(a) West zone (the Cordillera de Los Andes zone)

A pair of anticlinal and synclinal structures are recognized in the Tertiary sedimentary rocks. The axial length is 10 km and the wavelength is 2 km.

(b) Central-to-east zone (east of the Cordillera de Los Andes zone)

Many folding structures develop mainly in the Jurassic and Cretaceous sedimentary rocks, especially in the Lower Cretaceous rocks. The folding structures generally trend toward the N-S, though NW-SE folding structures are seen locally. The longest folding axis of an anticlinal structure is as long as 80 km with a total extension, though it plunges in midway. On the western side of this anticlinal structure, a lineament is particularly obvious that suggests the presence of a normal fault running in parallel to the axis orientation.

(2) Circular structure

24 circular structures were extracted in this area(Fig. II-2-6). All of the features were extracted from areas of the Upper Tertiary volcanic rock (geological unit: Tsv2). The circular structures are classified into two types; one having only a circular or semi-circular landslide scarp and the other having a landslide scarp with a circular or semi-circular drainage in it. The largest one is located in the southwest and has a diameter as large as 15 km. The alteration zone CM020 is recognized inside one of the circular structures.

3) The Zapala area

[Geological unit]

The rocks and sediments distributed in this area were classified into 29 geological units in total (Fig. II-2-9 and Table II-2-4). Eleven of them were comparable to the sedimentary rocks of the Permian to the Tertiary, and six units were comparable to the volcanic rocks of the Tertiary to Quaternary. Four units correspond to the unconsolidated or semi-consolidated sedimentary rocks of the Quaternary. One geological unit can be compared mainly to the Paleozoic schist and six units to the intrusive rocks generated from the Paleozoic to the Tertiary. Another geological unit was judged to be an alteration zone.

[Alteration zone]

In the central and southeastern zones of this area, 37 alteration zones (ZA001 to ZA037) trending toward the NNW-SSE were interpreted and extracted (Fig. II-2-9 and Table II-2-17). By assuming a singly or independently distributed zone as one alteration zone, and plural alteration zones closely located within a horizontal distance of 1 to 2 km from each other as one alteration zone, alteration zones were grouped into five areas. They can be summarized as follows according to the location and geological unit:

Table II-2-4 Characteristics of photogeologic units of the Zapala area

Unit	Photo-Characteristics		Mophologic Expression					Superficial Cover		Probable Lithology
	Tone	Texture	Drainage		Rock	Section	Bedding	Vegetation	Cultivation	(Correlation with available Geologic Map)
			Pattern	Density	Resistance					
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)
Qt	gray	fine	meandering	very low	very low		none	none	partly	Unconsolidated sediments composed of gravel, sand, silt and clay (Holocene : Recent talus deposits)
Qsv	purplish gray	rough	radial	low	medium-high		none	none	none	Basic volcanic rocks (Holocene : Basalt, andesite, trachyte)
Qis2	light gray	medium	sub-parallel	low	low		none	none	none	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)
Qivb	reddish brown	rough	radial	medium	low		none	none	none	Basic volcanic rocks (Pleistocene : Basalt, pyroclastic rocks)
Tsv2	brown	fine	radial, sub-parallel	low	high		massive	partly	partly	Volcanic rocks (Pliocene : Andesite, basaltic andesite, basalt and pyroclastic rocks)
Tmv2	brown	coarse	sub-dendritic	medium	medium		massive	partly	partly	Mainly pyroclastic rocks (Miocene : Pyroclastic rocks, basalt, andesite)
Tmv1	brown	rough	sub-dendritic	medium	high		massive	none	none	Volcanic rocks (Miocene : Ignimbrite, basalt, tuff)
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)
Kss2	gray	fine-medium	pinnate	medium	low-medium		bedded	none	none	Fine to medium grained sedimentary rocks (Upper Cretaceous : Sandstone, mudstone, conglomerate)
Kss1	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	sup-parallel	medium-high	medium-high		well bedded	none	none	Fine to medium grained sedimentary rocks (Lower Cretaceous : Sandstone, mudstone, gypsum, limestone etc.)
Kis1	brown	medium	sub-parallel	medium-high	medium-high		well bedded	none	none	Medium grained sedimentary rocks (Lower Cretaceous : Lutite, limestone, fanglomerate, mudstone, sandstone)

Table II-2-4 Characteristics of photogeologic units of the Zapala area

Unit	Photo-Characteristics		Mophologic Expression					Superficial Cover		Probable Lithology
	Tone	Texture	Drainage		Rock	Section	Bedding	Vegetation	Cultivation	(Correlation with available Geologic Map)
			Pattern	Density	Resistance					
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.)
TRs	gray	medium	sub-parallel	medium	medium		bedded	partly	none	Sedimentary rocks (Upper Triassic :Tuff, conglomerate, sandstone)
TRif	gray	medium	sub-parallel	medium	medium		bedded	none	none	Sedimentary rocks (Lower Triassic : Tuffs composition andesitic to dacitic)
TRi	brown	coarse	sub-dendritic	high	high		rare	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)
αTm	gray	coarse	sub-dendritic	medium	high		massive	none	none	Felsic igneous rocks (Miocene : Granite, granodiorite, tonalite and diorite
αTi	gray	coarse	sub-dendritic	medium	high		massive	none	none	Igneous rocks (Eocenee-Oligocene : Andesite, microdiorite, diorite and dacite)
αKT	brown	coarse	sub-dendritic, rectangular	medium	high		massive	partly	none	Igneous rocks (Cretaceous-Tertiary : Plutonic rocks and hypabyssal rocks)
αJT	brown	coarse	sub-dendritic, rectangular	medium	high		massive	partly	none	Igneous rocks (Jurassic-Tertiary : Plutonic rocks and hypabyssal rocks)
αJ	brown	coarse	sub-dendritic, rectangular	medium	high		massive	partly	none	Igneous rocks (Jurassic : Plutonic rocks and hypabyssal rocks)
αP	gray	coarse	sub-dendritic, rectangular	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)

Zapala

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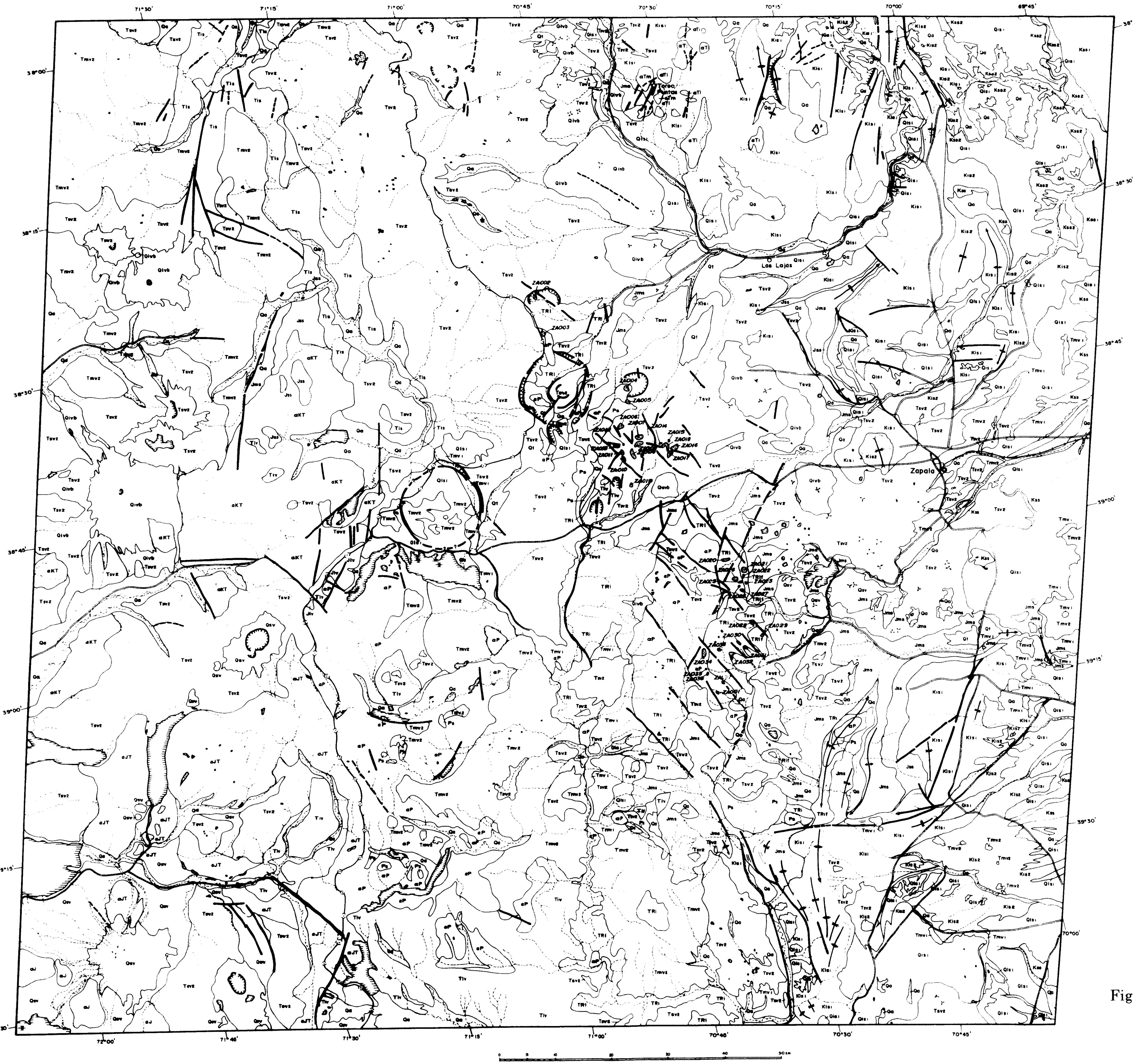
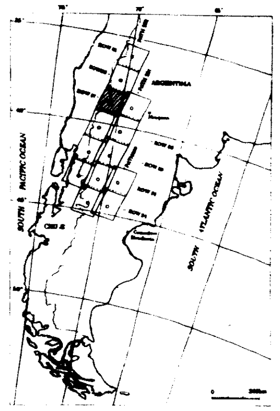
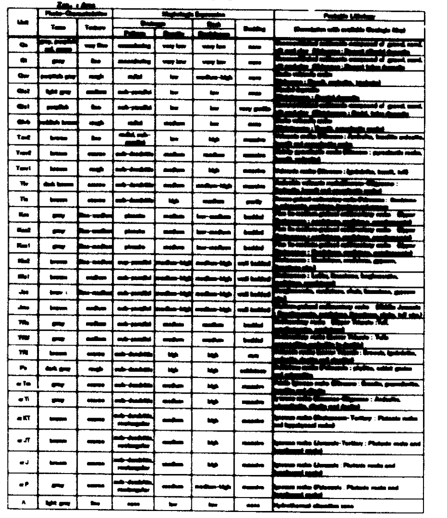






LEGEND

Geology/Structure

- Boundary of photogeologic unit
- Alteration zone
- Lineament(certain)
- Lineament(uncertain)
- Annular structure
- Bedding trace
- 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-2-9　The Zapala area: Photogeologic interpretation map

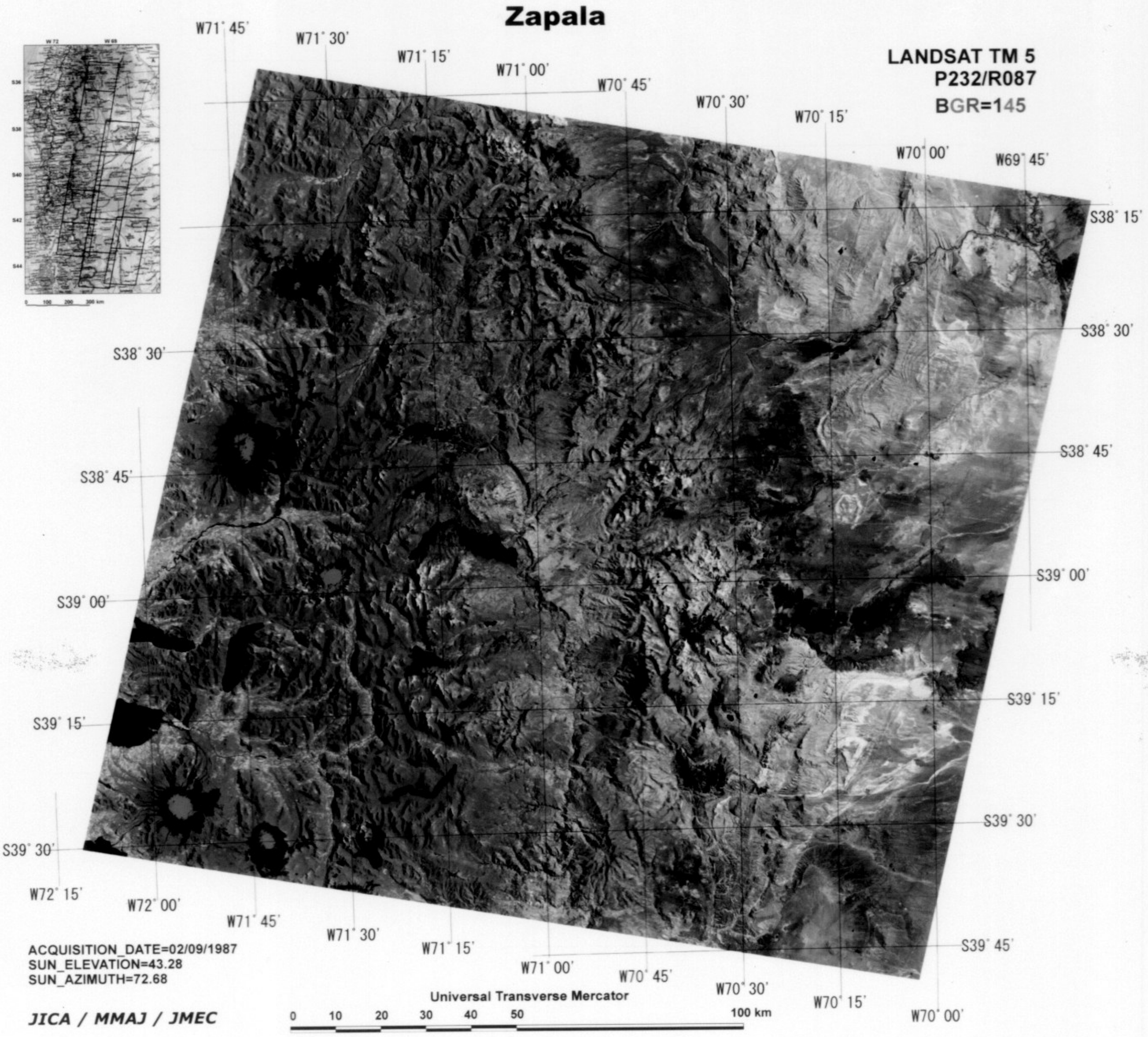


Fig. II -2-10 The Zapala area: Landsat TM false color image

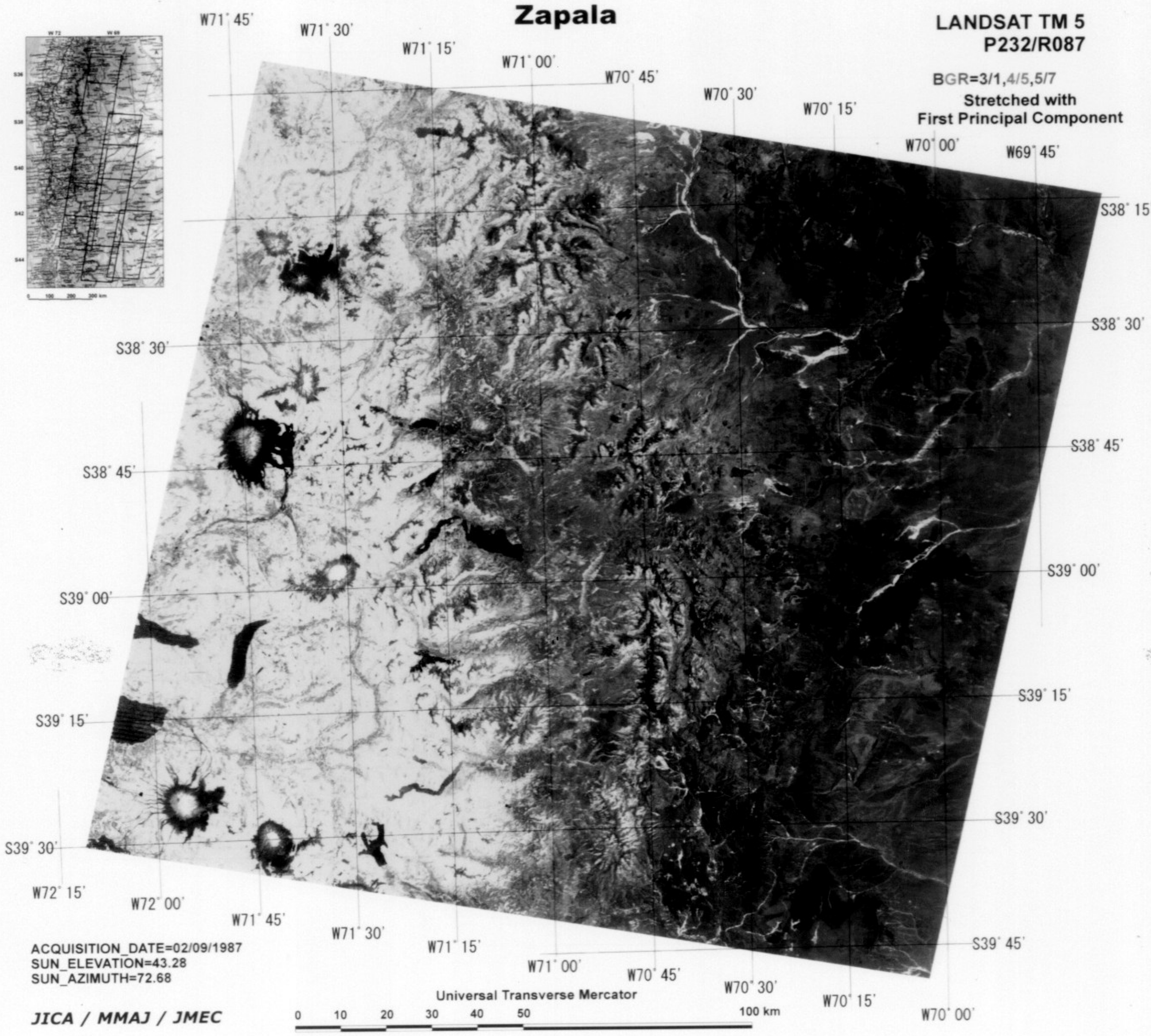


Fig. Ⅱ -2-11 The Zapala area: Landsat TM ratio image

(1) Northern alteration zone (ZA002) recognized in the Triassic volcanic rocks (geological unit: TRi) distributed in the north

(2) Central northern group of three alteration zones (ZA003 to ZA005) observed in the Paleozoic intrusive rocks (geological unit: αP) distributed in the central north

(3) Central group of 14 alteration zones (ZA006 to ZA019) recognized in the Tertiary volcanic rocks (geological unit: Tsv2) distributed in the central area

(4) Central southeastern group of 14 alteration zones (ZA020 to ZA033) witnessed in the Triassic volcanic and sedimentary rocks (geological unit: TRi, TRif) distributed in the central southeast

(5) Central southern group of five alteration zones (ZA001 and ZA034 to ZA037) recognized in the Paleozoic intrusive rocks (geological unit: αP) distributed in the central south

Morphology of alteration zones is in general ellipsoid or irregular amoeboid. The largest one has a major axis of 1.5 to 2 km. Many of these alteration zones are found in areas with dense lineaments, and within or on the periphery of circular structures. On the whole, they are scattered in the NW-SE direction. Especially alteration zones of group (3) is alligned in parallel five zones bounded with the NW-SE lineament.

[Lineament]

The following characteristics were recognized in distribution and direction of lineaments interpreted and extracted from this area (Fig. II-2-9):

(1) Near the central area, lineaments trending toward the NW-SE and those intersecting these NW-SE lineaments at right angles were extracted as one group. Generally, dense lineaments trending toward the NW-SE are divided at three points by lineaments trending toward the NE-SW, each tending to deviate toward northeast in a rectangular form. The extent of the NW-SE lineaments is about 10 km, and that of the NE-SW is as large as 30 km with discontinuity.

(2) In the areas other than (1) described above, a number of lineaments are extracted that are characteristically continuous in some of the Jurassic to Cretaceous sedimentary rocks of the northeast and southeast and in the Tertiary volcanic rocks of the west However no lineaments are extracted which make up a group as found in the central area.

[Folding and circular structures]

(1) Folding structure

Good bedding develops in the Jurassic to Cretaceous sedimentary rocks distributed in the northeast and southeast zones of this area, and a folding structure can be apparently interpreted from the image (Fig. II-2-9). Consequently, 12 folding structures were extracted in the northeast and 16 in the southeast (structures closely located in alignment are counted as one structure; This criterion is also applied to the following interpretations). The northeastern zone has seven anticlinal structures and three synclinal structures. The northeastern structures develop repeatedly at a wavelength of 3 to 5 km. The folding axis tends to be in the N-S, NNE-SSW and NE-SW directions. In the southeastern zone, the structures develop repeatedly at a wavelength of 3 to 5 km. Like the northeast, the folding axis tends to be in the N-S, NNE-SSW and NE-SW directions.

(2) Circular structure

Circular structures that were extracted in this area totaled 10 (Fig. II-2-9). The distribution and size of the circular structures are as follows. It is to be noted that, as mentioned above, many alteration zones were extracted within or on the periphery of the Tertiary volcanic rocks.

(a) Three circular structures seen in the Tertiary volcanic rocks (geological unit: Tsv2) distributed in the north: The northern circular structure is about 2 km in diameter. It is of a subsidence type. The southern circular structures are about 5 km and 1 km in diameter, respectively. They also are of a subsidence type. No alteration zones are found around these structures.

(b) Five circular structures seen in the Tertiary volcanic rocks (geological unit: Tsv2 and Tiv) distributed in the central zone: The largest structure is about 7 km in diameter while the smallest one is about 1 km in diameter. All the structures are of a subsidence type. Alteration zones were observed within or on the periphery of the structures recognized in the northern and central zones.

(c) A circular structure seen in the Triassic volcanic rocks and the Tertiary volcanic rocks (geological unit: TRi and Tsv2) occurs in the central area: A maximum size of the circular structure is about 12 km in diameter. It is of a subsidence type. This circular structure is a composite structure having another circular structure within an external circular structure. No alteration zones are recognized around this structure.

(d) A circular structure seen in the Tertiary volcanic rocks (geological unit: Tmv2 and Tmvl) distributed in the region somewhat to the west of the central zone: A maximum structure is about 15 km in diamete, showing an apparent circular shape. It is of a subsidence type. No alteration zones are found around this structure.

4) The San Martin de Los Andes area

[Geological unit]

Rocks and sediments distributed in this area were classified into 25 geological units in total (Fig. II-2-12 and Table II-2-5). Four of them were comparable to the sedimentary rocks of

Table Ⅱ-2-5 Characteristics of photogeologic units of the San Martin de Los Andes area

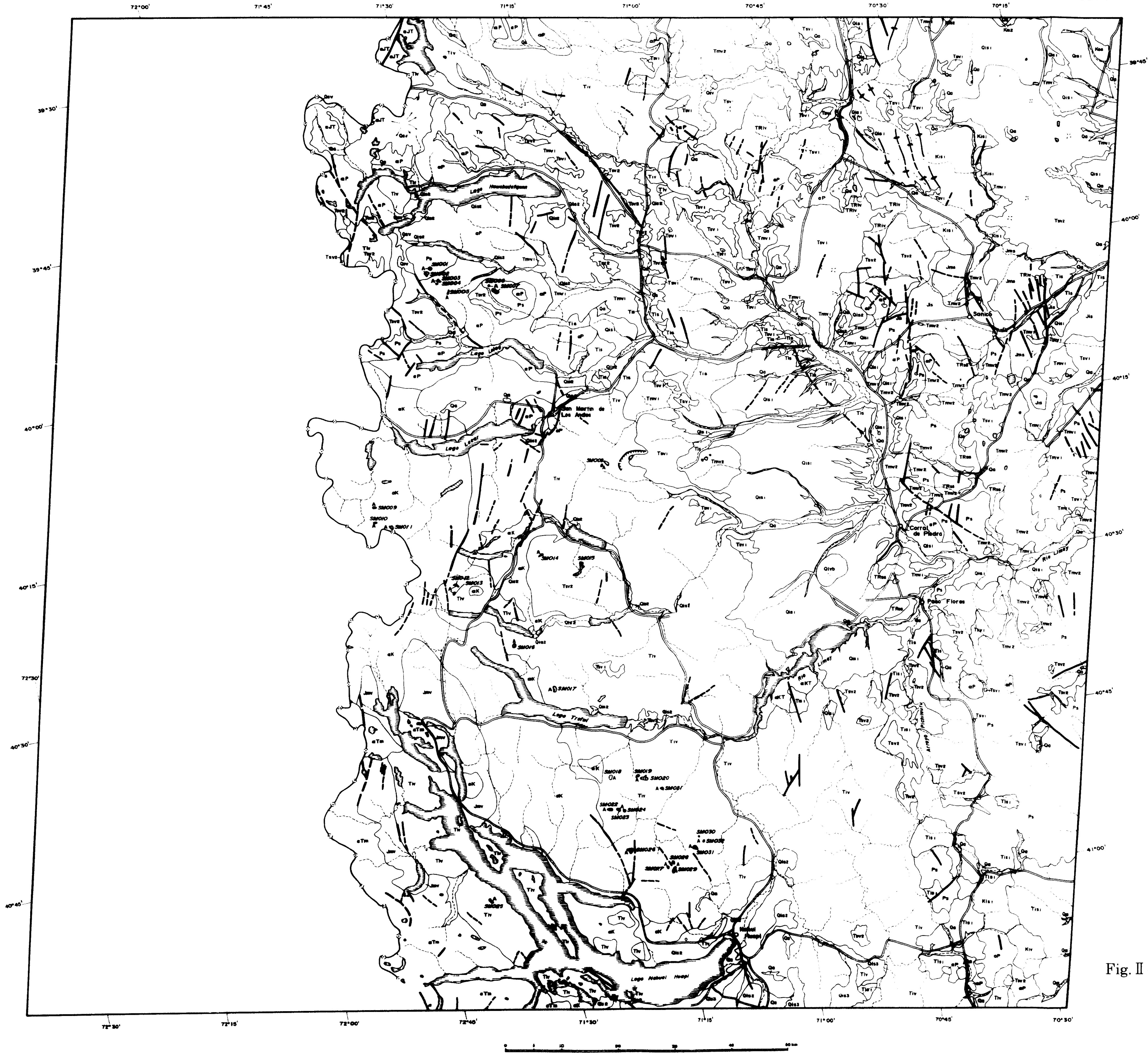
Unit	Photo-Characteristics		Mophologic Expression					Superficial Cover		Probable Lithology
	Tone	Texture	Drainage		Rock	Section	Bedding	Vegetation	Cultivation	(Correlation with available Geologic Map)
			Pattern	Density	Resistance					
Qa	gray, purplish red, green	very fine	meandering	very low	very 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
Qis2	light gray	medium	sub-parallel	low	low		none	none	none	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
Qivb	reddish brown	rough	radial	medium	low		none	none	none	Basic volcanic rocks (Pleistocene : Basalt, pyroclastic rocks)
Tsv2	brown	fine	dial, sub-paral	low	high		massive	partly	partly	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	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
Kis1	brown	medium	sub-parallel	medium-high	medium-high		well bedded	none	none	Medium grained sedimentary rocks (Lower Cretaceous : Lutite, limestone, fanglomerate, mudstone, sandstone)
Kiv	brown	medium	sub-parallel	medium-high	medium-high		well bedded	none	none	Volcanic rocks (Upper Cretaceous: Intermediate volcanic rocks (Devisadero Formation etc.)
Jmv	brown	medium	sub-parallel	medium-high	medium-high		massive	partly dense	none	Volcanic rocks (Middle-Upper Jurassic : Intermediate volcanic rocks, Lago La Plata, Lonco Trapia Formations etc.)
Jis	brown	medium	sub-parallel	low-medium	medium		partly	partly	none	Sedimentary rocks (Lower jurassic : Marine and continental sedimentary rocks , Piltriquitron Formation etc.)

Table Ⅱ-2-5 Characteristics of photogeologic units of the San Martin de Los Andes area

Unit	Photo-Characteristics		Mophologic Expression					Superficial Cover		Probable Lithology
	Tone	Texture	Drainage		Rock	Section	Bedding	Vegetation	Cultivation	(Correlation with available Geologic Map)
			Pattern	Density	Resistance					
TRss	brown	rough	sub-dendritic	medium	high		partly	partly	none	Sedimentary rocks(Upper Triassic: Marine and continental sedimentary rocks, Paso Flores Formation 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)
αTm	gray	coarse	sub-dendritic	medium	high		massive	none	none	Felsic igneous rocks (Miocene : Granite, granodiorite, tonalite and diorite)
αK	brown	coarse	sub-dendritic	medium	high		massive	partly dense	none	Igneous rocks (Upper Cretaceous : Granitic rocks)
αJT	brown	coarse	sub-dendritic, rectangular	medium	high		massive	partly	none	Igneous rocks (Jurassic-Tertiary : Plutonic rocks and hypabyssal rocks)
αJm	brown	coarse	sub-dendritic, rectangular	medium	high		massive	none	none	Igneous rocks (Middle Jurassic : Granodiorite, diorite, granite, tonalite and dacite)
αP	gray	coarse	sub-dendritic, rectangular	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)

San Martin de Los Andes

WR P232/88



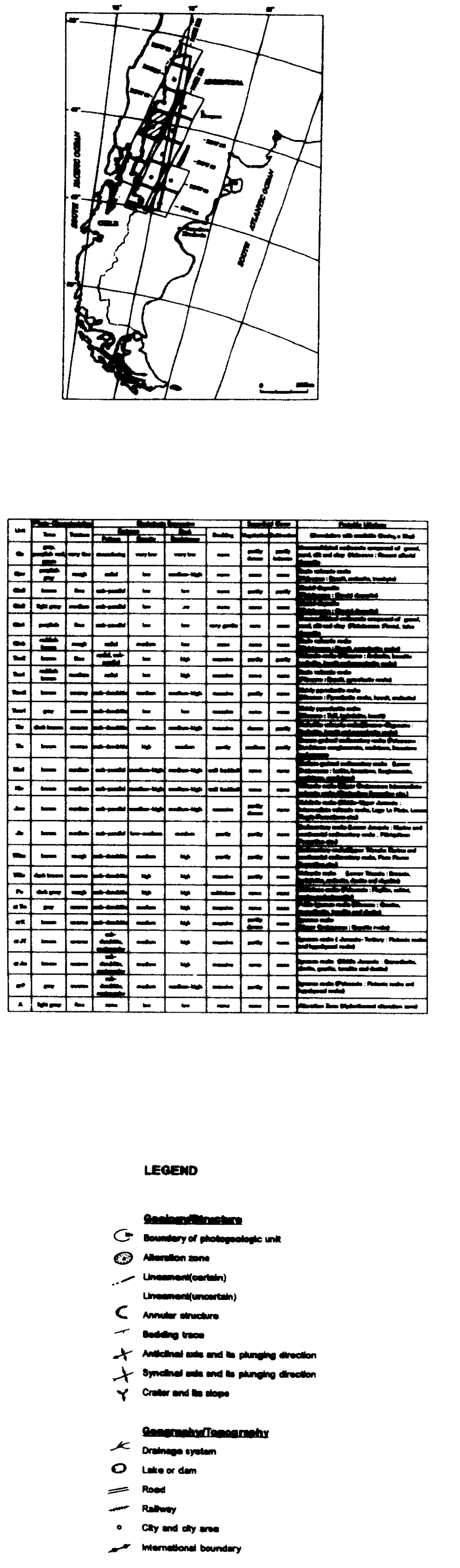


Fig. Ⅱ-2-12 The San Martin de Los Andes area: Photogeologic interpretation map

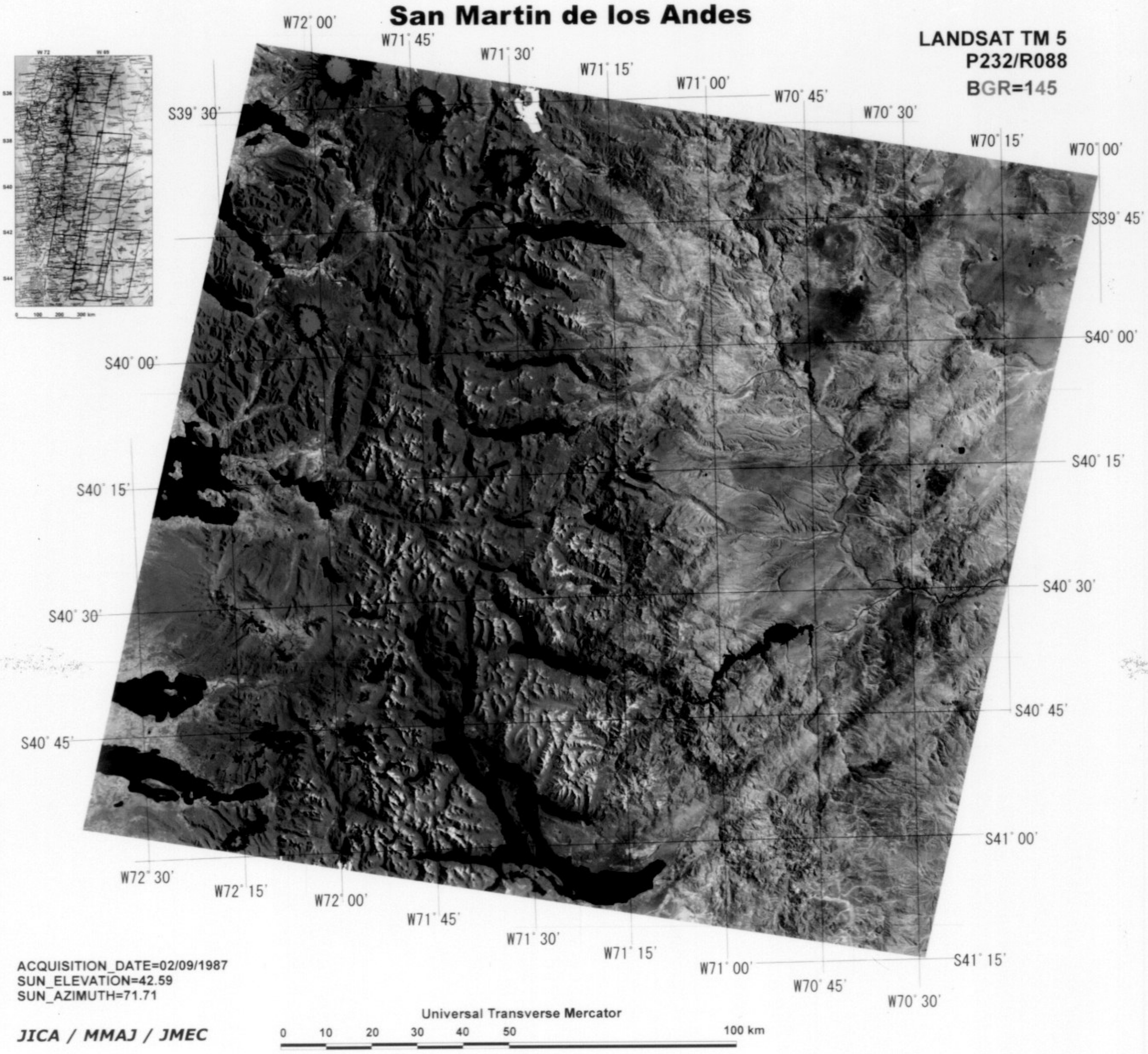


Fig. II -2-13 The San Martin de Los Andes area: Landsat TM false color image

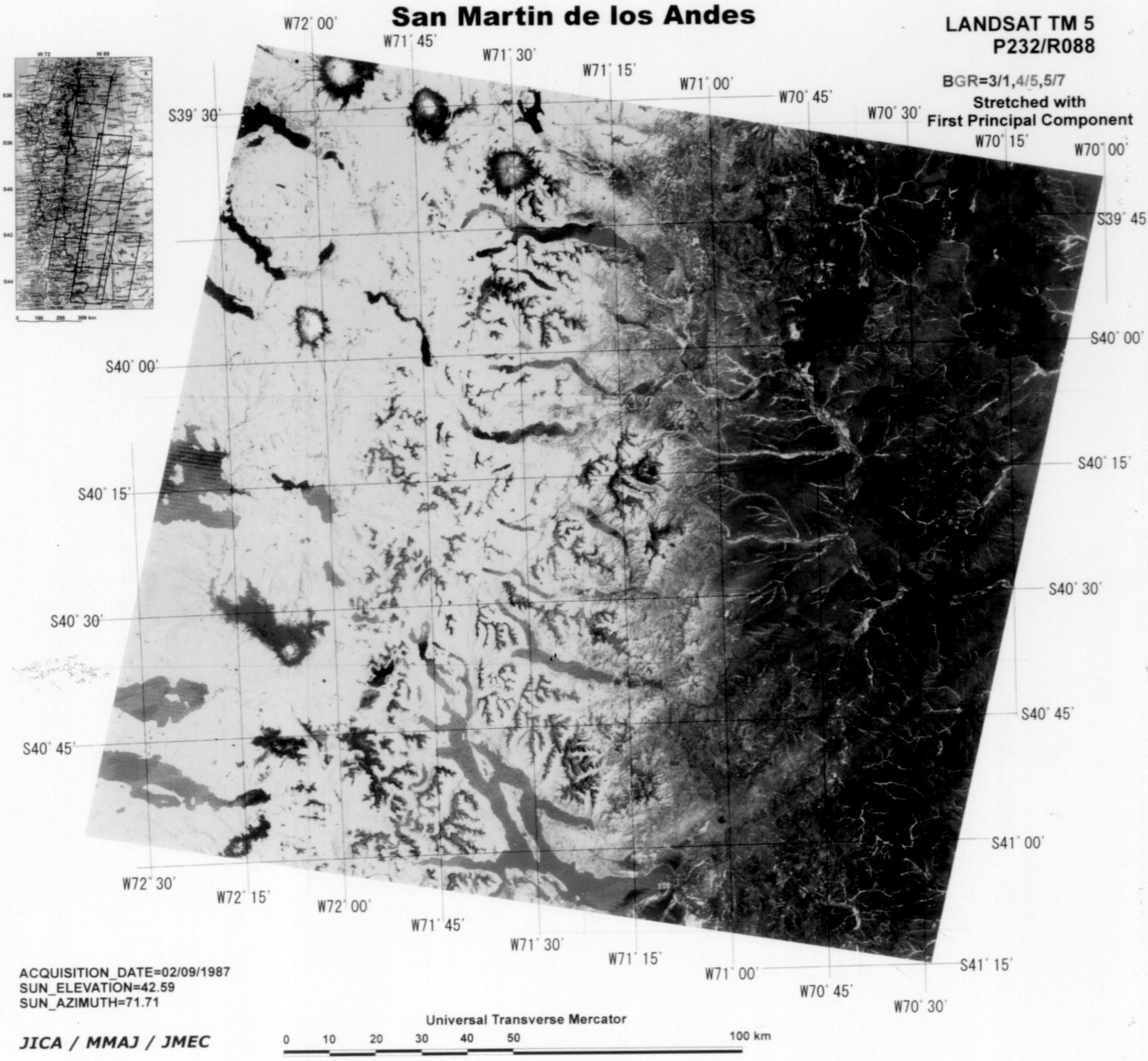


Fig. II -2-14 The San Martin de Los Andes area: Landsat TM ratio image the Triassic to Tertiary, and 10 units were comparable to the volcanic rocks of the Triassic to Quaternary. Four units correspond to the unconsolidated or semi-consolidated sedimentary rocks of the Quaternary. Another geological unit can be compared mainly to the schist formed in the Paleozoic. Another five units can be compared to the intrusive rocks generated in the Tertiary of the Paleozoic. Besides them, one unit was judged to be an alteration zone.

[Alteration zone]

Thirty-two alteration zones (SM001 to SM032) were interpreted and extracted in this area (Fig. II-2-12 and Table II-2-18). A majority of them were extracted near the Chilean border to the west of Long. 71°15' W. All the alteration zones are rather small, being 1 to 2 km in diameter. The distribution is in general irregular and massive. A sporadic alteration zone was regarded to be one zone, and plural zones closely located within at a horizontal distance of 1 to 2 km to each other were arbitrarily grouped as one zone. By this processing, the entire alteration zone was divided into eight zones.

The following eight zones can be summarized according to the difference in distribution and stratum:

(1) Group of five alteration zones (SM001 to SM005) recognized in the Paleozoic schist and intrusive rocks (geological unit: Ps, αP) distributed in the northwest.

(2) Group of two alteration zones (SM006 and SM007) recognized in the Paleozoic schist rocks (geological unit: Ps) distributed in the northwest.

(3) One alteration zone (SM008) recognized in the Tertiary volcanic rocks (geological unit: Tiv) distributed in the central zone.

(4) Group of three alteration zones (SM009 to SM011) recognized in the Cretaceous intrusive rocks (geological unit: αK) distributed in the central zone of the west.

(5) Group of four alteration zones (SM012 to SM013 and SM016 to SM017) recognized in the Tertiary volcanic rocks (geological unit: Tiv) distributed in the west.

(6) Group of two alteration zones (SM014 and SM015) recognized in the Tertiary volcanic rocks (geological unit: Tsv2) distributed among the alteration zone groups (3) and (5).

(7) Group of fourteen alteration zones (SM018 to SM024 and SM026 to SM032) recognized in the Tertiary volcanic rocks (geological unit: Tiv) distributed in the south.

(8) One alteration zone (SM025) recognized in the Tertiary volcanic rocks (geological unit: Tiv) distributed in the southwest.

Lineaments trending toward the NW-SE or the N-S were extracted near or on the periphery of the alteration zones except for the groups (4) and (8), and a semi-circular structure was found to the east of group (3).

[Lineament]

The distribution and direction of the lineaments interpreted and extracted from this area can be roughly classified into (1) the northeast region, (2) northwest region, (3) central west region, (4) southwest region and (5) southeast region, with the following characteristics observed for the respective regions:

(1) Northeast region

This region occupies the north of the NW-SE trending lineaments of good continuity (120 km intermittent continuity, though becoming ambiguous in the geological unit of Tmv1 distributed near the central region) observed on the boundary between the northwest and the southeast. The geology of this region is mainly composed of the Triassic to Tertiary volcanic rocks, the Paleozoic schist and the Cretaceous sedimentary rocks where the N-S, NNW-SSE and NW-SE lineaments are dominant. Four areas of lineament concentration are observed from the northwest to the northeast of this region. The continuity of respective lineaments is in general about 5 km.

(2) Nohthwest region

This region is an area enclosed by the lineaments of good continuity forming the boundary with the northeast region, and also by the lineaments of intermittent continuity tending to the NW-SE from the proximity of Lago Lolog to the west of Lago Heuchulafquen. Its eastern limit reaches the northeast of a town of San Martin de Los Andes. The geological units of this area are the Paleozoic schist, the Paleozoic intrusives and the Tertiary to Quaternery volcanic rocks that overly them. Lineaments of good continuity extracted in the northeast and southwest of this area are characterized by normal faults, and it is likely that there is a graben structure inside the lineaments

(3) Central west region

This region covers an area from the vicinity of Lago Lolog to the eastern coast of Lago Traful in the south. The main geological components are the Cretaceous intrusive rocks and the Tertiary volcanic rocks. In this region, lineaments trending toward the N-S with a continuity of about 10 km are dominant. Lineaments with high density are observed in the west of Lago Lolog and in the south of Lago Lacar. In areas of dense lineaments in the west of Lago Lolog, lineaments trending toward the NW-SE are also seen as well as those in the N-S orientation.

(4) Southwest region

This region covers an area from the Chilean border to the west of Lago Nahuel Huapi. The main geological components are the Jurassic and Tertiary volcanic rocks and the Cretaceous and Tertiary intrusive rocks. Lineaments trending toward the N-S with a continuity of about 10 km are dominant. Lineaments in the NW-SE orientation are found in the west of Lago Nahuel Huapi.