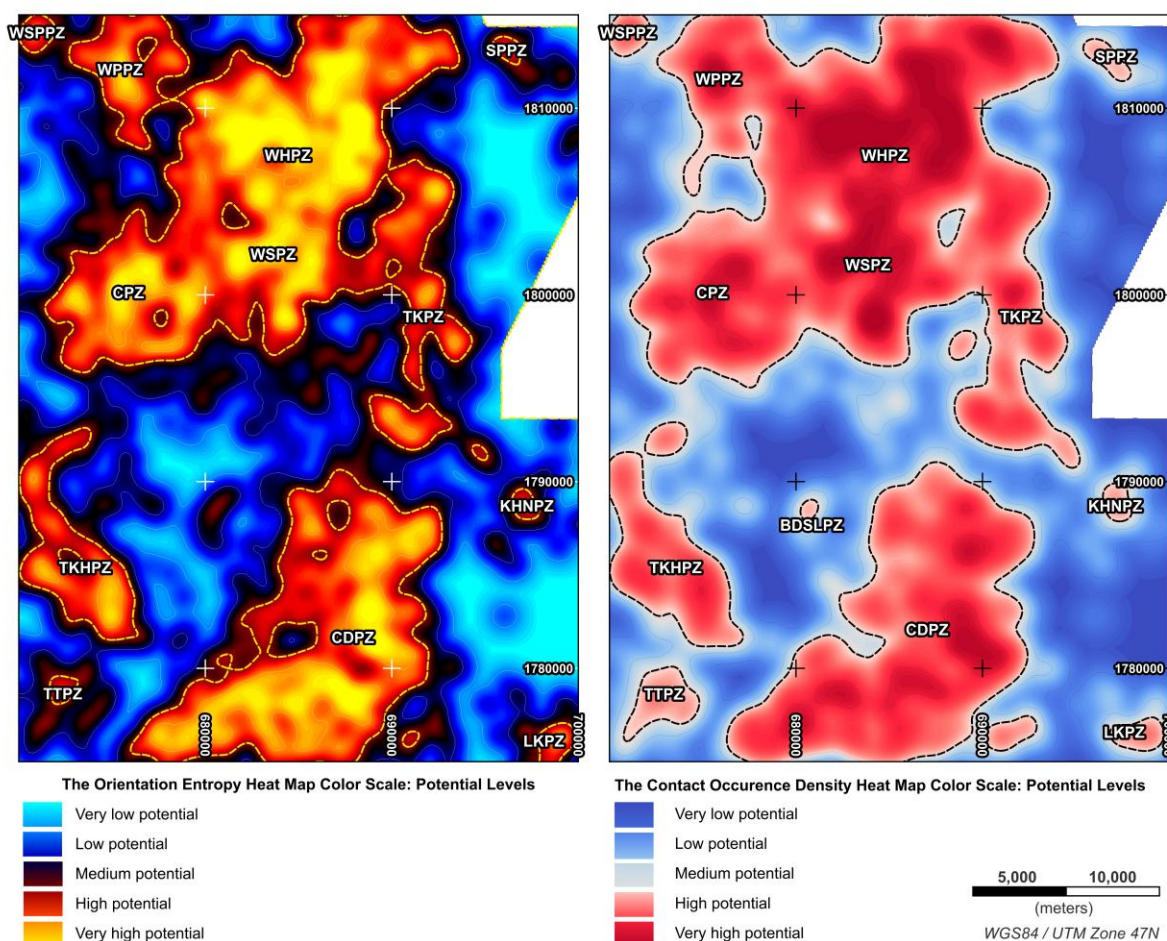


Figure 4.2 The potential level classification on the OE and COD heat maps with prospect zones highlighted in the dotted yellow and black lines respectively.

Based on the color gradients of the heat maps, potential areas were categorized into five classes (see Figure 4.2). Given the high degree of similarity between the two heat maps, they were combined for prospect zone classification. Consequently, only zones classified as 'high' and 'very high' potential were designated as 'prospect zones,' as illustrated in Figure 4.2. Consequently, only zones classified as 'high' and 'very high' potential were designated as 'prospect zones' for further geology and lineament investigation as illustrated in Figure 4.2.

Identifying Prospective Areas for the Chatree Epithermal Gold Region from Airborne Magnetic Data Using Advanced Analyzing Techniques, with Interpretative Correlation

These prospect zones, further subdivided into seven major and six minor zones based on their extent and geological context, will be discussed in detail in subsequent sections.

The seven major zones are: Wang Phrong Prospect Zone (WPPZ), Wang Hin Prospect Zone (WHPZ), Chatree Prospect Zone (CPZ), Wang San Prospect Zone (WSPZ), Tha Kham Prospect Zone (TKPZ), Thap Khlo Prospect Zone (TKHPZ), and Chon Daen Prospect Zone (CDPZ).

The six minor zones include: Wang Sai Phun Prospect Zone (WSPPZ), Sap Poep Prospect Zone (SPPZ), Ban Dong Suea Lueang Prospect Zone (BDSLPPZ), Thai Thung Prospect Zone (TTPZ), Khlong Huai Na Prospect Zone (KHNPZ), and Lat Khae Prospect Zone (LKPZ).

4.3 Geology and Lineament Interpretation

4.3.1 Wang Phrong Prospect Zone (WPPZ)

The WPPZ is one of the major prospect zones identified by the both heat maps with an extent approximately of 41 square kilometers, located in the northwest part of the study area. The circular clusters of positive anomalies observed within this prospect (see Figure 4.3) are spatially correlated with porphyry diorite intrusions and minor granite bodies (see Figures 2.4 and 2.5). According to Akara's geological map (see Figure 2.4), the region is predominantly underlain by rhyolite volcanism, predating and partially obscured by the overlying porphyry complex. However, given that rhyolite typically exhibits low magnetic responses in this region (Hill, 2004b), the observed magnetic anomalies may indicate that the rhyolite in this region has undergone secondary remanent magnetization alteration, potentially influenced by the overlying intrusions.

Considering lineament interpretation (see Figure 4.3), the prospect zone is influenced by the CFZ, resulting in the presence of N-S trending lineaments that appear as faults in moderately defined magnetic trends. E-W trending lineaments are the most prominent, interpreted as faults associated with the movement of magnetic bodies. The NW-SE and NE-SW variants are among the weakest defined lineaments. The NW-SE trend is predominantly characterized by older faults or shear zones across the area. However, in the southeastern portion near the WHPZ, this orientation may be linked to linear intrusions, particularly reactive shear zones or faults. In contrast, the NE-SW trends are the least well-defined, likely representing older fractures or faults. Notably, a distinct NE-SW lineament is observed in the northwestern part of the WHPZ, serving as the divider between the two prospect zones. This lineament displays sharply contrasting magnetic responses, potentially indicating the presence of a major shear or fracture zone responsible for juxtaposing rocks with differing magnetic properties.

4.3.2 Wang Hin Prospect Zone (WHPZ)

The WHPZ is one of the major prospects with an extent approximately around 52 square kilometers, situated in the northeastern part of the study area. The most prominent lithology in the KKPZ is diorite, characterized by a 5-km radius positive magnetic response late diorite intrusion (see Figure 2.6 and 4.3) and NE-SW trending diorite dyke swamp (see Figure 2.4, 2.5 and 4.3). An extensive positive magnetic anomaly also occurs dominantly in the eastern part of the prospect zone (see Figure 4.3). This anomaly may be associated with altered andesite (Crossing, 2004) where its remanent magnetization may have been altered due to the influence of intrusions.

The prospect zone exhibits several areas with adjacent significantly low and high magnetic anomalies. In the northeastern part of the prospect zone, these low anomalies might be associated with skarn deposits due to the presence of limestone in the vicinity. Additionally,

such anomalies are observed in the southern part of the late diorite intrusion, mapped as basaltic andesite on Akara's geological map (see Figure 2.4). These anomalies may represent remanent magnetization of basaltic andesite, where the rock retains an original magnetic domain alignment that does not align with the current field. However, further investigation through a comprehensive paleomagnetic study is required to confirm this hypothesis.

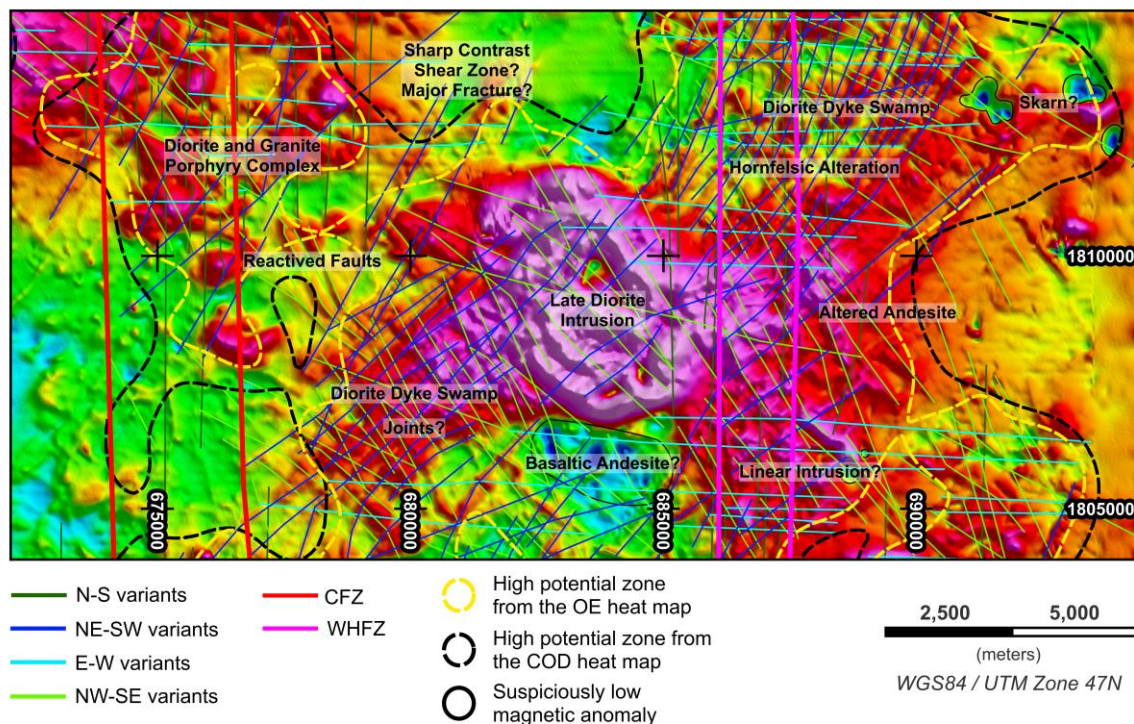


Figure 4.3 Geology correlation and lineament interpretation of the WPPZ and WHPZ visualized on the RTP grid. The color intensity scale can be found in Figure 1A on image b. The extent of each prospect zone is represented in Figure 4.2.

Regarding lineament interpretation (see Figure 4.3), the central area of the prospect zone lies under the influence of the WHFZ (see Figure 2.6), resulting the presence of N-S trending within the prospect zone. NE-SW variants, apart from the dyke swamp, can be observed in two areas including the southern and southeastern part of the late diorite intrusion. The southern section is viewed as faults or fractures which may potentially correlate with the CPZ. The southeastern NE-SW trend is interpreted as a felsic linear intrusion overlying altered andesite, potentially representing sills or dykes. However, it is believed to be not the same part of the dyke swarm, as its magnetic characteristics do not fully align, and have different magnetic signatures. The exact rock type remains unidentified as no related lithologies have been mapped here specifically.

NW-SE trending lineaments are observed both within the late diorite intrusion and intersecting the dyke swarm. These features are interpreted to have formed simultaneously with or shortly after the intrusions, as their magnetic characteristics appear disrupted but not sharply. Within the dyke swarm, particularly in its southwestern wing, the NW-SE pattern resembles a set of joints intersecting the dykes, or possibly secondary fractures resulting from post emplacement deformation. Other NW-SE lineaments are interpreted as simple fractures with no significant movement. However, (Hill, 2004b) suggested that this trend is associated with hornfelsic alteration, deconstructed the magnetic property of the diorite dykes. Similarly, E-W trending lineaments observed in the northeastern wing of the dyke swarm and the felsic linear intrusion area are also interpreted as fractures formed concurrently with or slightly after the intrusions.

4.3.3 Chatree Prospect Zone (CPZ)

The CPZ is one of the major prospect zones, covering an area of 74 square kilometers in the central western part of the study area. This prospect has been previously discussed in Chapter 2: Literature Review, within the Gold Mineralization and Structural Controls section. Hill (2004b) conducted an earlier interpretation of this zone because this zone is a known gold mineralization area with economically viable gold deposits, which serves as the foundation of the Akara Gold Mine. In addition to Hill's (2004b) work, this study conducts new lineaments identified from my analysis, some of which may not perfectly align with Hill's interpretation.

Regarding lineament interpretation (Figure 4.4), the prospect area contains several high- and low-magnetic anomalies and highly complex lineaments (see Figure 4.4). High-anomaly lineaments may correspond to post-mineralization basaltic or plagioclase porphyritic andesite dykes, commonly observed in the lower sections of the Akara Gold Mine (Salam, 2013). Alternatively, these anomalies could relate to diorite stocks, sills, or dykes as observed by Crossing (2006) in areas west of the CPZ that exhibit similar magnetic signatures. Intrusions with high magnetic anomalies located between the lineaments have been mapped as diorite porphyry on Crossing's geological map (see Figure 2.5). However, they could also be linked to altered andesites or porphyritic andesites, including plagioclase-hornblende porphyritic andesite and plagioclase porphyritic andesite, as mapped by Salam (2013).

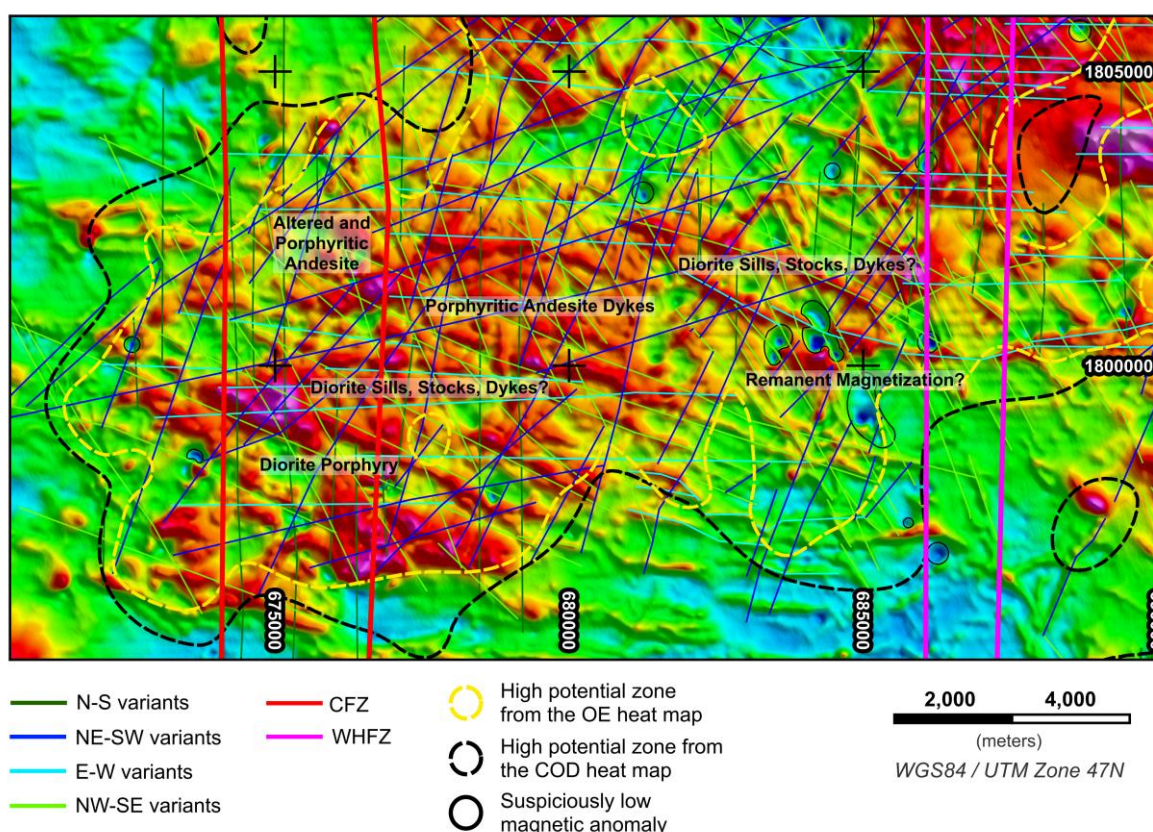


Figure 4.4 Geology Correlation and lineament interpretation of the CPZ and WSPZ visualized on the RTP grid. The color intensity scale can be found in Figure 1A on image b. The extent of each prospect zone is represented in Figure 4.2.

The area lies under the influence of the CFZ, resulting in the presence of numerous N-S trending lineaments. This trend is interpreted to be related to the horst-graben structures identified in resistivity surveys, as already discussed in Chapter 2. These lineaments display significant complexity within the prospect zone, making it challenging to determine their

relative chronological order. Among them, the NE-SW and NW-SE trends appear to control major structures in the area. Many of these lineaments are interpreted as faults, fractures, or shear zones, while others are linked to linear intrusion.

4.3.4 Wang San Prospect Zone (WSPZ)

The WSPZ is a major prospect area located at the eastern center of the study area, specifically to the south of WHPZ and to the east of the CPZ, with an extent around 45 square kilometers. There was no clear understanding of the lithologies of the prominent positive magnetic lineaments in the area (see Figure 4.4). However, diorite intrusions, mapped as sills, stocks, or dykes in the region (see Figure 2.4), suggesting that these lineaments may correlate with these intrusions. Similar to the WHPZ, notably low magnetic responses are observed, which might correspond to remanent magnetization of the underlying unaltered basaltic andesite.

The prospect zone lies under the influence of the WHFZ, resulting in the presence of N-S trending lineaments in the area. The E-W lineaments present a notable pattern, particularly in the northern region near the WHPZ. These lineaments exhibit slightly to moderately magnetic responses and are observed as relatively long faults, shear zones, or fractures. Another E-W lineament appears as a positive magnetic anomaly with a distinctive flattened U-shape. Similar magnetic responses are observed in certain NE-SW and NW-SE lineaments. These strongly magnetic features are interpreted as dioritic intrusions, potentially exhibiting in the form of sills, stocks or dykes.

4.3.5 Tha Kham Prospect Zone (TKPZ)

The TKPZ is a major prospect area located at the central eastern part of the study area, covering an area of 60 square kilometers. The high magnetic anomalies are mapped as diorites, granodiorite and syenite, found alongside with the limestone and chert deposits to the east (see Figure 2.4 and 2.5 and 4.5). Similar to the WHPZ and WSPZ, the adjacency of significantly low and high magnetic anomalies can be observed. These low anomalies are seen to be associated with potentially skarn deposits due to the presence of the limestone in the vicinity.

In the northern part of the prospect zone, adjacent to the WHPZ, E-W and NW-SE trending fractures and joints can be identified which might associate with the same trending lineaments observed along WHPZ diorite intrusions. However, moving southward, the lineaments mostly exhibit weakly defined magnetic responses. They lack of a clear directional pattern and display a high variability in orientation. It remains uncertain whether these lineaments are the features of interest. They could potentially represent boundaries of differing magnetic properties within the same rock units. Alternatively, they might represent old, buried, reactive faults or shear zones that facilitating the emplacement of the intrusions. Additionally, a set of NE-SW lineaments located in the southernmost part of the prospect zone is believed to be associated with the CDPZ, which will be discussed in detail in its own section.

4.3.6 Thap Khlo Prospect Zone (TKHPZ)

The TKHPZ is one of the major prospect zones located on the western part of the study area with an extent of 40 square kilometers. The NE-SW series of high magnetic anomalies in the TKHPZ (see Figure 4.5) is linked to a variety of intrusive bodies, including diorite and granodiorite, and extrusive rocks, including basaltic andesite, andesite, and rhyolite (see Figure 2.4 and 2.5). However, extrusive rocks in the area typically do not produce such high positive magnetic anomalies considering this region (Hill, 2004b). This suggests that these anomalies are more likely associated with deeper, buried intrusive bodies rather than surficial volcanic deposits, which are not exposed as outcrops and remain unmapped.

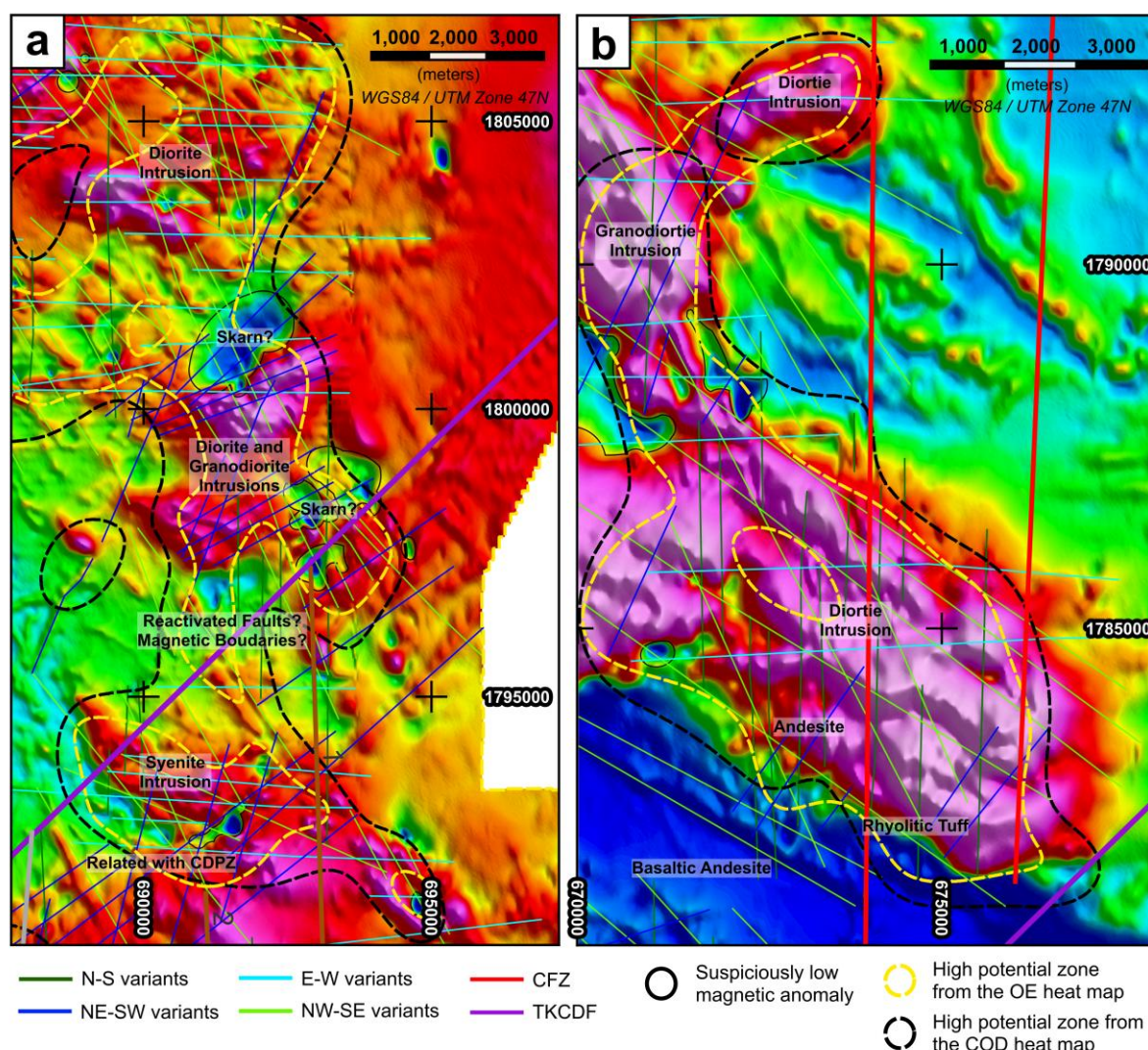


Figure 4.5 Geology correlation and lineament interpretation of the TKPZ (a) and THKPZ (b) visualized on the RTP grid. The color intensity scale can be found in Figure 1A on image b.

Similarly to the other aforementioned prospect zones, adjacent areas with significantly low and high magnetic responses can also be observed in the southern part of this prospect zone. The low magnetic response is mapped as basaltic andesite on Akara's geological map (see Figure 2.4) and may result from remanent magnetization of the rock.

Considering lineament interpretation (see Figure 4.5), the most prominent magnetic trend is NW-SE that wholly associated with the intrusions trend. However, some portions of this trend may predate the intrusions, representing older faults or shear zones that reactivated and hosted the emplacement of the NW-SE intrusions. Furthermore, the eastern part of the TKHPZ is influenced by the CFZ, resulting in several N-S trending lineaments observed within and around the fault zone. They are interpreted to have occurred simultaneously with the intrusions as most of them are subtle but still relatively easy to reconstruct. Additionally, less prominent trends include E-W and occasionally NE-SW, likely representing deeper, buried lineaments that may predate the intrusion.

4.3.7 Chon Daen Prospect Zone (CDPZ)

The CDPZ is an extensive prospect zone, covering approximately 170 square kilometers. This prospect zone is characterized by high magnetic anomalies (see Figure 4.6), featuring a series of felsic plutonic intrusions, ranging in composition from diorite to granodiorite and granite

(see Figures 2.4 and 2.5). Additionally, areas with both significantly low and high magnetic responses can be observed scattered across the region. The low magnetic response may correlate with the remanent magnetization of basaltic andesite (see Figure 2.4), as this volcanism was the first magnetism in the area and may still preserve its paleo-direction of magnetic domains. However, Hill (2004b) suggested in his report that the chaotic magnetic responses might be associated with magnetic deconstruction of hornfelsic alteration caused by the surrounding extensive intrusive bodies.

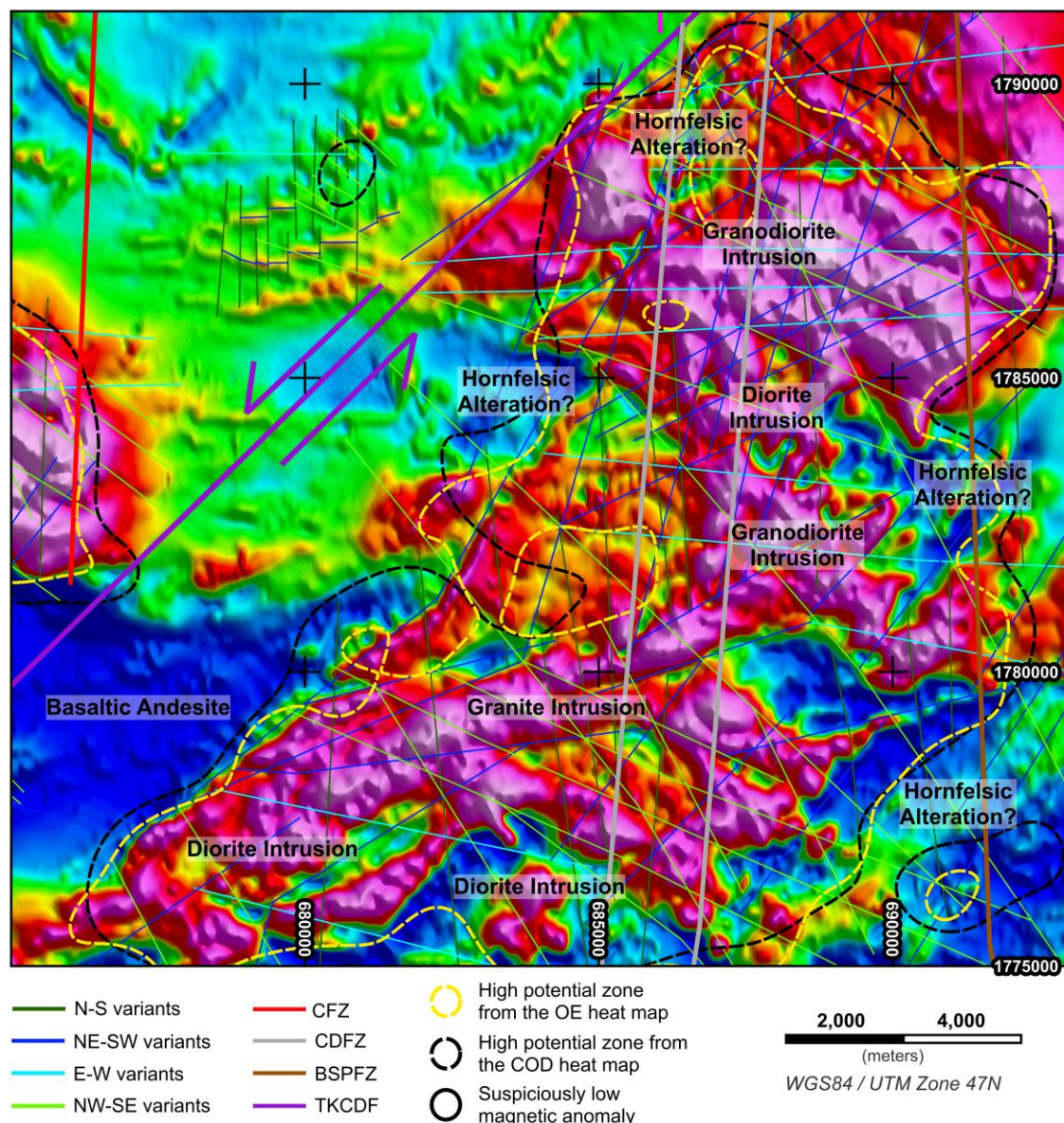


Figure 4.6 Geology correlation and lineament interpretation of the CDPZ visualized on the RTP grid. The color intensity scale can be found in Figure 1A on image b.

Considering lineament interpretation, there are numerous lineaments are present in this zone, particularly in the NW-SE and N-S directions. These are not included in the map due to their large number and complexity. However, it is uncertain whether these lineaments represent old faults that hosted the intrusions or if they resulted from errors during grid interpolation, causing a significantly high density of these two directional lineaments. Therefore, in this prospect zone, only the major lineaments that appear to control the intrusions are drawn and discussed in this section.

The prospect area is situated within the influence of the CDFZ and BSPFZ, but only a few N-S lineaments are observed. This may be due to the alteration in magnetic properties, as these fault zones appear to have been captured during physical field observations (Hill, 2004b). The main trends controlling the intrusions are NE-SW, followed by NW-SE, N-S and E-W. The intrusions are aligned with these lineaments, but the lineaments are not sharp, more diffuse and less well-defined, suggesting they are reactivated faults or shear zones that facilitated the intrusions. However, these lineaments could also be interpreted as faults or fractures that occurred simultaneously with the intrusions, with the extensive intrusion series potentially altering the surrounding rocks, resulting in less obvious in the lineament visibility.

4.3.8 Wang Sai Phun Prospect Zone (WSPPZ)

The WSPPZ is a minor prospect area located at the northwestern edge of the study area, covering an extent of 4 square kilometers. The prominent positive magnetic anomaly in the entire zone (see Figure 4.7a) is characterized by a late diorite intrusion (see Figures 2.4, 2.5 and 2.6), which is interpreted to share the same age of occurrence as the diorite intrusion in the WHPZ (Hill, 2004b), as mentioned earlier in the Chapter 2 Literature Review under the Gold Mineralization and Structural Controls section.

Regarding lineament interpretation (see Figure 4.7a), the structural framework of the WSPPZ is defined by a network of intersecting lineaments, primarily oriented NE-SW and NW-SE, with a few N-S trending lineaments. These lineaments are obscured beneath the diorite intrusion, resulting in fragmented lineaments of which only some could be reconstructed.

4.3.9 Sap Poep Prospect Zone (SPPZ)

The SPPZ is a minor prospect area, covering 4.5 square kilometers, located on the northeastern edge of the study area. The positive magnetic responses (see Figure 4.7b) are mapped as granite and diorite intrusions (see Figures 2.4 and 2.5). A notable low magnetic anomaly is found northwest of the intrusion, but the area also mapped as granite, raising questions about its magnetic properties.

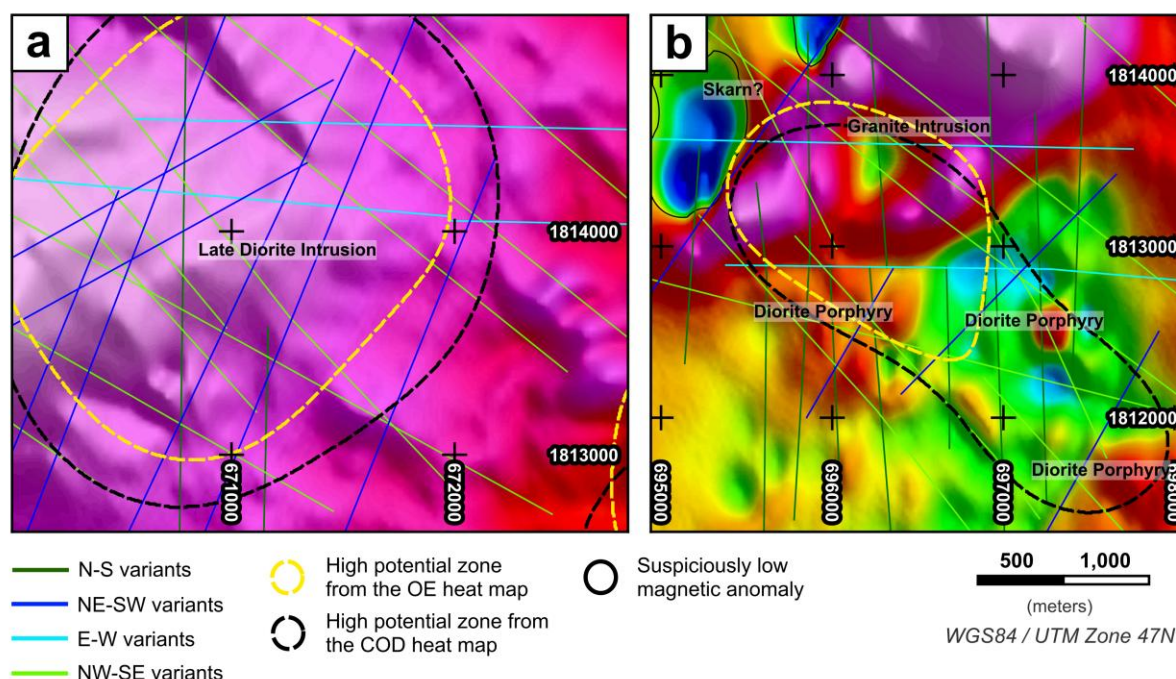


Figure 4.7 Lineament interpretation of the WSPPZ (a) and SPPZ (b) visualized on the RTP grid. The color intensity scale can be found in Figure 1A on image b.

Alternatively, solely based on Crossing's geological map (See Figure 2.5), the low magnetic anomaly might correspond to skarn deposits, because limestone was mapped to the west of the prospect area. However, is subject to further investigation where further field studies and geophysical surveys are needed to clarify this discrepancy.

E-W trending lineaments are the most prominent in this prospect zone and appear to be associated with the WHPZ and WSPZ, which resulted in these fractures. This shared tectonic history suggests that the areas underwent similar deformation events, causing the E-W oriented fractures to form in response to the regional stress field. Other lineament trends include NE-SW, NW-SE, and N-S, which are more subtle than the E-W trends and may predate the intrusions, potentially representing a crustal weakness zone, facilitating the intrusions.

4.3.10 Ban Dong Suea Lueang Prospect Zone (BDSLPPZ)

The BDSLPZ is a minor prospect zone, covering less than 1 square kilometer, located in the central part of the study area. This zone is identified as a high-potential area solely on the COD heat map. None of the available geological maps can define the elongated, faulted NE-SW lineaments within this zone (see Figure 4.8a). However, Crossing's geological map (see Figure 2.5) identifies a faulted diorite dyke or sill at the northeastern margin of the prospect area which aligns with a faulted NE-SW positive anomaly on the magnetic image that was observed there. Due to the similarity of their magnetic signature these faulted NE-SW features are then interpreted as diorite sills or dykes.

It is crucial to note that these intrusions differ from the diorite dykes observed in the WHPZ as they are associated with pre-gold mineralization, occurring before the major gold mineralization period. In contrast, the diorite dykes in the KKPZ are interpreted as post-dating gold mineralization, occurring after the major gold mineralization period (Crossing, 2004, 2006). This will be discussed again in the Conclusion section.

Considering lineament interpretation (see Figure 4.8a), the dominant lineaments are the faulted NE-SW trending intrusions, which are cross-cut by younger N-S trending faults. Additionally, NW-SE lineaments are observed as weakly defined magnetic trends, which appear to be the oldest trend in the area. These may potentially correlate with deeper buried shear zones or faults, which are challenging to reconstruct.

4.3.11 Khlong Huai Na Prospect Zone (KHNPZ)

The KHNPZ is a minor prospect zone with an extent of 5 square kilometers, located at the central eastern margin of the study area. Both geological maps classify this area as andesite, which typically exhibits a neutral magnetic response. However, the presence of high magnetic anomalies (see Figure 4.8b) suggests that both mapped lithologies have likely undergone alteration processes, which altered their magnetic remanence and subsequently enhanced their magnetization.

In the northern part of the area, a lower magnetic response is observed, which is mapped as shale, mudstone, and siltstone in Crossing's geological map (see Figure 2.5), and as lithic arenite in Akara's map (see Figure 2.3). This response is not considered to represent a sharp contrast, but rather a boundary between areas with differing magnetic properties. While in the southwestern part of the prospect area, a contrasting low magnetic anomaly is observed. This feature may correspond to skarn due to the presence of limestone nearby. However, both low magnetic responses could also be associated with the unaltered portion of the andesite body.

All lineaments observed in the prospect area are poorly defined. Some N-S lineaments are barely visible, and it is uncertain whether they are small fractures or simply magnetic discontinuities due to varying magnetic properties within the andesite body. E-W lineaments

are exhibited as fractures. Both of these trends appear to predate the altered andesite. The NW-SE trend controls the entire structure, extending northwest to the boundary of the TKPZ and southeast beyond the study area. This trend may also suggest that the alteration is linked to a specific structural feature, such as a shear zone or fault, which has influenced both the alteration and the realignment of magnetic minerals in the rock.

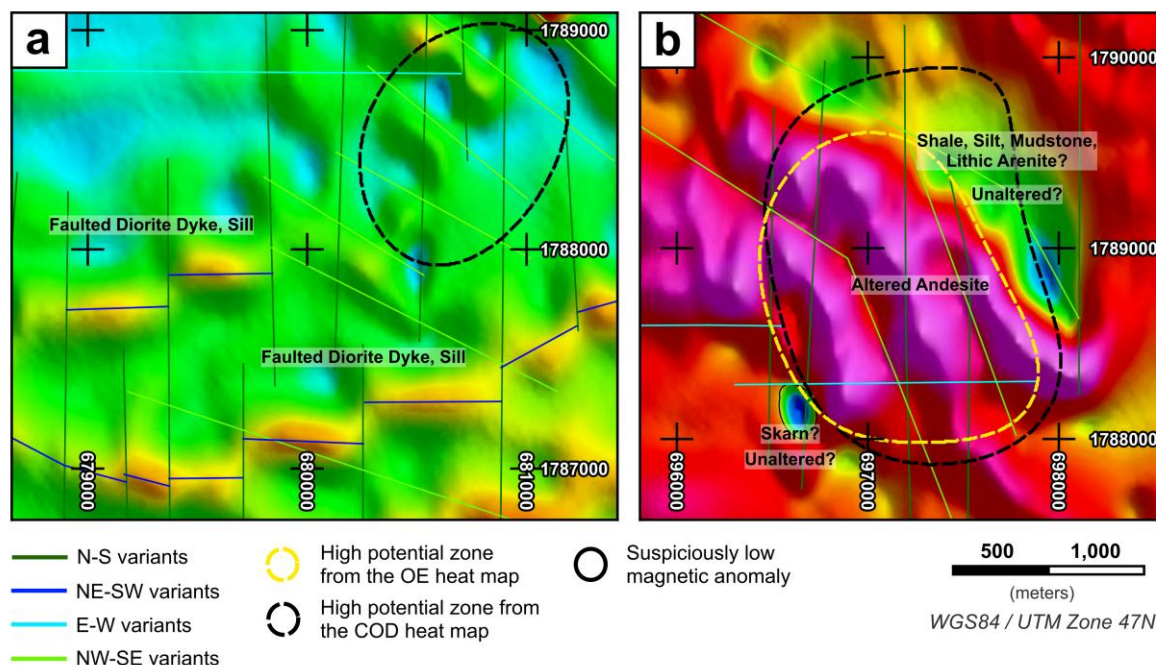


Figure 4.8 Geology correlation and lineament interpretation of the BDSLPZ (a) and KHNPZ (b) visualized on the RTP grid. The color intensity scale can be found in Figure 1A on image b.

4.3.12 Thai Thung Prospect Zone (TTPZ)

The TTPZ is a minor prospect area, covering 8.6 square kilometers, located along the southwestern margin of the study area. The correlation between the magnetic signature and lithologies in the TTPZ is unclear. According to Crossing's geological map (see Figure 2.5), the southeastern positive magnetic response NE-SW lineament (see Figure 4.9a) is mapped as a diorite sill, but the central NW-SW lineament is not defined. Given their similar magnetic responses, it is reasonable to interpret both as diorite sills.

In contrast, Akara's geological map (see Figure 2.4) associates the NE-SW lineament in the southeastern part of the zone with granite, while the central lineament is identified as andesite (see Figure 4.9a). To emphasize, andesite typically exhibits a neutral magnetic response, aligning with its mapping on Akara's geological map. However, granite generally produces higher magnetic responses in this region. Upon comparison, certain mapped features do not align with the magnetic responses observed in the data. This discrepancy could result from several factors, including limitations in the resolution of the magnetic survey or variations in subsurface geology that are not evident at the surface.

Additionally, regarding paleomagnetization, the area is characterized by a negative magnetic anomaly (see Figure 4.9a), which is practically wholly mapped as basaltic andesite. This supports the relationship between the negative anomaly and the remanent magnetization of the basaltic andesite, as previously mentioned in the CDPZ, THKPZ, and WHPZ. The negative response is likely caused by an inverse dipole at the time the basaltic andesite formed, as proposed in Hill (2004b)'s study. This suggests that the basaltic andesite retains remanent magnetization, misaligned with the current geomagnetic field.

The prospect zone lies under the influence of the NE-SW trending TKCDF, which might influence the presence of other NE-SW lineaments in the area. However, most of these lineaments are poorly defined and are cross-cut by younger NW-SE lineaments. These NW-SE lineaments, in turn, are cross-cut by the youngest N-S trending lineaments, which exhibit as faults. Additionally, the presence of the regional fault in the area may have played a key role in the development of the diorite intrusions in some of the older, obscured NE-SW lineaments, as visualized by the only positive anomalies in the area.

4.3.13 Lat Khae Prospect Zone (LKPZ)

The LKPZ is a minor prospect area with an extent of 3.8 square kilometers, located in the southeastern corner of the study area. The entire LKPZ is mapped as diorite (see Figure 2.4). However, the magnetic signature, characterized by adjacent high and low magnetic anomalies (see Figure 4.9b), suggests that the diorite intrusion may have occurred in multiple phases. This could result in one portion of the diorite retaining remanent magnetization, which exhibiting a negative magnetic anomaly. Alternatively, there might some error with spatial distribution during mapping. The low magnetic anomaly could correspond to basaltic andesite or potentially skarn deposits, as these rocks are presented in the vicinity, and typically produces negative anomalies in the study area. However, further fieldwork and analysis are needed to clarify this discrepancy.

Regarding lineament interpretation (see Figure 4.9b), several pre-existing N-S trending faults can be reconstructed terminating beneath the intrusions, suggesting that the northern intrusion is younger than these faults. The dominant NW-SE trending lineaments control the intrusion and extend southeastward beyond the study area. This trend is interpreted as reactivated structures that facilitated the intrusion's emplacement. While the E-W and NE-SE lineaments are poorly defined but appear to represent faults, fractures, or shear zones predating the intrusions, or they may simply reflect magnetic disruptions caused by alteration.

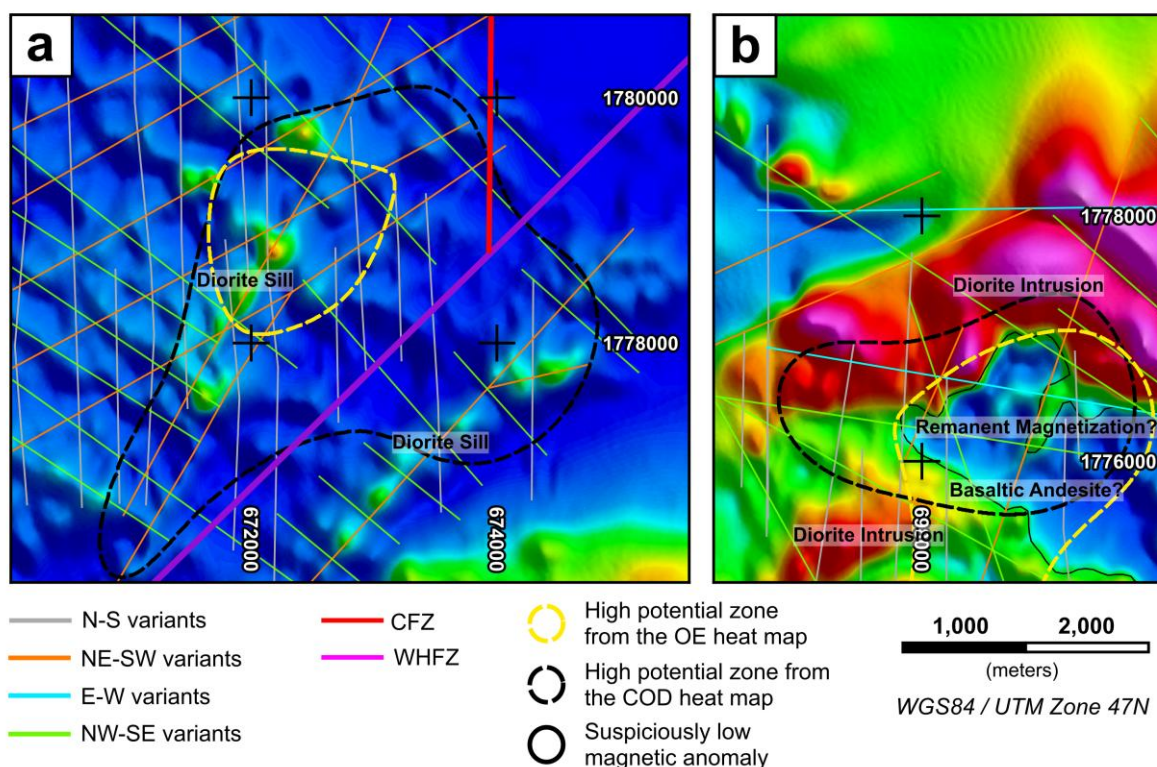


Figure 4.9 Geology correlation and lineament interpretation of the TTPZ (a) and LKPZ (b) visualized on the RTP grid. The color intensity scale can be found in Figure 1A on image b.

Chapter 5 Conclusion

“Identifying Prospective Areas for the Chatree Epithermal Gold Region from Airborne Magnetic Data Using Advanced Analyzing Techniques, with Interpretative Correlation” is an applied geophysics study employing the Central of Exploration (CET) Grid Analysis with magnetic anomaly enhancement filters to identify prospect zones for gold mineralization based on structural complexities. The results of this analysis are further used to interpretate lineaments and geological correlations within the area, revealing a more comprehensive framework for understanding the structural controls of gold mineralization, and offering a valuable tool for future explorations in the Chatree Region.

The results of the automated approach, including the COD and OE heat maps, served as the initial screening tool that highlighting areas with high potential for gold mineralization. These heat maps provided the first set of results, indicating prospective zones for further investigations. Following this, more detailed manual interpretation was applied, involving geological correlation and lineament interpretation to refine the understanding of each identified zone producing the final results of the study.

This integrated approach allows for efficient and systematic identification of structural features while maintaining the geological accuracy achieved through manual refinement. The application of automated screening techniques successfully identifies areas with high gold mineralization potential by detecting subtle structural discontinuities that may have been overlooked through manual inspection. This not only helps reduce exploration time and costs but also minimizes human bias, offering consistent and substantial results. However, manual interpretation remains crucial when considering the geology and lineament interpretations, as most automated linear detection methods rely on color gradient contrasts that may not accurately capture the complexity of disrupted and fragmented lineaments in the study area.

In addition, human expertise in geological interpretation, specifically in correlating lithological units, ensures that the results accurately reflect subsurface conditions. The successful integration of automated and manual approaches has led to the identification of several high-potential gold prospect zones and a significantly improved understanding of the regional geological framework, and showcasing the value of combining automated techniques with human expertise in mineral exploration.

Several limitations influenced the results of this study, including data quality issues due to inadequate micro-leveling of the derived aeromagnetic RTP grid. This inconvenience can be observed in areas with high geological complexity where the effect of transverse flight lines is risk to remove. Additionally, the application of DWC and AGC did enhance the visibility of the obscured lineaments, but this introduced noise beyond the wanted lineaments which affecting further analysis. Therefore, adjusting parameters suitable for the data is significantly advised.

Regarding the results of lineament interpretation, this data has to be utilized carefully because airborne magnetic images cannot determine the exact age of lineament formation, and some lineaments are pre-mineralization lineaments. Previous studies conducted in the Chatree Region of geochemical, geochronological and geological field observation studies (Corbett, 2004a, 2004b, 2005; Crossing, 2004, 2005, 2006; Salam, 2013; Salam et al., 2014), have shown that gold mineralization aligns with a specific geological stage. Structures formed outside this specific stage are likely lack of economically viable gold deposits. Practically, gold prospecting should not rely solely on this analysis. A multidisciplinary approach utilizing various

geological and geophysical techniques, including radiometric, gravity, resistivity, and others, is recommended for identifying authentic gold prospects.

Furthermore, it is crucial to acknowledge that the region hosts a variety of deposit styles apart from epithermal low-sulphidation, which including porphyry and skarn. These aforementioned types are not always associated with lineaments, indicating a limitation for employing the CET Grid Analysis method. Another limitation of this analysis, similar to lineament interpretation, is its inability to distinguish the age of structures associated with gold deposits. The method detects all magnetic discontinuities on the grid, regardless of their age.

This thesis study emerges several opportunities and directions for further investigations associated with gold exploration and the Chatree Region itself. This raises several questions about the paleomagnetic implications of the region's magnetic anomalies, particularly those related to reversed magnetic responses. A detailed paleomagnetic study could help clarify whether these responses are due to remanent magnetization during periods of reversed polarity.

Additionally, the prospect zones identified in this study were solely based on structural complexities, which may not be directly applicable to other deposit types such as porphyry or skarn. Therefore, additional exploration approaches targeting these deposit styles are essential for fully assessing the region's gold potential. Moreover, this study focused solely on magnetic images, which leading a significant opportunity to integrate magnetic data with other geophysical methods, or even geochemical and geological techniques, to enhance the results for identifying gold prospect zones more efficiently and precisely.

In closing, the results of this study emphasize the critical role of integrated techniques in advancing the field of mineral exploration, paving the way for more efficient, cost-effective, and accurate identification of gold prospect zones in complex geological settings like the Chatree Region. By leveraging the strengths of both automated and manual interpretations, this approach enhances the accuracy and reliability of prospect zone identification, providing valuable insights into the geological framework of the region and contributing to the future of exploration practices.

Bibliography

- Aghaee, A., Shamsipour, P., Hood, S., & Haugaard, R. (2021). A convolutional neural network for semi-automated lineament detection and vectorisation of remote sensing data using probabilistic clustering: A method and a challenge. *Computers & Geosciences*, 151, 104724. <https://doi.org/10.1016/j.cageo.2021.104724>
- Akara Resources Public Company Limited. (2004). *Regional Magnetics & Radiometrics 2004* [Unpublished geophysical survey data].
- Akara Resources Public Company Limited. (2009). *Geological Map of Akara SPK/SPLa Area* [Unpublished geological map].
- Assran, A. S. M., El Qassas, R. A. Y. & Yousef, M. H. M. (2019). Detection of prospective areas for mineralization deposits using image analysis technique of aeromagnetic data around Marsa Alam-Idfu road, Eastern Desert, Egypt. *Egyptian Journal of Petroleum*, 28(1), 61–69. <https://doi.org/10.1016/j.ejpe.2018.11.002>
- Atayos, P. (2024a). *The methodology employed for creating the Akara's geological map* [Personal communication].
- Atayos, P. (2024b). *The number of cardinal directions employed in the company's geological mapping* [Personal communication].
- Canny, J. (1986). A Computational Approach to Edge Detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, PAMI-8(6), 679–698. <https://doi.org/10.1109/TPAMI.1986.4767851>
- Cascone, L., Green, C., Campbell, S., Salem, A., & Fairhead, D. (2017). ACLAS — A method to define geologically significant lineaments from potential-field data. *GEOPHYSICS*, 82(4), G87–G100. <https://doi.org/10.1190/geo2016-0337.1>
- Charusiri, P., Daorerk, V., Archibald, D., Hisada, K. & Ampaiwan, T. (2002). Geotectonic evolution of Thailand: A new synthesis. *Journal of the Geological Society of Thailand*, 1, 1–20.
- Corbett, G. (2004a). *Comments on Controls to Gold Mineralisation at Gold Prospects in The Vicinity of The Chatree Gold Mine, Thailand* [Unpublished Document].
- Corbett, G. (2004b). *Comments on Controls to Gold Mineralisation at The Chatree Gold Mine and Environs, Thailand* [Unpublished Document].
- Corbett, G. (2005). *Comments On Controls to Gold Mineralisation At Chatree, Thailand* [Unpublished Document].
- Corbett, G. J., & Leach, T. M. (1998). *Southwest Pacific Rim gold-copper systems: Structure, alteration, and mineralization*. Society of Economic Geologists.
- Crossing, J. (2004). *Geology of the Chatree Region* [Unpublished Report].
- Crossing, J. (2005). *Additional Geological Mapping of The Chatree Regional Thailand* [Unpublished Report].

- Crossing, J. (2006). *Additonal Geological Mapping of the Chatree Region, Thailand* [Unpublished Report].
- Cumming, G. V., James, R., Salam, A., Zaw, K., Meffre, S., Lunwongsa, W., & Nuanla-Ong, S. (2008). Geology and mineralization of the Chatree epithermal gold-silver deposit, Phetchabun Province, Central Thailand. *PACRIM Congress 2008*. 24-26 November 2008, 409–416.
- Diemar, M. G. (1999). Chatree, a greenfields discovery in Thailand. *Case Histories of Discovery*, 109–116.
- DMR, D. of M. R. (1999). *Geological map of Thailand* [Map]. Geological Survey Division, Department of Mineral Resources.
- Duda, R. O., & Hart, P. E. (1972). Use of the Hough transformation to detect lines and curves in pictures. *Communications of the ACM*, 15(1), 11–15. <https://doi.org/10.1145/361237.361242>
- Elkhateeb, S. O., & Abdellatif, M. A. G. (2018). Delineation potential gold mineralization zones in a part of Central Eastern Desert, Egypt using Airborne Magnetic and Radiometric data. *NRIAG Journal of Astronomy and Geophysics*, 7(2), 361–376. <https://doi.org/10.1016/j.nrjag.2018.05.010>
- Enlyft (2024). Companies using QGIS [Business Intelligence (BI) Platform]. *Top Industries That Use QGIS*. <https://enlyft.com/tech/products/qgis>
- Hill, R. (2004a). *Additional Targets and Comments—Chatree* [Unpublished Report].
- Hill, R. (2004b). *Interpretation of 2004 Aeromagnetic Data, Thailand* [Unpublished Report].
- Holden, E.-J., Dentith, M. & Kovesi, P. (2008). Towards the automated analysis of regional aeromagnetic data to identify regions prospective for gold deposits. *Computers & Geosciences*, 34(11), 1505–1513. <https://doi.org/10.1016/j.cageo.2007.08.007>
- Holden, E.-J., Kovesi, P., Dentith, M. C., Wedge, D., Wong, J. C. & Shih Ching Fu. (2010). Detection of regions of structural complexity within aeromagnetic data using image analysis. *2010 25th International Conference of Image and Vision Computing New Zealand*. 2010 25th International Conference of Image and Vision Computing New Zealand (IVCNZ), Queenstown, New Zealand. <https://doi.org/10.1109/IVCNZ.2010.6148856>
- Holden, E.-J., Wong, J. C., Kovesi, P., Wedge, D., Dentith, M. & Bagas, L. (2012). Identifying structural complexity in aeromagnetic data: An image analysis approach to greenfields gold exploration. *Ore Geology Reviews*, 46, 47–59. <https://doi.org/10.1016/j.oregeorev.2011.11.002>
- Hough, P. V. C. (1962). *Method and means for recognizing complex patterns* (Patent US3069654A).
- Intasopa, S. B. (1993). *Petrology and geochronology of the volcanic rocks of the central Thailand Volcanic Belt*.

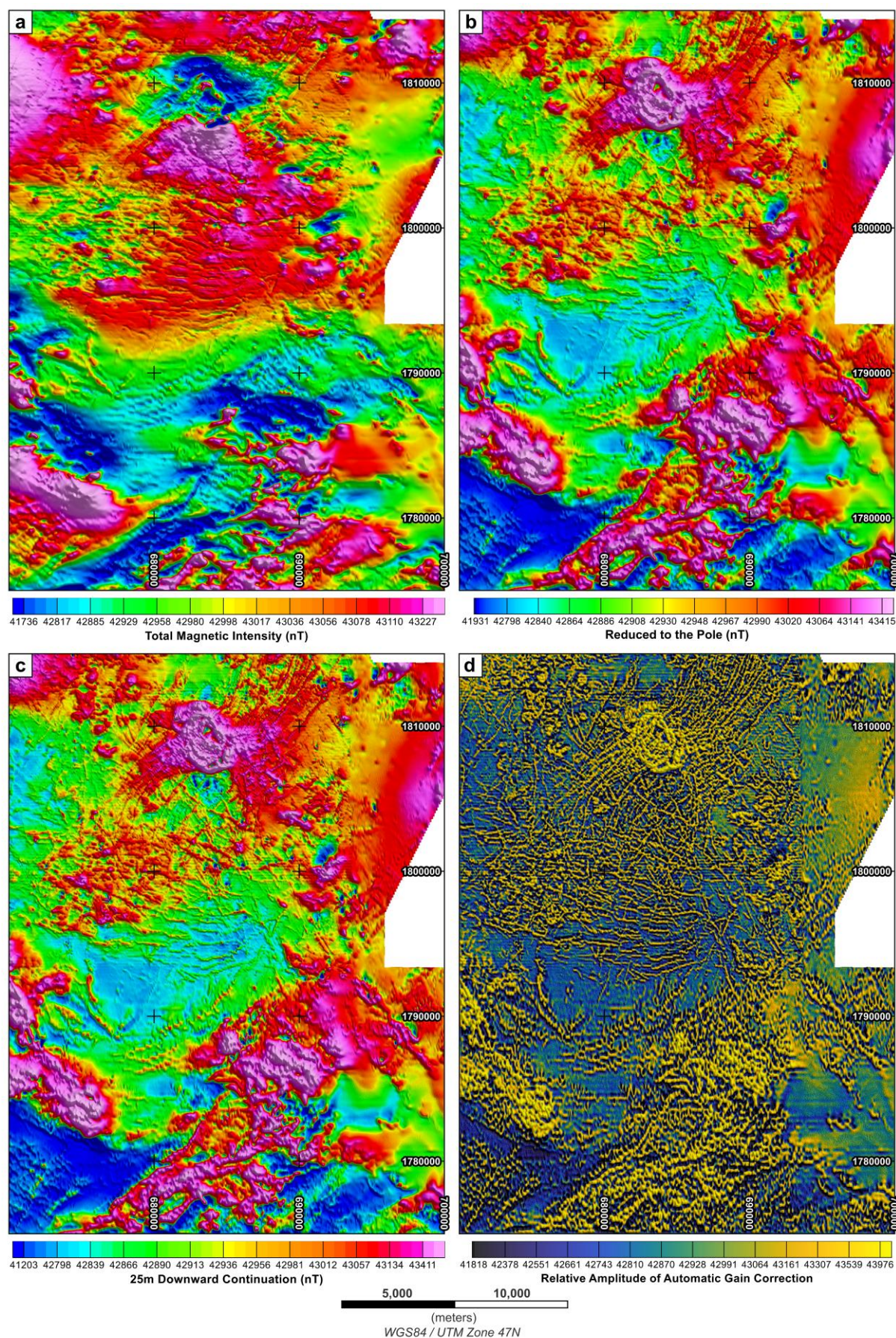
- Jungyusuk, N., & Khositantont, S. (1992). Volcanic rocks and associated mineralization in Thailand. *Proceedings of a National Conference on Geologic Resources of Thailand: Potential for Future Development*, 522–538.
- Khositantont, S. (2008). *Gold and iron-gold mineralisation in the Sukhothai and Loei-Phetchabun Fold Belts* [Unpublished PhD Thesis].
- Kingsgate Consolidated NL. (2004). *2004 Annual Report* (p. 13). Kingsgate Consolidated NL. https://www.kingsgate.com.au/wp-content/uploads/documents/KCN_AR2001.pdf
- Kovesi, P. (1997). *Symmetry and Asymmetry from Local Phase. I*, 185–190.
- Masoud, A. A., & Koike, K. (2011). Auto-detection and integration of tectonically significant lineaments from SRTM DEM and remotely-sensed geophysical data. *ISPRS Journal of Photogrammetry and Remote Sensing*, 66(6), 818–832. <https://doi.org/10.1016/j.isprsjprs.2011.08.003>
- Metcalf, I. (1984). Stratigraphy, palaeontology and palaeogeography of the Carboniferous of Southeast Asia. *Memoirs of the Geological Society of France*, 147, 107–118.
- Metcalf, I. (2011). Palaeozoic–Mesozoic history of SE Asia. *Geological Society, London, Special Publications*, 355(1), 7–35. <https://doi.org/10.1144/SP355.2>
- Middleton, M., Schnur, T., Sorjonen-Ward, P., & Hyvönen, E. (2015). *GEOLOGICAL LINEAMENT INTERPRETATION USING THE OBJECT-BASED IMAGE ANALYSIS APPROACH: RESULTS OF SEMI-AUTOMATED ANALYSES VERSUS VISUAL INTERPRETATION*. <https://api.semanticscholar.org/CorpusID:41020199>
- Mussett, A. E., & Khan, M. A. (2000). *Looking into the earth: An introduction to geological geophysics*. Cambridge University Press.
- Ogah, A. J., & Abubakar, F. (2024). Solid mineral potential evaluation using integrated aeromagnetic and aeroradiometric datasets. *Scientific Reports*, 14(1), 1637. <https://doi.org/10.1038/s41598-024-52270-6>
- Prewitt, J. M. S. (1970). *Object enhancement and extraction*. Academic Press.
- QGIS Project Steering Committee (PSC). (2024). QGIS overview [GIS (Geographic Information System) Platform]. *Key Features*. <https://www.qgis.org/project/overview/>
- Rajagopalan, S. & Milligan, P. (1994). Image Enhancement of Aeromagnetic Data using Automatic Gain Control. *Exploration Geophysics*, 25(4), 173–178. <https://doi.org/10.1071/EG994173>
- Reeves, C. (2005). *Aeromagnetic surveys: Principles, Practice & Interpretation*. e-Published by GEOSOFT. <http://www.geosoft.com/knowledge>
- Reynolds, J. M. (2011). *An introduction to applied and environmental geophysics* (2nd ed). Wiley-Blackwell.
- Salam, A. (2013). *A geological, geochemical and metallogenic study of the Chatree epithermal deposit, Phetchabun Province, central Thailand* [Unpublished PhD Thesis]. https://figshare.utas.edu.au/articles/thesis/A_geological_geochemical_and_metallogen

ic_study_of_the_Chatree_epithermal_deposit_Phetchabun_Province_central_Thailand/23207384

- Salam, A., Zaw, K., Meffre, S., McPhie, J., & Lai, C.-K. (2014). Geochemistry and geochronology of the Chatree epithermal gold–silver deposit: Implications for the tectonic setting of the Loei Fold Belt, central Thailand. *Gondwana Research*, 26(1), 198–217. <https://doi.org/10.1016/j.gr.2013.10.008>
- Sangsrichan, C. (2024). *The typical spatial separation between known gold deposit areas* [Personal communication].
- Seequent (2023a). *Course Guide for Oasis montaj Fundamentals: Vol. 2023.2*. e-Published by Seequent, The Bentley Subsurface Company. <https://lms.seequentlearning.com/>
- Seequent (2023b). *The CET Grid Analysis [Tutorial]* (Version 2023.2) [Computer software].
- Seequent (2024). *Automatic Gain Correction* (Version 2023.2 (20231121.28)) [Computer software].
- Sobel, I., & Feldman, G. (2015). *An Isotropic 3x3 Image Gradient Operator*. <https://doi.org/10.13140/RG.2.1.1912.4965>
- Soulaimani, A., Chakiri, S., Soulaimani, S., Manar, A., Bejjaji, Z., Miftah, A., Zerdeb, M. A., Zidane, Y., Boualoul, M., & Muzirafuti, A. (2022). Semi-Automatic Image Processing System of Aeromagnetic Data for Structural and Mining Investigations (Case of Bou Azzer Inlier, Central Anti-Atlas, Morocco). *Applied Sciences*, 12(21), 11270. <https://doi.org/10.3390/app122111270>
- Tangwattananukul, L., Ishiyama, D., Matsubaya, O., Mizuta, T., Charusiri, P., Sato, H., & Sera, K. (2014). Characteristics of Triassic epithermal Au mineralization at the Q prospect, Chatree mining area, Central Thailand. *Resource Geology*, 64. <https://doi.org/10.1111/rge.12035>
- Telford, W. M., Geldart, L. P., & Sheriff, R. E. (1990). *Applied Geophysics*. Cambridge University Press. <https://books.google.co.th/books?id=Q8ogAwAAQBAJ>
- UTS Geophysics Pty. Ltd. (2004). *Logistics Report for a DETAILED AIRBORNE MAGNETIC, RADIOMETRIC AND DIGITAL TERRAIN SURVEY for the PHITSANULOK PROJECTS carried out on behalf of AKARA MINING LIMITED* [Unpublished Report].
- Uwiduhaye, J. d'Amour, Ngaruye, J. C., & Saibi, H. (2021). Defining potential mineral exploration targets from the interpretation of aeromagnetic data in western Rwanda. *Ore Geology Reviews*, 128, 103927. <https://doi.org/10.1016/j.oregeorev.2020.103927>

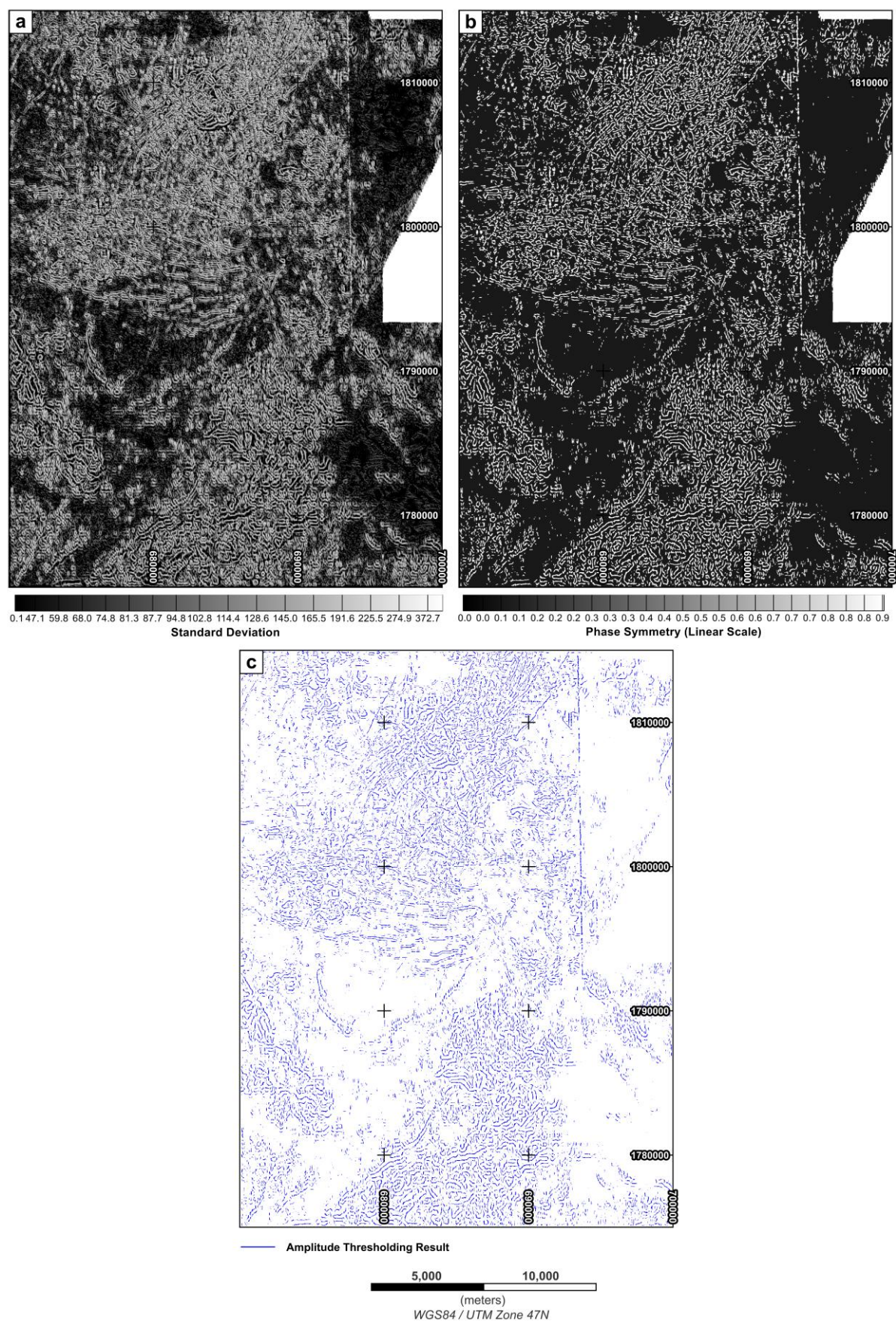
Appendix A

Filtered Magnetic Images and the CET Grid Analysis Results



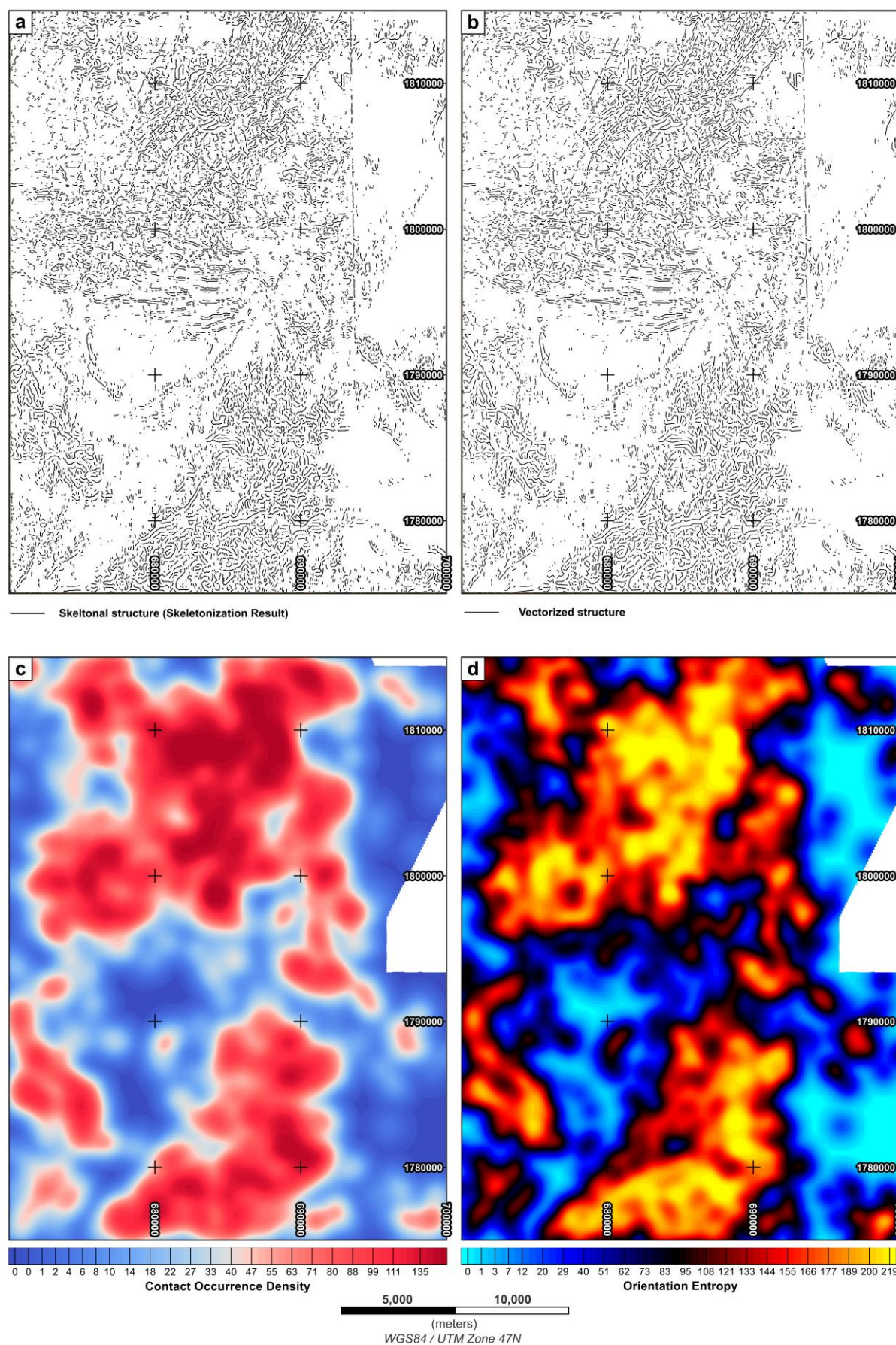
Appendix 1A Maps showing images and results for (a) TMI, (b) RTP, (c) DWC, and (d) AGC.

Identifying Prospective Areas for the Chatree Epithermal Gold Region from Airborne Magnetic Data Using Advanced Analyzing Techniques, with Interpretative Correlation



Appendix 2A Maps displaying results of (a) Standard Deviation, (b) Phase Symmetry, and (c) Amplitude Thresholding.

Identifying Prospective Areas for the Chatree Epithermal Gold Region from Airborne Magnetic Data Using Advanced Analyzing Techniques, with Interpretative Correlation

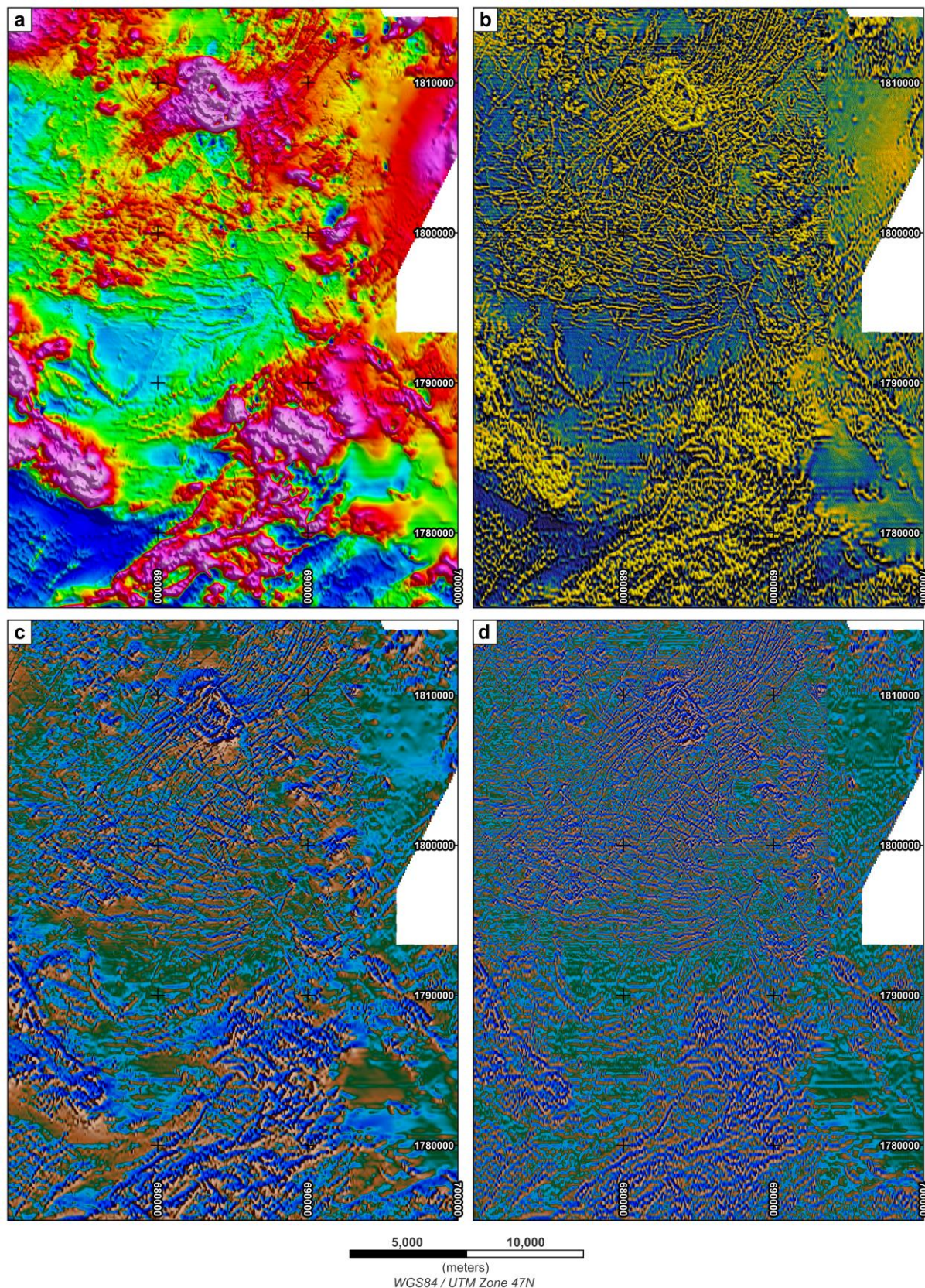


Appendix 3A Maps displaying results of (a) Skeletonization (b) Skeleton to Vector (c) COD and (d) OE.

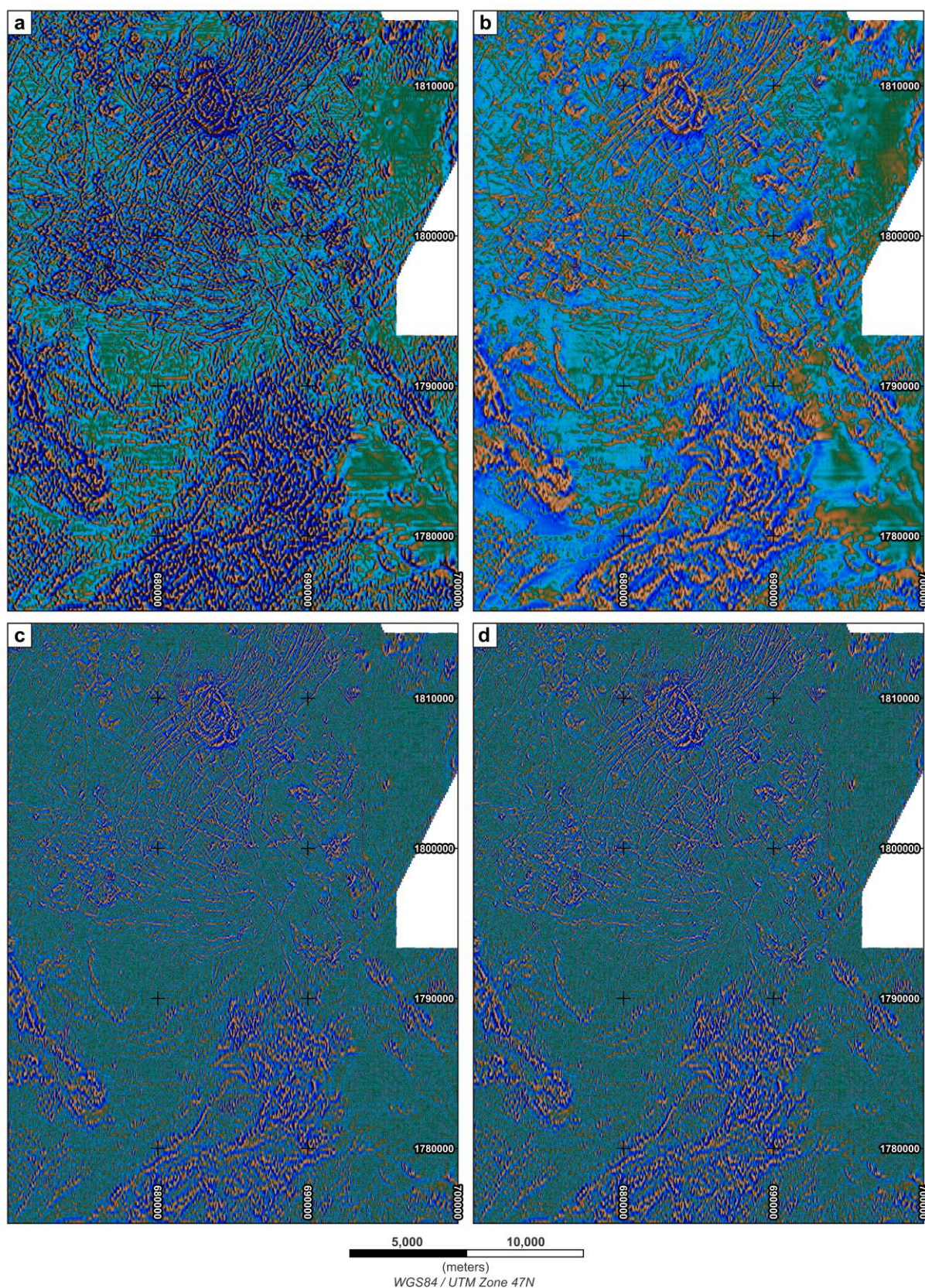
Identifying Prospective Areas for the Chatree Epithermal Gold Region from Airborne Magnetic Data Using Advanced Analyzing Techniques, with Interpretative Correlation

Appendix B

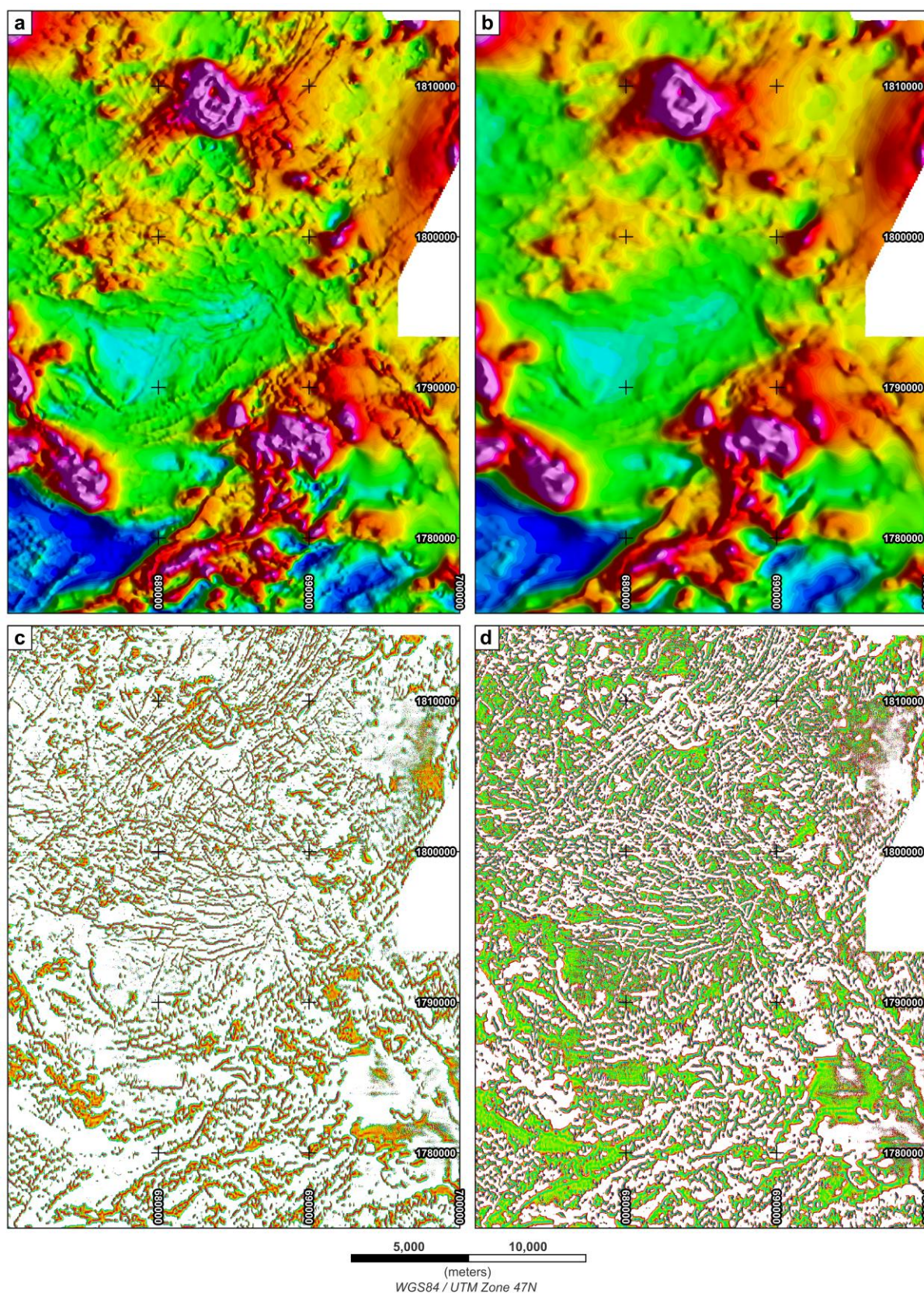
Filtered Magnetic Images Used for Lineament Interpretation



Appendix 1B Maps displaying filtered magnetic images of (a) TMI→RTP, (b) RTP→DWC-25→AGC, (c) RTP→1VD and (d) RTP→2VD. The RTP and RTP→DWC→AGC shown here (previously presented in Appendix A) are referenced again to aid in the process of lineament interpretation. The c and d are derived from Akara Resources Public Company Limited (2004).



Appendix 2B Maps displaying filtered magnetic images of (a) RTP→AGC, (b) RTP→1VD, (c) RTP→2VD and (d) RTP→2VD→AGC. All maps are derived from Akara Resources Public Company Limited (2004).



Appendix 3B Maps displaying filtered magnetic images of (a) RTP→UWC-100, (b) RTP→UWC-250, (c) RTP→TDR→AGC→Cut-off low, and (d) RTP→TDR→AGC→Cut-off high. All maps are derived from Akara Resources Public Company Limited (2004).

Appendix C

Own Results

Exclusively for the OTDK

Own Results

Solved Scientific Questions

- Identified gold mineralization prospect zones of the Chatree Region by employing symmetric analyzing techniques
- Determined the relationships between magnetic anomalies and lithological geology in the Chatree Region.
- Established correlations between the presence of lineaments in the area and structural geology of the Chatree Region.

Methodologies Personally Applied

- Conducted gold mineralization potential identification analysis utilizing the CET Grid Analysis, an advanced technique integrated into the Oasis Montaj software.
- In prior of applying the CET Grid Analysis, the visibility of lineaments was enhanced by applying DWC and AGC filters.
- Interpreted the presence of lineaments visually. The interpretation was based on the 12 filtered magnetic images including RTP, RTP → DWC → AGC, TMI → 1VD, TMI → 2VD, RTP → AGC, RTP → 1VD, RTP → 2VD, RTP → 2VD → AGC, RTP → 25m UWC, RTP → 100m UWC, RTP → TDR → AGC → Cut-off High, and RTP → TDR → AGC → Cut-off Low.

Results Obtained

- OE and COD heat maps were generated to visualize potential gold mineralization, where potential levels were categorized into very low, low, medium, high, and very high.
- Six major and seven minor gold prospect zones were identified based on high and very high potential levels and were characterized geologically and spatially. The seven identified major zones are the WPPZ, the KKPZ, the CPZ, the WSPZ, the TKPZ, the TKHPZ, and the CDPZ. The six minor zones include the WSPPZ, the SPPZ, the BDSLPZ, the TTPZ, the KHNPZ, and the LKPZ.
- A detailed lineament analysis was conducted for each prospect zone, resulted in a structural framework within the area.
- Established correlations between lithological and structural geology with magnetic anomaly patterns and lineament occurrences across the 13 identified prospects, providing understanding of the geological controls on gold mineralization in the Chatree Region.