

**Regional Study of Applied Satellite Data for Evaluation of Resource Potential  
in the Northern Area of the Republic of Peru, Phase II**

March, 1999

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**Abstract**

The purpose of this study is to evaluate the regional resource potential of northern Peru by satellite image analysis. This study is being jointly carried out with Instituto Geológico Minero y Metalúrgico del Perú "INGEMMET" and Perupetro S.A. The term of this project is scheduled to be three years with this year being the second year of the project. The study area for this year was between latitudes 4° 30' S and 7° S in the N-S direction, and the Pacific Ocean and Brazilian border in the E-W direction.

The western portion of the study area, the Andean mountain range region, is known as a metallogenic region, and numerous metallic ore deposits, such as Yanacocha mine (gold dissemination type in massive silicified rocks), La Ganja mine (porphyry copper type) and Hualgajoc mine (polymetallic vein type) are located here. Geologic interpretation and spectral analysis of LANDSAT TM data and field survey for alteration mapping in this region have been carried out, as well as a prototype of computer programme to aid potential evaluation analysis by geologists, using GIS data set as input data, have been developed. This programme will be completed and applied for evaluation of the whole Andean mountain range region in the next fiscal year. As a result of the study in the metallogenic region so far, concentration of mercury and arsenic is recognised in one of the silicified zones causing a TM spectral anomaly in the Chota area where the Yanacocha and Hualgajoc mines are located. It suggests a possibility that this silicified zone might be accompanied by gold mineralization. The test case of the prototype programme for potential evaluation shows its effectiveness applied to regional evaluation of resource potential.

The eastern portion of the study area, the Sub-Andean mountain range and low lands in the up stream region of the Amazon river, is a major oil producing area in Peru and so far the Yanayacu oil field has been developed in the area. Interpretation of LANDSAT TM and JERS-1 SAR mosaic images for geotectonic analysis and existing geological/geophysical data collection and subsequent analysis have been carried out. Two sub-areas of interest have been selected and detailed studies have been done in these areas. As a result of the studies so far, some geotectonic characteristics related to possible new play for the oil/gas exploration have been identified by satellite images. Based on the newly acquired geological, geophysical and geochemical data from Perupetro S. A., the "Local Kitchen Hypothesis" which have been proposed to explain the situation of oil/gas fields in the Ucayali basin in 1998 was also tested. Although there is a strong relationship between local heating and oil fields, details are not still clear. Further data collection such as gas composition analysis etc. and study are necessary.

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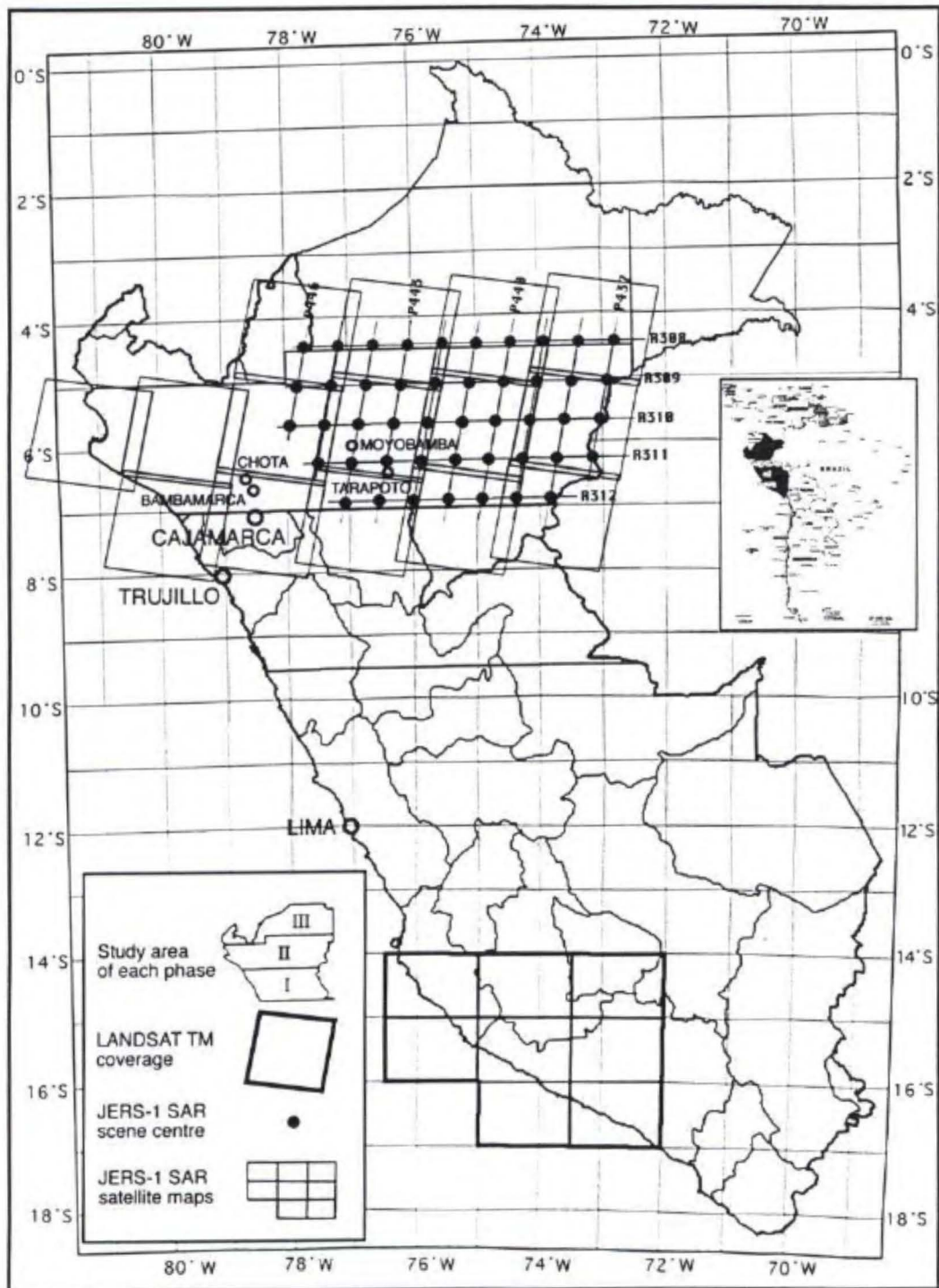
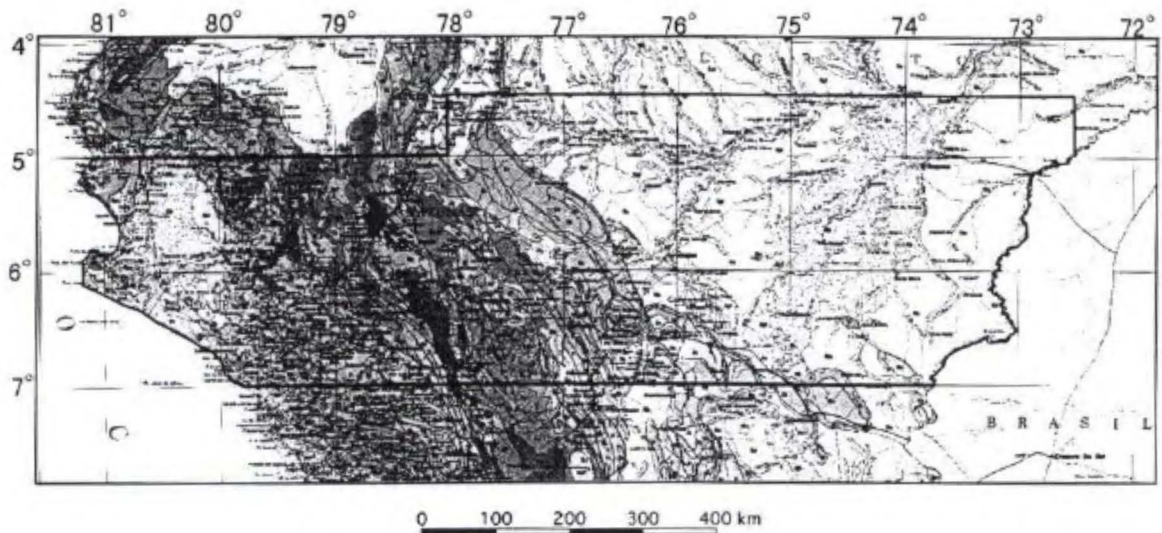


図 1. 対象地域の位置と使用画像データ

Fig. 1. Location of the study areas and data used.



ERA	SISTEM	SERIES	SIMBOL	INTRUSIVE ROCK
CENOZOIC	QUATERNARY	HOLOCENE	Ch	Batolito de Cordillera Blanca, Batolito de Apacoy, Plutones Patuca, Sayan, Pico San Gerónimo, Batolito de Orco de la Cordillera de la Costa
		PLEISTOCENE	Qpl	
			Qo	
	NEOGENE	PLIOCENE	Nc	
		MIOCENE	Nvs	
	PALEOGENE	OLIGOCENE	P	
		EOCENE	KsP	
		PALEOCENE	Ks	
			Ki	
			Ji	
MESOZOIC	CRETACEO	UPPER	Trs Ji	
		LOWER	Ps	
	JURASICO	UPPER	CP	
		LOWER	Pi	
	TRIASICO	UPPER	Pe	
		LOWER		
PALAEZOIC	UPPER	PERMIAN	Pm	
		CARBONIFERO	UPPER	
			LOWER	
		LOWER	DEVONIAN	
	SILURIAN			
	ORDOVICIAN			
	CAMBRIAN			
	PROTEROZOIC			

図 2. 対象地域の地質図

Fig. 2. Geologic map of the study area.

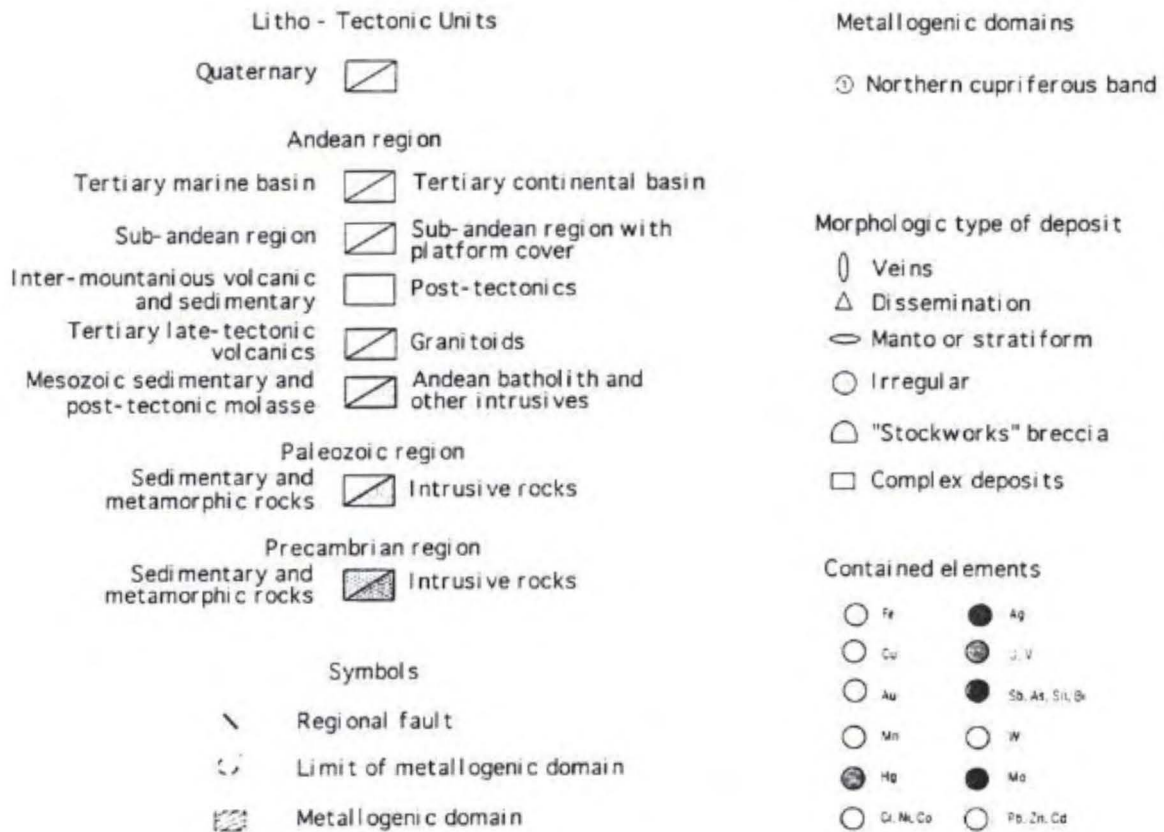
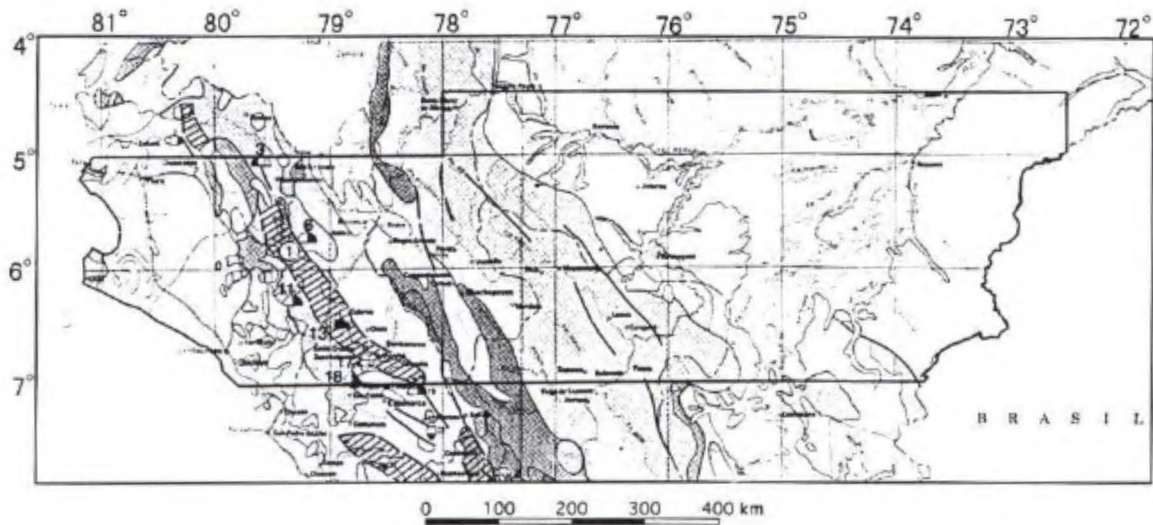


図 3. 対象地域の金属鉱床分布

Fig. 3. Metallogenic map of the study area.

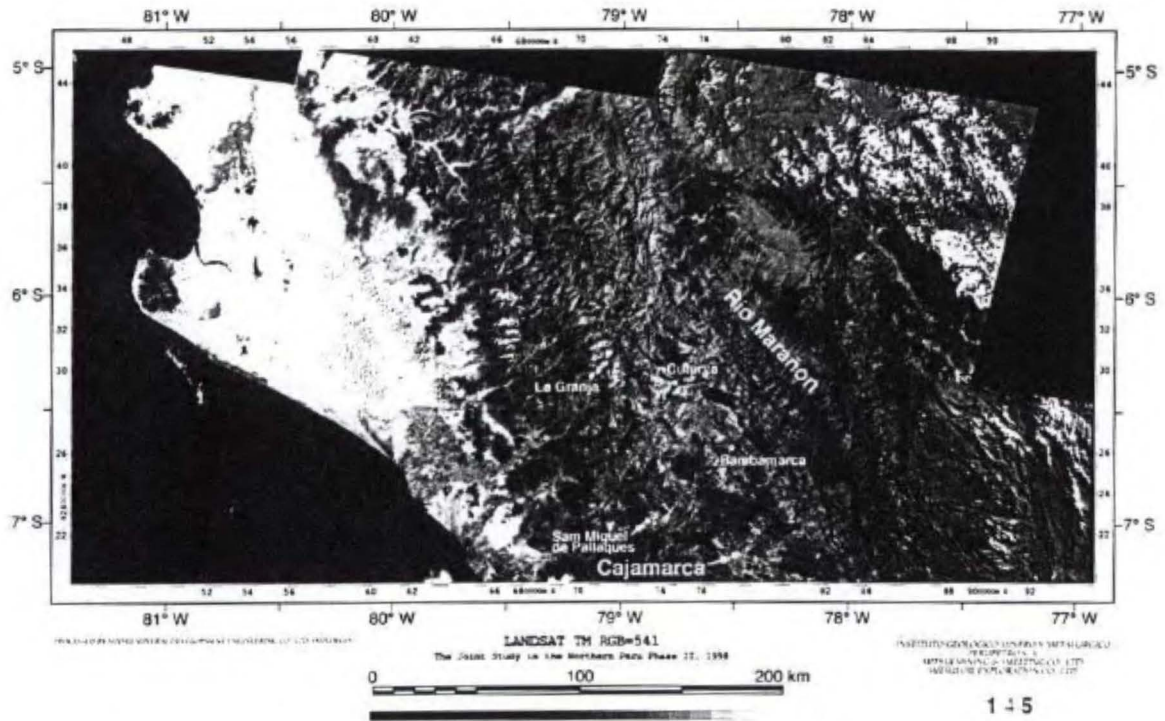


図 4. アンデス地域TMモザイクカラー合成画像  
 Fig. 4. TM colour composite image of the Andean region.

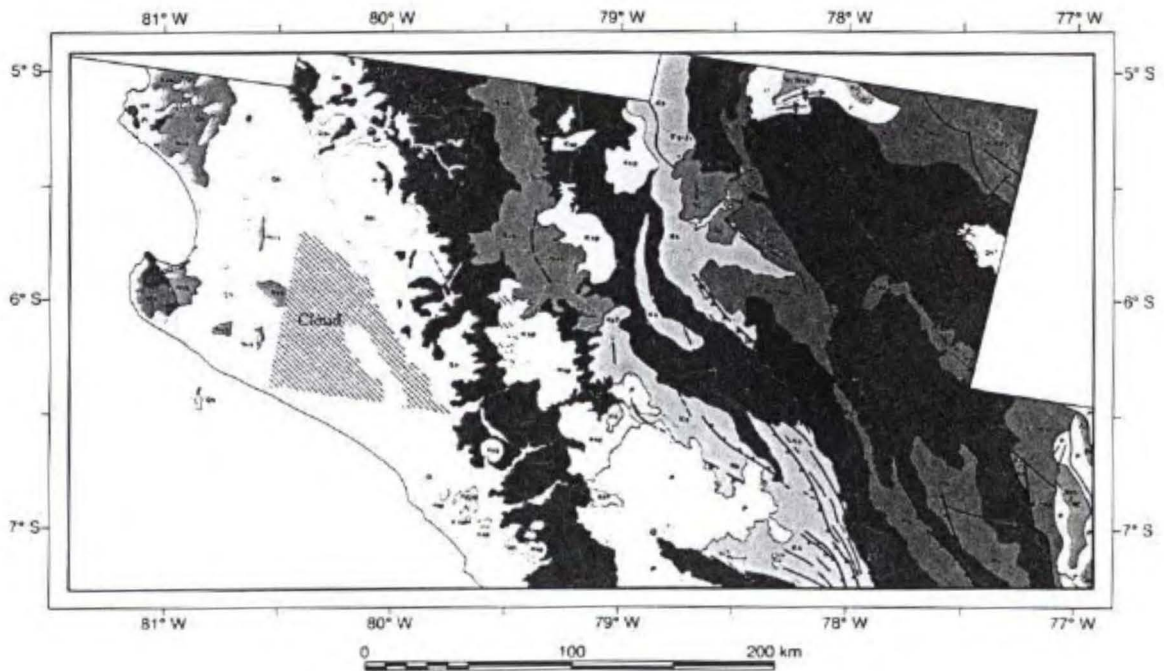


図 5. アンデス地域TM地質判読図  
 Fig. 5. TM geologic interpretation map of the Andean region.

表 1. アンデス地域TM判読図地質単元

Table 1. Geologic units of the TM interpretation map of the Andean region.

Geologic Age		Units in the interpretation map		Units after INGEMMET (1995)	Lithology (inferred)
Cenozoic	Quaternary	Qh		Qh	gravel, sand, silt
		Qpl		Qpl	gravel, sand, silt
	Pliocene- Miocene	Nc/Nvs	Nc	Nc	sedimentary
	Oligocene-Miocene		Nvs	Nvs	volcanic
	Eocene	P		P	sedimentary
Mesozoic	Cretaceous-Palaeogene	Ksp		Ksp	intrusive
	Cretaceous	Ki/Ks	Ks	Ks	sedimentary
			Ki	Ki	sedimentary
	Jurassic			J	sedimentary
Triassic-Jurassic			Trs-Ji	sedimentary	
Palaeozoic	Permian	Ps		Ps	sedimentary
	Ordovician-Silurian	Pi		Pi	sedimentary
Proterozoic	Pre-Cambrian	Pe		Pe	metamorphic

表 2. マラニオン地域画像判読図地質単元

Table 2. Geologic units of the image interpretation map of the Marañon region.

Geologic Age		Units in the interpretation map		Units after INGEMMET (1995)	Lithology (inferred)
Cenozoic	Quaternary	Q		Qh	gravel, sand, silt
				Qpl	gravel, sand, silt
	Pliocene- Miocene	T2		Nc	sedimentary
	Oligocene-Miocene			Nvs	sedimentary
Eocene	T1		P	sedimentary	
Mesozoic	Cretaceous-Palaeogene	K	K2	Ksp	intrusive
	Cretaceous		Ks	Ks	sedimentary
	Jurassic			Ki	sedimentary
	Triassic-Jurassic			J	sedimentary
Palaeozoic	Permian			Trs-Ji	sedimentary
	Ordovician-Silurian			Ps	sedimentary
Proterozoic	Pre-Cambrian			Pi	sedimentary
				Pe	metamorphic



図 6. アンデス地域TMリニアメント図

Fig. 6. TM lineament map of the Andean region.

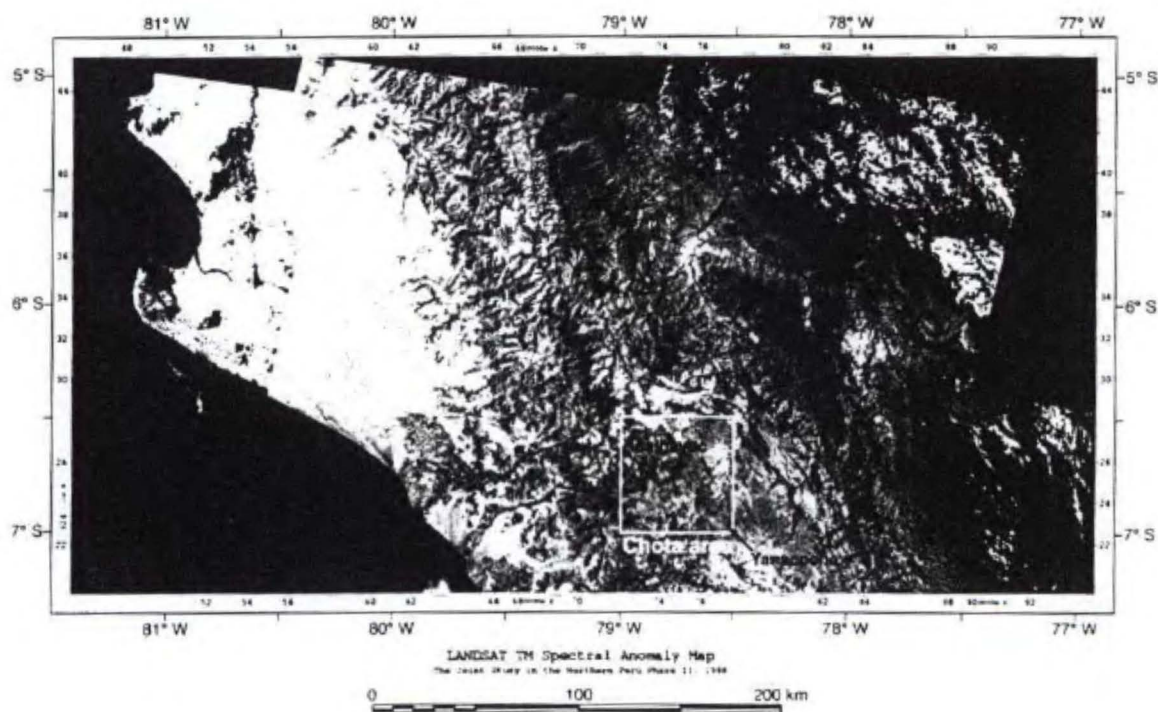


図 7. アンデス地域TMスペクトル異常図

Fig. 7. TM spectral anomaly map of the Andean region.





図 8. Chota地区TMカラー合成画像

Fig. 8. TM colour composite image of the Chota area.



図 9. Chota地区TMスペクトル異常図

Fig. 9. TM spectral anomaly map of the Chota area.



図 10. 調査地点9 (Cerro Cimarronas) の状況  
Fig. 10. View of the site 9 (Cerro Cimarronas).



図 11. 調査地点9 (Cerro Cimarronas) の珪化岩  
Fig. 11. Silicified rock at site 9 (Cerro Cimarronas).

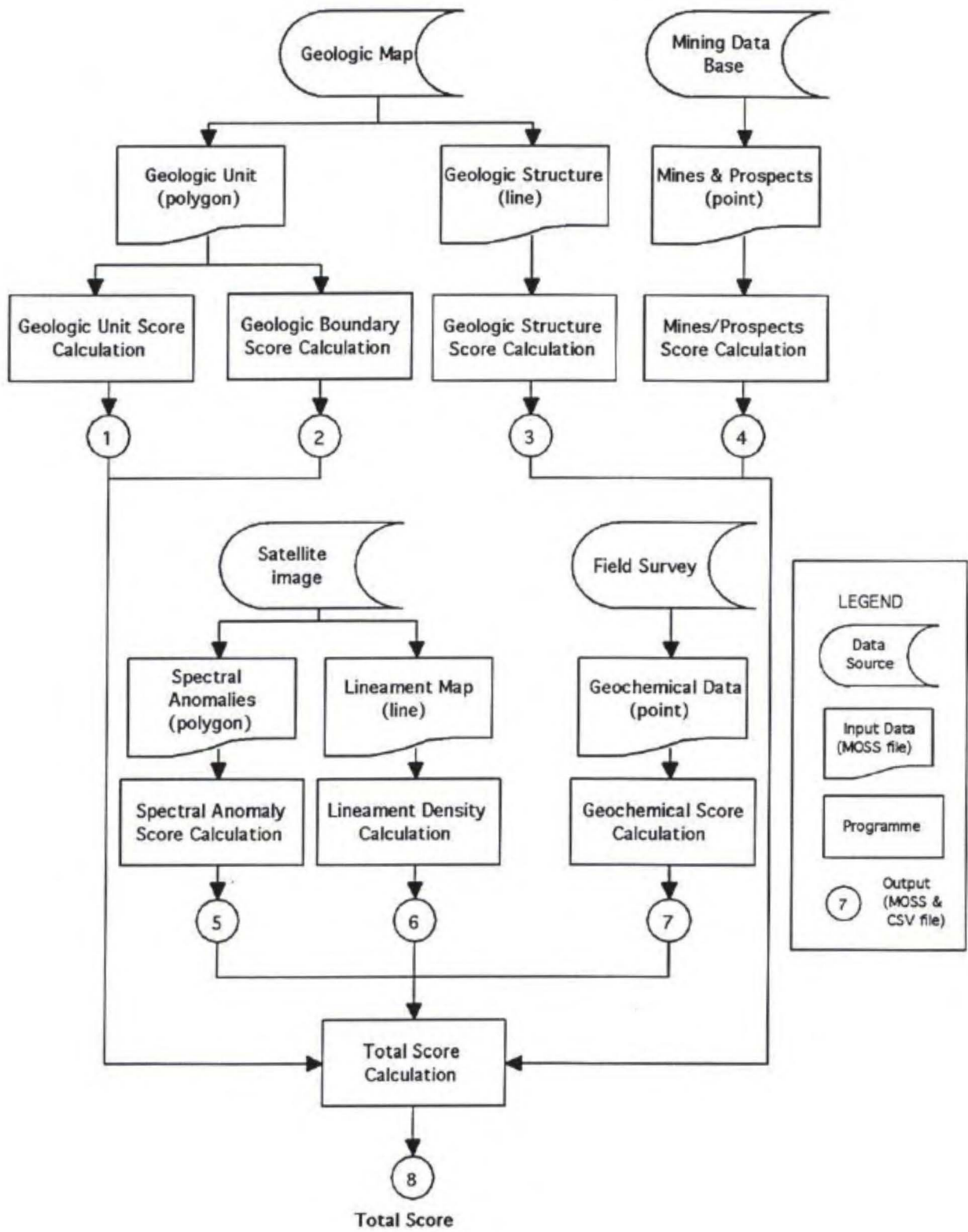
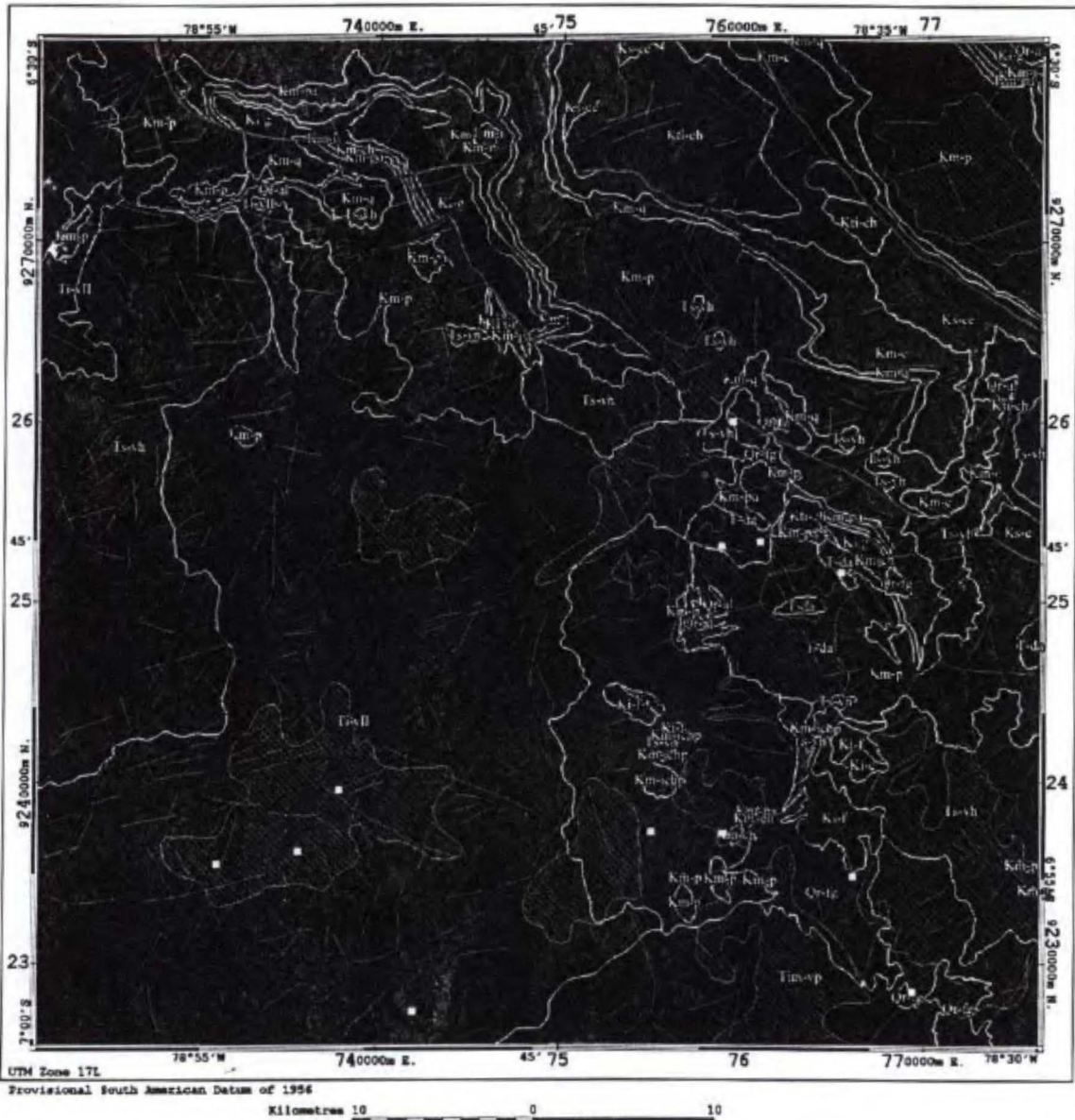


図 12. 有望度評価ツールの概要

Fig. 12. Overview of the potential assessment tool.



Sedimentary & volcanic units					
Cenozoic	Quaternary	Holocene	Qr-al	Alluvium	
			Qr-fg	Glacier deposits	
	Tertiary	Upper	Ts-vh	Huambos volcanic	
		Middle	Tim-vp	Calipuy Group Porcualla volcanic	
	Lower	Ti-vll	Llama volcanic		
Mesozoic	Cretaceous	Upper	Kti-ch	Chota formation	
			Ks-c	Celendin formation	
			Km-c	Cajamarca formation	
		Middle	Km-q	Quillquinan group	
			Km-p	Pullucana group	
			Km-ichp	Km-pa	Pariatambo formation
				Km-ch	Chulec formation
		Km-l		Inca formation	
		Lower	Ki-g	Ki-f	Farrat formation
				Ki-c	Carhuaz formation
Intrusive unit					
Cenozoic	Tertiary	Middle	T-da	Dacite	

	Thrust faults
	Faults
	Synclines
	Anticlines
	Lineaments
	Spectral anomalies
	Gold mines or prospects
	Copper mines or prospects
	Polymetallic mines or prospects
	Geochemical sampling points

図 13. 有望度評価ツール入力データ

Fig. 13. Input data of the potential assessment tool.

表 3. 判定ツール入力変数一覧  
Table 3. Input parameters for the potential assessment tool.

Geologic units		
Proportional multiplier		1.00
Weights	Qr-al	0.00
	Qr-fg	0.00
	Ts-vh	1.00
	Tim-vp	1.00
	Ti-vII	1.00
	KTi-ch	0.00
	Ks-c	0.00
	Km-c	0.50
	Km-q	0.00
	Km-p	0.50
	Km-ichp	0.00
	Km-pa	0.00
	Km-ch	0.00
	Km-i	0.00
	Ki-f	0.00
Ki-c	0.00	
Ki-g	0.00	
T-da	1.00	

Geologic boundary		
Inverse-proportional multiplier		0.50
Minimum distance (meter)		1.00
Maximum distance (meters)		3000.00
Weight of boundar	T-da	2.00
Weights of contact	T-da / Kmc	2.00
	Tda / Km-p	2.00

Mines & Prospects		
Inverse-proportional multiplier		0.20
Minimum distance (meter)		1.00
Maximum distance (meters)		5000.00
Weights of type	Gold	3.00
	Copper	2.00
	Polymetalli	1.00
Weights of size	Big	5.00
	Medium	3.00
	Small	2.00
Prospect		1.00

Geologic structure		
Inverse-proportional multiplier		0.30
Minimum distance (meter)		1.00
Maximum distance (meters)		3000.00
Weights	Thrust	1.00
	Fault	2.00
	Syncline	2.00
	Anticline	4.00

Geochemical data		
Inverse-proportional multiplier		0.20
Minimum distance (meter)		1.00
Maximum distance (meters)		3000.00
Weights of elements	Au	5.00
	Ag	5.00
	Cu	5.00
	Pb	5.00
	Zn	5.00
	As	3.00
	Sb	3.00
	Te	3.00
	Hg	3.00

Spectral anomaly		
Proportional multiplier		1.00
Weight	Iron	1.00

Lineament density		
Proportional multiplier		0.50
Weight	Lineament	1.00

Total score		
Weights	Geologic unit	5.00
	Unit boundary	15.00
	Geologic structure	10.00
	Mines & Prospects	20.00
	Geochemical data	50.00
	Spectral anomaly	0.75
	Lineament density	0.50

Minimum X (meters)	719000
Minimum Y (meters)	9225000
Maximum X (meters)	777000
Maximum Y (meters)	9282000
Grid size (meters)	1000

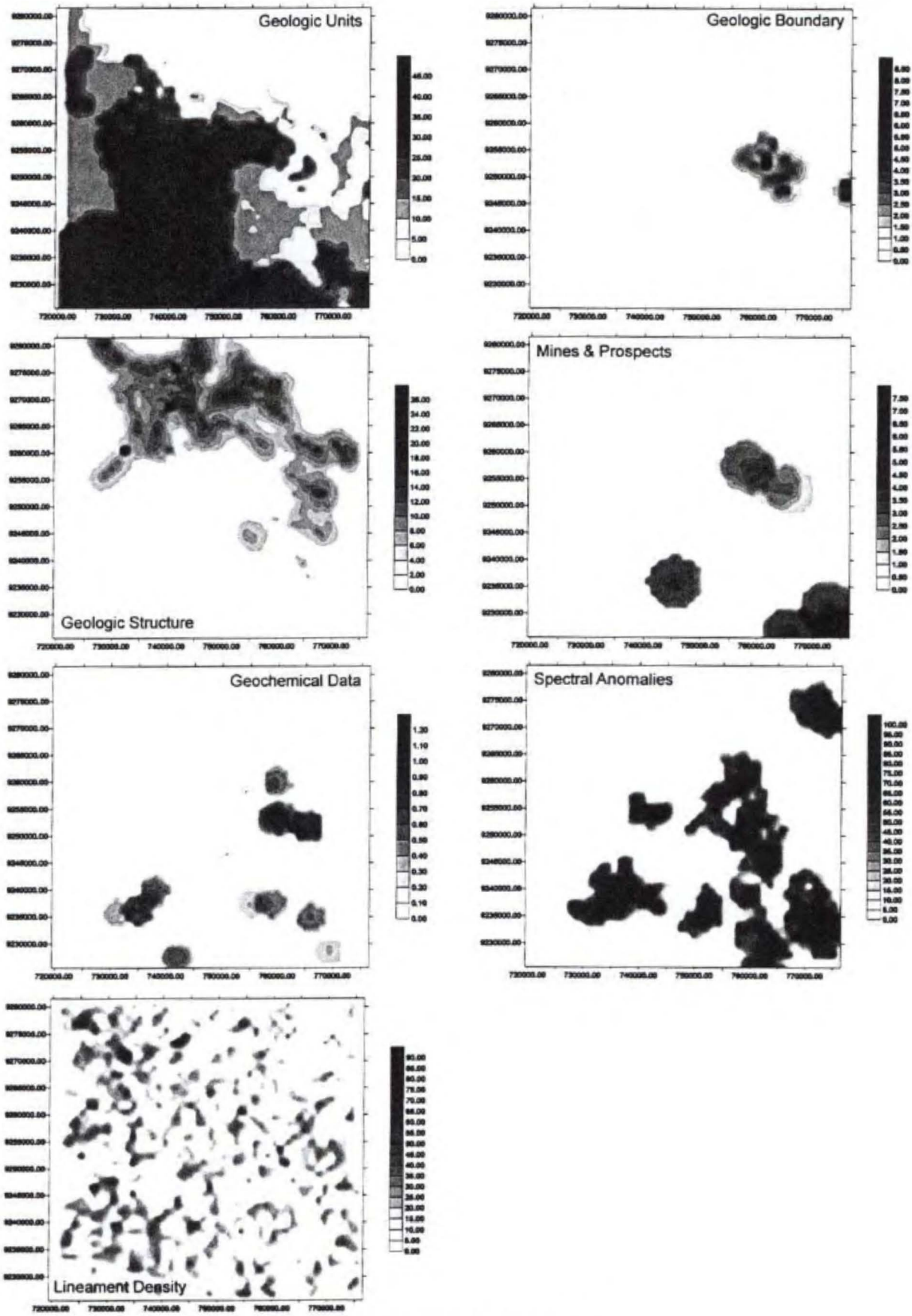


図 14. 評価要素の計算結果出力

Fig. 14. Output charts of the assessing elements.



CHOTA 14-f  
 LANDSAT TM Colour Composite Image RGB-541  
 Kilometres 0 5 10 15

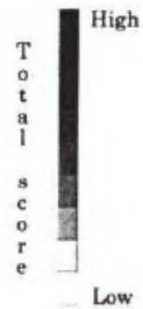


图 15. Chota地区有望度评估图

Fig. 15. The potential assessment map of Chota area.

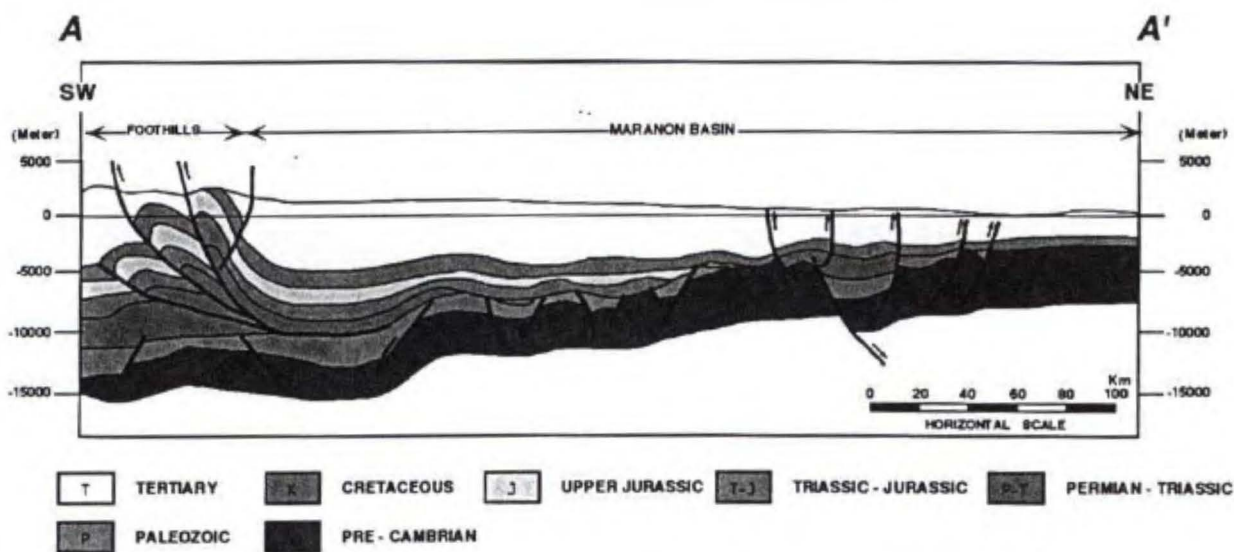
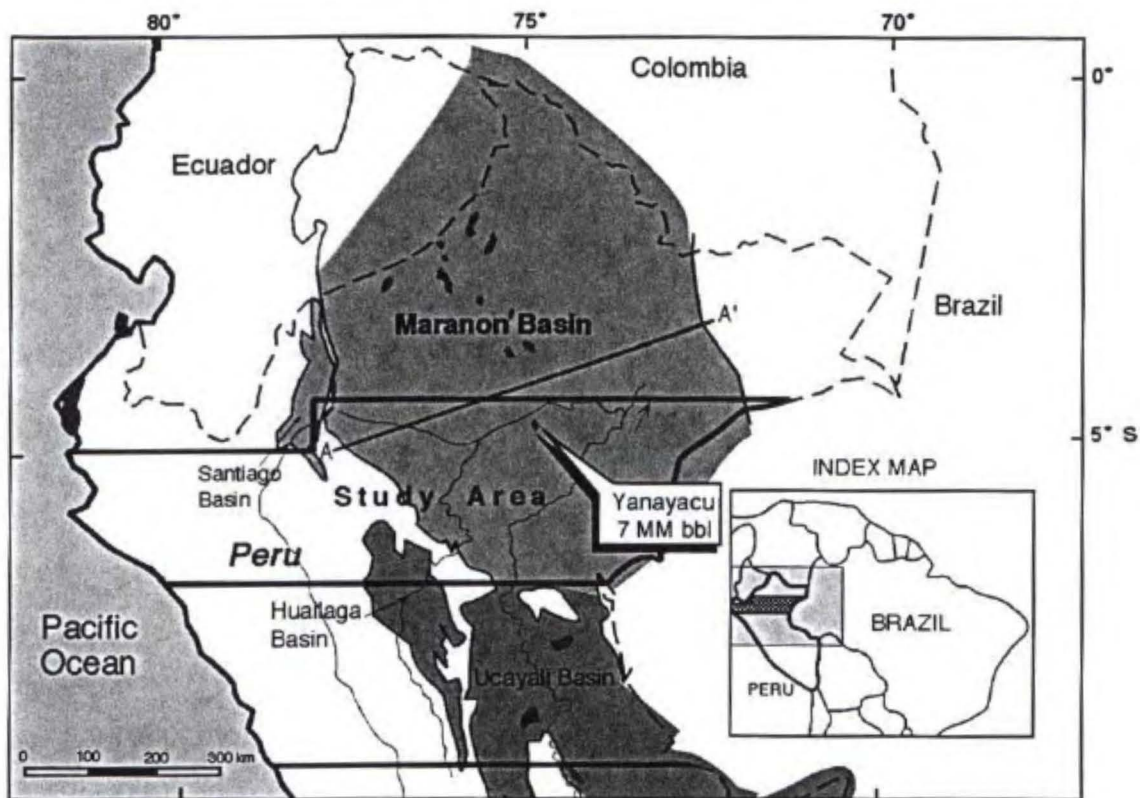


図 16. ペルーの内陸堆積盆地（マラニョン/ウカヤリ）及び地質断面図  
 Fig. 16. Location map of Sub-Andean basin in Peru (Marañon/ Ucayali)



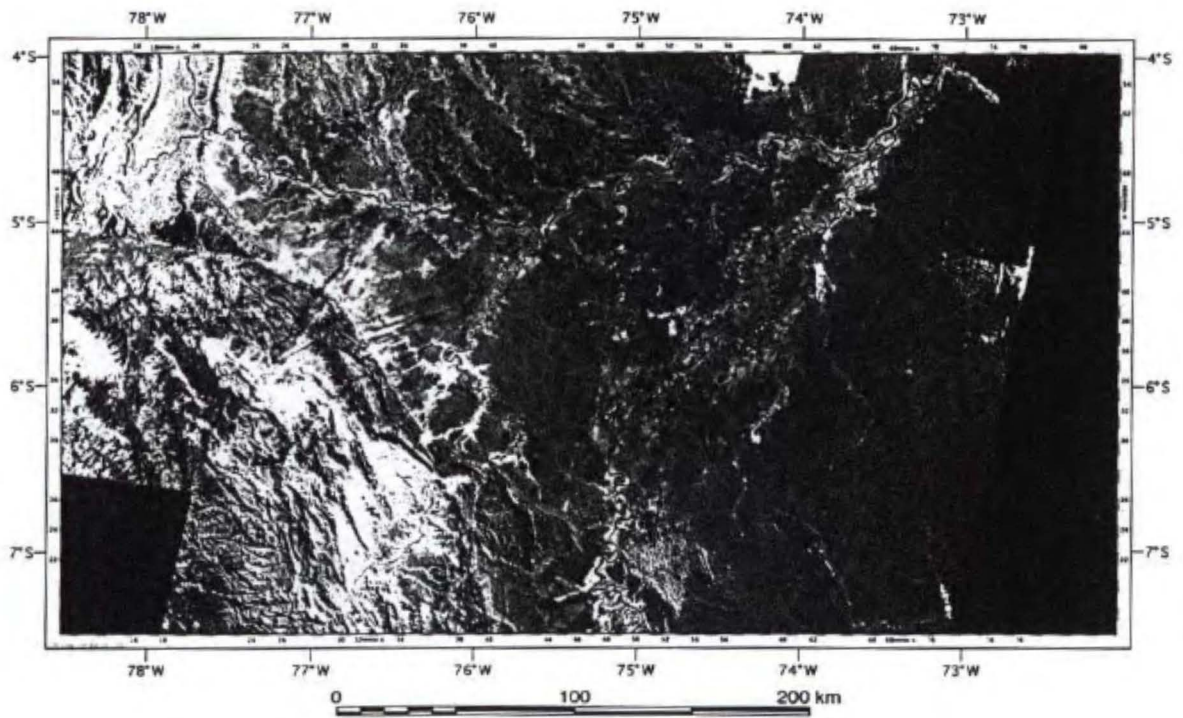


図 17. マラニョン地域 TM モザイクカラー合成画像  
 Fig. 17. TM color composit image of the Marañon region.

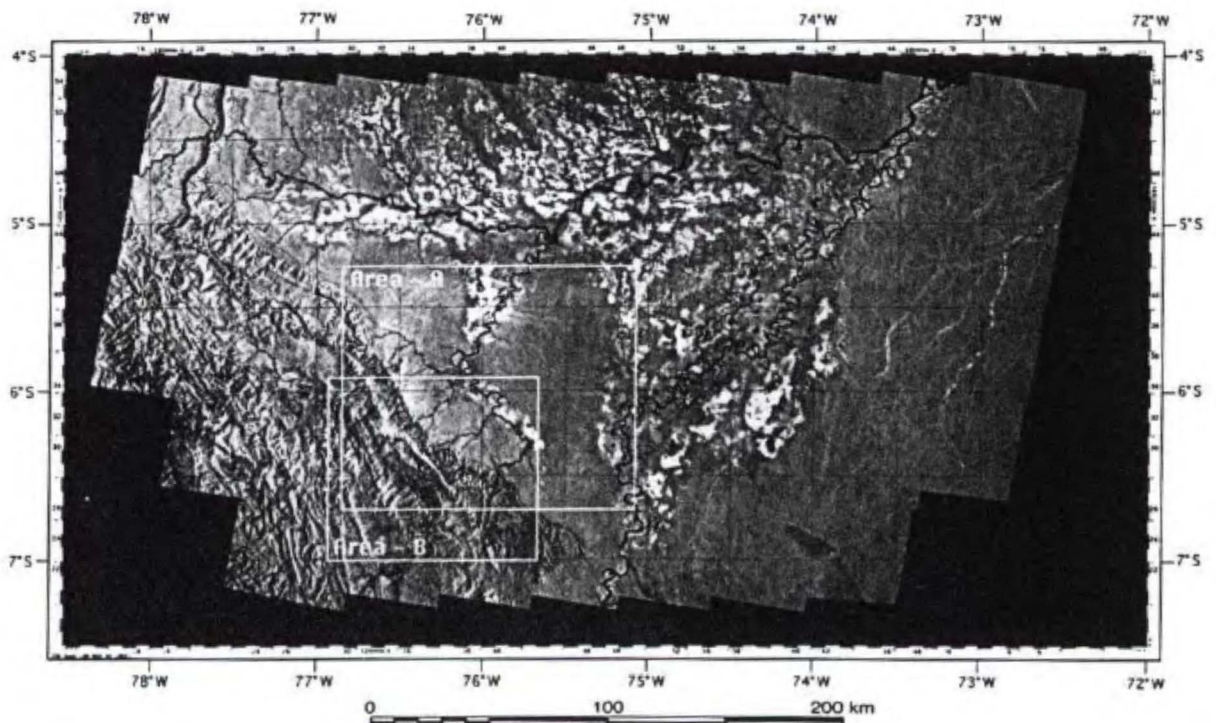


図 18. マラニョン地域JERS-1 SAR モザイク画像  
 Fig. 18. JERS-1 SAR mosaic image of the Marañon region.

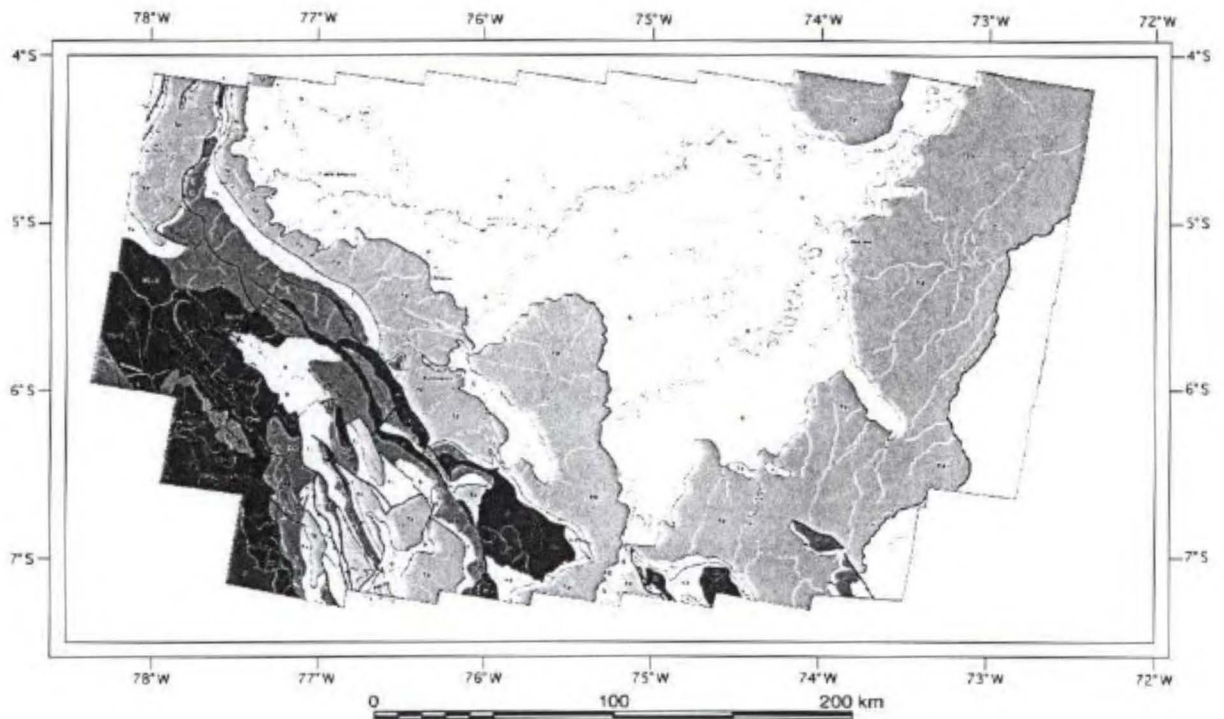


図 19. マラニオン地域画像地質判読図

Fig. 19. JERS-1 SAR geologic interpretation map of the Marañon region.

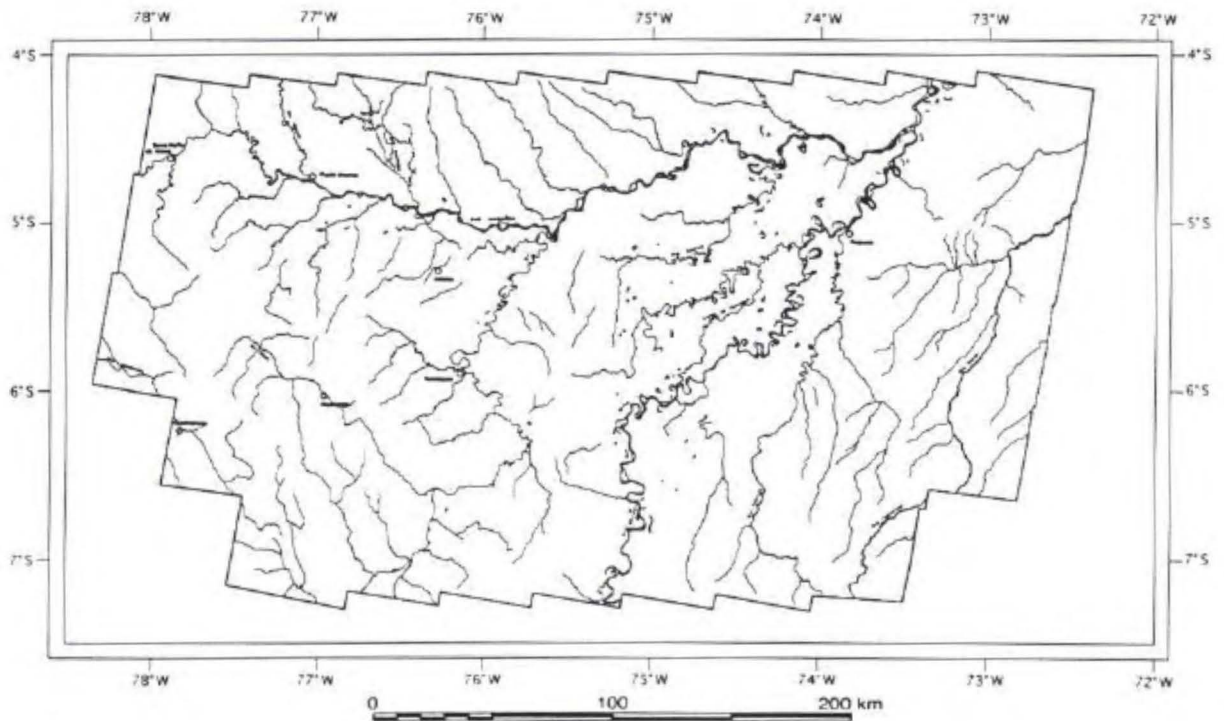


図 20. マラニオン地域水系図

Fig. 20. Drainage system of the Marañon region.

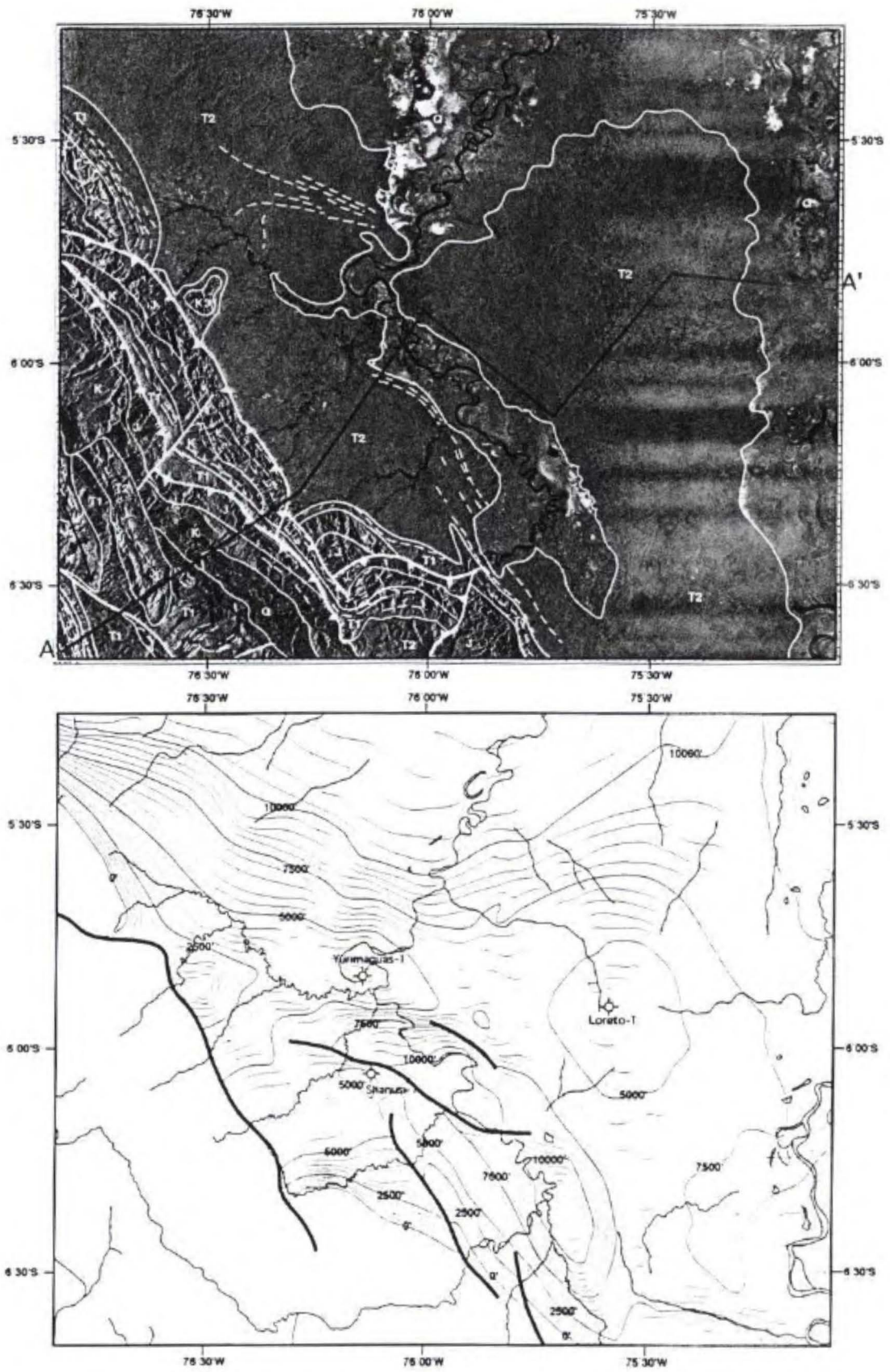


図 21. 詳細解析地域 A の SAR 画像と地質判読図及び白亜系頂部構造図  
 Fig. 21. JERS-1 SAR mosaic image, geologic interpretation map and Top Creta. Structure map of the detailed study area-A.

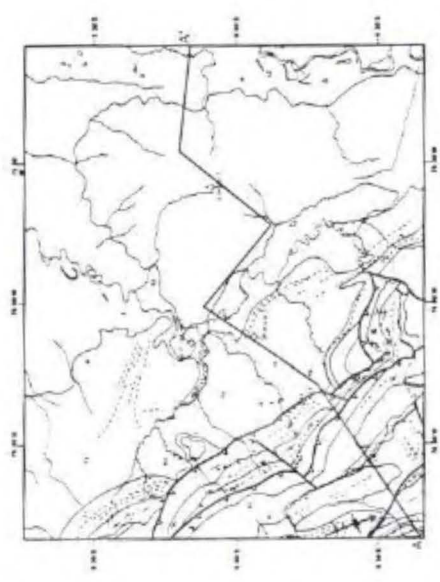
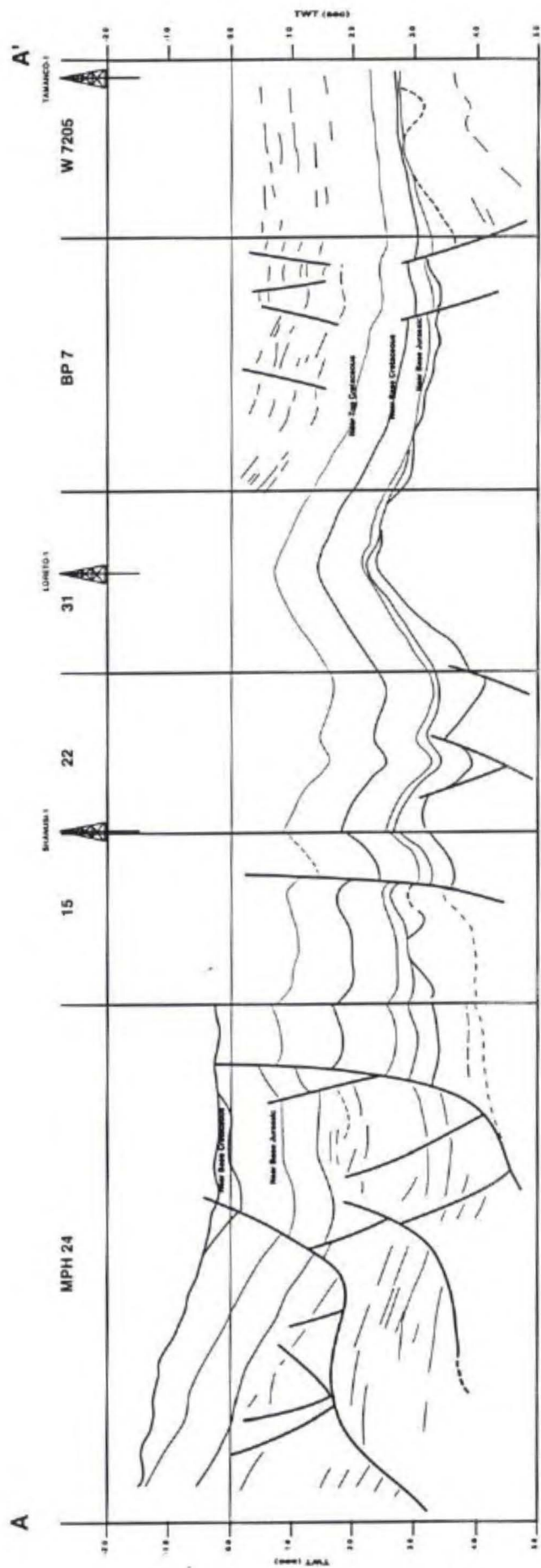


図 22. マラニオン地域地質断面図  
 Fig. 22. Geological cross-section of southern part of Marañón basin.

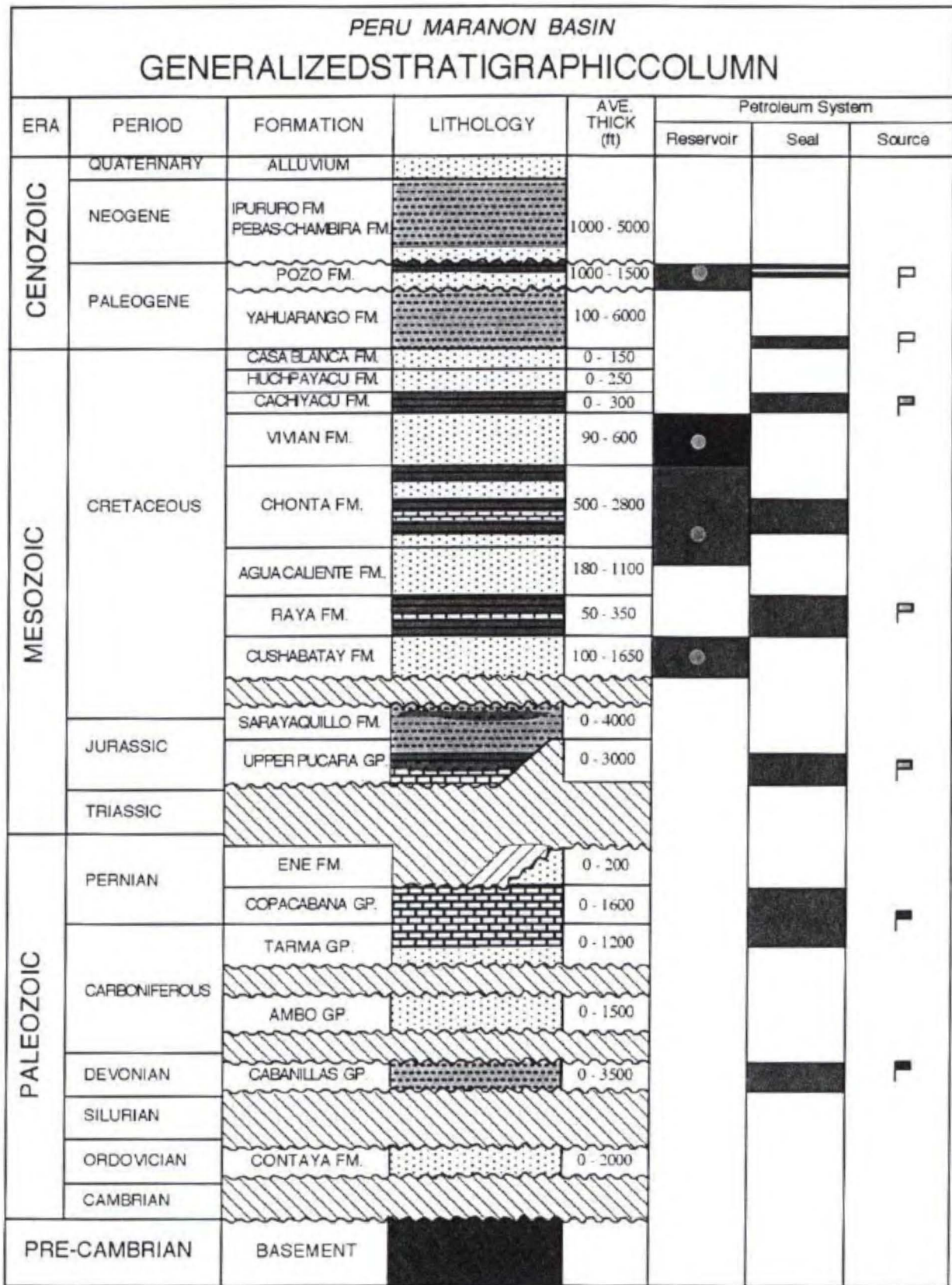


図 24. マラニオン堆積盆地の標準地質柱状図  
Fig. 24. Standard stratigraphic section of the Marañon basin.

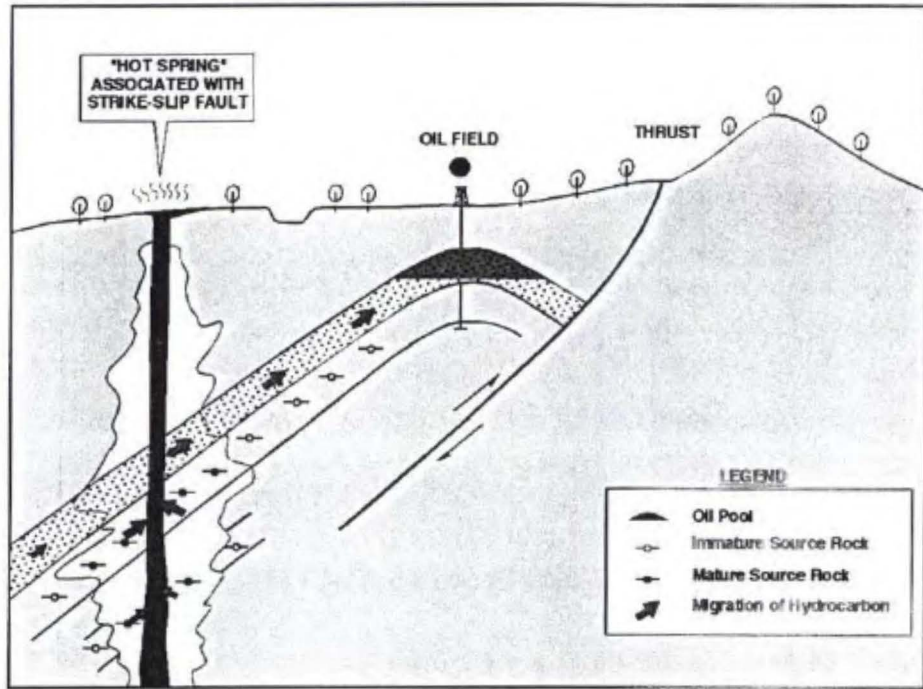


図 25. 「ローカルキッチンエリア」仮説モデル  
 Fig. 25. "Local kitchen area" model in Ucayali basin.

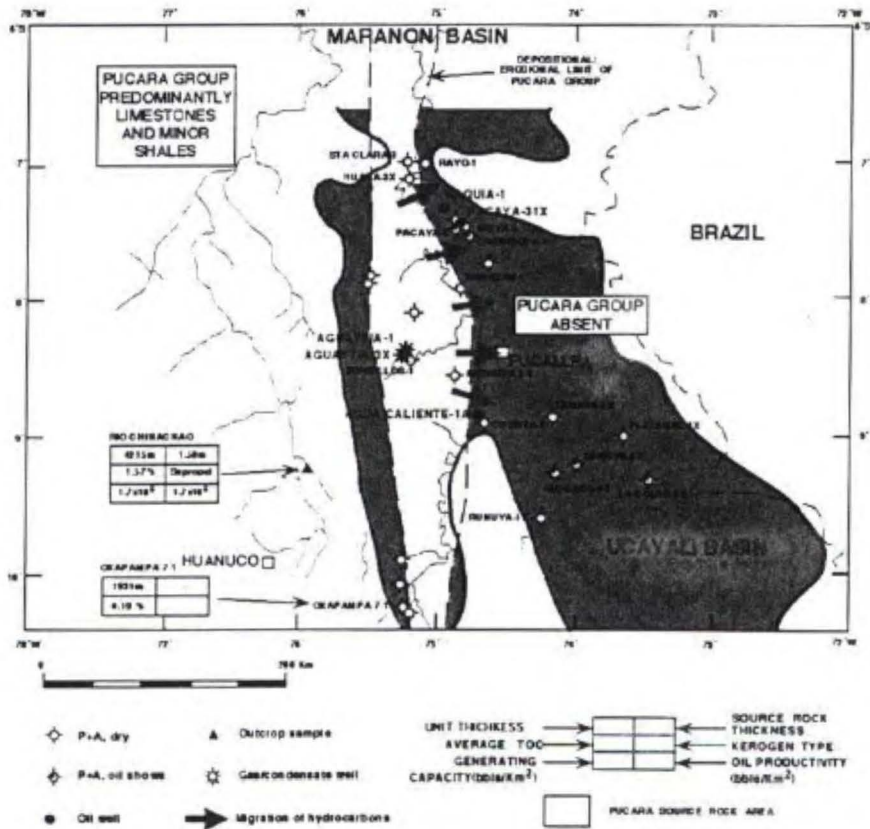


図 26. ウカヤリ堆積盆地の主要根源岩 (Pucara層群) の分布  
 Fig. 26. Pucara Group source rock in the Ucayali basin.

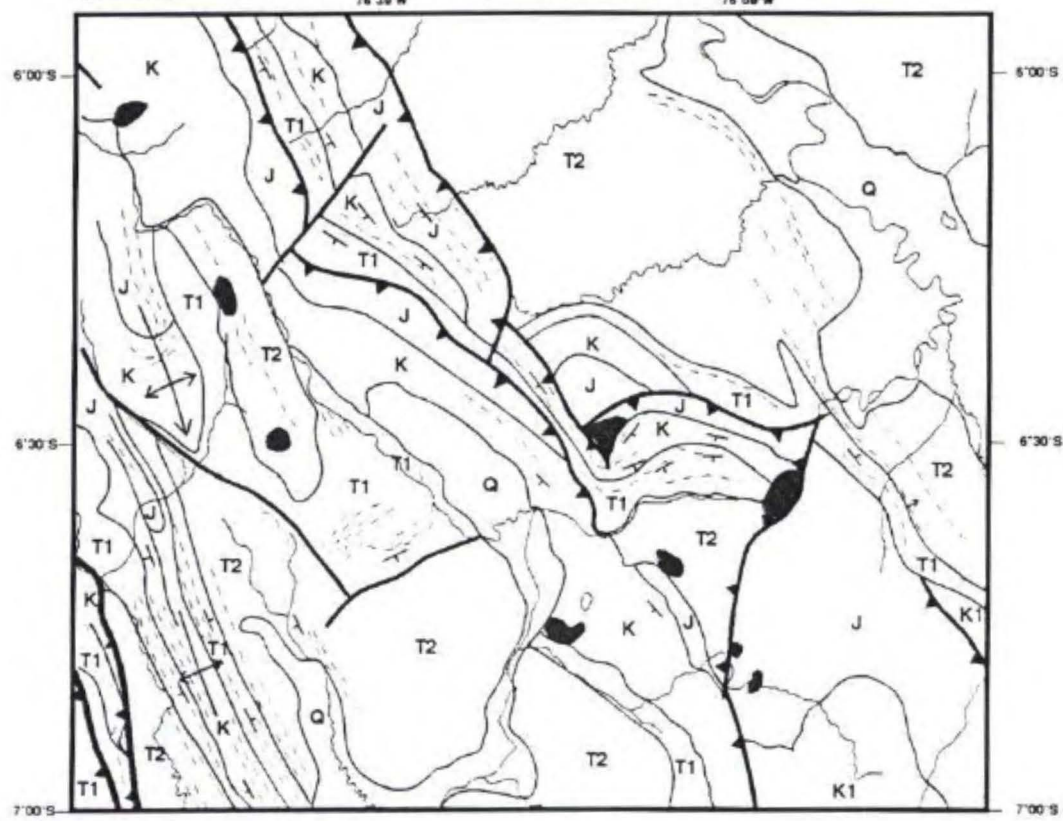


図 23. 詳細解析地域 B の SAR 画像と地質判読図及び白亜系頂部構造図  
 Fig. 23. JERS-1 SAR mosaic image, geologic interpretation map and Top Creta. Structure map of the detailed study area-B.