

Topographical features key to judging the above items have local characteristics depending on the rock type, geological structure or geological age of areas in question; therefore, the degree of their appearance is variable from area to area. In the studied area, topographical features of Items (a), (b), (c) and (e) were conspicuous and those of Items (f), (g), (h) and (i) were also observed in part. In the meantime to interpret the topographies of Items (i), (j) and (k), it would be necessary to use larger-scale scenes of Landsat TM image, SPOT HRV image or aerial photographs with three-dimensional observation.

2-2-3 Result of analysis

The following is the result of interpretation of geology and geological structure and extraction of alteration zones for each scene (13 areas in total) of the image. Used for the analysis are the Landsat TM false color synthetic image (B = Band 1, G = Band 4, R = Band 5 ; scale = 1: 250,000) and the ratio image (BGR = 3/1, 4/5, 5/7 ; scale=1:250,000). Description is made separately on geological unit classification, alteration zone distribution, lineament, folding structures and circular structures.

The result of interpretation of geology and geological structure and extraction of alteration zones was expressed onto a interpretation map which is followed by Landsat TM false color image and ratio image (Fig. II-2-3 to Fig. II-2-41). Further, on the geological stratigraphy, comparison was made with the existing geological maps, that is the Mapa Geológico de la Provincia del Chubut (scale = 1:750,000), the Mapa Geológico de la Provincia del Rio Negro (scale = 1:750,000), the Mapa Geológico de la Provincia del Neuquén (scale = 1:500,000), the Mapa Geológico de la Provincia del Mendoza, and a Chilean geological map (scale = 1:1,000,000). The result of these interpretations is summarized in Table II-2-2 to Table II-2-14.

1) The Malargue area

[Geological unit]

The rocks and sediments distributed in this area were classified into 20 geological units in total (Fig. II-2-3 and Table II-2-2). Of these, eight units are comparable to the sedimentary rocks of the Triassic to the Tertiary, seven units to the volcanic rocks of the Triassic to the Quaternary, and three units to unconsolidated or semi-consolidated sediments of the Quaternary. Another geological unit can be compared mainly to schist of the Paleozoic while another unit is comparable to intrusive rocks generated in the Paleozoic. One geological unit was determined to be an alteration zone.

Table II -2-2 Characteristics of photogeologic units of the Malargue area

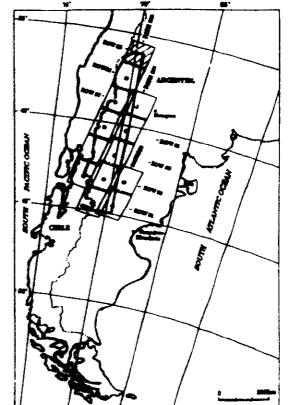
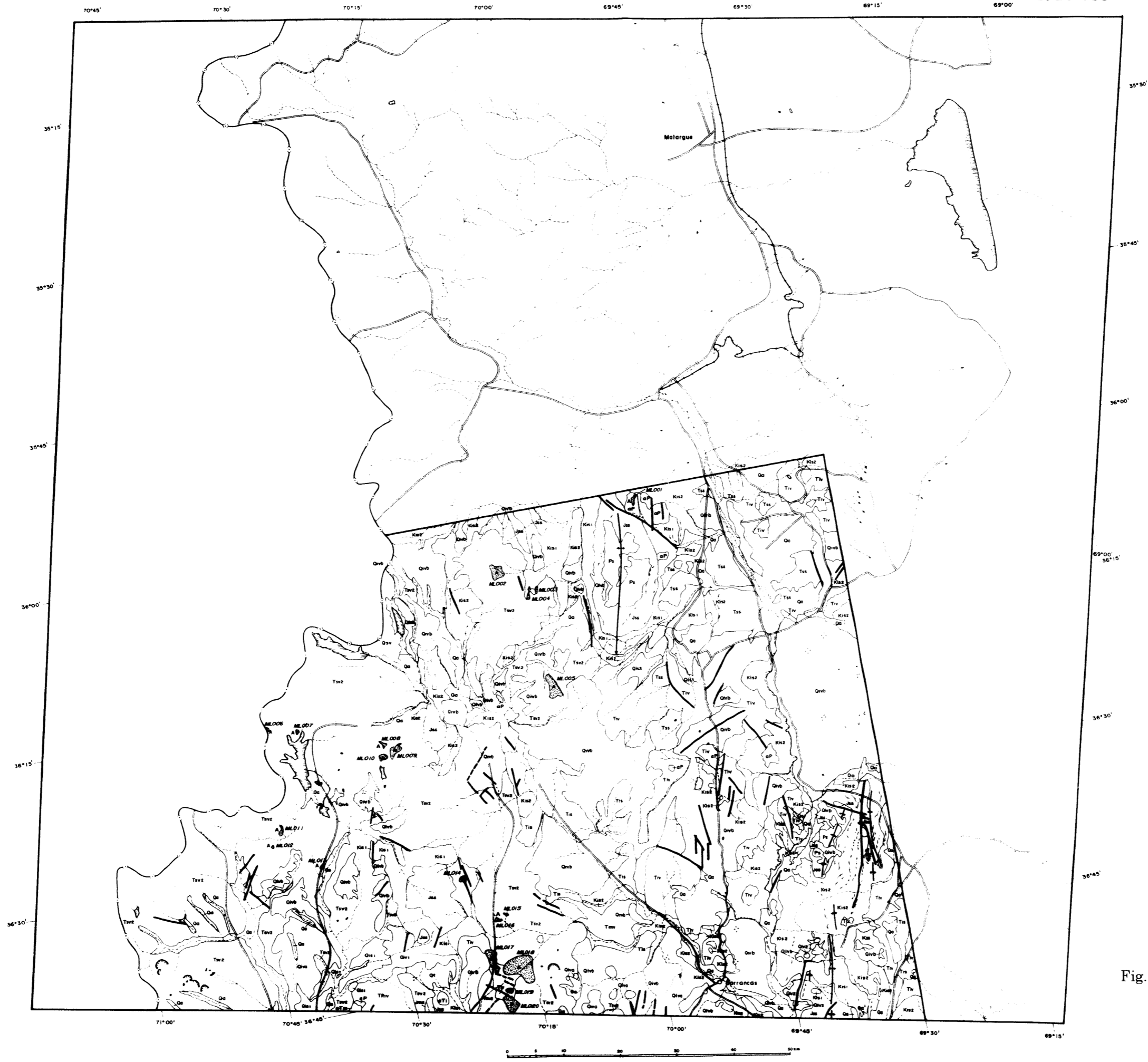
Unit	Photo-Characteristics		Morphologic Expression				Superficial Cover		Probable Lithology (Correlation with available Geologic Map)	
	Tone	Texture	Drainage		Rock Resistance	Section	Bedding	Vegetation		Cultivation
			Pattern	Density						
Qa	gray, purplish red, green	very fine	meandering	very low	very low		none	partly dense	partly intense	Unconsolidated sediments composed of gravel, sand, silt and clay (Holocene : Recent alluvial deposits)
Qsv	purplish gray	rough	radial	low	medium-high		none	none	none	Basic volcanic rocks (Holocene : Basalt, andesite, trachyte)
Qis3	brown	fine	sub-parallel	low	low		none	partly	partly	Glacial deposits (Pleistocene : Gracial deposits)
Qis1	purplish	fine	sub-parallel	low	low		very gentle	rare	none	Unconsolidated sediments composed of gravel, sand, silt and clay (Pleistocene : Fluvial, talus deposits)
Qiva	purplish gray	fine-medium	sub-parallel	medium	low-high		none	none	none	Volcanic rocks (Pleistocene : Andesite, dacite, trachyandesite, trachytic rhyodacite)
Qivb	reddish brown	rough	radial	medium	low		none	none	none	Basic volcanic rocks (Pleistocene : Basalt, pyroclastic rocks)
Qivr	gray	fine-coarse	sub-parallel	low	high		massive	none	none	Acidic volcanic rocks (Pleistocene : Rhyolite, pyroclastic rocks)
Tss	brown	fine	sub-parallel	low	low		rare	none	none	Continental sedimentary rocks (Miocene : Collon Cura Formation)
Tmv	brown	coarse	sub-dendritic	medium	medium-high		massive	partly	rare	Mainly pyroclastic rocks (Miocene : Basaltic rocks, El Mirador Formation)
Tiv	dark brown	coarse	sub-dendritic	medium	medium-high		massive	dense	partly	Andesitic volcanic rocks (Eocene-Oligocene : Andesite, basalt and pyroclastic rocks)
Tis	brown	coarse	sub-dendritic	high	medium		partly	medium	partly	Coarse grained sedimentary rocks (Paleocene : Sandstone conglomerate, mudstone, limestone and gypsum)
Kss	gray	fine-medium	pinnate	medium	low-medium		bedded	none	none	Fine to medium grained sedimentary rocks (Upper Cretaceous : Sandstone, mudstone, conglomerate)
Kis2	brown	fine-medium	sub-parallel	medium-high	medium-high		well bedded	none	none	Fine to medium grained sedimentary rocks (Lower Cretaceous : Sandstone, mudstone, gypsum, limestone)
Kis1	brown	medium	sub-parallel	medium-high	medium-high		well bedded	none	none	Medium grained sedimentary rocks (Lower Cretaceous : Lutite, limestone, fanglomerate, mudstone, sandstone)
Jss	brown	fine-medium	sub-parallel	medium-high	medium-high		well bedded	none	none	Medium grained sedimentary rocks (Upper Jurassic : Conglomerate, sandstone, shale, limestone, gypsum etc.)
Jms	brown	medium	sub-parallel	medium-high	medium-high		well bedded	partly	none	Medium grained sedimentary rocks (Middle Jurassic : Conglomerate, sandstone, limestone, shale, tuff etc.)
TRiv	dark brown	coarse	sub-dendritic	high	high		massive	partly	none	Volcanic rocks (Lower Triassic : Breccia, ignimbrite, andesite, dacite and rhyolite)
Ps	dark gray	rough	sub-dendritic	high	high		schistose	none	none	Schistose rocks (Paleozoic : Phyllite, schist, gneiss and migmatite)

Table II-2-2 Characteristics of photogeologic units of the Malargue area

Unit	Photo-Characteristics		Morphologic Expression				Superficial Cover		Probable Lithology (Correlation with available Geologic Map)	
	Tone	Texture	Drainage Pattern	Density	Rock Resistance	Section	Bedding	Vegetation		Cultivation
α P	gray	coarse	sub-dendritic	medium	medium-high		massive	partly	none	Igneous rocks (Paleozoic : Plutonic rocks and hypabyssal rocks)
A	light gray	fine	none	low	low		none	none	none	Alteration Zone (Hydrothermal alteration zone)

Malargue

WR 232/85



Unit	Symbol	Stratigraphic Position	Thickness	Color	Remarks	Photo. Linkage
Tsv2
Qvb
Ks1
Ks2
Tss
Oo
...

LEGEND

- Geology/Structures**
 - Boundary of photogeologic unit
 - Alteration zone
 - Lineament (certain)
 - Lineament (uncertain)
 - Angular structures
 - Bedding traces
 - Anticlinal axis and its plunging direction
 - Synclinal axis and its plunging direction
 - Crater and its slope
- Geography/Topography**
 - Drainage system
 - Lake or dam
 - Road
 - Railway
 - City and city area
 - International boundary

Fig. II -2-3 The Malargue area:
Photogeologic interpretation map

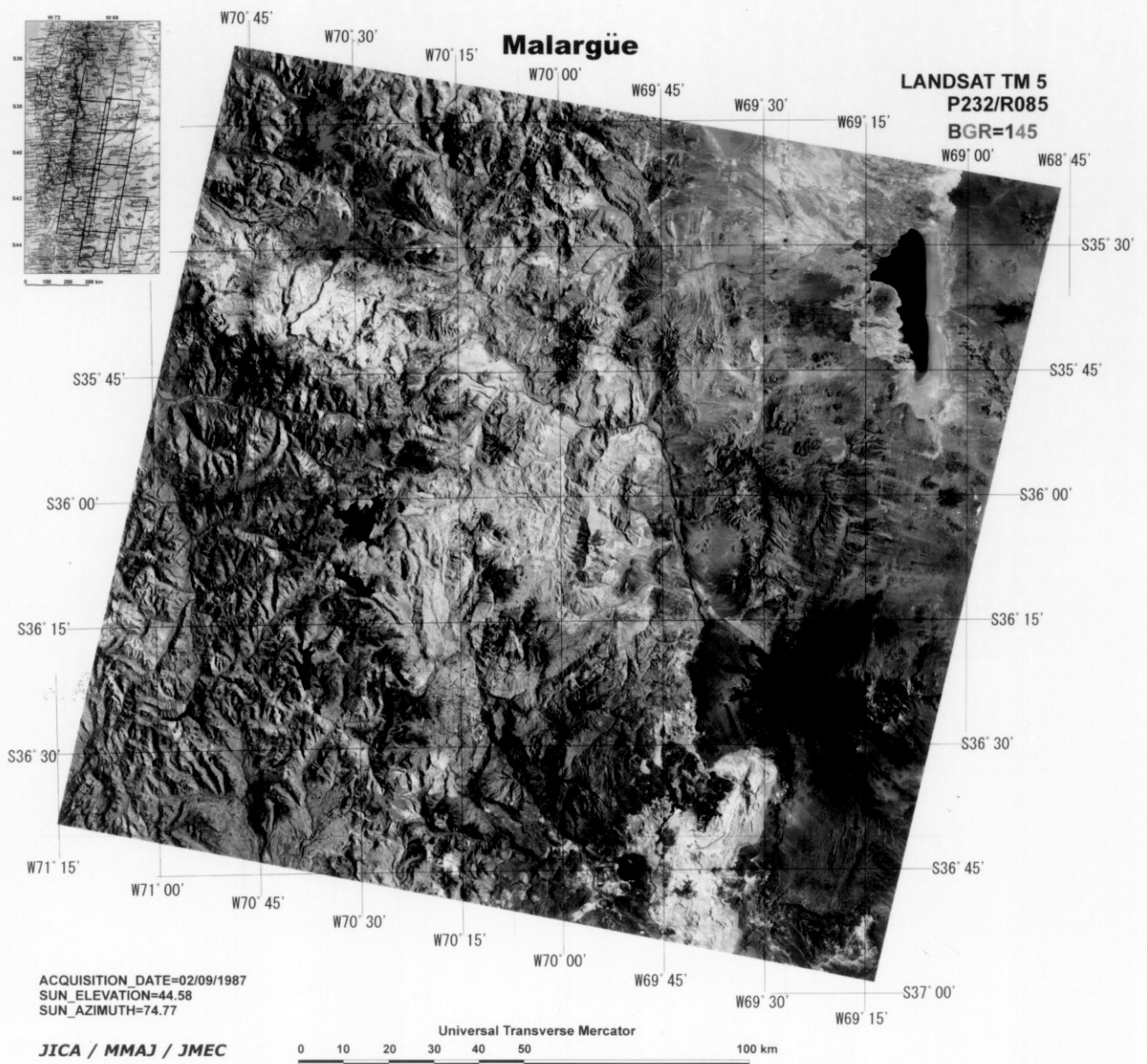


Fig. II -2-4 The Malargüe area: Landsat TM false color image

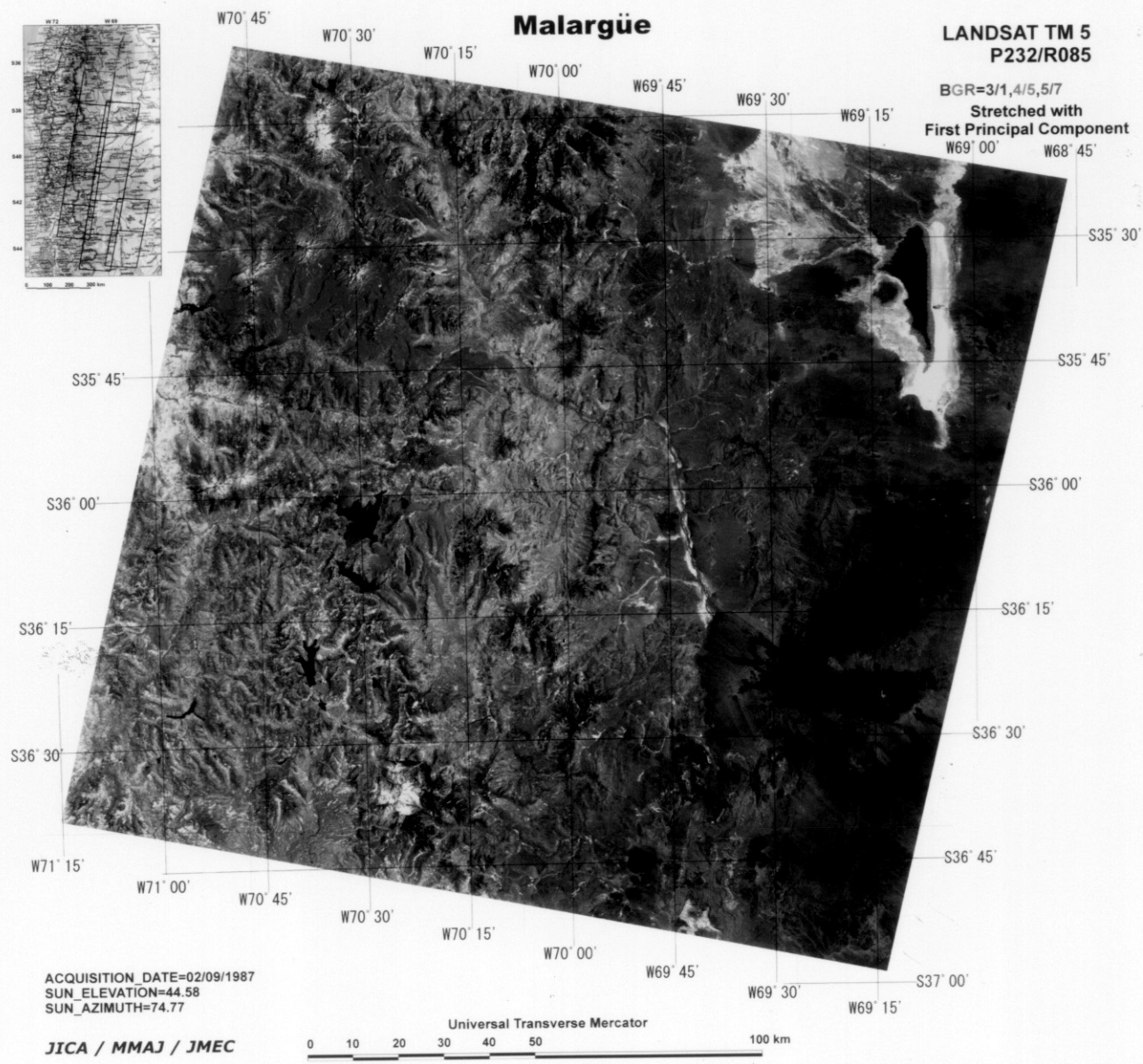


Fig. II -2-5 The Malargüe area: Landsat TM ratio image

[Alteration zone]

In this area, 20 alteration zones (ML001 to ML020) were recognized and extracted (Fig. II-2-3 and Table II-2-15). These were generally oriented in the NNW-SSE direction, showing four parallel zones. Their individual distribution configuration is generally oval or irregularly massive. The largest one is the ML018 alteration zone (9.2 km x 9.2 km) distributed in the south of this area, followed by the ML005 alteration zone (7.6 km x 2.4 km).

[Lineament]

Lineament of Fig. II-2-3 was extracted from the result of interpretation and extraction executed in accordance with the criteria described in Chapter 2-2-2. Solid lines of the figure show clear and continued topographical phenomena on which criteria of interpretation and extraction is based, and broken lines show discontinued and somewhat ambiguous topographical phenomena. These criteria have been applied to the following areas of images.

Distribution and direction of lineaments interpreted and extracted from this area is classified into the east and west zone, each having the following characteristics of their own:

(1) East zone

This zone mainly consists of the Quaternary to Tertiary volcanic rocks and the Cretaceous volcanic rocks with dominance of N-S oriented lineament. In addition, the E-W and NW-SE oriented lineaments lying at right angles or diagonally to the N-S oriented lineament are recognized. Density of lineaments is higher toward the middle and the south. The best continuity is found in the lineament located in the east, which lies in the N-S direction and extends as long as 23 km. Lineaments can be found around a number of alteration zones, including ML001 and ML003.

(2) West zone

The Jurassic and Cretaceous sedimentary rocks and the Tertiary to Quaternary volcanic rocks are mainly distributed in this zone with the dominance of N-S and NW-SE oriented lineaments. Their length is around 2.5 km, and 7 to 8 km at the longest. Lineaments with high density are observed in the east-central and south-eastern regions. Lineaments are also recognized around the alteration zones of ML014 and ML017 to ML020.

[Folding and circular structures]

(1) Folding structure

Bedding develops in the Paleozoic schist and the Jurassic to Cretaceous sedimentary rocks distributed in the east zone of this area, and a folding structure is apparently recognized from the image. In particular, an anticlinal structure with N-S orientation of the Paleozoic schist in the northeast and southeast of this area (Fig. II-2-3). In addition, anticlinal structures and synclinal structures of the Jurassic to Cretaceous sedimentary rocks are

repeatedly seen in the N-S direction on both sides of this anticlinal structure.

No distinct folding structures were observed in the western area where the Jurassic to Cretaceous sedimentary rocks were distributed.

(2) Circular structure

Six large or small circular structures were extracted in this area. All of them were extracted from an area where the Upper Tertiary volcanic rocks are distributed (geological unit; Tsv2). Each circular structure extracted from this area was in a shape of semi-circle about 2 km in diameter. As far as this area is concerned, no direct relation is observed between the alteration zone and the circular structure (Fig. II-2-3).

2) The Chos Malal area

[Geological unit]

The rocks and sediments distributed in this area were classified into 28 geological units in total (Fig. II-2-6 and Table II-2-3). Seven of them were comparable to the sedimentary rocks of the Jurassic to the Tertiary, 11 units to the volcanic rocks of the Carboniferous to the Quaternary, and four units to the unconsolidated or semi-consolidated sedimentary rocks of the Quaternary. Another five geological units can be compared to the intrusive rocks generated during the Permian to the Tertiary ages. Another geological unit was judged to be an alteration zone.

[Alteration zone]

Twenty-one alteration zones (CM001 to CM021) were interpreted and extracted in this area (Fig. II-2-6 and Table II-2-16). All of them showed a trend of N-S and can be divided into three zones from west to east; i.e., (1) the Cordillera de Los Andes zone, (2) the Cordillera de Viento zone and (3) the mountain zone to the northeast of Chos Malal town. Morphology of the alteration zone is generally ellipsoidal or irregularly massive except for the Cordillera de Los Andes zone in which thick vegetation makes it difficult to extract alteration zones.

(1) Cordillera de Los Andes zone

This zone includes three alteration zones (CM001 to CM003), that were extracted from areas of the Tertiary volcanic rocks. The alteration zone CM003 is distributed in the southwest of this zone over the Chilean border. It is about 2.0 km by 1.5 km in size and has the N-S orientation.

(2) Cordillera del Viento zone

This zone includes 12 alteration zones (CM004 to CM015). One alteration zone were extracted from areas of the Carboniferous to Devonian volcanic rocks, seven from areas of the Triassic volcanic rocks, one from the Tertiary volcanic rocks, and three from the Tertiary

Table II -2-3 Characteristics of photogeologic units of the Chos Malal area

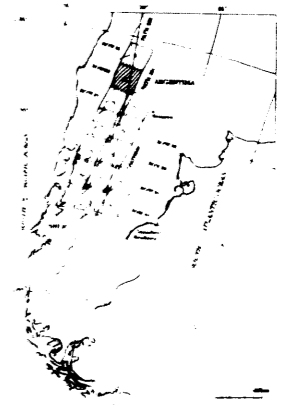
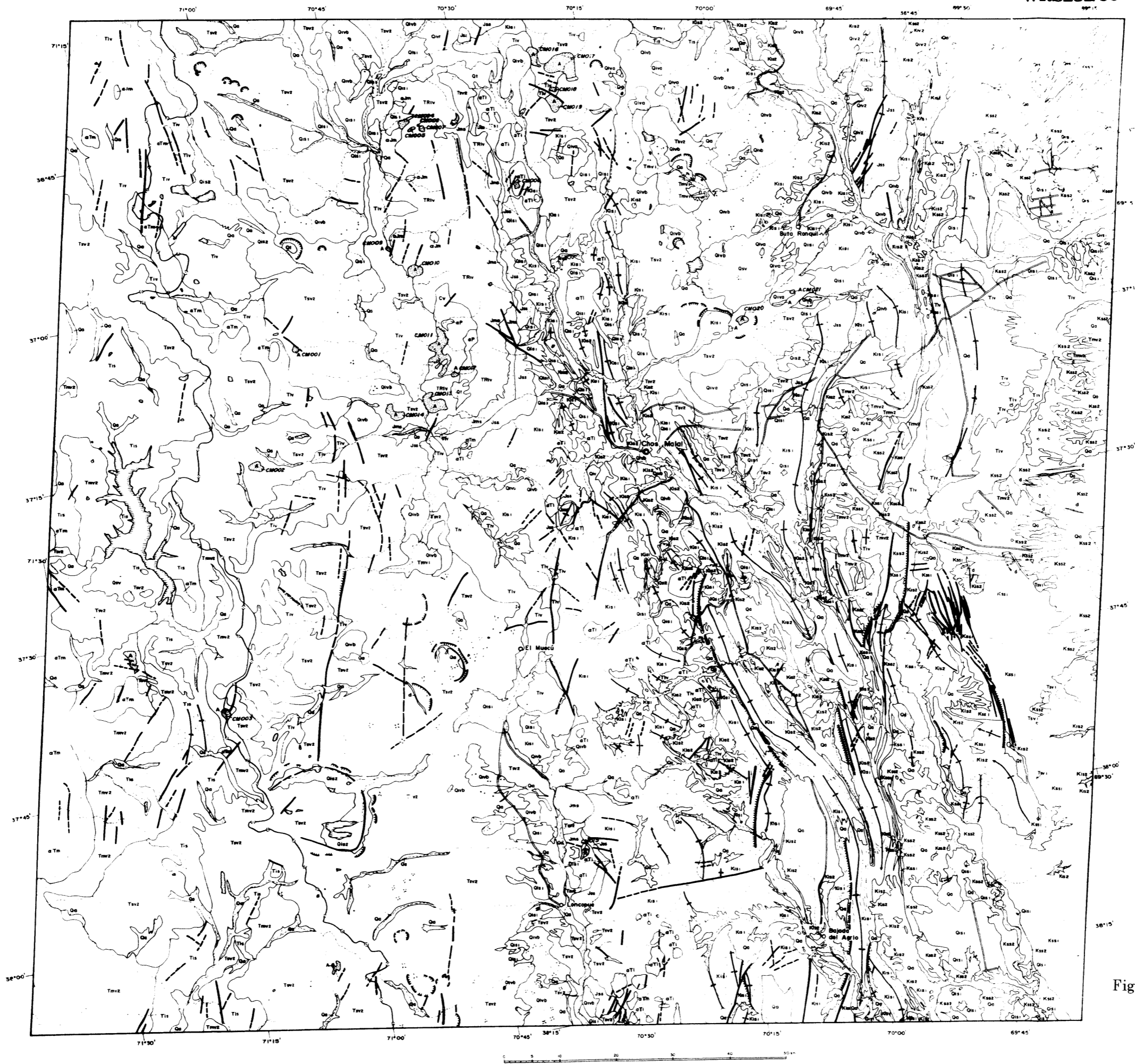
Unit	Photo-Characteristics		Morphologic Expression					Superficial Cover		Probable Lithology (Correlation with available Geologic Map)
	Tone	Texture	Drainage Pattern	Density	Rock Resistance	Section	Bedding	Vegetation	Cultivation	
Qa	gray, purplish red, green	very fine	meandering, parallel	very low	very low		none	partly dense	partly intense	Unconsolidated sediments composed of gravel, sand, silt and clay (Holocene : Recent alluvial deposits)
Qt	gray	fine	distributary	low	very low		none	none	none	Talus deposits (Holocene: Talus deposits)
Qsv	purple, reddish	coarse	radial	low	medium-high		none	none	none	Basic volcanic rocks (Holocene : Basalt, andesite, trachyte)
Qis2	light brown, purple, yellow	medium	sub-parallel	low	low		none	none	none	Glacial deposits (Pleistocene: Glacial deposits)
Qis1	purplish gray	fine	sub-parallel	low	low		rare	rare	none	Unconsolidated sediments composed of gravel, sand, silt and clay (Pleistocene : Fluvial, talus deposits)
Qiva	purplish gray	fine-medium	sub-parallel	medium	low-high		none	none	none	Volcanic rocks (Pleistocene : Andesite, dacite, trachyandesite, trachytic rhyodacite)
Qivb	reddish brown	coarse	radial	medium	low-high		none	none	none	Basic volcanic rocks (Pleistocene : Basalt, pyroclastic rocks)
Qivr	gray	fine-coarse	sub-parallel	low	high		massive	none	none	Acidic volcanic rocks (Pleistocene : Rhyolite, pyroclastic rocks)
Tsv2	brown, gray	fine	radial sub-parallel	low	high		massive	partly	rare	Volcanic rocks (Pliocene : Andesite, basaltic andesite, basalt and pyroclastic rocks)
Tsv1	reddish brown	medium	radial	low	high		massive	none	none	Basic volcanic rocks (Pliocene : Basalt, pyroclastic rocks)
Tmv2	brown	coarse	sub-dendritic	medium	medium-high		massive	partly	none	Mainly pyroclastic rocks (Miocene : Pyroclastic rocks, basalt, andesite)
Tmv1	gray	coarse	sub-dendritic	low	low		massive	none	none	Mainly pyroclastic rocks (Miocene : Tuff, ignimbrite, basalt)
Tiv	dark brown	coarse	sub-dendritic	medium	medium-high		massive	partly	none	Andesitic volcanic rocks (Eocene-Oligocene : Andesite, basalt and pyroclastic rocks)
Tis	brown	coarse	sub-dendritic	high	medium-high		partly	partly dens	none	Fine to coarse-grained sedimentary rocks (Paleocene : Sandstone, conglomerate, mudstone, limestone,
Kss2	pinkish gray	fine-medium	pinnate	medium	low		bedded	none	none	Fine to medium-grained sedimentary rocks (Upper Cretaceous : Sandstone, mudstone, conglomerate)
Kss1	purplish gray	fine-medium	sub-dendritic	medium	medium-high		bedded	none	none	Fine to medium-grained sedimentary rocks (Upper Cretaceous : Sandstone, mudstone, conglomerate)
Kis2	pinkish brown	fine-medium	sub-parallel	medium-high	low-medium		well bedded	none	none	Medium to fine-grained sedimentary rocks (Lower Cretaceous : Sandstone, mudstone, gypsum etc.)
Kis1	pinkish brown	fine-medium	sub-parallel	medium-high	low-high		well bedded	none	none	Fine to medium-grained sedimentary rocks (Lower Cretaceous : Lutite, limestone, fanglomerate, mudstone)

Table II -2-3 Characteristics of photogeologic units of the Chos Malal area

Unit	Photo-Characteristics		Morphologic Expression				Superficial Cover		Probable Lithology (Correlation with available Geologic Map)	
	Tone	Texture	Drainage		Rock Resistance	Section	Bedding	Vegetation		Cultivation
			Pattern	Density						
Jss	brown	fine-medium	sub-parallel	medium-high	medium-high		bedded	none	none	Medium-grained sedimentary rocks (Upper Jurassic : Conglomerate, sandstone, shale, limestone, gypsum)
Jms	brown	medium	sub-parallel	medium-high	medium-high		well bedded	partly	none	Medium-grained sedimentary rocks (Middle Jurassic : Conglomerate, sandstone, limestone, shale, tuff etc.)
TRiv	dark brown	coarse	sub-dendritic	high	high		massive	partly	none	Volcanic rocks (Lower Triassic : Breccia, ignimbrite, andesite, dacite and rhyolite)
Cv	brown	coarse	sub-dendritic	high	high		massive	none	none	Mainly pyroclastic rocks (Carboniferous-Devonian: Andestic tuff, sandstone, shale)
d	dark gray	linear	none	none	high		none	none	none	Dikes (Upper Cretaceous-Pliocene? : Dikes)
α Tm	gray	coarse	sub-dendritic	medium	high		massive	none	none	Igneous rocks (Miocene : Granite, granodiorite, tonalite and diorite)
α Ti	gray,brown	coarse	sub-dendritic	medium	high		massive	none	none	Igneous rocks (Eocene-Oligocene : Andesite, microdiorite, diorite and dacite)
α Jm	brown	coarse	sub-dendritic, rectangular	medium	high		massive	none	none	Igneous rocks (Middle Jurassic : Granodiorite, diorite, granite, tonalite and dacite)
α P	brown	coarse	sub-dendritic	medium	medium-high		massive	none	none	Igneous rocks (Permian : Granite, granodiorite, diorite and tonalite)
A	white, pinkish gray	fine	sub-dendritic	low	medium-low		massive	none	none	Alteration zone (Hydrothermal alteration zone)

Chos Malal

WRS232/86



Legend of Photogeologic Map

Symbol	Description
(Circle with dot)	Boundary of photogeologic unit
(Circle with horizontal lines)	Alteration zone
(Dashed line)	Lineament (certain)
(Dotted line)	Lineament (uncertain)
(Circle with vertical lines)	Annular structure
(Circle with diagonal lines)	Bedding trace
(Line with 'X' marks)	Anticlinal axis and its plunging direction
(Line with 'Y' marks)	Synclinal axis and its plunging direction
(Line with 'Z' marks)	Crater and its slope
(Line with arrows)	Drainage system
(Circle with 'X' inside)	Lake or dam
(Double line)	Road
(Line with cross-ticks)	Railway
(Circle with 'X' inside)	City and city area
(Dashed line with dots)	International boundary

LEGEND

Geology/Structure

- (Circle with dot) Boundary of photogeologic unit
- (Circle with horizontal lines) Alteration zone
- (Dashed line) Lineament (certain)
- (Dotted line) Lineament (uncertain)
- (Circle with vertical lines) Annular structure
- (Circle with diagonal lines) Bedding trace
- (Line with 'X' marks) Anticlinal axis and its plunging direction
- (Line with 'Y' marks) Synclinal axis and its plunging direction
- (Line with 'Z' marks) Crater and its slope

Geography/Topography

- (Line with arrows) Drainage system
- (Circle with 'X' inside) Lake or dam
- (Double line) Road
- (Line with cross-ticks) Railway
- (Circle with 'X' inside) City and city area
- (Dashed line with dots) International boundary

Fig. II -2-6 The Chos Malal area:
Photogeologic interpretation map

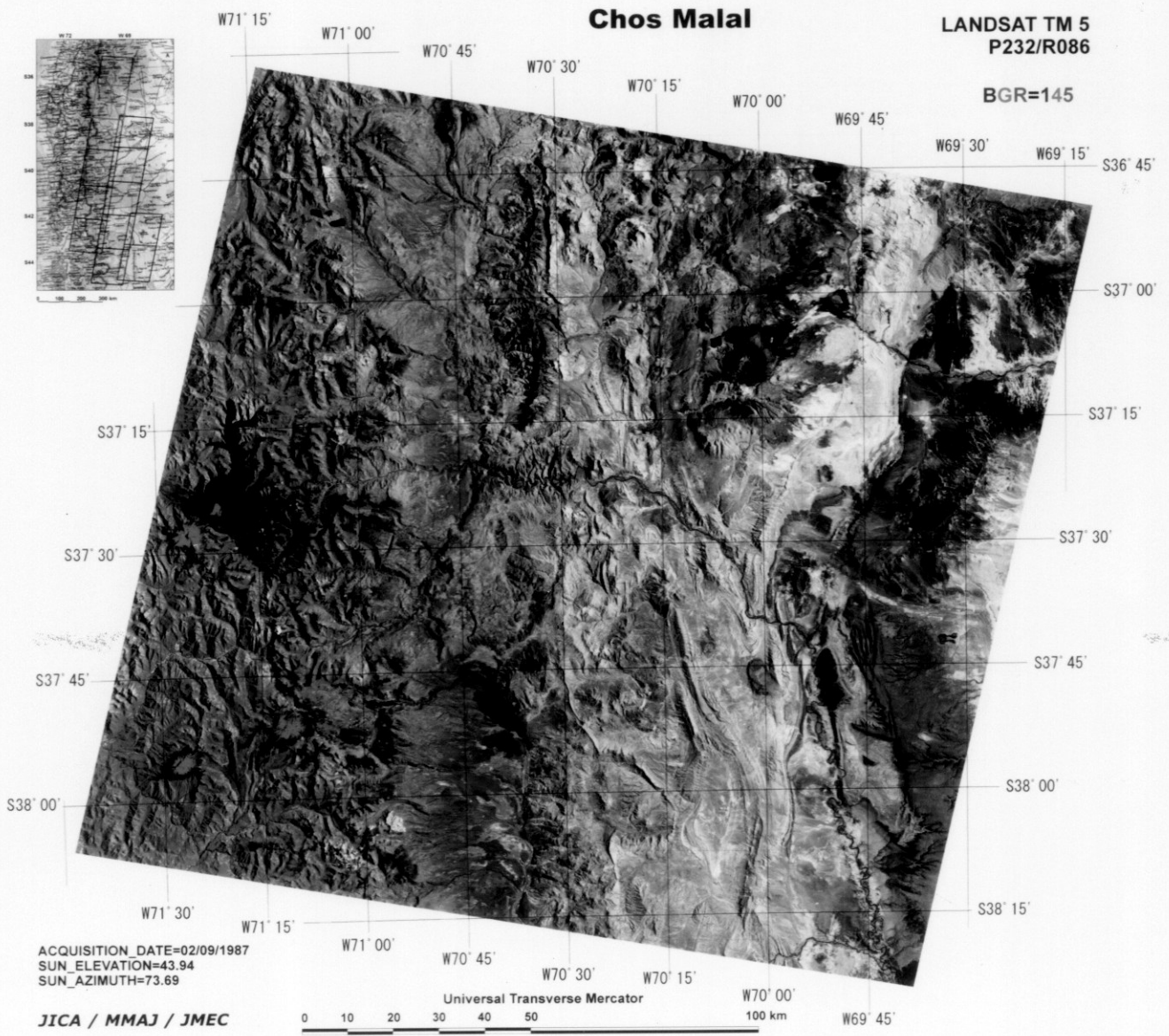


Fig. II -2-7 The Chos Malal area: Landsat TM false color image

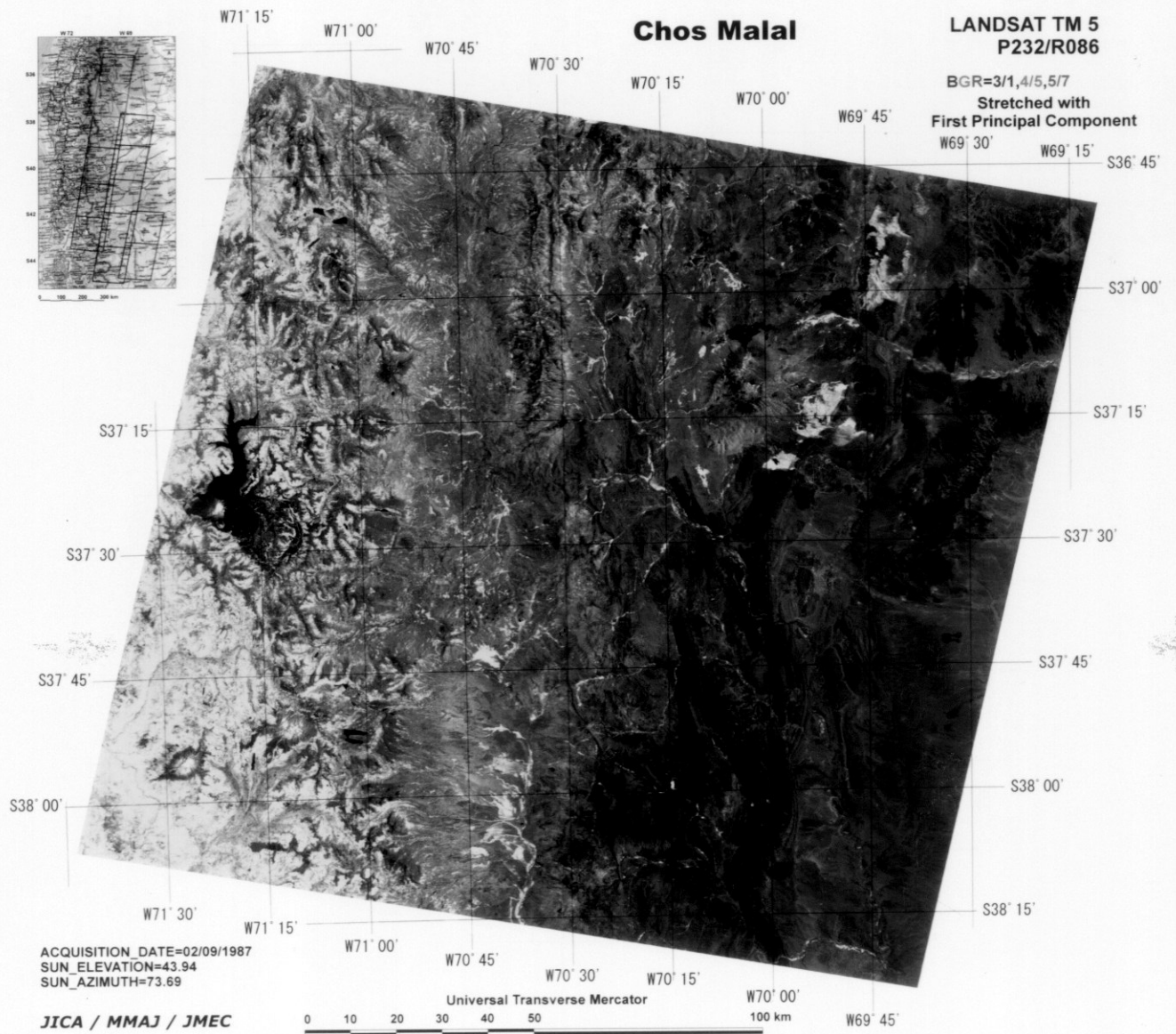


Fig. II -2-8 The Chos Malal area: Landsat TM ratio image

igneous rocks. The largest one is CM011, which lies near the center of this zone. It is 9.0 km by 2.5 km in size, trending toward N-S, and is distributed in the Lower Triassic volcanic rocks.

(3) Mountain zone to the northeast of Chos Malal town

This zone includes six alteration zones (CM016 to CM021), all of which were extracted from the Tertiary volcanic rocks. The largest one is located in the north with size of 5.5 km by 4.5 km.

[Lineament]

The distribution and direction of lineaments interpreted and extracted from this area are divided into two parts, that is the west zone (corresponding to the Cordillera de Los Andes zone mentioned above) and the central to east zone (Cordillera del Viento zone - including the mountain area to the northeast of Chos Malal town). They have the following characteristics (Fig. II-2-6):

(1) West zone

This is mainly composed of the Tertiary volcanic rocks and sedimentary rocks with the N-S trend lineaments. Lineaments with high density are observed in the north, central and southeast. The longest lineament is located near the central zone, trending toward the NNE-SSW and extending as long as 40 km.

(2) Central-to-east zone

This zone has the Carboniferous volcanic bedrocks and is composed of the Triassic volcanic and sedimentary rocks, the Jurassic sedimentary rocks, the Cretaceous sedimentary rocks, the Tertiary volcanic and sedimentary rocks, and the Quaternary volcanic and sedimentary rocks. Generally, the N-S trending lineaments are dominant, which develop in the Cretaceous sedimentary rocks that are most widely distributed in this zone. The direction in which the lineaments are dominant is the same as that of the axis of the folding structure to be discussed later. Lineaments with high density are observed in the southeast. The longest lineament is located in the south, trending generally toward the N-S and extending as long as 38 km. Lineaments are observed around the alteration zone CM010.

[Folding and circular structure]

(1) Folding structure

Bedding develops in the Jurassic and Tertiary sedimentary rocks of this area with folding structures apparently interpreted from the image (Fig. II-2-6). In particular, many folding structures, which generally trend toward the N-S, are found in the Jurassic sedimentary rocks. The following uneven distributions are observed: