PART IV LANDSAT DATA ANALYSIS

The investigation of the LANDSAT data obtained as multispectral image of the earth's surface is attempted to analyse the geology and structure, to provide basic data for the exploration of mineral resources, and to guide the follow-up geological survey in and around the project district.

IV.1 Outline of Analysis

(1) Data to be used

Multi Spectral Scanner (MSS)'s Film Image of 70 mm and Computer Compatible Tape (CCT).

The project district is covered by two scenes of LANDSAT images (Fig. IV-1).

(2) Method of analysis

The procedure of LANDSAT data analysis is presented in Fig. IV-2, and classified into two kinds as follows:

1) Analog analysis (using 70 mm Film Image)

(i) Geological interpretation by False Color Image

(ii) Interpretation of geological structure by lineaments analysis on Edge-Enhanced Image

2) Digital analysis (using Computer Compatible Tape)

(i) Discrimination of geologic units using the spectral characteristics of training samples of the known geologic objects

(ii) Discrimination of mineralized zones using the spectral characteristics of training samples of the known mineralized zones

The results of these analysis were finally compiled to various kinds of discrimination maps on the scale of 1:250,000.

Fig. IV-I Index Map of LANDSAT Images, Northern Coahuila

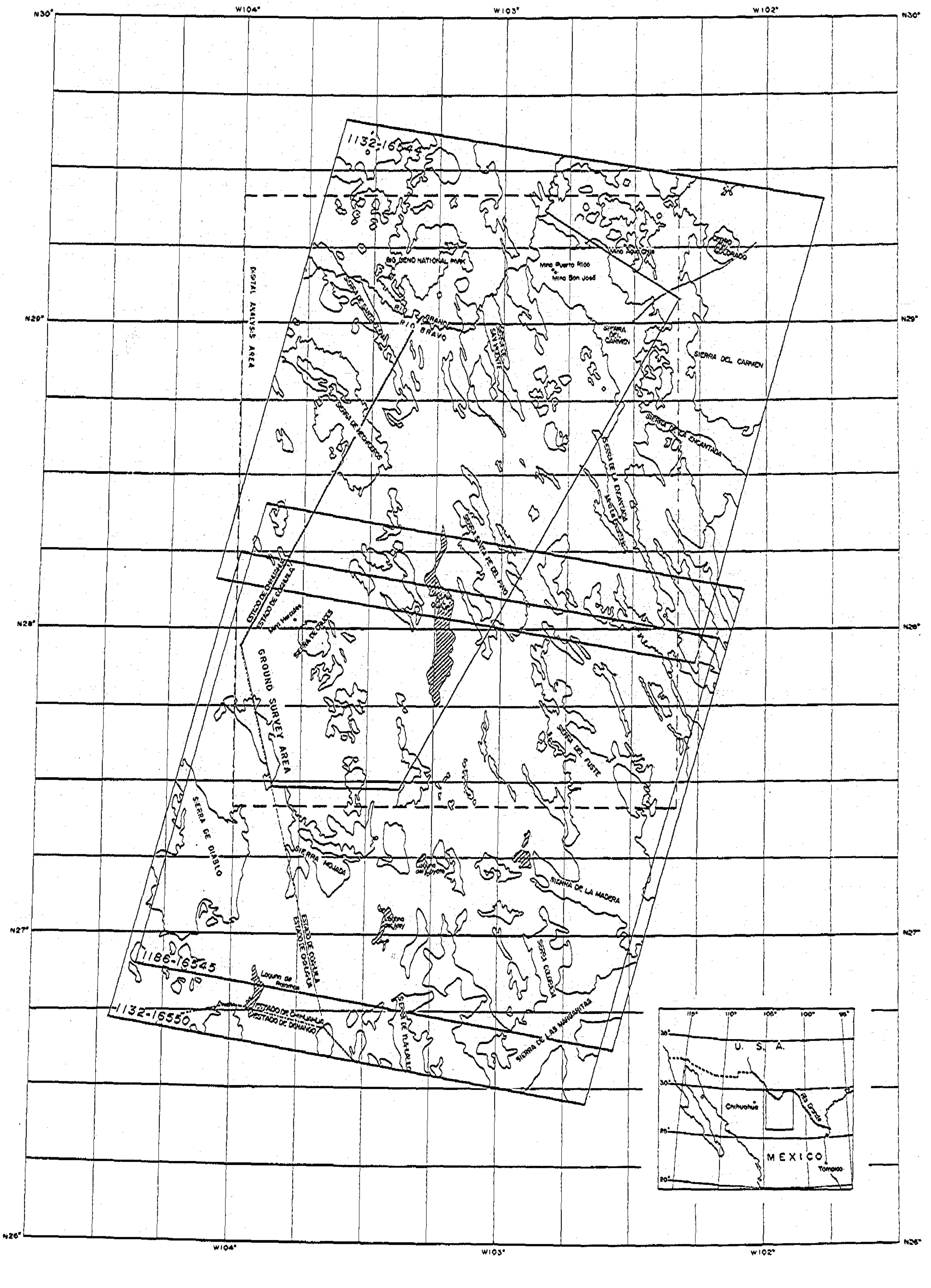
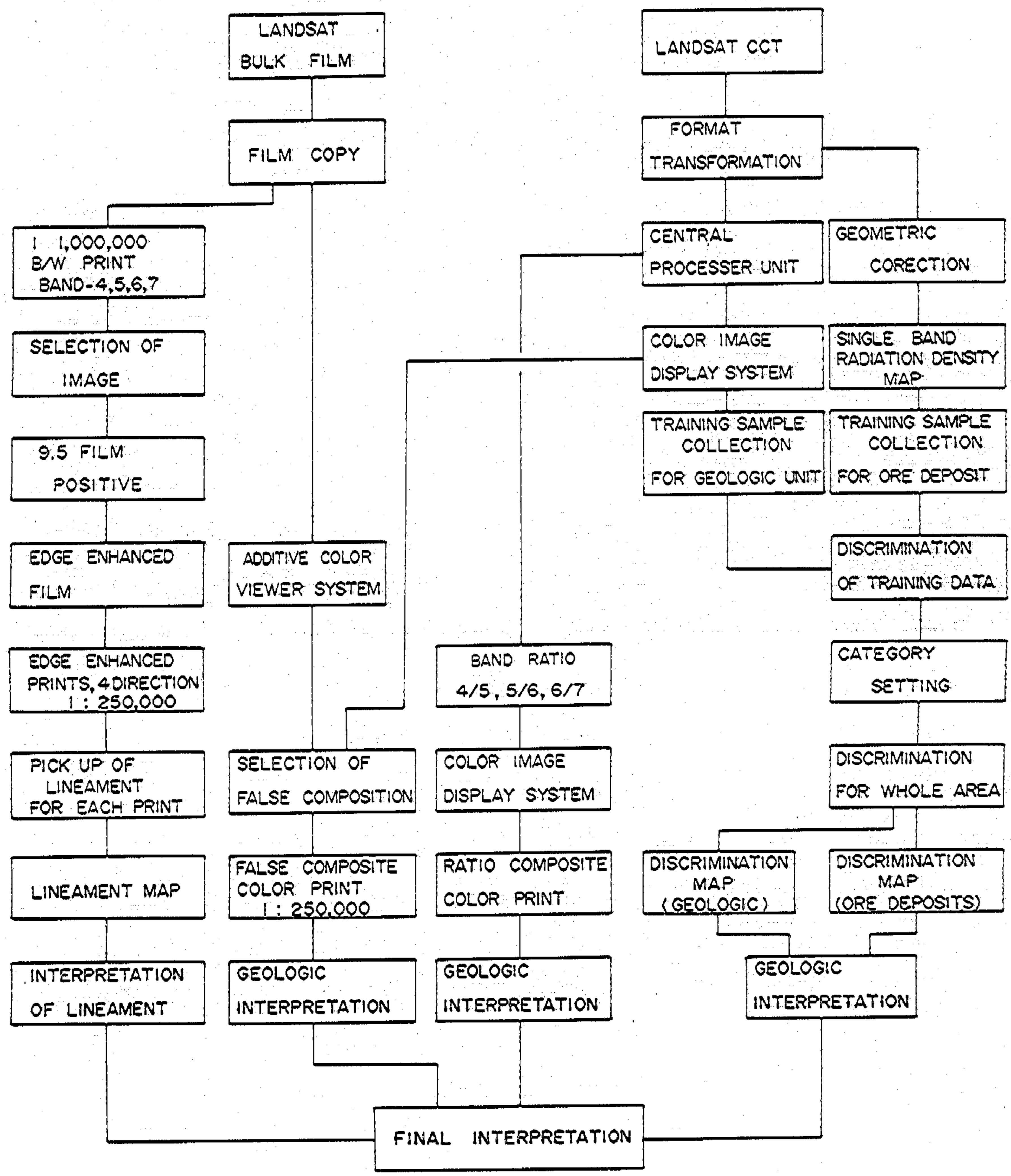


Fig. IV-2 LANDSAT DATA ANALYSIS FLOW CHART



IV.2 Analog Analysis

IV.2.1 Geological Interpretation by Pseudo-Natural Color Composite Image

Color composite analysis is a kind of techniques to extract objective themes by color images composed of three bands 70 mm film image data.

Various composite color images were obtained by the additive color viewer system and the color display system, but the attempt at identifying the geological units by means of colors alone did not prove very successful.

Consequently, the geological units could have been best identified by the use of photogeological factors such as drainage, topography and texture, in addition to colors.

The composite color images used are composite false color images which were developed approximately to natural color so as to facilitate geological interpretation of the meaning of colors, and their scale was 1:250,000. Although they were enlarged about ten times the original films, the obtained images were distinct enough to discriminate the objective themes.

The factors for discrimination thus obtained are shown in Table IV.1.

The geological units were roughly grouped into Cretaceous sedimentary rocks, Tertiary volcanic rocks, intrusive igneous rocks, and Quarternary sediments.

Cretaceous sedimentary rocks were subdivided into upper and lower series, Tertiary into four types, and intrusive rocks into five types, making a total of 12 geological units. Geological structures such as sycline and anticline were discriminated by the banding of geological units of specific color, texture, and state of erosion as well as the arrangement of cuestas.

The results of geological interpretation of LANDSAT images were checked by the interpretation of usual air photographs carried out at the same time and by the surface geological survey conducted after that, and it was proved to be sufficiently effective for regional reconnaissance.

Table IV-1 Classification Standard of Geological Unit by LANDSAT Pseudo-Natural Color Composite Image

Geological Unit		Color	Photographic Texture	Drainage: Pattern	Drainage: Density	Drainage: Length	Resistivity	Topography: Form	Topography: Section: Valley	Topography: Section: Ridge	Others	Probable Lithology	Known Geologic Data
Cretaceous Sedimentary Rocks	K_i	green-yellowish green, in high land partially brownish in low land	fine smooth	parallel, lattice, partially dendritic or radial	dense	short ~ medium	medium ~ strong	long range or flat massive	V	Λ	green color is assumed to show relatively dense vegitation.	sedimentary rock with high resistivity.	mainly of (1) comanche series (lime stone, mud stone)
	K_s	green with brown tint, grayish green	smooth (fine - coarse)		very dense	short	weak ~ medium		U	⌒	radial drainage area corresponds to curvicular structure. well bedded	sedimentary rock with low resistivity.	mainly of (1) Gulf series (mud stone with lime stone)
Tertiary Volcanic Rocks	Vac	green - deep green	fine smooth	irregular	poor	medium	medium	massive	V	∧	deep green color is assumed to show dense vegitation.	accidic volcanic rock	volcanic (1) rock and intrusive rock.
	Vbt	brown, greenish brown	fine smooth	irregular partially parallel	poor	short	medium	flat	V	⌒	partially bedded.	basalt lava	-
	Vand	dark brown, reddish brown	rugged, dappled	irregular	dense	short	weak	massive, irregular range	U	∩	partially bedded with surrounding reddish brown soil.	andesite lava	unidentified (2) volcanic rock
	Vrhy	P. brownish green, P. grayish green	rugged,	irregular	dense	short	weak	massive	U	∩		rhyolite lava	(2) rhyolite lava
Igneous Intrusive Rocks	I_{g1}	brownish	coarsely rugged	radial	medium	short	medium ~ strong	circular	V	Λ		intrusive rock	-
	I_{g2}	pale yellowish to grayish green	rugged ~ smooth	radial	poor	short	strong	circular	V	∧		intrusive rock	(1) intrusive rock
	I_{g3}	greenish to yellowish brown	coarsely rugged	irregular	dense	short	medium	circular	U	∩		intrusive rock	(2) quartzmonzonite
	I_{g4}	pale greenish brown, greenish brown	smooth	radial	poor ~ medium	short	medium	circular	U	⌒		intrusive rock with covering or fringing of sedimentary rock	(1) intrusive rock
	I·V	brown - reddish brown, pale greenish brown	rugged, dappled	irregular	poor medium	short	weak ~ strong	subcircular ~ irregular	U	∩		complex of volcanics, sedimentary rock and intrusives.	rhyolite and basalt lava, intrusive igneous rock. (3)
Quaternary Sediments	Q	white, dark to pale brown greenish brown reddish brown	fine smooth, linear, rugged,	irregular, parallel	very poor	long	very weak	flat low land, fan shaped				sand, gravel, evaporite.	(1)(2)(3) Quaternary sediments.

(1) Geochemical Prospecting Map by C.R.N., originated by Smith C.I.(1970)

(2) Hernández, J.V.(1964)

(3) Maxwell R.A., Lonsdale J.T., Hazzard R.T., and Wilson J.A.(1967)

The interpretation of geology by means of color composition is, however, done by two-dimensional observation, unlike the air-photo interpretation. Therefore, it will be impossible to trace each stratum in detail, which apparently leads to confine the accuracy of interpretation within the limit of regional geological reconnaissance.

Consequently, it will be concluded that the interpretation by analog analysis is highly effective in the initial stage of regional survey to infer the outline of geology and to observe large-scale geological structures of the region.

IV.2.2 Interpretation of Geologic Structures by Lineament Analysis

A. Extraction of lineaments

Lineaments are classified into straight and curvicular ones. At first, the curvicular lineaments were extracted on the images by the procedure shown below.

i) The negative films were made from 70 mm LANDSAT films of each band.

ii) The positive prints were made in each band on the scale of 1:1,000,000. Band 7 was selected as the most distinct band.

iii) From 70 mm positive film of band 7, negative films enlarged to 9.5 inches were made, from which black and white prints were prepared on the same scale of 1:250,000 as topographic maps. The curvicular lineaments were selected on the black and white prints of 1:250,000 scale.

The straight lineaments were extracted from edge-enhanced images in four sliding directions intersecting at 45! to the scanning line direction of LANDSAT images.

An experienced geologist was assigned to do the lineament extraction and observation in a consistent manner paying attention to the following items.

(a) The artificial lineaments such as roads and pasture boundaries were eliminated referring to the topographic maps.

(b) Lineaments over 2.5 km in length were adopted.

B. Curvicular structure (Fig. IV-3)

(1) Circular structure

Circular curvilineaments are generally 4 to 15 km in diameter, and nearly all intrusive igneous bodies have this structure, most of which are associated with dissected dome structure having exposures of intrustive plug at the center surrounded by the intruded host rocks with ring structure.

A typical example of circular structure not accompanied by intrustive igneous bodies can be found in the northern part of the Sierra del Carmen. This structure, 10 km in diameter, has a shape of circular dome characterised by well-developed radial drainages of high density. Circular structures were also identified in the Sierra de la Encantada and others.

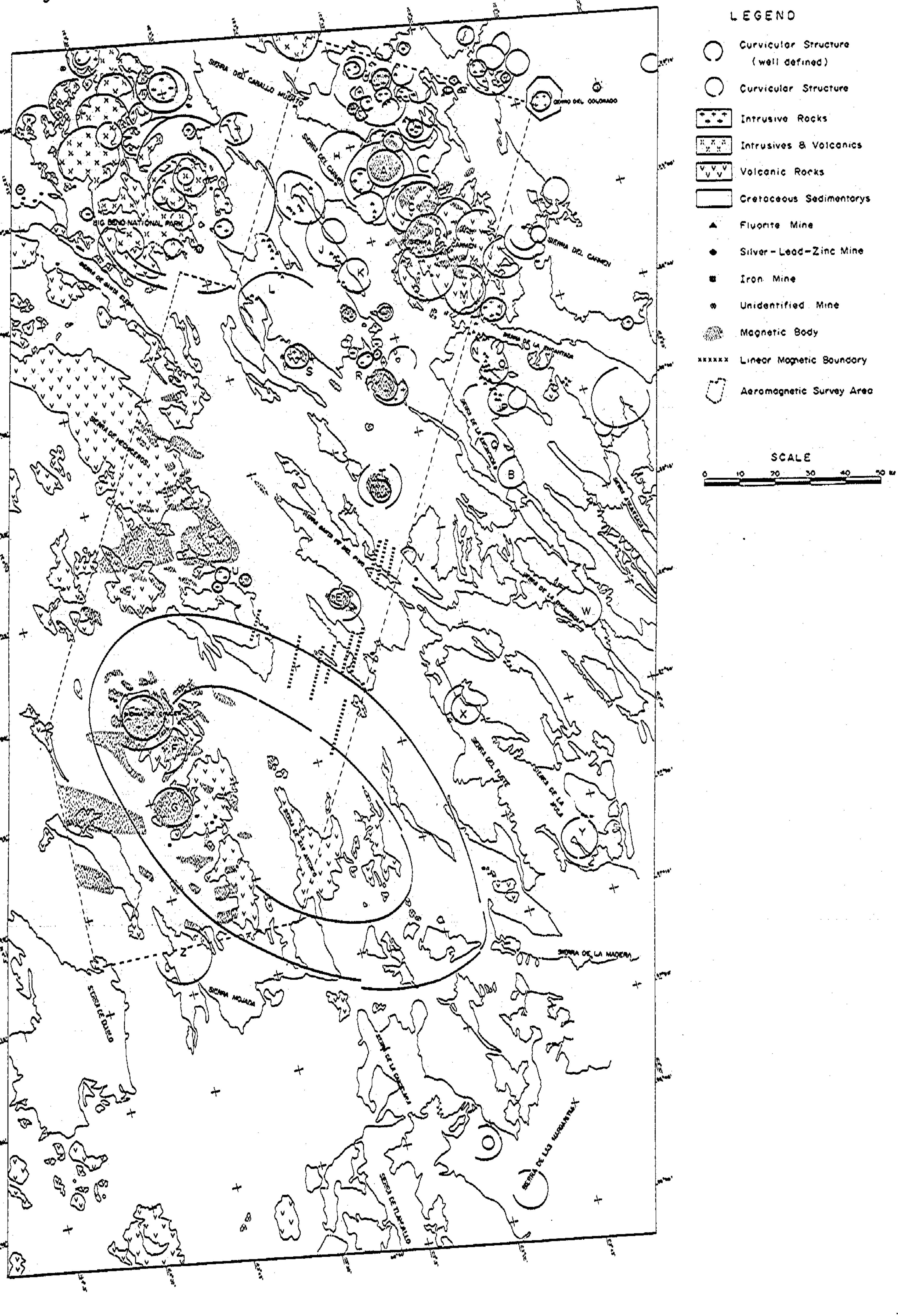
Many of the blind magnetic bodies detected by airborne magnetic survey conducted in Phase I have shown remarkable coincidence with the circular structure detected by LANDSAT images.

It is considered, therefore, that most of circular lineaments reflect the dissected dome or dome structure caused by exposed or deep-seated intrusive igneous rocks.

(2) Eliptical structure

A large elliptical curvilineament is found in the surrounding area of the Sierra de San Antonio in the central part of the southern half of the survey district. This structure is 135 x 75 km in area and is accompanied by a concentric inner elliptical structure (85 x 40 km). This double elliptical structure is identifiable by an elliptical arrangement of relatively large drainages as observed in an arid basin. Unlike the circular structure, however, it has no topographical characteristics of dome or radial drainages.

Fig. IV-3 DISTRIBUTION MAP OF CURVICULAR STRUCTURE



Although the geological significance of the double elliptical structure is not clear, it may be interpreted that the structure may represent a basin of Tertiary volcanic rocks, since it substantially defines the distribution of Tertiary volcanic rocks around the Sierra de San Antonio and the Sierra de San José.

C. Straight lineament (Refer Figs. IV-4 and 5)

(1) Direction

Four directions composed of two sets of approximately orthogonal systems were detected, and these directions were classified into types, A, B, C and D.

Type A	System of N55° ~ 60°W
Type B	System of N 5° ~ 10°W
Type C	System of N25° ~ 30°E
Type D	System of N65° ~ 70°E

(2) Distribution

Type A of lineaments was found largely in the areas of fauls and tectonic lines with the same direction. This type of lineaments and tectonic lines had been collectively summarized as Texas zone or Texas lineaments in the previous works (Albritton et al. 1946).

Type C shows a distribtuion similar to that of Type A, and crosses Type A substantially at right angles. It is assumed, therefore, that these two types of lineaments form a conjugate set.

Type A and Type C show a predominant distribution on the Tertiary volcanic rocks and on some intrustive rocks. Taking the results of K-Ar dating into consideration, it can be possibly infered that Type A and Type C were formed by younger tectonic movements than those relating to Type B and Type D mentioned below.

Fig. IV-4 DISTRIBUTION MAP OF LINEAMENT, A AND C TYPE

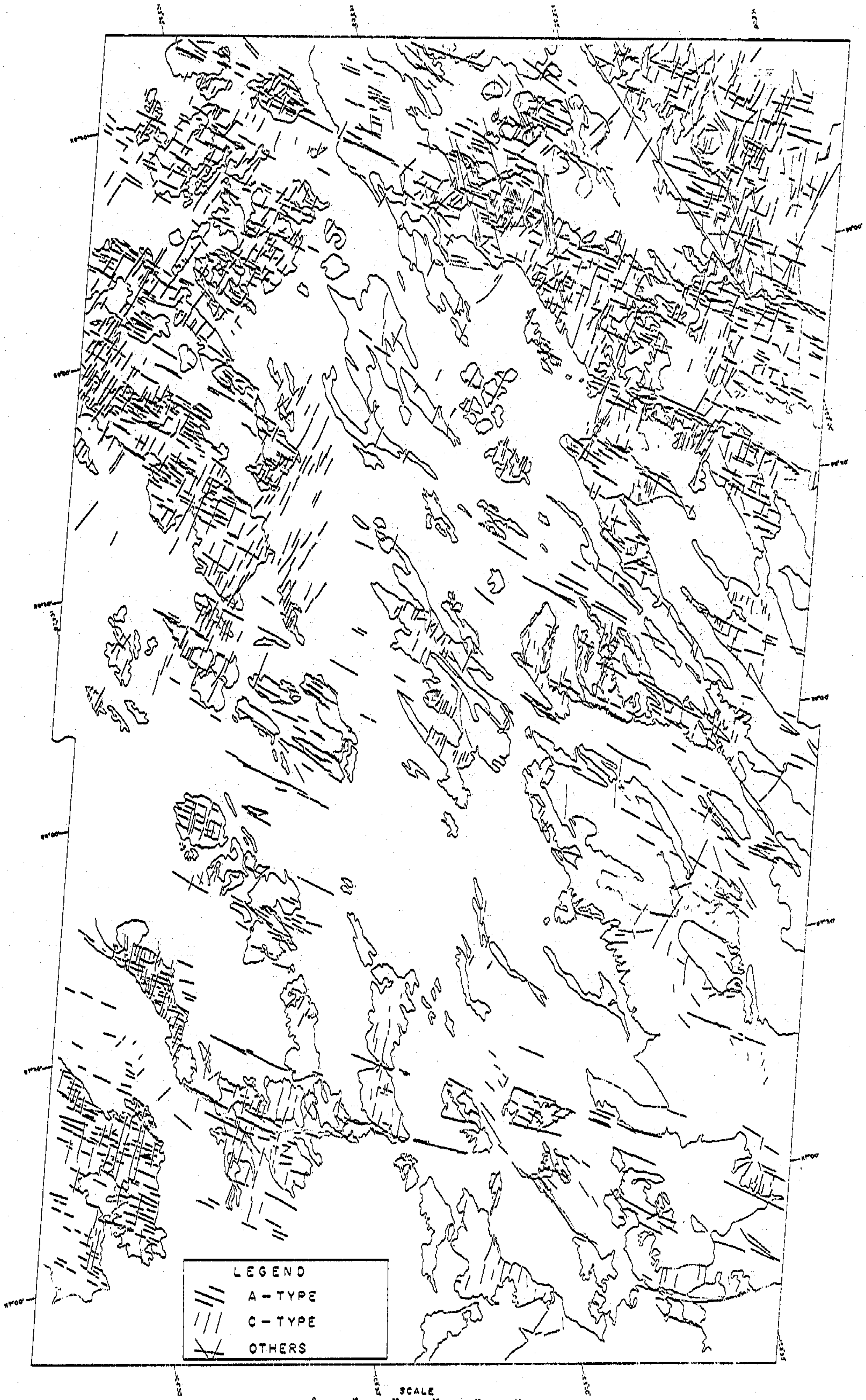
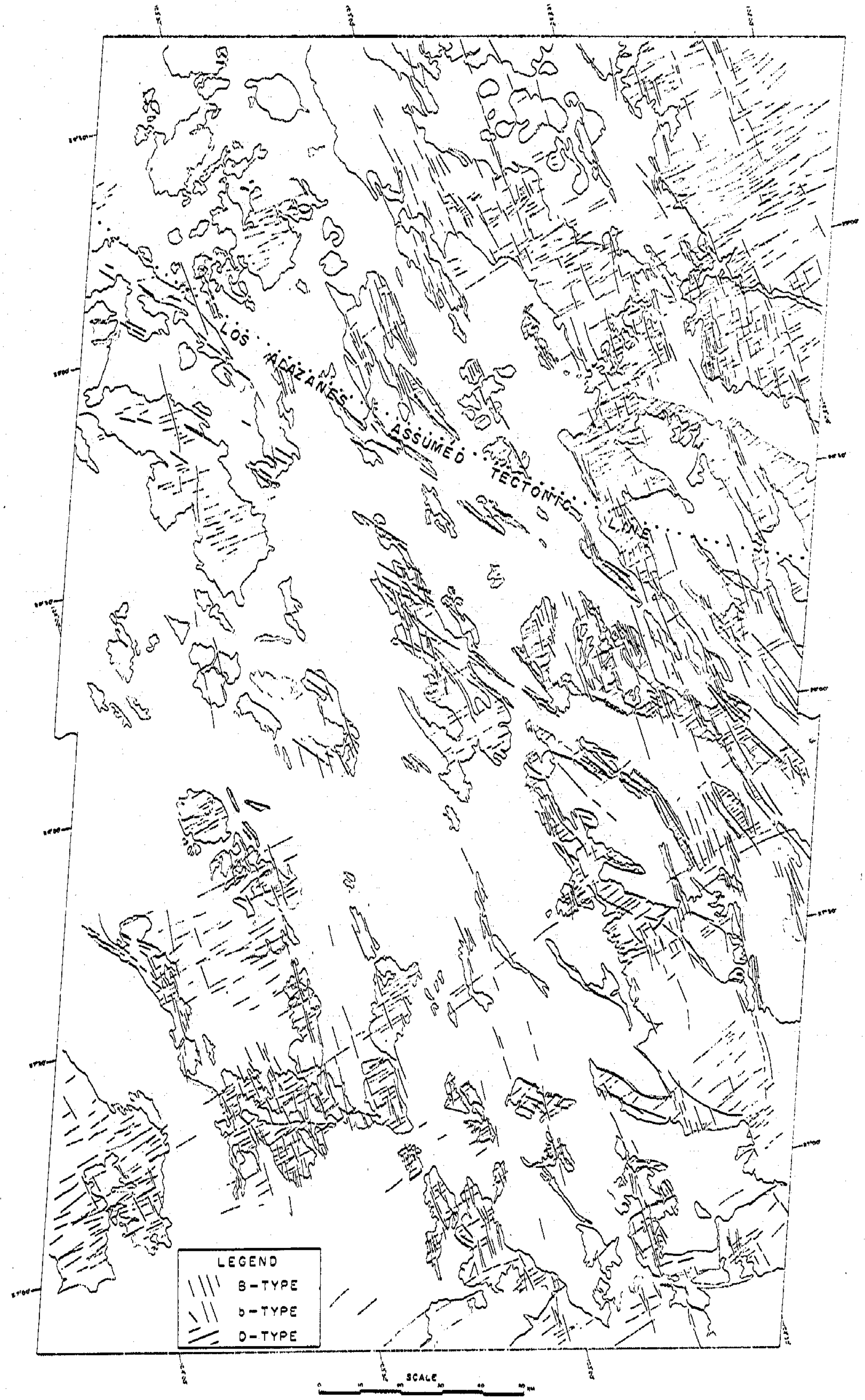


Fig. IV-5 DISTRIBUTION MAP OF LINEAMENT, B AND D TYPE



Type B is formed mainly in Cretaceous sedimentary rocks together with Type D.

Type B is parallel to the folding axis of NNW-SSE which are of the first-class geological structure in the surveyed district. Two kinds of occurrences are considered; one represents strike fault, and the other is identified as bedding plane of Cretaceous strata. The latter was, therefore, subdivided to Type B. Since Type D crosses a-proximately at right angles the main folding axes, it is considered to be a cross joint or cross fault involved in folding movements.

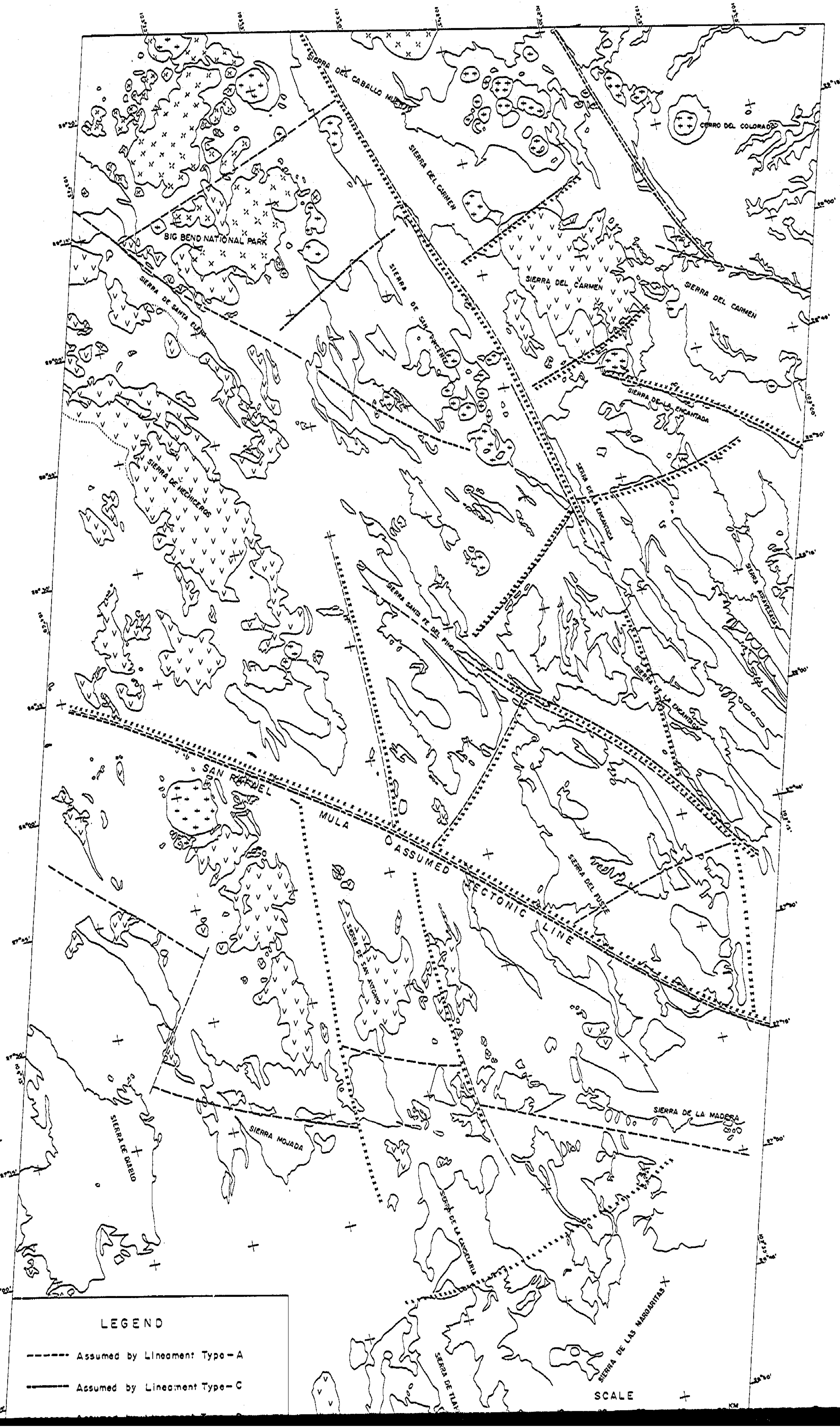
(3) Assumed tectonic lines by lineaments (Refer Fig. IV-6)

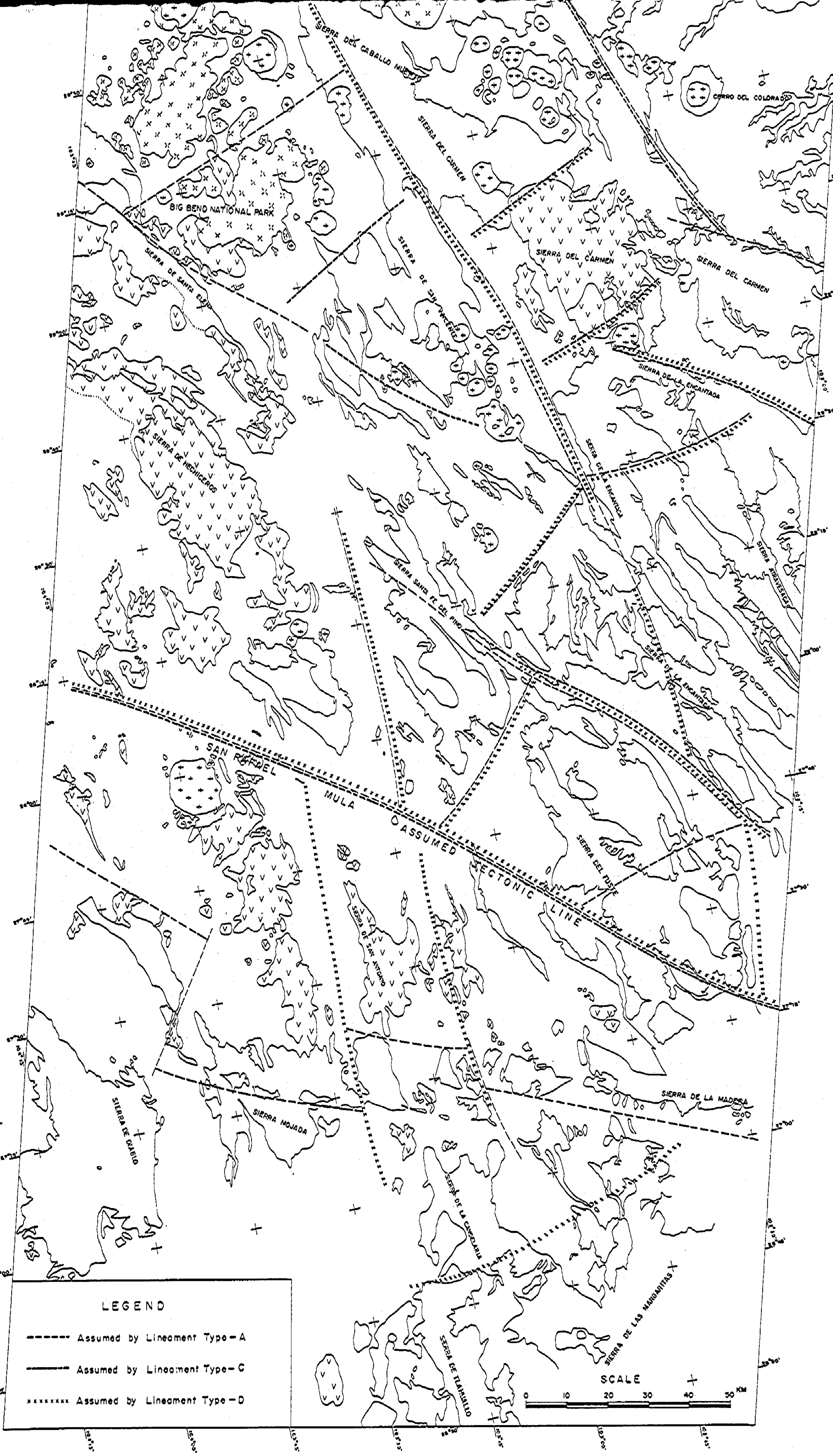
Frequency distribution of lineaments in each of 31 blocks within the entire surveyed district is given in a rose diagram (PL-IV-1). In the diagram, deflections from the reference directions are denoted by arrows. The reference directions are the directions with the greatest frequency determined in respect of Types A, B, C and D. If adjoining blocks show a deflection in the same direction or do not show any deflection at all, they are considered to be continous.

On the other hand, if adjoining blocks show a defection in opposite directions or either of them shows a deflection, it is assumable that there exists a geological discontinuity between these blocks. The assumed tectonic lines were drawn on the assumption as just mentioned aboove (Fig. IV-6).

As the result, the assumed tectonic lines include those which had failed to be detected by the conventional methods because of the Quarternary sediments covering them, especially the tectonic lines in WNW-ESE direction.

Fig. IV-6 ASSUMED TECTONIC LINE BY DECLINATION OF LINEAMENT





SIERRA DEL CABALLO MUERTO
CERRO DEL COLORADO
SIERRA DEL CARMEN
SIERRA DEL CARMEN
SIERRA DEL CARMEN
BIG BEND NATIONAL PARK
SIERRA DE SAN VICENTE
SIERRA DE SANTA ELENA
SIERRA DE LA ENCANTADA
SIERRA DE LA ENCANTADA
SIERRA DE LA ENCANTADA
SIERRA DE HECHICEROS
SIERRA ATRAVESADA
SIERRA SANTA FE DEL PINO
SAN RAFAEL
MULA
ASSUMED
TECTONIC
LINE
SIERRA DEL FUSTE
SIERRA DE SAN ANTONIO
SIERRA DE LA MADERA
SIERRA MOJADA
SIERRA DE DIABLO
SIERRA DE LA CANDELARIA
SIERRA DE LAS MARGARITAS
SIERRA DE TLAHUALLO
LEGEND
Assumed by Lineament Type-A
Assumed by Lineament Type-C
Assumed by Lineament Type-D
SCALE
0 10 20 30 40 50 KM

IV.3 Digital Analysis

IV.3.1 Outline of the Method

Aside from analog analysis of 70 mm images, digital analysis with CCT was attempted.

Multispectral data reflecting the known geologic units, mineralized zones, alteration zones, etc., are processed statistically to represent these characteristic in digital form. Thus the criteria of discrimination are made, which are called training dta. That is to say, for each geologic object (called category), the statistical values (mean vector of four bands and variance-covariance matrix) of multispectral data are computed, and assigned to show a representative pattern for each category. Then the pattern of multispectral data of unknown geologic object was compared with a set of the standard patterns of known categories. After that, the unknown geologic object was discriminated to a category which showed the most similar pattern.

IV.3.2 Number of Category

From theoretical stand point, the more detailed discrimination will require the more number of categories. The increase of categories in number, however, lowers the accuracy of discrimination because of the increase of similarity in spectral patterns among the categories. For example, the discrimination done by means of only two categories of Cretaceous sedimentary rocks and Tertiary volcanic rocks will get considerably high accuracy. However, the sttempt to discriminate nine groups of Cretaceous sedimentary rocks by calculating representative spectral pattern for each of the nine categories was proved to be impractical resulting in lowering the accuracy because of the mutual similarity of the patterns.

In this case, setting of two categories of upper and lower Cretaceous would have led to the better result.

As the result of these trial and error, 28 categories provided at initial stage were limited to 13 by grouping and rejecting (Table III-4,5,8).

Table IV-2 Classification of Training Samples, Final 10 Geologic Categories

(Threshold Value 95%)

CLASS	NO. OF SAMPLES CLASSIFIED INTO											NO. OF SAMPLES	HIT-RATIO
	3	11	13	17	18,21	23	25	27	28	8	OTHERS		
3	64	0	0	0	1	11	0	0	0	1	3	80	0.800
11	0	24	0	0	0	0	0	0	0	0	0	24	1.000
13	0	0	10	0	0	0	0	0	0	0	0	10	1.000
17	0	0	0	54	8	0	0	0	1	0	3	74	0.730
18,21	0	0	0	18	87	21	0	4	23	2	7	162	0.537
23	8	0	0	7	6	30	0	0	5	0	0	56	0.536
25	0	0	0	0	0	0	27	0	0	0	1	28	0.964
27	0	0	0	0	1	0	0	54	2	0	2	59	0.915
28	0	0	0	0	6	0	0	1	30	0	5	42	0.714
8	4	0	0	1	8	0	0	0	3	48	1	65	0.738

Table IV-3 Mean Reflected Intensity of Geologic Categories

CATEGORY	SYMBOL	CLASS	BAND			
			4	5	6	7
Lower Cretaceous Sedimentaries in Northern Region		3	28.74	26.58	29.46	15.21
Evaporite	■	11	78.67	87.83	81.67	35.30
Pit or Artificial Matters		13	50.40	53.70	46.00	18.40
Quartz Monzonite		17	33.18	35.32	35.39	16.39
Rhyolitic, Trachyandesitic Volcanics	✧	18,21	29.51	28.19	27.78	12.27
Lower Cretaceous Sedimentaries in Southern Region		23	30.18	28.21	29.38	13.80
Saline Water		25	47.82	50.75	51.04	14.64
Basaltic Volcanics		27	25.53	21.75	19.37	7.42
Unidentified Volcanics near the Sierra de Cruces	//	28	26.10	22.74	23.21	9.91
Unidentified Volcanics near the Sierra del Carmen	//	8	26.28	25.52	29.37	13.88

Table IV-4 Classification of Training Samples Including "Mineralization" Categories

(Threshold Value 95%)

CLASS	NO. OF SAMPLES CLASSIFIED INTO													NO. OF SAMPLES	HIT-RATIO
	3	11	13	17	18,21	23	25	27	28	A	B	C	OTHERS		
3	48	0	0	0	0	12	0	0	0	0	6	12	2	80	0.600
11	0	24	0	0	0	0	0	0	0	0	0	0	0	24	1.000
13	0	0	10	0	0	0	0	0	0	0	0	0	0	10	1.000
17	0	0	0	49	2	6	0	0	1	6	6	0	4	74	0.662
18,21	0	0	0	9	51	20	0	4	23	40	9	1	5	162	0.315
23	7	0	0	6	5	28	0	0	5	1	1	3	0	56	0.500
25	0	0	0	0	0	0	0	27	0	0	0	0	1	28	0.964
27	0	0	0	0	1	0	0	54	2	0	0	0	2	59	0.915
28	0	0	0	0	6	4	0	1	30	0	1	0	0	42	0.714
A	0	0	0	0	7	3	0	0	0	29	1	0	3	43	0.674
B	1	0	0	3	0	0	0	0	0	1	12	1	0	18	0.667
C	12	0	0	0	0	2	0	0	1	0	5	53	2	75	0.707

These informations were stored in computer, and the results were plotted on the digital maps with symbol marks correspoinding to each category.

IV.3.3 Result of Classification

(1) *Geology*

The discrimination efficiency in Cretaceous sedimentary rocks was satisfactory, and good results were obtained. Andesitic rocks of Tertiary volcanic rocks were fairly distincly discriminated, but basalts and rhyolites were not discriminated well. Intrusive rocks were not discriminated (PL-IV-2).

(2) Ore depoit (Refer PL-IV-3)

i) *Iron ore deposit (Category A)*

The symbol mark of iron ore deposit was plotted in semi-desert plain, which does not serve as an indicator of iron mineralization. The primary possible reason for this is that the Mina Hércules from which the training data were taken is located in a semi-desert lowland and is not associated with any characteristic alteration zone to provide chracteristic pattern for multispectral data.

ii) Fluorite deposit (Category C)

Many of the fluorite zones were discriminated well. At the same time, however, a substantial part of the lower Cretaceous, the host rock of fluorite, was also descriminated mistakenly in spite of absense of fluorite deposit.

iii) Lead and zinc deposites (Category B)

The training data of this category were taken at Mina la Encantade. Among the areas of concentration of the symbol mark of this category, those contained in the region in which igneous rocks are predominantly distributed are rejected in order to avoid the misidentification. This was because of the consideration that the area in which calcareous rocks of lower Cretaceous were distributed predominantly and training data were taken showed different pattern of multispectral data obtained from mineralized zones occurring in the region of igneous rocks. As the result, concentration of the symbol mark was observed in 10 areas. Among these areas, five areas are in and around the known location of lead-zinc mines, two areas are in the vicinity of the intrusive igneous bodies, two areas are around the circular structures which suggest the existence of deep-seated intrusive bodies, and an area was in other situation.

IV.3.4 Summary

The result obtained from ten categories for geological units and three categories for mineralized zones were summarized in the discrimination map on the scale of 1:250,000. The efficiency of the identification is concluded as follows:

A. The units identified with satisfactory efficiency

i) Cretaceous sedimentary rocks

ii) Andesites

B. The units discriminated with some misidentification

i) Lead and zinc mineralization zone

ii) Fluorite mineralization zone

C. The units proved to be poor in efficiency due to misidentification

i) Intrusive rocks

ii) Rhyolites and basalts

iii) Iron mineralization zones

The reasons why the different accuracy of discrimination was caused according to the kind of category are considered as follows:

(i) The training data for discrimination category did not always have the pattern to represent the category. This is because of the difficulties to obtain the representative spectral pattern which is sufficient for each discrimination category by the reason that the training data were taken only in a few known localities, despite of a wide area of the district to be surveyed.

(ii) Relative difficulty for each category

That is to say, to be identified efficiently means that the spectral patterns which represent the discrimination category is different from those of other categories. In the contrary, therefore, the discrimination will be quite difficult.

Moreover, the accuracy of discrimination of the present investigation can be hardly said to be useful enough. In order to obtain the efficient and reliable discrimination maps, the following considerations are to be required.

(a) The number of discrimination categories should be minimized.

(b) The number of the training data to obtain the representative spectral pattern for each discrimination category should be increased as much as possible.

(c) When a comparison of the similarity and separability between the spectral pattern representing each category and that of any point in the district is made, some steps must be taken to emphasize the main elements of each pattern.

(d) The reliability limit of discrimination should be raised. As the result of it, should the increase of the parts not to be discriminated be incurred, it would have been originally the portion of difficult discrimination. Other measures must be taken to solve such peculiar problems.

PART V PHOTOGEOLOGICAL INTERPRETATION

Photogeological interpretation was carried out as a link of reginal survey conducted in Phase II. The result of interpretation was checked and corrected by the reginal geological survey following the photogeological interpretation. Finally it was completed as the regional geologic map on the scale of 1:100,000.

The geology and geological structure interpreted are described in the third chapter. In this chapter, therefore, a special mention associated with photogeology will be made.

V.1 Topographic Map and Aerial Photograph

Aerial photographs and topographic maps used in the photo-interpretation are as follows:

(1) Aerial photograph

Aerial photographs on the scale of 1:50,000 or 1:65,000
(706 sheets in total)

Photomosaics on the scale of 1:50,000

LANDSAT composite false color images on the scale of 1:250,000

(2) Topographic map

Topographic maps on the scale of 1:250,000, covering the whole district.

Drainage maps on the scale of 1:50,000, prepared during the Phase II work to cover the whole district.

Topographic maps on the scale of 1:50,000, limited to the south of Lat. 28°N.

V.2 The Unit for Interpretation

Geological and structural features were interpreted based on the classification standard of geological units prepared by comparing the previously published geological data with their photogeological characteristics. The results of interpretation were at first transferred on the photomosaics, then they were compiled to the drainage maps on the scale of 1:50,000 to use for the field survey.

At first, geological units were roughly classified into the Cretaceous system, Tertiary system and intrusive rocks, and then subdivided into formations and lithofacies as shown in Table III-1.

Thin vegetation and good correspondence between geology and topography of the survey district led to a favorable result of photo-interpretation. Especially in the Cretaceous sedimentary rocks, the banding constituted by the exposure lines of the beds and their boundaries were districtly shown on the photographs, and it was possible to trace these on the photographs.

As the result of interpretation, it was made distinct that the folded mountain ranges, composed of the Cretaceous system extending in the direction of NNW-SSE, are characterized by the asymmetric anticlinoria with axes of the same direction.

The distribution of the volcanic rocks and intrusive rocks were interpreted with considerable accuracy. It is natural, however, that it was required for the classification of lithofacies to correct by surface geological survey.

It can be concluded, in any way, that the photo-interpretation maps greatly contributed as a guide to surface geological survey.

Table V-1 Classification Standard of Geological Unit for the Cretaceous System by the Photogeological Interpretation

Geological Unit				Photographic tone	Photographic texture	Drainage pattern	Drainage density	Resistivity	Topography form	Topography section valley	Topography section ridge	Banding pattern of stratification	Lithofacies confirmed by field checks
Cretaceous System	Upper	Gulf Series	Kog	gray to light gray	fine, granular	dendritic	dense	low	rounded, gentle	∪	⌒	indistinct	fine sandstone, siltstone
			Kpf	gray to light gray	rugged, spotted	dendritic	dense	low	rounded, gentle	∪	⌒	indistinct	calcareous claystone, mudstone
			Kav	alternation of white and gray	fine, smooth	dendritic & primatic	dense	low	rounded, gentle	V	⌒	distinct	alternation of chalk, limestone, shale and sandstone
			Kbo	gray including white band	fine, smooth	dendritic & primatic	moderate	low	rounded gentle	V	⌒	distinct	alternation of thin-bedded limestone, dark gray marl and mudstone
		Comanche Series	Kbu	gray to light gray	fine, smooth, partly rugged	parallel & primatic	dense	high	moderatly steep	V	∩	distinct	thin-to-medium-bedded limestone
			Kdr	light gray to white	fine, smooth	indistinct	-	low	indistinct	–	⌒	indistinct	calcareous mudstone
	Lower		Kse	dark gray to gray	fine, irregularly rugged	parallel & primatic	moderate	high	steep	U	⊓	distinct	thick-bedded limestone
			Kap	light gray	fine, smooth and granular	parallel	dense	low	rounded, gentle	V	⌒	-	marl and dark gray limestone
			Kdc	dark gray	fine, granular	parallel	rough	high	steep	V	⊓	distinct	limestone
			Kcu	light gray	fine, smooth	parallel & feather	rough	low	rounded, gentle	∪	∩	indistinct	mainly marl
			Kgr	light gray	fine, smooth and rugged	parallel	dense	moderate	steep	∪	⊓	distinct	alternation of limestone, marl and shale
			Kau	gray to dark gray	granular, spotted	grid & parallel	dense	high	steep	V	⊓	distinct	upper part: marl, thin bedded limestone mainly: thick-bedded limestone
			Kpe	dark gray	granular, spotted	parallel & feather	dense	low	rounded, gentle	V	∩	distinct	mainly calcareous mudstone intercalating with marl and limestone
		Coahuila S.	Kcu	gray	granular, partly spotted	parallel	rough	low, partly high	steep	U	⊓	distinct	upper and lower: limestone middle: marl, shale and limestone
			Kpr	gray	granular, partly spotted	parallel	moderate	low	rounded gentle	U	∩	indistinct	upper part: sandstone lower part: conglomerate

Table V-2 Classification Standard of Geological Unit for the Tertiary System and Intrusive Rocks by the photogeological Interpretation

Geological Unit				Photographic		Drainage		Resistivity	Topography			Lithofacies confirmed by field check
				tone	texture	pattern	density		form	section valley	section ridge	
Tertiary System	South Sierra del Carmen	Volcanic rocks	rh-2	light gray to dark gray	coarse, granular, rugged	dendritic	rough	high	steep	V	∧	white alkaline rhyolite and pyroclastics
			bs	gray to light gray	fine, granular	dendritic	rough	low	rounded	⊔	⌒	basalt
			an	gray to light gray	granular, rugged	dendritic	dense	high	steep	V	∩	trachytic andesite lava and pyroclastics
			rh-1	gray to light gray	granular	dendritic	rough	moderate	rounded	V	∩	white rhyolite lava
	Sierra de Rechiceros	Volcanic rocks	hs	gray to dark gray	fine, smooth	dendritic	rough	low	rounded	⊔	⌒	basalt lava and dolerite
			dc	gray to light gray	fine, smooth	dendritic & grid	rough	moderate	somewhat steep	V	∩	dacite lava and pyroclastic
			rh	gray	granular, rugged, smooth	grid to parallel	dense	high	steep	V	⋀⋀	dacite, rhyolite lava and pyroclastics
			tr	light gray	smooth	feather	dense	low	rounded	◡	⌒	rhyolitic tuff
			an-2	gray to light gray	rugged and spotted	grid	dense	moderate	somewhat rounded	V	∩	alkaline andesite lava
			ca	light gray	fine, smooth	dendritic & parallel	rough	low	rounded	⊔	∩	andesitic pyroclastics
			bs	gray	spotted	irregularly dendritic	dense	low	rounded	⊔	∩	basalt lava
			an-1	dark gray	spotted	irregularly dendritic	dense	low	rounded	⊔	∩	basaltic andesite, andesite and pyroclastics
	Sierra de San José	Volcanic rocks	bs-2	dark gray	fine, smooth	dendritic	rough	low	rounded flat	◡	⌒	
			an-3	gray to dark gray	smooth	grid to dentritic	rough	high	inter-mediate	V	⋀⋀	compact andesite lava
			rh	light gray to gray	fine, smooth	dendritic to prisma-tic	rough	moderate	inter-mediate	V	⊓	rhyolite lava and welded tuff
			bs-1	gray to dark gray	fine, smooth	dendritic	rough	moderate	inter-mediate	⊔	⌒	dark gray basalt

Table V-2 (Continued)

Geological Unit				Photographic		Drainage		Resistivity	Topography			Lithofacies confirmed by field check
				tone	texture	pattern	density		form	section		
										valley	ridge	
Tertiary System	Sierra de San José	Volcanic rocks	an-2	gray	rugged and spotted	dendritic	dense	low	rounded flat			porous andesite lava
			tr	light gray	rugged and spotted	dendritic	dense	low	rounded flat			rhyolitic tuff, lapilli tuff and tuff breccia
			do	light gray	fine, smooth, partly rugged	dendritic	rough	low, partly high	rounded, gentle			dacite lava
			an-1	light gray to gray	fine, smooth, partly rugged	dendritic	rough	-	inter-mediate			brownish gray andesite lava and pyroclastics
			Tss	light gray	fine, smooth	feather	dense	low	rounded flat			pale green tuffaceous sandstone
		Intrusive rocks	igb	light gray	coarse, rugged	ring-like	rough	inter-mediate	rounded hill-like			mainly gabbro
			idi	dark gray to gray	coarse, rugged	dendritic to prismatic	rough	inter-mediate	rounded hill-like			coarse-to-medium-grained
			iad	light gray	smooth and coarse, rugged	prismatic to grid	rough	high	steep			adamellite to quartz monzonite
			imn	dark gray	fine, smooth	prismatic	moderate	inter-mediate	rounded hill-like			monzonite
			ibs	dark gray	rugged	dendritic	rough	inter-mediate	rounded hill-like			andesitic basalt
			ian	gray	rugged and spotted	dendritic	dense	low	rounded flat			andesite
			irh	gray to light gray	rugged	-	-	inter-mediate	steep			rhyolite
			ido	dark gray	coarse, smooth	-	-	-	-	-	-	dolerite sill
			ipy	light gray	smooth to rugged	dendritic	rough	high	steep			quartz porphyry
			ipo	dark gray	smooth to rugged	grid to dendritic	dense	inter-mediate	inter-mediate			porphyrite

PART VI GEOCHEMICAL SURVEY

VI.1 General Remarks

Geochemical survey was performed with the purpose of detecting the geochemical anomalies due to mineralization and obtaining the basic data for mineral exploration in the second and the third phases of the project.

The second phase investigation comprises following surveys: 1) regional survey all over the entire district, 2) semi-detailed survey on the selected five areas, and 3) detailed survey on the parts where the mineralization was recognized. In the regional and the semi-detailed surveys, stream sediments were collected, whereas soil samples were taken in the detailed survey.

On the basis of the results of overall analysis of Phase II of the project, nine areas were selected for the third phase survey.

The third phase investigation comprises following surveys: 1) regional survey on the two areas, 2) semi-detailed survey on the four areas, and 3) detailed survey on the six mineralized areas. In the third phase, rock samples were primarily collected, and soil samples were taken to stand for rock samples where no bedrock exposures were found.

The regional and the semi-detailed geochemical surveys of Phase II in five areas showed that Ag, Cu, Pb, and Zn indicated those of mineralized and altered zones with greater sensitivity. Phase III geochemical survey, therefore, directed to detect geochemical anomalies by means of the four elements of Ag, Cu, Pb and Zn.

Table VI-1 gives the number of geochemical samples collected and sampling density.

VI.2 Soil Profile

In general, soil is hardly developed in the survey district reflecting the arid condition. Especially in the limestone areas, sand and gravel beds under the topsoil are so hardened by secondary deposition of calcareous material in the interstices as to make the soil sampling difficult.

Table VI-1 Number of Geochemical Samples

		Number of Samples				Area(km^2)	Density
		Stream Sediments	Soil	Rock	Total		
Phase II	Regional Survey	939			939	16,000	1/17 km^2
	Semi-detailed Survey	1,822	25		1,847	1,500	1/0.8 km^2
	(Puerto Rico)	(593)				(300)	
	(Cerro La Vasca)	(201)				(200)	
	(Cerro de Minerva)	(66)				(100)	
	(Sierra Santa Fé del Pino)	(556)				(375)	
	(Cerro Blanco)	(406)				(300)	
	(Laguna del Guaje)		(25)			(25)	
	Detailed Survey		423		423	1.73	244/1 km^2
	(Cerro La Vasca)		(192)			(0.43)	
	(Cerro de Minerva)		(80)			(0.20)	
	(Sierra Santa Fé del Pino)		(97)			(1.00)	
	(Cerro Blanco)		(54)			(0.10)	
Phase III	Regional Survey		6	233	239	412	1/1.7 km^2
	(Sierra del Palomino)		(2)	(133)		(212)	
	(Sierra de Puerto Blanco)		(4)	(100)		(200)	
	Semi-detailed Survey		363	660	1,023	340	3/1 km^2
	(South Sierra del Carmen)		(46)	(256)	(302)	(87)	
	(Cerro Chalio)		(68)	(83)	(151)	(36)	
	(El Volcan)		(104)	(105)	(209)	(59.5)	
	(Sierra de Cruces)		(145)	(216)	(361)	(157.5)	
	Detailed Survey		672	1,147	1,819	108	17/1 km^2
	(Puerto Rico)		(157)	(686)	(843)	(28)	
	(South Sierra del Carmen)		(10)	(158)	(168)	(7)	
	(Cerro de Minerva)		(274)	(-)	(274)	(30)	
	(El Volcan)		(52)	(-)	(52)	(0.5)	
	(Mina La Morena)		(83)	(200)	(283	(20)	
	(Sierra de Cruces)		(96)	(103)	(199)	(22.5)	
Total		2,761	1,489	2,040	6,290	18,361.73	

VI.3 Sample Preparation

Geochemical samples were sent to the Sabinas Lab. of CRM. After drying for a given time in a oven, the rock samples were crushed by a crusher and pulverizer, and then divided by the method of conical quartering. A given amount of the crushed samples was ground under 100-mesh in a mortar for use in analysis. Soil and stream sediment samples were screened under 80-mesh, and after division by the conical quartering method, they were ground under 100-mesh in mortar for use in analysis.

VI.4 Chemical Analysis

All samples were gathered in the Sabinas office of CRM, where the samples were checked and the chemical analyses of Cu, Pb, Zn and Ag were done by using the newly installed analytical equipment. Analysis of fluorine was performed in the central laboratory of CRM in Mexico City. The analytical procedure is as follows:

(1) Cu, Pb, Zn and Ag

Check the samples, dry in the sun, dry in the electric oven, sieve and collect the -80 mesh fraction, quarter to requisite quantity (about 100 grams or so), ground to -100 mesh, weigh 2 grams, transfer to a 100ml Pyrex beaker, add 5ml conc. $HNO_3$2ml conc. H_2SO_4 and some deionized water, and mix, heat until white fume of H_2SO_4 is generated, allow to cool, make up to 50ml with water and stir, filter the solution, and determine the concentration of Cu, Pb, Zn and Ag by usual atomic-absorption method.

(2) F

Weigh a 100mg sample into a 10ml platinum crucible, mix with 0.5 gram of anhydrous sodium carbonate and 0.1 gram of zinc oxide, heat at 900°C for 30 minutes, place the cooled crucible in a 50ml borosilicate glass beaker, add 30ml of water, cover the beaker, digest the contents overnight at steam bath temperature, remove and wash the crucible, break up any lumps present, allow the solution to cool to room temperature, filter into a 100ml volumetric flask. wash the residue several times with small portions of a 0.1% sodium carbonate solution, reject the residue, add slowly 2ml of 6-N hydrochloric acid to the solution shaking vigorously to expel the carbon dioxide, dilute to volume with water, mix well, and dilute a 10ml aliquot of this solution with 10ml of 0.2 M sodium citrate -0.2M potassium nitrate. Fluride ion contents in the sample solution were detected with the fluoride ion electrode method developed by B. L. Ingram (1970).

VI.5 Data Processing

A.1 Regional Reconnaissance

In the regional reconnaissance, the geochemical background values generally show delicate and complicated variation all over the survey region due to complexing of the factors of bedrock geology, subsurface geology, topography, hydraulics, climatology, etc. It is, therefore, quite difficult to analyse the background variation into the above mentioned factors, and the convenient method described below was applied in the present reconnaissance work.

(1) At first, arithmetic mean of the values of chemical analysis on all the sampling points located in a square which has the edges of 10km long in the EW and NS directions is calculated. The mean value is regarded as "background in the first approximateion" in the center point of the square. This is a kind of ROLLING MEAN ANALYSIS to smooth out the regional variation and to approach the regional trend of geochemical data.

(2) The difference between the observed value C(xy) and the background in the first approximation $\overline{C}_1(xy)$ at a sampling point (xy) is called the residual in the first approximation $\Delta C_1(xy)$ at the point, that is,

$$\Delta C_1(xy) = C(xy) - \overline{C}_1(xy)$$

(3) Residual in the first approximation is treated statistically by the convenient graphical technique developed by C. Lepeltier (1969), and the deviation from normal distribution is detected. The de-

viated samples are considered as "anomaly in the first approximation".

(4) After omitting the anomalies in the first approximation, the remaining population is treated in the same way as mentioned in (1) to (3), and the background and residual in the second approximation are calculated.

(5) Same procedure is repeated successively until the remaining population shows no longer any deviation from normal distribution.

(6) Using the finally remaining population which has residual of normal distribution, final background $C_f(xy)$ is calculated on all of the sampling points. The difference between the observed value $C(xy)$ and final background $\overline{C}_f(xy)$ is called the final residual $\Delta C(xy)$, that is,

$$\Delta C_f(xy) = C(xy) - \overline{C}_f(xy)$$

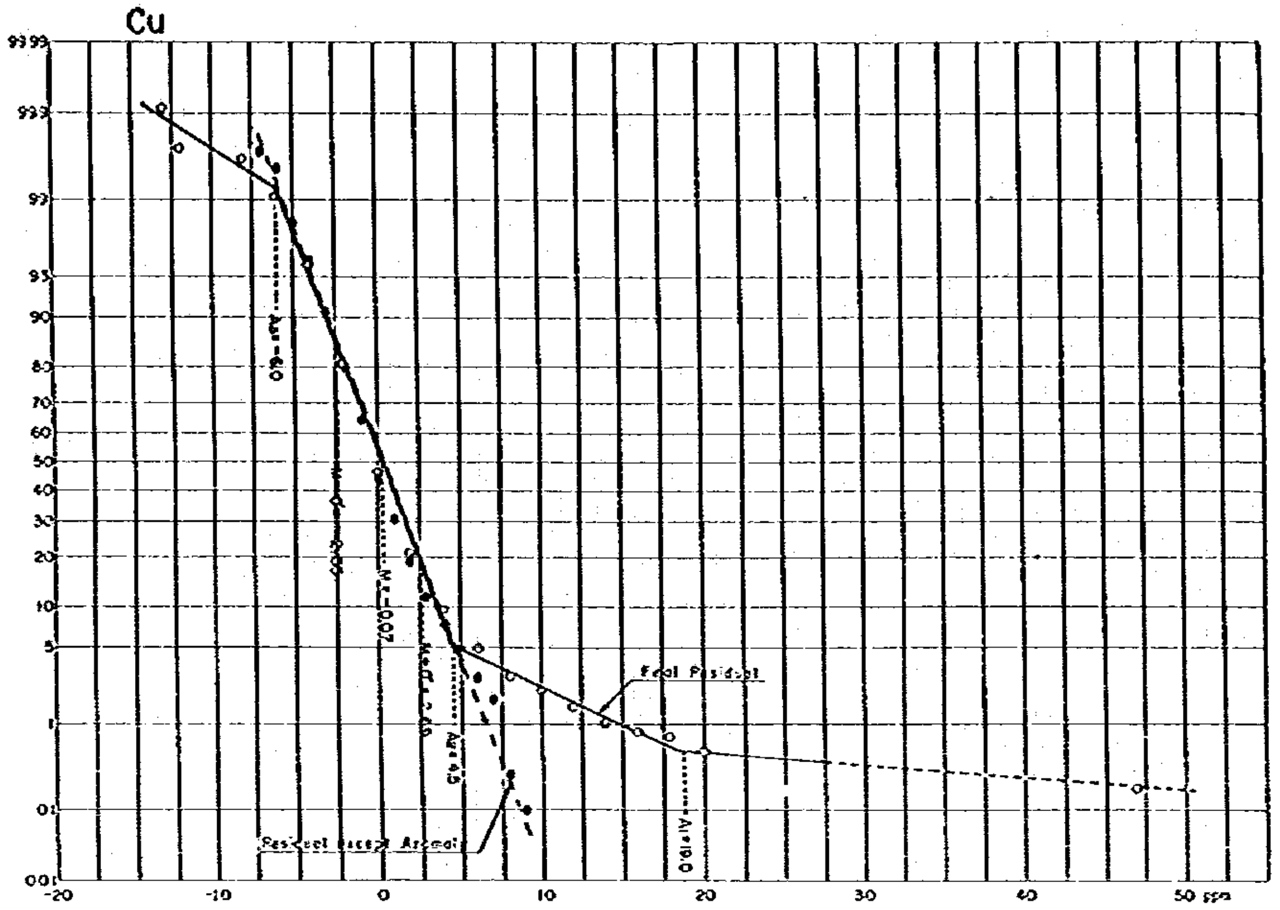
Residual of the population after omitting the anomalies shows naturally a kind of normal distribution around zero point, which is called as "residual after omitting the anomalies".

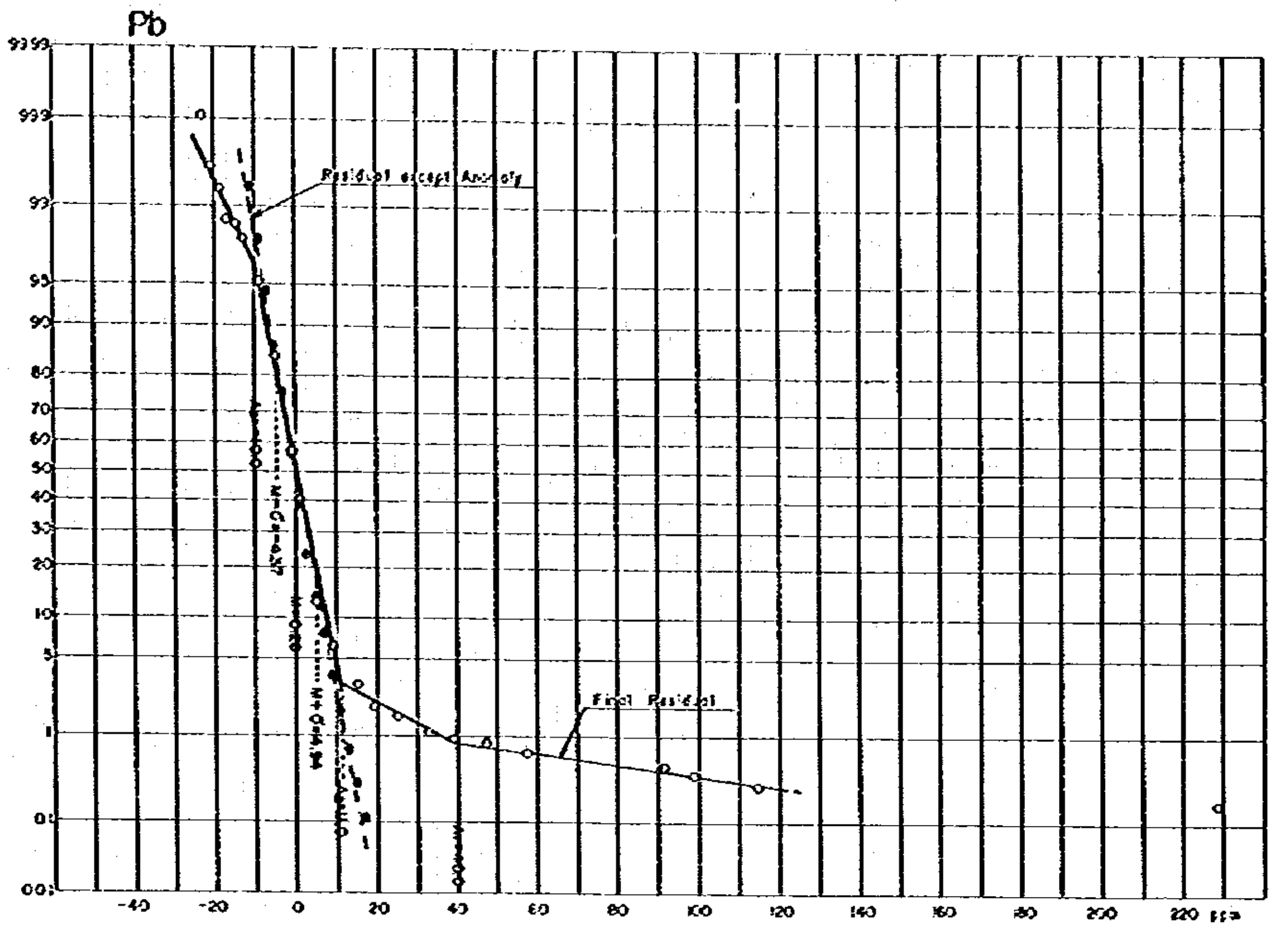
Anomalies of each element can be omitted from whole population by the above-mentioned successive approximation of one to three rounds.

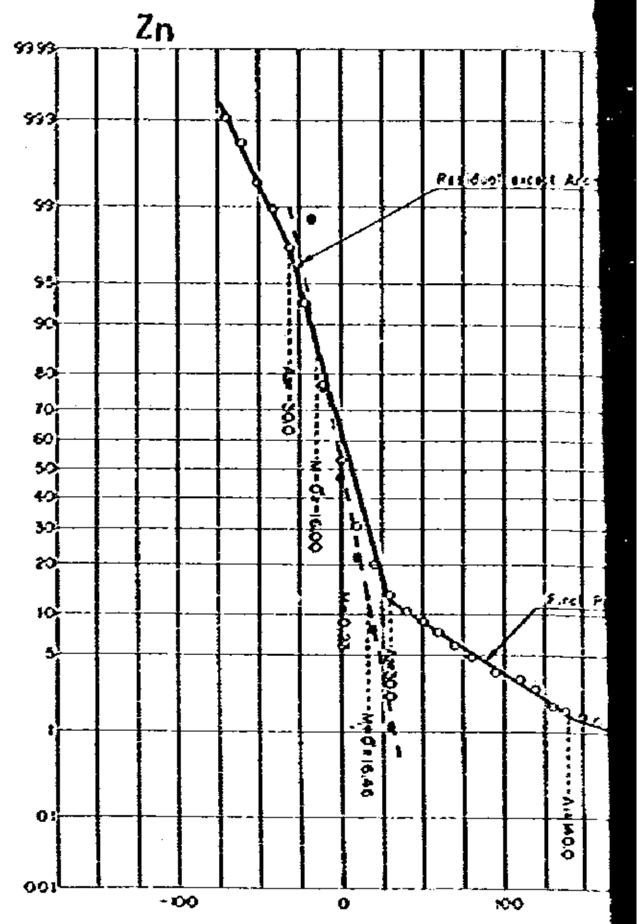
Cumulative frequency distribution of the final residual and that of the residual after omitting the anomalies of each element are shown in Fig. VI-1.

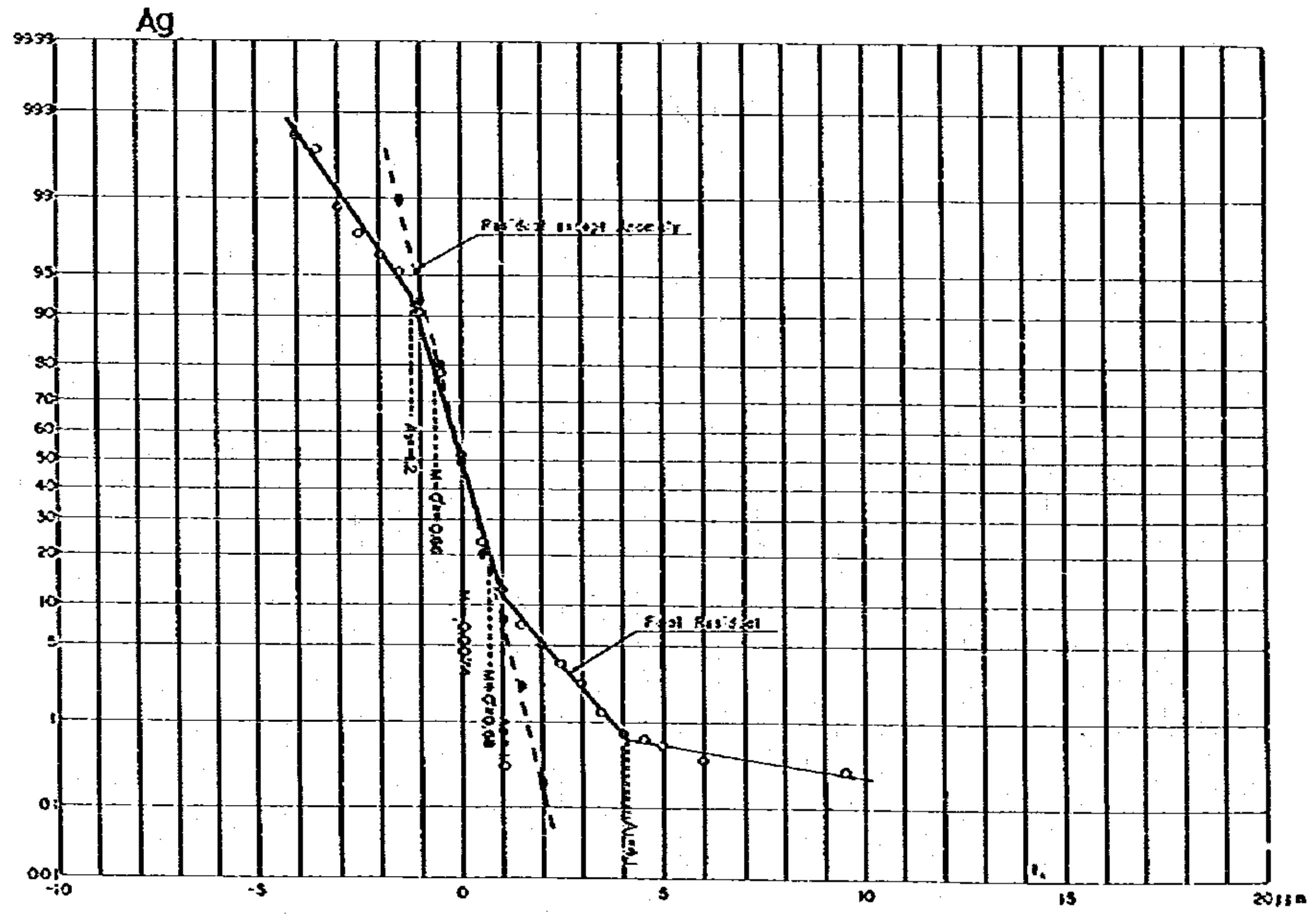
The residual after omitting the anomalies exhibits naturally a distribution very close to the normal type around zero point, and its cumulative frequency distribution is shown by a straight line approximately on probability paper. Mean value M and standard deviation σ of the residual after omitting the anomalies were calculated, and the positions equavalent to $M - \sigma$, M, and $M + \sigma$ were shown in Fig. VI-1.

Although the final residual has also a distribution around zero point, it contains some excess in both plus and minus sides compared with normal distribution. Generally speaking, cumulative frequency distribution has two skewed points in the plus side and one skewed point in the minus









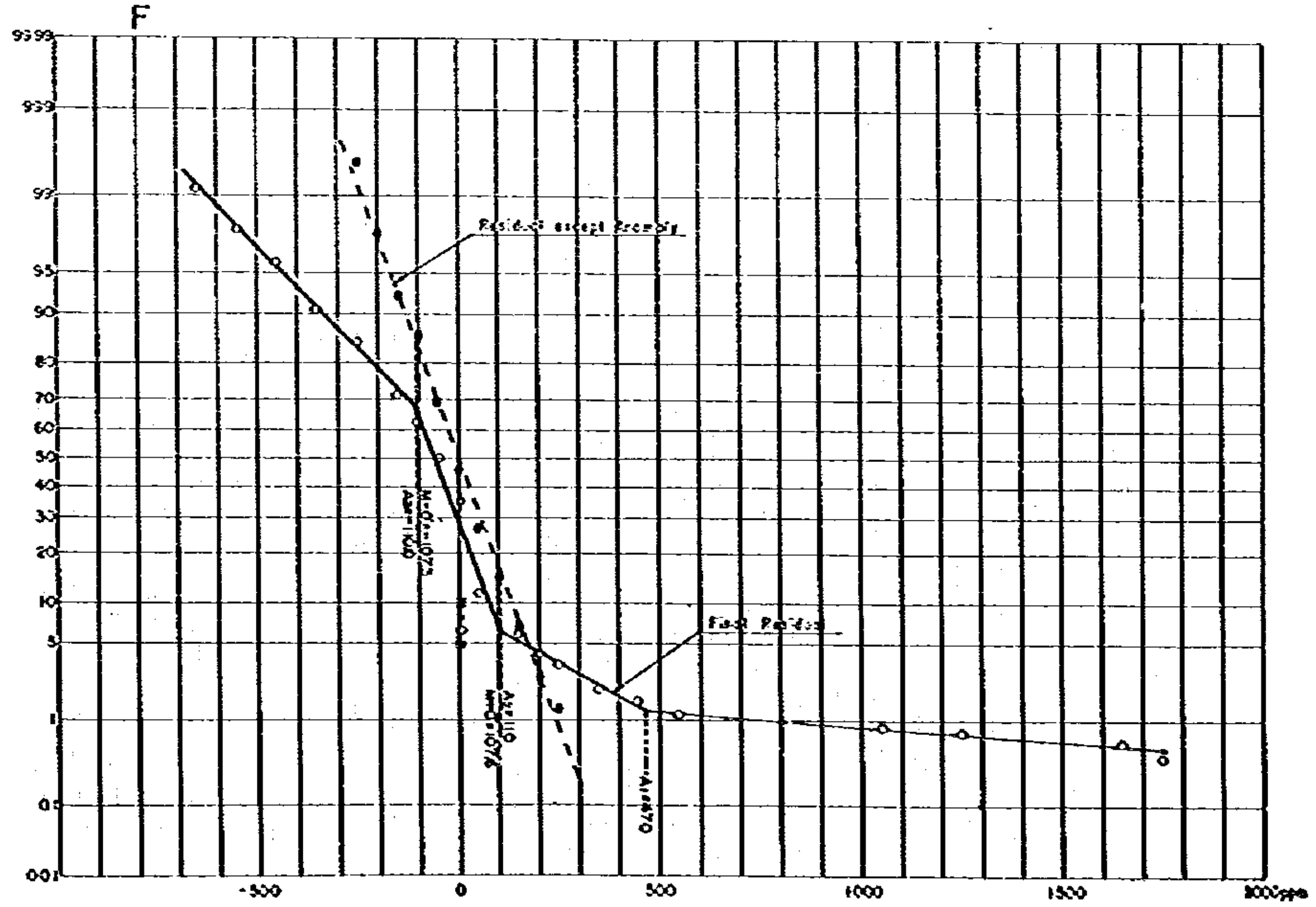
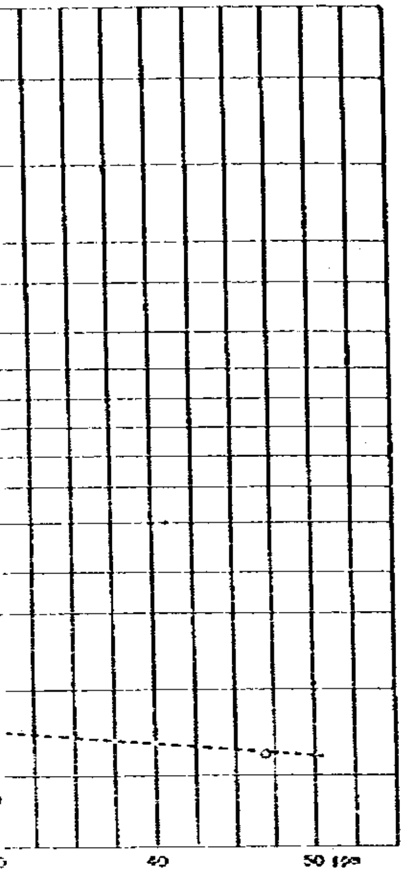
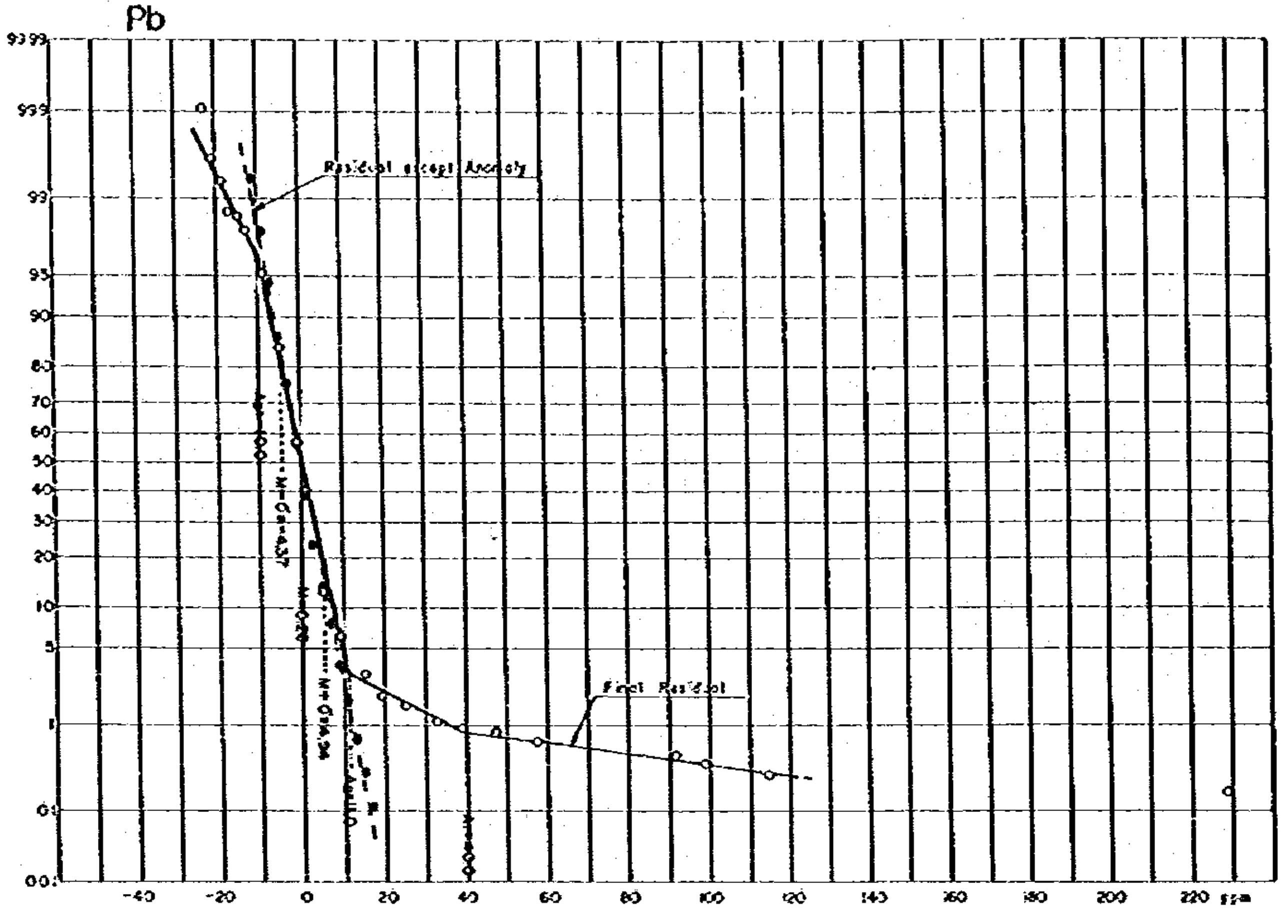


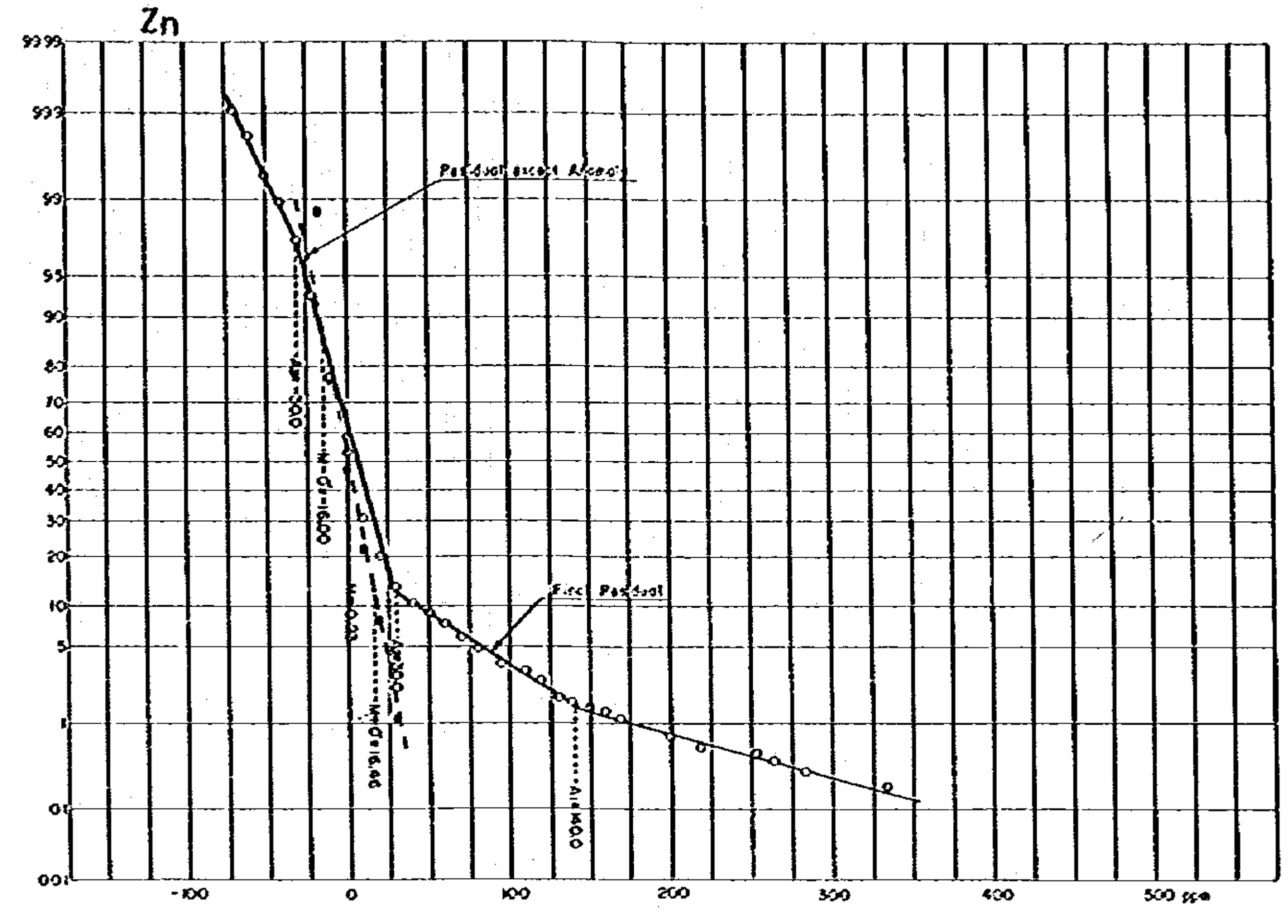
Fig. V

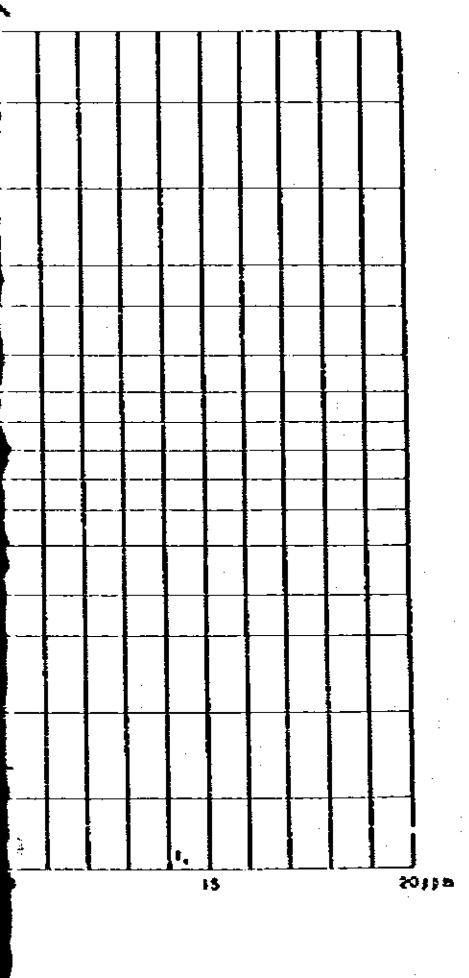
Regional Geoche

Cumulative Frequency Distribut









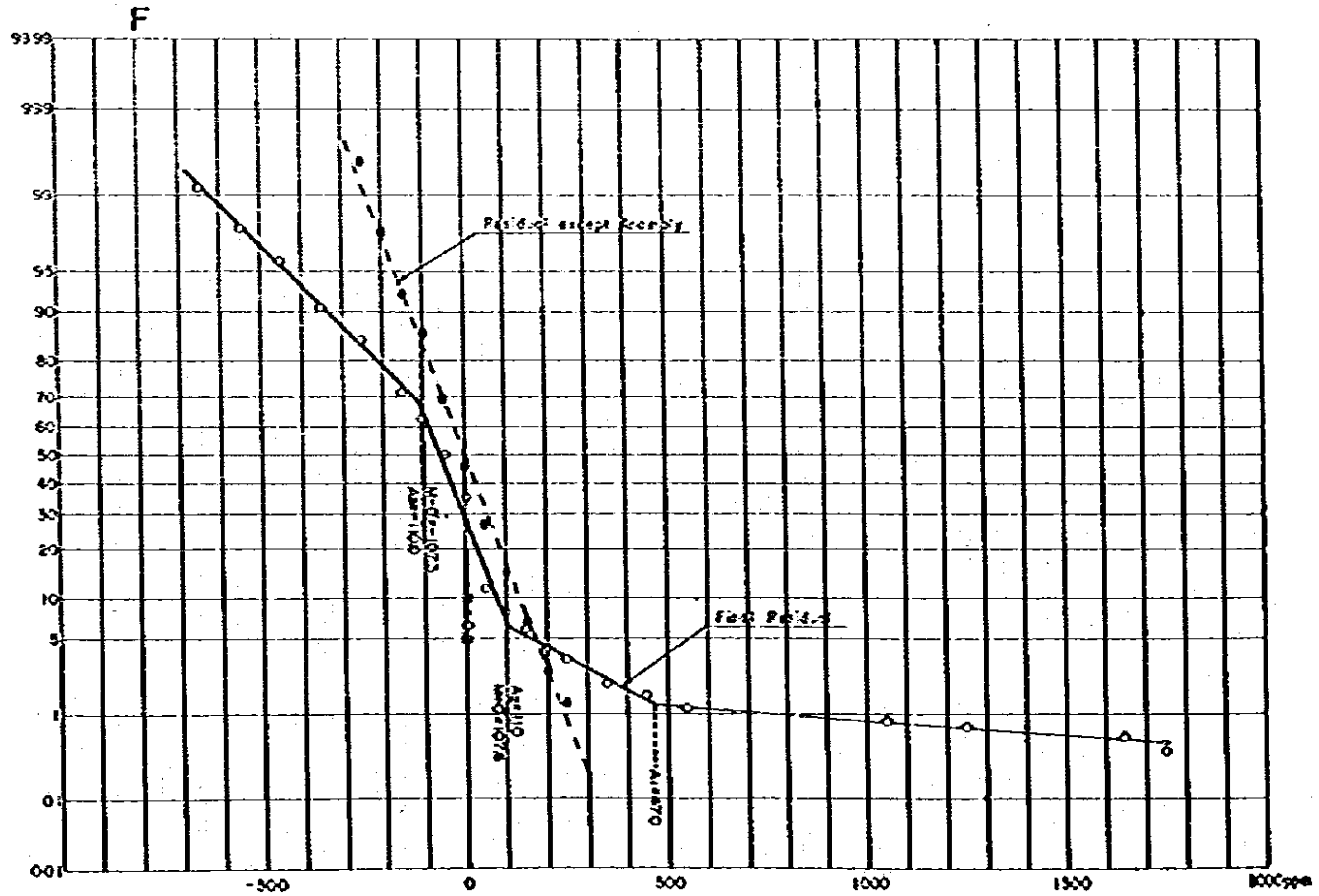


Fig. VI-1

Regional Geochemical Survey

Cumulative Frequency Distribution of Residuals (Phase II) side. In the plus side, a skewed point of higher residual value is called as A_1 and that of lower residual value A_2. Also the skewed point of minus side is called A_3. These points are shown in Fig. VI-1. In general, the residual value at A_2 is higher than $M + \sigma$, while that at A_3 is lower than $M - \sigma$. Also the absolute values of residuals at A_2 and A_3 are usually of same size.

The values of $M - \sigma$, M and $M + \sigma$ of the residual after omitting the anomalies, and the values at A_1, A_2 and A_3 of the final residual are listed in Table VI-2, which are the statistical fundamentals of frequency distribution of residuals.

Regional distribution of the final background of each element is shown in series of PL-VI-1 ∿ 5 as contour maps.

Final residuals are grouped into seven grades of (1) lower than A_3, (2) A_3 to $M - \sigma$, (3) $M - \sigma$ to M, (4) M to $M + \sigma$, (5) $M + \sigma$ to A_2, (6) A_2 to A_1, and (7) higher than A_1. These grades are shown in PL-VI-1 ∿ 5 by specific symbol marks on every sampling point.

Regional distribution of final background of each element as shown in PL-VI-1 ∿ 5 gives information on a trend of long wavelength. That is, the variation of trend over a range roughly same as the averaging area in the ROLLING MEAN ANALYSIS stated on (1) of A.1 or wider is shown in the final background distribution. On the other hand, the final residual varies usually point to point and shows a variation of short wavelength. Therefore, the effect of "extensive" secondary dispersion from a mineralization zone may be detected by the background distribution, while that of shortly decayed dispersion may be shown by the residual distribution. From the exploratory point of view, high background zones which have the final background higher than the surroundings, and high residual points which have the final residuals higher than A_2 are thought to be very important.

Table VI-2 Some Fundamental Values of Geochemical Statistics of the Regional Geochemical Survey (Phase II)

Unit: ppm

	Cu	Pb	Zn	Ag	F
A_3	-6.0	-10.0	-30.0	-1.20	-110
$M-\sigma$	-2.55	-4.37	-16.0	-0.66	-107.3
M	0.07	0.028	0.23	0.007	0.20
$M+\sigma$	2.69	4.94	16.46	0.68	107.6
A_2	4.5	11.0	30.0	1.0	110
A_1	19.0	40.0	140.0	4.1	470

Meanings of the symbols are given in the text.

A.2 Semi-Detailed Survey

For statistical analysis of the behavior of Cu, Pb, Zn, Ag and F in stream sediments in the five areas of the semi-detailed survey, the same procedures of successive approximation as in the regional survey were employed to data processing. In the semi-detailed survey, however, the averaging area of ROLLING MEAN ANALYSIS was a square of 2km x 2km.

The values of $M - \sigma$, M and $M + \sigma$ of the residual after omitting the anomalies, and A_1, A_2 and A_3 of the final residual together with the final background value at T in each area are given in Table VI-3-(A) to (E) which are the statistical fundamentals of frequency distribution of background and residual.

Table VI-3 Some Fundamental Values of Geochemical Statistics of the Semi-detailed Geochemical Survey (Phase II)

unit: ppm

A. Puerto Rico

	Cu	Pb	Zn	Ag	F
A_3	-4.8	-12.0	-25.0	-0.33	-90
$M-\sigma$	-1.57	-5.76	-12.49	-0.27	-50
M	0.019	0.14	0.16	0.009	0
$M+\sigma$	1.61	6.03	12.81	0.25	50
A_2	3.0	8.0	20.0	0.5	90
A_1	8.0	50.0	75.0	1.7	300
T	10	33	66	2.1	400

B. Cerro la Vasca

	Cu	Pb	Zn	Ag	F
A_3	-	3.0	-	(0.20)	-
$M-\sigma$	-1.29	-2.26	-12.43	-0.26	-152
M	0.013	-0.026	0.055	0.005	0
$M+\sigma$	1.32	2.20	12.54	0.27	152
A_2	2.0	4.0	20.0	0.35	-
A_1	-	-	100.0	-	-
T	12	-	80	1.8	-

C. Cerro de Minerva

	Cu	Pb	Zn	Ag	F
A_3	-2.0	-	(0.0)	(0.0)	-
M-σ	-1.15	-3.86	-8.36	0.12	-97
M	0.010	-0.086	-0.11	0.00	-5
M+σ	1.17	3.69	8.14	0.12	88
A_2	1.5	6.0	10.0	(0.12)	120
A_1	-	-	-	-	-
T	-	-	80	2.0	-

D. Sierra Santa Fe del Pino

	Cu	Pb	Zn	Ag	F
A_3	-6.0	-12.0		-0.50	-100
M-σ	-2.26	-5.45	-10.99	-0.25	-64
M	0.008	0.035	0.086	0.006	0.7
M+σ	2.27	5.52	11.16	0.26	65
A_2	3.5	11.0	20.0	0.50	120
A_1	-	40.0	85.0	-	-
T	16	25	80	1.6	650

E. Cerro Blanco

	Cu	Pb	Zn	Ag	F
A_3	-2.5	-11.0	-35.0	-0.55	-100
M-σ	-1.60	-4.38	-17.32	-0.22	-66
M	0.014	-0.007	0.60	0.003	0
M+σ	1.62	4.37	18.51	0.23	66
A_2	2.5	10.0	20.0	0.30	100
A_1	10.0	30.0	90.0	-	250
T	16	35	120	1.6	650

Meanings of the symbols are given in the text.

Table VI-4 Some Statistical Values of Geochemical Elements(Phase III)

Surveyed area (sample number)	Ele-ment	Min.	M	M+σ	(T) Skew point	M+2σ	(ppm) Max.	Correlation coefficients Cu	Pb	Zn	Ag
All samples	Cu	1	11.3	26.0		60.1	111,600	1.000	0.026	0.004	0.553
	Pb	6	37.2	80.4		173.4	49,000		1.000	0.958	0.253
	Zn	2	51.0	156.0		476.9	75,000			1.000	0.148
(3081)	Ag	0.1	2.02	4.40		9.58	341.0				1.000
All of rock samples	Cu	1	10.8	27.6		70.3	111,600	1.000	0.026	0.471	0.573
	Pb	6	39.0	88.6		201.2	49,000		1.000	0.225	0.252
	Zn	2	39.2	131.3		438.3	75,000			1.000	0.252
(2040)	Ag	0.1	2.17	4.80		10.62	341.0				1.000
All of soil samples	Cu	2	12.3	22.0		39.4	750	1.000	0.253	0.806	0.687
	Pb	10	34.0	65.0		124.3	2,857		1.000	0.452	0.333
	Zn	25	85.4	166.1		322.8	16,998			1.000	0.700
(1041)	Ag	0.1	1.77	3.72		7.81	56.0				1.000
1-(1) Puerto Rico, Detailed survey	Cu	1	8.8	18.0	19	36.6	750	1.000	0.095	0.710	0.634
	Pb	10	50.4	110.0	75	239.1	2,857		1.000	0.355	0.276
	Zn	5	46.0	148.0	80	477.6	8,400			1.000	0.788
(408)	Ag	1.0	2.89	4.89	7.4	8.27	56.0				1.000
1-(2) Puerto Rico, Further detailed survey	Cu	1	14.3	31.0	-	67.2	750	1.000	0.126	0.362	0.581
	Pb	10	80.2	206.0	150	528.9	49,000		1.000	0.844	0.488
	Zn	15	91.1	250.0	200	685.0	18,000			1.000	0.488
(595)	Ag	1.0	4.01	6.86	6.5	11.95	150.0				1.000
2-(1) South Sierra del Carmen, Semi-detailed survey	Cu	1	13.4	29.3	-	63.9	3,048	1.000	0.982	0.266	0.940
	Pb	7	24.5	39.5	44	63.7	1,316		1.000	0.237	0.956
	Zn	6	53.8	120.0	-	266.0	250			1.000	0.158
(302)	Ag	0.1	0.90	2.37	2.4	6.26	75.0				1.000
2-(2) South Sierra del Carmen, Detailed survey	Cu	5	8.7	14.2	22	22.9	92	1.000	-0.113	0.327	-0.135
	Pb	8	28.7	41.6	-	60.3	61		1.000	-0.162	0.590
	Zn	20	20.4	61.0	-	182.8	321			1.000	-0.344
(168)	Ag	0.2	1.76	3.80	-	8.22	14.0				1.000
3. Cerro Chalio, Semi-detailed survey	Cu	7	19.5	33.9	-	59.1	100	1.000	-0.087	0.292	-0.376
	Pb	14	27.6	40.7	43	60.1	568		1.000	0.002	0.170
	Zn	8	68.5	124.1	-	224.9	481			1.000	-0.014
(151)	Ag	0.2	1.35	2.30	-	3.93	4.0				1.000

Table VI-4 (continued)

Surveyed area (sample number)	Element	Min.	M	M+σ	(T) Skew point	M+2σ	(ppm) Max.	Correlation coefficients Cu	Pb	Zn	Ag
4.	Cu	2	9.2	15.7	15	26.8	33	1.000	0.239	0.051	0.263
Cerro de Minerva, Detailed survey	Pb	14	25.0	32.9	37	43.2	81		1.000	0.380	0.093
	Zn	29	61.4	83.7	80	115.6	269			1.000	-0.027
(274)	Ag	0.8	2.79	4.71	-	7.94	7.0				1.000
5-(1)	Cu	1	16.4	49.7	25	150.9	116,000	1.000	0.120	0.755	0.038
El Volcan, Semi-detailed survey	Pb	13	48.3	121.7	65	307.5	1,875		1.000	0.345	0.538
	Zn	5	113.3	401.4	220	1,421	26,630			1.000	0.202
(261)	Ag	0.2	1.64	2.97	28	5.40	47.0				1.000
5-(2)	Cu	8	15.7	23.0	-	33.6	44	1.000	0.855	0.868	0.139
El Volcan, Detailed survey	Pb	22	54.4	108.4	-	216.0	415		1.000	0.929	0.248
	Zn	53	159.4	357.4	-	801.3	1,630			1.000	0.141
(52)	Ag	1.0	1.64	2.31	-	3.27	4.0				1.000
6.	Cu	1	12.5	45.3	18	164.4	98,214	1.000	0.697	0.418	0.981
Mina la Morena, Detailed survey	Pb	13	39.8	76.3	52	146.2	1,500		1.000	0.194	0.560
	Zn	2	41.3	159.3	-	614.1	75,000			1.000	0.266
(283)	Ag	1.0	2.14	3.67	-	6.29	341.0				1.000
7-(1)	Cu	2	11.5	23.3	-	47.4	248	1.000	0.212	0.292	-0.067
Sierra de Cruces, semi-detailed survey	Pb	6	28.0	50.8	45	92.1	1,667		1.000	0.666	0.069
	Zn	2	46.5	129.7	175	363.5	10,652			1.000	0.057
(361)	Ag	1.2	1.58	2.89	3.9	5.29	33.0				1.000
7-(2),(3) Sierra de Cruces	Cu	2	9.6	16.2	15	27.2	76	1.000	0.128	0.190	-0.109
(Santa Elena, Picacho),	Pb	6	28.4	47.4	40	79.1	300		1.000	0.636	0.141
Detailed survey	Zn	6	54.6	143.5	155	376.8	4,211			1.000	0.071
(317)	Ag	0.1	1.38	3.30	5.0	7.90	33.0				1.000
8.	Cu	1	5.2	7.9	7.0	12.0	24	1.000	0.311	0.721	0.342
Sierra del Palomino, Regional survey	Pb	11	29.2	42.7	-	62.5	65		1.000	-0.042	0.891
	Zn	5	15.2	26.6	17	46.3	152			1.000	-0.035
(135)	Ag	0.7	2.34	3.68	-	5.79	5.0				1.000
9.	Cu	3	6.6	9.8	9.2	14.6	31	1.000	0.032	0.271	0.188
Sierra de Puerto Blanco,	Pb	13	27.1	40.0	38	58.8	250		1.000	-0.018	0.343
Regional survey	Zn	10	15.7	22.0	17	30.9	40			1.000	-0.166
(104)	Ag	0.6	2.55	3.88	-	5.89	10.0				1.000

B. Rigional, Semi-Detailed and Detailed Survey of Phase III

In the Phase III, convinient graphical method (Lepeltier, 1969) is used for data processing, because each survey area is in rather limited range.

Based on the results of the population analysis, geochemical analysis was made under the assumption in which both the rock and soil samples were treated to belong to the same sample group in each survey area. A cumulative frequency distribution curve was prepared for each of the four indicator elements to definite anomalous values in respect of each survey area, and calculations were made to obtain logarithmic mean value (M), standard deviation (σ), minimum value (Min.0) and maximum (Max.) values (Table VI-4).

Where the high-content population was clearly distinguishable on the cumulative frequency distribution curve for each element, that is, the positive skewness was distinct, all values above the breaking point (T) were considered anomalous values, and all values below the point background. Where the breaking was indistinct and where the breaking point was above $M + \sigma$ value, this value ($M + \sigma$) was taken as a thereshold of anomaly. The anomalous value was classified by the $M + 2\sigma$ value into Class A and Class B, and the background was divided by the M value into high background (C) and low background (D). This classification is illustrated below.

Anomalous value of Class A	....	$M + 2\sigma$ value
Anomalous value of Class B	....	T value or $M + \sigma$ value
High background of Class C	....	M value
Low background of Class D		

VI.6 Geochemical Anomaly Zones

Based on the fundamental statistical values described on preceding chapter, geochemical anomaly zones were extracted as shown in follows:

VI.6.1 Regional Reconnaissance of Phase II

Summarizing the geochemical features of each element, twenty three zones of geochemical anomalies can be picked up from the whole district as listed in Table VI-5. In this table, existence of the geochemical anomalies of background and residual is separately shown on each element.

By the mutual relationship to geology and mineralization, these geochemical anomalies are classified into four groups as follows:

A. Nine anomalies in the areas where thermal metamorphism, mineralization, alteration and old mines are observed.

B. Seven anomalies in the areas situated on the northern half of the district where numerous fluorite mines are located.

C. Five anomalies in igneous rock areas where Cu, Pb, Zn, Ag mineralization and alteration are not observable.

D. Two anomalies in others.

Table VI-5 List of Geochemical Anomalies of Regional Geochemical Reconnaissance
(Bg.: High Background Zone, Res.: Anomalous Residual Swarm) (Phase II)

Anomalous Zone	Cu		Pb		Zn		Ag		F		Geology	Mineralization
	Bg.	Res.	Bg.	Res.	Bg.	Res.	Bg.	Res.	Bg.	Res.		
1) Downstream of Arroyo del Veinte		o				o	o	o		o	Boquillas f. Rhyolite	
2) Agua Chile ∿ Cuatro Palmas	o	o			o	o	o	o	o		Santa Elena f.	Massive-type fluorite
3) East of Boquillas del Carmen			o	o	o	o					Santa Elena∿Cupido f.	Mina Puerto Rico, etc. (Pb Zn)
4) Jardin			o								Santa Elena f.	Manto-type fluorite
5) South Sierra del Carmen		o	o		o	o		o			Santa Elena∿ Boquellas f.	Mina Fronteriza (Pb Zn)
6) Cerro del Veinte		o				o		o		o	Santa Elena f.	Manto-type fluorite
7) Cerro Chalio	o	o			o	o	o	o	o		Santa Elena f.	Massive-type fluorite
8) Sierra de San Vicente							o	o			Santa Elena f.	Manto-type fluorite
9) Sierra de Juntas				o	o	o	o	o			Santa Elena f.	Manto-type fluorite
10) Sierra del Alazan					o	o				o	Santa Elena f.	Manto-type fluorite
11) Rancho Santa Margarita							o	o			Santa Elena f. Diorite	
12) Cerro de Minerva			o		o				o	o	Santa Elena f.	Mina de Minerva (Pb Zn, Fe)
13) Sierra Santa Fe del Pino	o		o	o	o			o			Cupido f.	Mina de Oso (Pb, Zn)
14) East of Sierra de Hechiceros		o		o	o	o	o	o	o		Tertiary volcanics	
15) South of Sierra de Hechiceros						o		o			Tertiary volcanics	
16) El Volcan		o		o		o		o			Boquillas f(?)	Mina Volcan (Pb, Zn, Fe)
17) Sierra la Morena		o	o	o	o	o					Aurora f.	Mina la Morena (Pb, Zn)
18) Cerro Blanco	o	o	o	o		o	o	o			Q-porplyry Santa Elena-Boquillas f.	
19) South of Cerro la Maquina				o				o			Aurora-Santa Elena f. Q-monzonite	
20) East of Sierra de Cruces						o			o		Cupido-Santa Elena f.	Mina Santa Elena (Pb, Zn, Fe)
21) South of Sierra de Cruces		o	o	o	o	o	o	o			"Magnetic Body" Aurora f.	Picacho∿Ano Nuevo (Pb, Zn, Fe)
22) Sierra de San Jose		o		o		o		o		o	Tertiary volcanics	Abandoned mine
23) Rancho el Refugio	o	o	o		o		o				Tertiary volcanics	

A. Anomalies in the Areas where Thermal Metamorphism, Mineralization, Alteration and Old Mines are Observed.

Causes of the geochemical anomalies of this type are considered as follows:

i) East of Boquillas del Carmen

The area is situated downstream of the drainage system which flow down through the mineralized zones of Mina Puerto Rico and Mina San José, so that it is probable that these anomalies reflect these mineralized zones.

ii) South Sierra del Carmen

Known mineralized zones represented by Mina Fronteriza and Mina Teresita are distributed, which are considered to cause the anomalies.

iii) Cerro Chalio

Cerro Chalio is situated in fluorite zone and also has a dome strucutre by intrusive rock in the central part. Around the intrusive rock, contact metamorphic and hydrothermally altered zones are recognized. Geochemical anomalies may indicate these zones around the intrusive rock.

iv) Cerro de Minerva

There are dome structure by intrusive rock, contact metamorphic and hydrothermally altered zones, and old working of abandoned mines. Geochemical anomalies may indicate them.

v) Sierra Santa Fe del Pino

Geochemical anomalies situated in the middle east of the Sierra Santa Fe del Pino, coincide with hydrothermal alteration zones around Mina de Oso.

vi) El Volcan

Contact metamorphic zone by acidic intrusive and mineralization zone represented by Mina el Volcan and Mina Collan are observed to coincide with geochemical anomalies.

vii) Sierra la Morena

Geochemical anomalies of this area coincide with and indicate two mineralized zones, that is, Mina la Morena and Mina el Refugio zone located in the northeastern Sierra la Morena, and Mina la Diana zone with a large-scale recrystallized zone of limestone in the central Sierra la Morena.

viii) Eastern to southern peripheries of the Sierra de Cruces

Almost all of mineralized and contact metamorphic zones are detected as geochemical anomalies, in which Mina Santa Elena zone and Mina Livertad - Año Nuevo - Noria del Picacho zone are prominent.

B. Anomalies on the Fluorite Zone

Fluorite ore deposits occur in the limestone beds of Cretaceous system, and show various modes of occurrence such as manto, irregular massive and vein. By the surface geological survey, weak hydrothermal alteration with a small amount of impregnated pyrite is observed around the fluorite ore deposits, but disinct effects of Cu, Pb, Zn and Ag mineralization are not confirmed.

Relation between fluorite mineralization and metallization can not be interpreted clearly yet.

It is assumed, however, that causative hydrothermal solution for fluorite mineralization is responsible for some geochemical anomalies of Ag, Cu, Pb and Zn around the fluorite deposits. These anomalies are, therefore, excluded from the indications of Ag - Cu - Pb - Zn metallization.

C. Anomalies on Igneous Rock Areas of no Mineralization and Alteration

Tertiary igneous rocks generally have rather higher metal contents than calcareous rocks of the Cretaceous system.

Consequently, geochemical anomalies on the Tertiary igneous rocks are inferred to reflect such lithological characteristics of bedrock, and are excluded from the indications of metallization.

D. Other Anomalies

Cause of these anomalies is not clear. One anomaly is located in the vicinity of a private ranch and the other is in downstream of a river.

Considering the possibility of artificial contamination, these are neglected.

VI.6.2 Semi-Detailed and Detailed Surveys of Phase II

Semi-detailed geochemical survey was carried out in the five selected areas in parallel with the semi-detailed geological survey.

The five areas were selected by the results of photogeological interpretation and previous works. Detailed survey was also done supplementary on some parts of mineralized zones.

The results of these surveys are summarized as follows:

i) Puerto Rico Area

From the western piedmont of the Sierra del Carmen to the east of Boquillas del Carmen, background and residual anomalies of four elements except F are detected.

Background anomaly occupies broadly an area from Mina Puerto Rico and Mina San José to their downstream zone in E-W direction, while residual anomaly is observed along the Las Norias Tectonic Belt in NNW-SSE direction.

As the result of this survey, geochemical anomalies detected by the regional survey were clarified in details.

ii) Cerro la Vasca area

No geochemical anomaly is obtained by the regeional survey. Also in this semi-detailed survey, background anomalies of Cu, Zn and Ag are scattered in small scale, and residual anomalies are not notable.

In and around the contact zones between limestone and adamellite, however, tactite outcrops have been found in more than ten localities.

Therefore, detailed survey by soil samples was attempted. As the results, Cu, Pb, Zn elements show anomalous value only in small scale on the tactite zone.

iii) Cerro be Minerva Area

The area is located in the northwest of Cerro de Minerva dome, and composed of limestone, alternation of shale-sandstone and small dykes of adamallite and microdiorite. Occurrence of tactite and dissemination of pyrite are recognized throughout the area.

Background anomalies of Pb, Zn and F and residual anomalies of F are detected by the regional survey. On the semi-detailed survey by stream sediments, background anomalies of Ag and Zn, and sporadical residual anomalies are observed only in small scale.

After detailed survey on the mineralized zones of the northeastern and northwestern parts of Cerro de Minerva, geochemical anomalies of Cu, Pb, Zn and Ag are found along the intrusion contact. Particularly, Zn contents of some samples are far over, percent Zn.

Anomalies other than these are only sporadic. Geochemical anomalies of F are weak and sporadic, and have different mode of distribution from other elements.

iv) Sierra Santa Fe del Pino Area

Geochemical anomalies of Cu and Ag are weak and sporadic, while those of Pb and Zn are significant in the neighborhood of Mina de Oso and in the downstream. Fluorine does not show any geochemical anomaly. Generally speaking, the content of each element tends to be higher in the western part and lower in the eastern part.

v) Cerro Blanco

This is subdivided into two areas, that is, the Cerro Blanco dome area and the Sierra la Morena area.

a. Cerro Blanco

Cerro Blanco dome area includes the anamalous background zones of Cu and F. Background values of Pb, Zn and Ag, however, are not anomalous in the area. Results of the detailed soil survey also suggest the same features, that is, Cu anomalies are found in the west and east of the dome, and F anomalies are detected in the north of the dome, while the anomalies of Pb, Zn and Ag are weak and sporadic. It is doubtful whether the anomalies of Cu and F are caused from mineralization, that is, they may reflect possibly the effect of lithology of the bed rock.

b. Sierra la Morena area

Background anomalies of Cu, Pb, Zn and Ag are broadly distributed from Mina la Morena to the southwest, and residual anomalies also swarm over the same zone.

The mineralized zone, which is distributed from Mina la Morena and Mina el Refugis to Mina la Diana in the recrystallized zone at the center of Sierra la Morena, is included in the zone of geochemical anomalies.

VI.6.3 Geochemical Survey of Phase III

Geochemical survey of Phase III was carried out in nine areas selected on the basis of the results of overall analysis in Phase II.

Geochemical analysis of the 14 cases in the nine survey areas resulted in the detection of nearly all of the known ore showings as the zones of geochemical anomalies. Given below is the summary of the anomalous zones indicative of known ore showings as well as other interesting geochemical anomalies and phenomena.

(1) Puerto Rico Area

The detailed survey covering the entire area showed that the anom - lous zone extending from Mina Puerto Rico having a concentration of ore showings to Mina Venos is characterized by a greater abundance of Cu than the other anomalous zones. A further detailed survey of this characteristic zone revealed that Cu anomalies are closely related to the basement rocks, the Puerto Rico formation and intrusive monzosyenite bodies. Major ore deposits are formed in the zones of Pb-Zn anomalies located around the zones of Cu anomalies indicative of the monzosyenite. Therefore, adjacent parts of the Cu anomalies outside of the distribution zones of the basement rocks and the Puerto Rico formation in the vicinity of Mina Puerto Rico and Mina San Jose may be considered as zones requiring further prospecting.

(2) South Sierra del Carmen Area

In this area, anomalies found in quartz syenite porphyry and rhyolite I tend to be rich in Cu in comparison with those in calcareous sedimentary rocks. If anomalous Zones II-C, II-E and III detected in the rhyolite I during the semi-detailed survey are attributable to the quartz syenite porphyry, mineralization may be expected to have taken place in the underlying calcareous sedimentary rocks. In the detailed survey area, the minor Zone II composed of Cu anomalies indicative of known ore deposits, and the wider Zone VI composed of Pb-Ag anomalies are formed in calcareous sedimentary rocks. Both zones should be further investigated in future.

(3) Cerro Chalio Area

Igneous rocks are rich in Cu anomalies, and Pb, Zn and Ag anomalies are concentrated in fluorite zones formed in the sedimentary rocks. This area contains no zones requiring further exploration.

(4) Cerro de Minerva Area

This area extends over the Cretaceous system and intrusive complex. Anomalous zones containing ore showings consists of Pb-Zn anomalies rich in both Pb and Zn, while those zones where no ore showings have been found are all formed in intrusive complex and composed of Pb-Zn anomalies rich in Zn. No anomalous zone has been found which deserves further exploration.

(5) El Volcan Area

Anomalies are concentrated around Mina Collan, Mina el Volcan and Mina la India. Any other important anomalous zones have been found.

(6) Mina la Morena Area

Major anomalous zones are distributed in the vicinity of Mina la

Morena and Mina la Diana. The two zones are arranged in the N-S direction which coincides with the elongation of recrystallized zone around Mina la Diana. For this reason, both anomalous zones are assumed to be the product of a series of mineralization developing in the N-S direction. The zone ranging from Mina la Diana to Mina la Morena should preferably be further explored.

(7) Sierra de Cruces Area

The Sierra de Cruces igneous complex is characterized by Cu anomalies. Almost all of the silver-bearing lead and zinc deposits occurring in the lower Cretaceous system are indicated by Pb-Zn anomalies. Anomalous Zone IV in the semi-detailed area is of small scale, but similar mineralization may possibly have taken place there.

The most notable anomalous zone in this area is Zone II lying along the Santa Elena anticline located in the detailed survey area at Santa Elena. The northern plunge, its nearby western wing, southern plunge and its nearby eastern wing of the anticline constitute the zones of high anomalies, and these zones have undergone strong mineralization. The northern plunge and its adjacent western wing are characterized by abundance of Pb and Zn, while the southern plunge and its adjacent eastern wing are featured by abundance of Cu. The subsurface portion of Zone II has been almost thoroughly prospected. The only parts remaining to be prospected are the lower extensions of the northern and southern plunges of the Santa Elena anticline.

(8) Sierra del Palomino Area

This area contains no anomalous zone requiring further exploration.

(9) Sierra de Puerto Blanco Area

This area also does not have any anomalous zone which needs further exploration.

PART VII GEOPHYSICAL SURVEY

VII-1. General Remarks

In the first phase of the project, airborne magnetic survey was carried out in order to examine the potential occurrence of mineral resources in northern Coahuila over the area of 17,000 square kilometers with total flight of 19,000 line-kilometers.

As the result of this survey, a number of magnetic anomalies were detected. Most of the magnetic rock bodies which caused these anomalies are andesite, basalt, and diorite of Tertiary in age. As the result of analysis, three dimensional distribution of these magnetic bodies was explicated, and geological structure in shallow and deep depths was inferred. Beside the intrusive rock exposures which had been delineated by the photo-interpretation, a number of deep-seated intrusive rocks were detected by the analysis.

Most of the metallic ore deposits are located in the surrounding areas of these intrusive rocks, and it was made distinct that the intrusive rocks closely associated with the formation of ore deposits are distributed mainly in the northeast and southwest of the surveyed district. Therefore, the result of this survey was very useful for the selection of the detail survey areas and promising areas for exploration.

In the third phase, electric survey of IP method (20 line-km) and electromagnetic survey of TURAM method (40 line-km) were conducted in the Puerto Rico area in order to obtain the information on subsurface geological structures, mineralized zones, and ore deposits.

As a result of IP survey, geological structure of the basement in the area which is mainly composed of crystalline schist was able to be inferred, and a number of electromagnetic anomalies were delineated, which were considered to have a close relationship with the occurrence of many lead and zinc deposits distributed in the area.

As the result of ground magnetic survey with total survey length of 45.5 kilometers in the area of Sierra de Cruces and Mina Picacho, the distribution of magnetic rock bodies was made certain at the eastern periphery of the intrusive rocks which constitute the Sierra de Cruces massif. Some of these magnetic bodies are considered to be iron ore deposits.

In the fourth phase, electric survey of IP method with total length of 34.9 line-kilometers was carried out to limit the extent of mineralized zones and to obtain the information for the selection of drill sites.

The area surveyed in this phase was the most promising area among eight areas geologically surveyed in the third phase in which remarkable geochemical anomalies were detected.

The result of survey showed a lot of weak IP anomalies about twice as high as the background value. Most of these anomalies are distributed in low apparent resistivity zone lower than 3,000 Ω-m surrounding the recrystallized zone of limestone. These were possibly caused by pelitic beds containing sulfide minerals or carbonaceous matters. From the magnitude of anomalies, however, it is inferred that the metallic content is small in amount.

Some anomalies which are located in zones of higher apparent resistivity (more than 10,000 Ω-m) are considered to be associated with the mineralized zones or ore deposits by putting all data together such as the results of measurement of rock samples and geological survey.

VII-2. SURVEY METHOD

(1) Survey in the first phase

Airborne magnetic survey was conducted in the first phase, outline of which is described below.

The surveyed area is situated in the northwestern part of Coahuila State in northern Mexico which is bordered on the Texas State, the United States of America, by the Rio Grande River, and is located in the northern-most part of the Sierra Madre Oriental.

Several mountain ranges extend in the direction of NNW-SSE in which some mountains rise high up to 2,500 ~ 3,000 m above sea level, but wide valleys between ranges are of semi-arid peneplain with the altitude of about 1,000 m above sea level.

Area surveyed ; 17,000 km^2

Survey lines ;

	Direction	Line Spacing	Number of Lines	Total Length
Main traverse line	N30°E - S30°E	1 km	83	17,350 km
Tie line	N60°W - S60°E	10 km	25	1,750 km
			Total	19,100 km

Flight altitude ; 500 m clearance above the ground surface

Total magnetic intensity ; 48,000 γ

Inclination ; 57°N

Declination ; 10°E

Bases of flight ; Airport of Delicias City for southern half of the surveyed district. Airport of Sabinas City for northern half of the surveyed district

Stations for diurnal correction	;	Adjacent to airports described above
Survey period	;	Feb. 29 ~ Nov. 23, 1976
Instruments	;	
Aircraft		Small twin-engined Norman Islander
Airborne magnetometer		Varian V-85
Analog recorder for magnetic force		Hewlett Packard 7100 B
Digital recorder for magnetic force		Geometrics G 704
Intervalometer		Geometrics G 803-201
Positioning camera		Geocam G-2
Radar altimeter		Collius ALT-50
Analog recorder for altitude		Hewlett Packard 680
Crystal clock		Geometrics

(2) Survey in the third phase

In the third phase, electric survey of IP method and electromagnetic survey of TURAM method were conducted in the Puerto Rico area, and ground magnetic survey was carried out in the Sierra de Cruces and Mina Picacho area.

As for the IP survey, time domain method was used to obtain data to 300 meters straight below the measuring points with three kinds of electrode distance of 100 m, 200 m, and 300 m by application of pole-dipole electrode array.

Twenty survey lines of one kilometer long each were set with line spacing of 200 m, which made total length of 20 km, and total area of 3.8 km^2.

Instruments used are shown below.

IP transmitter - one set of SCINTREX (CANADA) IPC-7/15 KW,
Maximum output 20A, 5,000 V, DC

Generator - One set of SCINTREX (CANADA)MG 15 KW-AC,
Maximum output 15 KW, 400 Hz, 300 V

IP receiver - Two sets of SCINTREX (CANADA) IPR-8
Maximum sensitivity range 0.3 mV,
Chargeability range 0 ~ 100 milliseconds.

TURAM method was carried out in the same area of IP method putting additional lines in each line space of IP survey (line spacing : 100 m, survey line : 40). Total length of survey lines was 40 km, and the area surveyed was 3.9 km^2.

TURAM method applied in this survey was as follows:

Both ends of a power cable which intersects at the center of each survey line crossing at right angles with it were earthed, and three kinds of alternating current such as 200 Hz, 400 Hz (reference), and 800 Hz were supplied to measure the amplitude ratio and the phase difference of magnetic field by two receiver coils.

The instruments used in this survey were as follows:

SCINTREX (CANADA) MODEL SE-71 TURAM SYSTEM

Generator	12V DC 3A	1 set
DC-AC inverter	200 Hz, 400 Hz, 800 Hz, output 180 W	1 set
Receiver coil	....	1 set
Receiver	....	1 set
Range of phase difference	....	− 20° ~ +20°
Range of amplitude ratio	....	0 ~ 2.0

Magnetic survey was carried out in the selected area which was confined in the north to about two thirds (37 km^2) of the initial plan. The method of survey was as follows:

Number of survey lines	40
Line length	1 ~ 3 km
Total line length	45.5 km

Line spacing	400 ~ 1,000 m
Magnetometer	Two sets of SCINTREX (CANADA) MODEL MP-2 Protontype, sensitivity ± 1 γ
Measured component	Total magnetic intensity
Fixed measuring point	Adjacent to Mina Hércules

(3) Survey in the fourth phase

IP survey of time domain method was carried out in the Mina la Morena area (3.3 km^2). Dipole-dipole array was applied for electrode configuration.

Although at first line setting was planned to have line spacing of 100 m and each line length of 1.5 km, at last, the number of survey lines were 23 and total length surveyed were 34.9 km by addition of several additional survey lines of 0.7 ~ 2.0 km long in order to delineate the anomalies distinctly.

Electrode separation was 100 m, and four kinds of coefficient of electrode separation n = 1 ~ 4 were adopted to obtain information at the depth to 250 m below the surface. Instruments used are same as those in the third phase

VII-3. Summary of Survey Results

(1) Survey result of the first phase

Magnetic anomalies detected in the surveyed district are caused by Tertiary igneous rocks such as andesite, basalt, and diorite. As the result of analysis, three dimensional distribution of these magnetic rock bodies was explicated in detail and geological structure in shallow and deep depths was inferred. Consequently, a number of deep-seated intrusive rocks were detected by the analysis, beside exposures of intrusive rocks which had been delineated by the photo-interpretation.

Two kinds of intrusive rocks are found on the surface. The one is associated with strong magnetism, and the other does not show almost any anomaly. The former is diorite and the latter is granite. All the deep-seated intrusive rocks detected in this survey is considered to be dioritic taking the result of measurement of magnetic susceptibility into account.

Most of the metallic ore deposits distributed in the surveyed district are found in the surrounding areas of intrusive rocks, and as the result of the aeromagnetic survey of this time, distribution of the intrusive rocks closely associated with the formation of ore deposits was limited, and in combination with the photo-interpretation, six areas were selected for the semi-detailed survey program in the second phase.

(2) Survey result of the third phase

a. Puerto Rico area

IP anomalies detected in the surveyed area show a good agreement with the distribution of crystalline schist. However, the results of geological and geochemical surveys did not reveal any particular occurrence of sulfide minerals in the schist which would cause strong IP effect. Also the result of EE measurement of rock samples showed that all the rocks except graphite schist distributed in the area did not have remarkable IP effect.

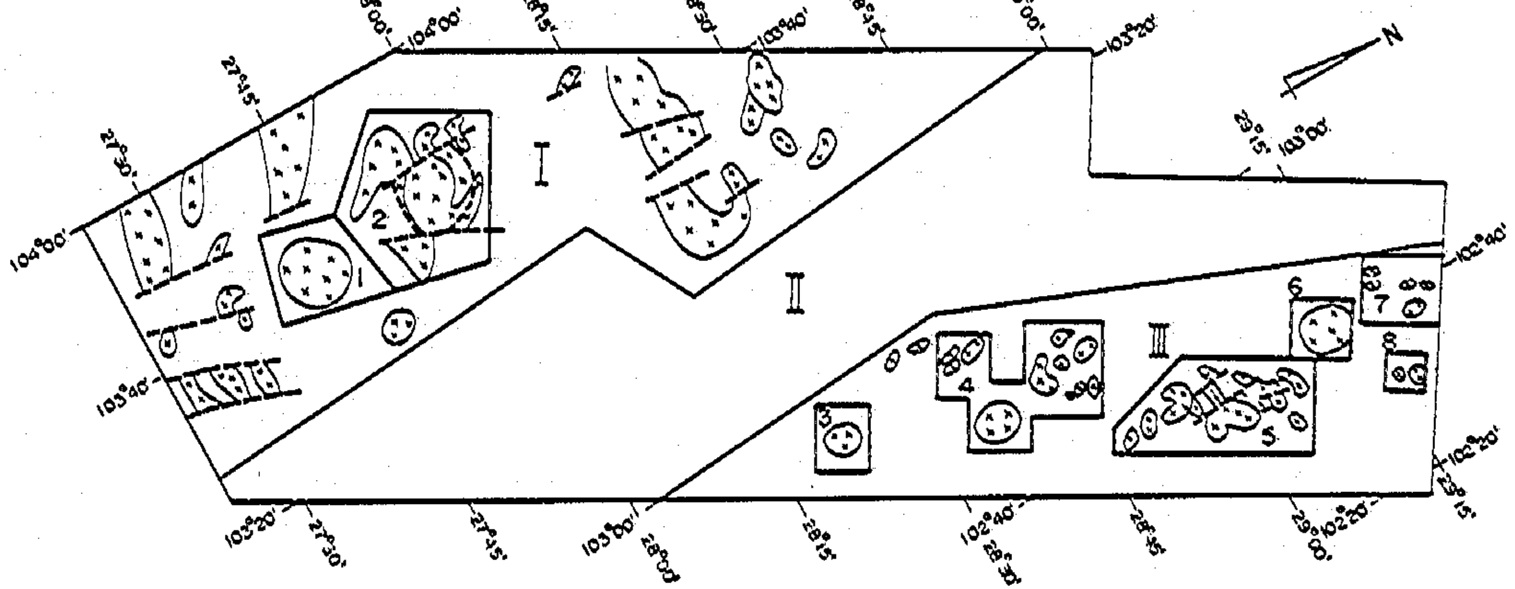


Fig. VII-1 Areas recommended to further investigation

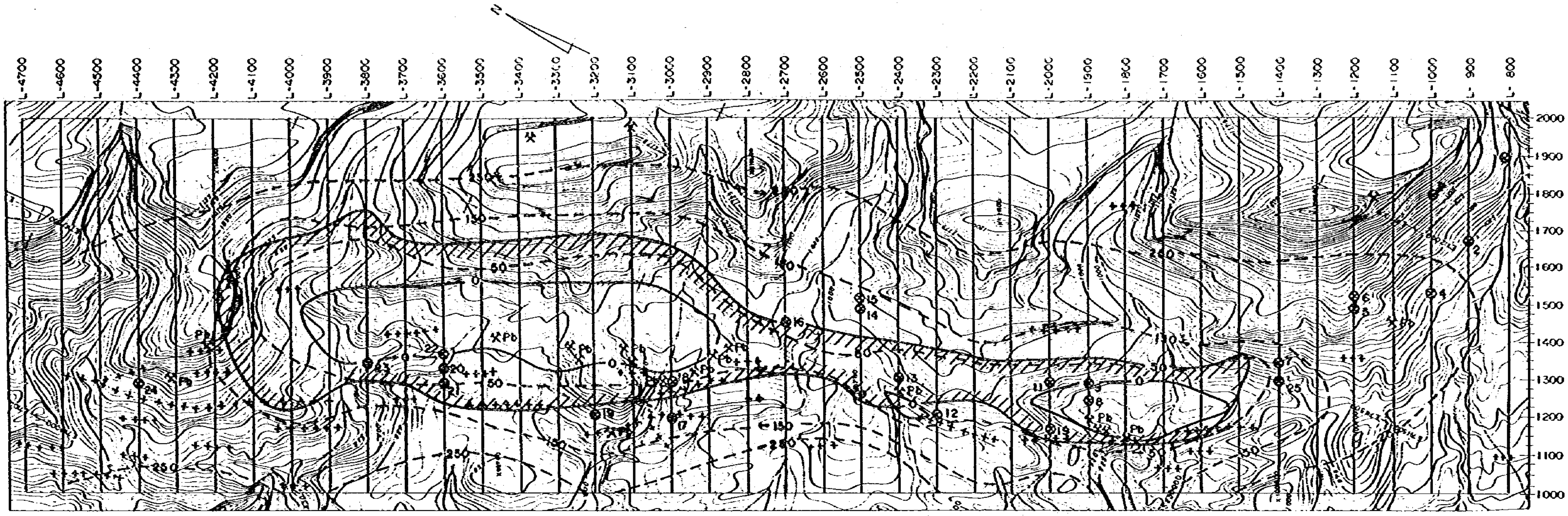


Fig. VII-2 INTERPRETATION MAP OF IP AND TURAM SURVEY

- IP anomalous zone at the depth of 100ms below the ground surface
- Mine site or location of mineral showing
- Boundary of outcrop of schist
- 50, 150, 250: Probable boundary of schist at 50ms, 150ms, 250ms respectively below the ground surface
- ⊗3 Location of rock sampling and rock number
- \+ + + Axis of low resistivity body found out by Turam survey

0 100 200 300m

S = 1:10,000

While some small-scale ore showings of lead and zinc were found in IP anomaly zones obtained, all these consist of oxide ores and are very small in scale, so that, judging from the extent of IP anomalies, it is difficult to consider that the IP anomalies in the surveyed area would be caused by these oxide ores. For the reasons described above, it is inferred that there is little possibility of occurrence of promising ore deposits in the IP anomaly zones obtained, and that the schistose rocks which consist the basement of the area, particularly the graphite schist, would have caused the IP anomalies. Consequently, the outline of geological structure of the basement was qualitatively estimated from the result of IP servey combined with other various informations.

On the other hand, many anomalies were detected by TURAM method in southwestern half of the area, which were assumed to be caused by lead and zinc deposits distributed in the area. The result of analysis of TURAM anomalies showed that apparent resistivity of these deposits was 0.2 ~ 1.2 Ω-m and the depth was mostly 0 ~ 20 m from the surface. These deposits are considered to be of vein-type judging from the pattern of anomalies, having the strike length of 30 m to 700 m.

It is, therefore, considered that the TURAM anomalies were caused by lead and zinc deposits and IP anomalies were caused by graphite-rich schistose rocks. However, the relation between those two kinds of anomalies remained unsolved.

b. Sierra de Cruces and Mina Picacho area

A number of magnetic anomalies were observed by the ground magnetic survey. From the result of analysis, it is inferred that magnetic susceptibility of magnetic bodies is $1.4 \sim 19.2 \times 10^3$ c.g.s.e.m.u./cc, and the depth is 10~120 m. These magnetic bodies are usually of dike-form having the dimensions of 60 ~ 360 m in width, and 300 ~ 1,800 m in length.

It is considered that these magnetic bodies correspond to the concentration of magnetite in skarn zones or in intrusive rocks. Especially the magnetic bodies such as Nos. 16, 21, and 22 showed high magnetic susceptibility, and therefore it is highly possible that these anomalies would indicate the iron ore deposits.

Also the existence of numerous small faults are inferred from the pattern of magnetic anomalies, which intersect many of the magnetic bodies.

(3) Survey result of the fourth phase

Most parts of the area surveyed were in a recrystallized zone of limestone. As the result of survey, chargeability was in the range between 5 and 55 millisec., where the values higher than 25 millisec. were regarded as anomalies. However, the anomalies are not so strong, since they are merely about twice as high as the background value.

Apparent resistivity varies in a wide range between 150 and 82,000 Ω-m, where central part of the recrystallized zone of limestone is in the zone of high apparent resistivity higher than 10,000 Ω-m.

Although many of the IP anomalies (about 70%) are distributed in the zone of relatively lower apparent resistivity lower than 3,000 Ω-m around the recrystallized zone. Some small-scale anomalies are found in the recrystallized zone of high apparent resistivity.

From the result of measurement of rock samples on apparent resistivity and chargeability, it was observed that the recrystallized limestone containing hematite had a tendency to have higher values of both resistivity and chargeability.

As mentioned above, some anomalies distributed in the higher apparent resistivity zone are inferred to be related with mineralization. However, many anomolies in lower apparent resistivity zone are thought to be caused by the pelitic beds containing fine-grained sulfide minerals or carbonaceous matters. Magnitude of the chargeability and the apparent resistivity of anomalies seems to suggest that the content of sulfide minerals and carbonaceous matters, particularly the sulfide, is small in amount.

PART VIII DIAMOND DRILLING

VIII. DIAMOND DRILLING

VIII.1 Outline

The diamond drilling was carried out in Puerto Rico area in 1977 (Phase III) and Mina la Morena area in 1978 (Phase IV).

The drilling in Puerto Rico area was purposed to examine the mineralization along the Las Norias fault taking the results of surveys such as geology, geochemistry and geophysics into consideration.

The drilling operation was started on October 1, 1977 and completed on March 9, 1978. Three vertical drill holes with a total depth of 600.70 m were drilled.

The drilling in Mina la Morena area was carried out with the purpose of obtaining the information of subsurface geological structures and to examine the potential occurrence of the ore deposits, showings of which had been found as the results of geological and geochemical surveys in Phase III and geophysical and geological surveys in Phase IV.

The drilling operation were started on July 17, 1978 and completed on November 19, 1978. Five holes were drilled during the period, and the total length reached to 1,240.90 m.

VIII.2 Drilling Operation

VIII.2.1 Method, Equipment and Materials

The rocks to be drilled in the Puerto Rico area consist of limestone, conglomerate and schist, and it was anticipated that the fractured zones, the beds of lost circulation and clayey brecciated zones along the faults would be encountered. Accordingly, the wire-line method with the use of bentonite mud water was adopted to cope with these conditions. The drilling in Phase III was planned to use mainly NQ and BQ sizes, but it was proved that the insertion of casing pipes was required to keep the bore holes from the caving of friable and/or fractured zones, so that in Phase IV * HQ-WL was supplemented to be used.

Note : * HQ-WL means HQ size-wire-line tools

Table VIII-1 Drilling Equipment

Item	Type	Quantity	Specification
Drilling machine	TGM-5A (Tone Boring, Co.)	1 set	Capacity: HQ 350m, NQ 510m, BQ 660m Inner diameter of spindle: 93m/m Spindle speed: 140,340,525,690r.p.m. Weight (excl. engine): 1,600kg
Wireline hoist	WHS-600 (Tone Boring, Co.)	1 "	Attached to drilling machine
Engine for drill	F3L-912 (Mitsui Deuts, Co.)	1 "	Diesel engine: 4 cycle air-cool type Revolution: 1800 ∿ 1500 r.p.m. Related power: 40 ∿ 33.5 P.S.
Drilling pump	NAS-3B (Tone Boring, Co.)	1 "	Type: 2 cylinders - Double acting Piston diameter: 75m/m Capacity: 105ℓ/min Pressure: 32kg/cm^2
Engine for pump	TS-130C (Yanmer Diesel Co.)	1 "	Diesel engine Revolution: 2200r.p.m. Related power: 11 P.S.
Mud mixer	MCE-100A	1 "	Tank capacity: 125ℓ Effective capacity: 100ℓ Propeller revolution: 800∿1000r.p.m.
Engine for mixer	TS-50	1 "	Diesel engine Revolution: 2000r.p.m. Related power: 4P.S.
Derrick	DRP9-5	1 "	Steel structural derrick(vertical) Maximum load capacity: 6t Effective length of pull rod: 6m
Generator	YSG-2SN	1 "	2KVA 100∿110A
Engine for generator	NS-40	1 "	Diesel engine Revolution: 2000r.p.m. Related power: 4P.S.
Water tank		8 sets	Plastic tank 5m^3 5 sets 1.5m^3 3 sets

Table VIII-2 Drilling Tools

Item	Type	Puerto Rico	Mina la Morena	Specification
Drill rod	HQ-3.05 m	pcs	50 pcs	
	" -1.52 "		2 "	
	NQ-3.00 "	70	70 "	
	" -3.05 "		20 "	
	" -1.50 "	2	2 "	
	BQ-3.00 "	110	67 "	
	" -3.05 "		33 "	
	" -1.52 "	2	2 "	
	AQ-3.05 "	10	15 "	
Casing pipe	HW-1.52 m	pcs	20 pcs.	
	" -0.61 "		20 "	
	NW-3.00 "	10	10 "	
	" -3.05 "		45 "	
	" -1.00 "	2	2 "	
	BW-3.00 "	93	43 "	
	" -3.05 "		46 "	
	" -1.00 "	2	2 "	
Wireline core barrels	HQ-3.05 m	sets	3 sets	
	NQ-3.00 "	3	3 "	
	" -3.05 "		1 "	
	BQ-3.00 "	3	3 "	
	" -3.05 "		1 "	
Single core tube	114m/m-1.50m	set	1 set	
	" -0.50"		1 "	
	99m/m-1.50"	1	1 "	
	" -0.50"	2	2 "	
Water swivel	EH	1 set	1 set	50J-25m/m
Hoisting swivel	B	1 set	1 set	
Rod holder	RH-85 E-7454	1 set 1 "	1 set 1 "	
Inclinater	Tro-Pari		1 set	
Diamond bit	NQ-WL BQ-WL	6 pcs 14 "	6 pcs 3 "	30 cts 20 "
Reaming shell	NQ-WLR BQ-WLR	2 pcs 6 "	3 pcs 1 "	6.6~8 cts 6 "
Casing shoe	HW BW	pc 1	1 pc	38 cts 15 "

Table VIII-3 Consumed Materials (Puerto Rico)

Article	Specification	Unit	Quantity			
			DDH-1	DDH-2	DDH-3	Total
Diesel fuel		ℓ	1,400	1,400	1,800	4,600
Gasoline		"	4,200	1,600	3,600	9,400
Mobil oil		"	70	60	70	200
Lubricant		"	100	-	-	100
Kerosene		"	20	100	100	220
Grease	#2	kg	6	4	6	16
Antifreeze solution		ℓ	-	20	-	20
Bentonite	25kg/bag	bag	30	49	28	107
BH		kg	-	50	25	75
Cement		pack	34	28	38	100
Potassium chloride		kg	-	20	-	20
Diamond bit	NQ	pcs	2	1	3	6
ditto	BQ	"	8	3	3	14
ditto	BW	"	1	-	-	1
Diamond reamer	NQ	"	1	-	1	2
ditto	BQ	"	3	1	2	6
Metal crown	BW	"	2	-	-	2
ditto	BQ	"	2	-	-	2
Drill rod	BQ - 3m	"	2	5	6	13
ditto	BQ - 1.5m	"	1	-	1	2
Casing pipe	BW - 3m	"	15	2	2	19
Core lifter	NQ	"	-	-	2	2
ditto	BQ	"	4	-	2	6
Core lifter case	NQ	"	-	-	2	2
ditto	BQ	"	2	-	2	4
Inner tube stabilizer	NQ	"	1	-	1	2
ditto	BQ	"	1	1	1	3
Inner tube	BQ - 3m	"	-	-	2	2
Outer tube assembly		"	1	-	1	2
Spare blade for casing cutter	BQ and BW	set	4	-	-	4
Spare piece for rod holder	RH-85 NQ	"	-	-	1	1
ditto	RH-85 BQ	"	-	1	-	1
TN-metal	5 x 5 x 8m/m	pcs	10	-	-	10
Wire rope	12.5m/m x 30m	vol	-	-	1	1
Steel wire	#10	kg	10	10	10	30
Old cloth		kg	5	5	5	15
Oil filter	for F3L-912 engine	pcs	-	1	-	1

Table VIII-4 Consumed Materials (Mina la Morena)

Article	Specification	Unit	Quantity					
			DDH-1	DDH-2	DDH-3	DDH-4	DDH-5	Total
Diesel fuel	Drilling machine & Drilling pump	ℓ	700	800	800	550	600	3,450
" "	Tank lorry	ℓ	500	500	500	450	500	2,450
" "	Generator	ℓ						1,000
" "	Water pump	ℓ						1,000
" "	Truck	ℓ						1,000
" "	Others	ℓ						700
Gasoline		ℓ	3,500	2,300	2,000	1,500	3,000	12,300
Engine oil		ℓ	60	10	10	10	50	140
Cylinder oil		ℓ	40	–	–	–	40	80
Grease	#2	kg	30	5	5	5	50	95
Bentonite		kg	150	–	–	–	–	150
Cement		t	1.5	–	–	–	–	1.5
Diamond bit	NQ	pcs	3	2	2	1	1	9
	BQ	"	1	3	–	–	–	4
	HW	"	–	–	1	–	–	1
Diamond reaming shell	NQ	"	2	1	1	0.5	0.5	5
	BQ	"	0.5	0.5	–	–	–	1
Metal crown	115 m/m	pcs	1	1	1	1	1	5
Core barrel	3.00 x BQ	"	0.5	0.5	–	–	–	1
Drill rod	3.00 x NQ	"	1	2	1	1	1	6
Core lifter	NQ	"	2	2	2	2	2	10
	BQ	"	2	2	–	–	–	4
Core lifter case	NQ	"	1	1	0.5	0.5	1	4
	BQ	"	1	1	–	–	–	2

The equipment and expendable materials used are listed in Tables VIII-1~4. Most parts of the equipment were shipped from Japan, but a part of casing pipes and drilling pipes, materials for mud water, fuel and oil, cement, etc. were procured in Mexico. Some diamond bits and reamers were reset in Mexico City.

The drill sites in Mina la Morena area in Phase IV were located in the remote country in the central part of the Sierra la Morena where no accommodations could not be get. Before commencing drill works, therefore, a wooden house was built as a base camp.

VIII.2.2 Preparation and Removal

Prior to the beginning of the drilling operation in Phase III, main parts of equipment and materials from Japan, upon arrival at Acapulco, were transported overland to the base camp at Ejido las Norias under the arrangements made by CRM.

The drilling operation was performed in two shifts each consisting of a Japanese engineer, a CRM's technician and two local workers. Besides, a tank lorry driver and his assistant were also engaged in the work.

Access roads to the drill sites were constructed by CRM. The total lengths of access roads were 2.8 km in Puerto Rico area and 11 km in Mina la Morena area.

Because of the lack of water source in the surroundings of the drill sites, the drilling water was taken from a water well in the nearest village and carried by a tank lorry (10 t) to each site, where it was stored to use in two sets of portable polyethylene tank (5 m^3).
The removal was done by a 10-ton truck and a 1.5-ton light truck.

VIII.2.3 Drilling Works

(1) Puerto Rico area

Summary and progress of drilling works for each hole are given in Tables VIII-5 to VIII-8, respectively.

At the beginning of drilling works in each hole, surface zone was drilled with *NQ-WL diamond bit, then NW casing pipes were inserted after reaming by themselves. After that, each hole was sunk by NQ-WL as long as possible. Then inserting *BW-CP, each hole was drilled by *BQ-WL to the planned depth.

Drilling works were carried out mainly in and around the fractured zones associated with the Las Norias fault. Fractured zones, lost circulation zones and clay zones were often encountered during the drilling works. In conglomerate zones rich in chert and quartzite pebbles, the drill hole were prone to cave because of low consolidation of the zones. For this reason, bentonite mud water with somewhat increased viscosity was circulated through the drill holes to prevent the loss of water and to protect the wall of drill holes from caving.

Particularly, heavily caved parts were cemented, repeatedly, which resulted in remarkable lowering of the drill efficiency.

The drill pipe stuck was experienced as the result of rapid precipitation of the slime and the caving of the hole caused by the lost circulation, which resulted in the redrilling of the hole.

(2) Mina la Morena area

Summary and progress of drilling works for each hole are shown in Tables VIII-9 to VIII-14, respectively.

The drilling was started with 115 mm metal crown and when the overburden was passed, HW-casing pipes were inserted. After this, NQ-WL was used as long as it can be tolerable, then, it was replaced with BQ-WL to the depth as initially planned.

Note: * NQ-WL means NQ-size wire-line tools
* BW-CP means BW-size casing pipe
* BQ-WL means BQ-size wire-line tools

Table VIII-5 Progress of Drilling Works (Puerto Rico)

	Item		1977 Sep.	1977 Oct.	1977 Nov.	1977 Dec.	1978 Jan.	1978 Feb.	1978 Mar.	Remarks
1	Trip (Japan-drilling site)		24—30				⊗ 25—30			
2	Preparation of camp		30							
	Construction of access road (by C.R.M.)		22—	2, 31—	12		4—26			
3	No. 1 hole (DDH-1)	Haulage, Preparation		3—8						
		Drilling		9—	—26					
		Dismounting			27					
	No. 2 hole (DDH-2)	Haulage, Preparation			28—	2				
		Drilling				3—31				
		Dismounting					1—3			
	No. 3 hole (DDH-3)	Haulage, Preparation					27—31			
		Drilling					4 * ~~ 26	1—26		*Waiting for completion of access road
		Dismounting						27—	4	
4	Haulage (Drilling site-warehouse)								5—9	⊗ ------ Geologist
5	Trip (Drilling site-Japan)								⊗ 10—15	
6	Inspection of core and others						31—⊗	----------	9	

Table VIII-6 Progress of Drilling Works (Mina la Morena)

		Item	Jul.	Aug.	Sep.	Oct.	Nov.	Remarks
1		Trip (Japan-drilling site)	14 19					
2		Preparation of camp	—					
		Construction of access road (by C.R.M.)	—					
3	DDH-M1	Haulage, Preparation	20 25					
		Drilling	26 –	– 14				
		Dismounting		15				
	DDH-M2	Haulage, Preparation		16 18				
		Drilling		19 –	– 8			
		Dismounting			9			
	DDH-M3	Haulage, Preparation			10 11			
		Drilling			12 – 24			
		Dismounting			25			
	DDH-M4	Haulage, Preparation			26 27			
		Drilling			28 –	– 3		
		Dismounting				4 5		
	DDH-M5	Haulage, Preparation				6 7		
		Drilling				8 – 15		
		Dismounting				16 19		
4		Haulage (Drilling site-Base Camp)						
5		Trip (Drilling site-Japan)				20 –	– 2	
6		Inspection of core and others		—	— —	— —		

Table VIII-7 Summary of Drilling Results: DDH-1 (Puerto Rico)

Item	Working period	Number of days	Actual working days	Repairing days	No working days	Total number of workers excl. Repair	Total number of workers incl. Repair
Preparation	1st Oct.'77~ 8th Oct.'77	7.5	7.5	-	-	55	55
Drilling	8th Oct.'77~26th Nov.'77	49.5	21	26.5	2	161	379
Dismounting	27th Nov.'77~27th Nov.'77	1	1	-	-	7	7
Total	1st Oct.'77~27th Nov.'77	58	29.5	26.5	2	223	441

Drilling length, etc.			
Planned length	200.00m	Overburden	0
Increase or decrease in length	-69.50m	Core length	113.85m
Length drilled	130.50m	Core recovery	87.2%

Core recovery for each 100m section: Depth of hole	Section	Total
0 ~ 98.75m	90.2%	90.2%
98.75 ~ 130.50m	77.8%	87.2%

Working time				
Drilling	Drilling	53^h05^m	10.0%	8.4%
Drilling	Hoisting & lowering rod, casing	238^h15^m	44.6%	37.7%
Drilling	Repairing	242^h30^m	45.4%	38.4%
Drilling	Sub total	533^h50^m	100.0%	84.5%
Preparation		68^h00^m		10.8%
Dismounting		13^h00^m		2.1%
Others		$*16^h10^m$		2.6%
Total		631^h00^m		100.0%

Drilling efficiency	
130.50m/Working period	2.25m/day
130.50m/Working days	4.42m/day
130.50m/Drilling period	2.64m/day
130.50m/Net drilling days	6.21m/day
Total workers/130.50m (incl. Repair)	3.38man/m
Total workers/130.50m (excl. Repair)	1.71man/m
Total drilling workers/130.50m (incl. Repair)	1.23man/m
Total drilling workers/130.50m (excl. Repair)	2.90man/m

Inserting casing pipe: Pipe size & inserted length (m)	Inserted length / Drilling length × 100%	Recovery of casing pipe (%)
BW.C.P. 97	100	88.65

Drilling length by each size (m)		
Bit size	NQ	BQ
Drilling length	91.65	38.85
Core length	85.05	28.80

Remarks: 1. *Waiting water
2. Water supply was done by C.R.M.

Table VIII-8 Summary of Drilling Results: DDH-2 (Puerto Rico)

Item	Working period	Number of days	Actual working days	No working days	Total number of workers
Preparation	28th Nov.'77 ~ 2nd Dec.'77	5	5	0	44
Drilling	3rd Dec.'77 ~ 31st Dec.'77	29	28	1	232
Dismounting	1st Jan.'78 ~ 3rd Jan.'78	3	2	1	17
Total	28th Nov.'77 ~ 3rd Jan.'78	37	35	2	293

Drilling length, etc.			
Planned length	0	Over burden	3.00m
Increase or decrease in length	+0.20m	Core length	172.56m
Length drilled	200.20m	Core recovery	86.2%

Core recovery for each 100m section		
Depth of hole	Section	Total
0 ~ 96.65m	98.7%	98.7%
96.65 ~ 200.20m	74.5%	86.2%

Working time				
Drilling	Drilling	116^h50^m	29.1%	24.4%
Drilling	Hoisting & lowering rod, casing	173^h10^m	43.1%	36.1%
Drilling	Repairing	112^h00^m	27.8%	23.4%
Drilling	Sub total	402^h00^m	100.0%	83.9%
Preparation		22^h00^m		4.6%
Dismounting		21^h00^m		4.4%
Others		*34^h00^m		7.1%
Total		479^h00^m		100.0%

Drilling efficiency	
200.20m/Working period	5.41m/day
200.20m/Working days	5.72m/day
200.20m/Drilling period	6.90m/day
200.20m/Net drilling days	9.50m/day
Total workers/200.20m	1.46man/m
Total drilling workers/200.20m	1.16man/m

Inserting casing pipe: Pipe size & inserted length (m)	Inserted length / Drilling length x 100%	Recovery of casing pipe (%)
NW.C.P. 9.00	100	100
BW.C.P. 109.85	100	100

Drilling length by each size (m)		
Bit size	NQ	BQ
Drilling length	109.85	90.35
Core length	108.60	63.96

Remarks

1. *Waiting water
2. Water supply was made by C.R.M.

Table VIII-9 Summary of Drilling Results: DDH-3 (Puerto Rico)

Item	Working period	Number of days	Actual working days	No working days	Total number of workers
Aid for construction of access road (C.R.M.)	(4th Jan.'78~26th Jan.'78)	(23)	(21)	(2)	(93)
Preparation	27th Jan.'78~31st Jan.'78	5	5	0	49
Drilling	1st Feb.'78~26th Feb.'78	26	26	0	220
Dismounting	27th Feb.'78 ~ 4th Mar.'78	6	6	0	47
Total	27th Jan.'78 ~ 4th Mar.'78 (4th Jan.'78 ~ 4th Mar.'78)	37 (60)	37 (58)	0 (2)	316 (409)

Drilling length, etc.

Planned length	200.00m	Overburden	0
Increase or decrease in length	+70.00m	Core length	244.75m
Length drilled	270.00m	Core recovery	90.6%

Core recovery for each 100m section

Depth of hole	Section	Total
0 ~ 107.50m	85.9%	85.9%
107.50 ~ 190.20m	98.5%	91.4%
190.20 ~ 270.00m	88.7%	90.6%

Working time

Drilling	Drilling	154^h00^m	36.2%	29.1% (22.1)
Drilling	Hoisting & lowering rod, casing	175^h00^m	41.2%	33.1% (25.1)
Drilling	Repairing	96^h00^m	22.6%	18.2% (13.8)
Drilling	Sub total	425^h00^m	100.0%	80.4% (61.0)
Preparation		46^h00^m		8.6% (6.6)
Dismounting		58^h00^m		11.0% (8.3)
Others		(168^h00^m)		(24.1)
Total		529^h00^m (679^h00^m)		100.0%

Drilling efficiency

270.00m/Working period	7.30m/day
270.00m/Working days	7.30m/day
270.00m/Drilling period	10.38m/day
270.00m/Net drilling days	10.38m/day
Total workers/270.00m	1.17man/m
Total drilling workers/270.00m	0.85man/m

Inserting casing pipe

Pipe size & inserted length (m)	$\frac{\text{Inserted length}}{\text{Drilling length}} \times 100\%$	Recovery of casing pipe (%)
BW.C.P. 190.20	100	100

Drilling length by each size (m)

Bit size	NQ	BQ
Drilling length	190.20	79.80
Core length	173.85	70.90

Remarks: 1. Parenthesized figures show the work for road construction in cooperation with C.R.M.
2. Water supply was made by C.R.M.

Table VIII-10 Summary of Drilling Results: DDH-M1 (Mina la Morena)

Item	Working period	Number of days	Actual working days	Repairing days	Road repairing days	Total number of workers: excl. Road repairs	Total number of workers: incl. Road repairs
Preparation	20th Jul.'78~25th Jul.'78	6	6	0	0	57	57
Drilling	26th Jul.'78~14th Aug.'78	20	16	0	4	155	246
Dismounting	15th Aug.'78	1	1	0	0	10	10
Total	24th Jul.'78~15th Aug.'78	27	23	0	0	214	305

Drilling length, etc.

Planned length	300.0 m	Over-burden	0 m
Increase or decrease in length	+2.25 m	Core length	288.69m
Length drilled	302.25 m	Core recovery	95.51%

Core recovery for each 100m section

Depth of hole	Section	Total
0~100.05 m	96.69 %	96.69 %
100.05~200.50 m	97.07 %	96.88 %
200.50~302.25 m	93.32 %	95.51 %

Working time

		Time	% of drilling	% of total
Drilling	Drilling	95h30m	51.9 %	33.5 %
Drilling	Hoisting & lowering rod, casing	33h30m	18.2 %	11.8 %
Drilling	Repairing	-	- %	- %
Drilling	Others	55h00m	29.9 %	19.3 %
Drilling	Sub total	184h00m	100.0 %	64.6 %
Preparation		57h00m		20.0 %
Dismounting		8h00m		2.8 %
Others *		36h00m		12.6 %
Total		285h00m		100.0 %

Drilling efficiency

302.25 m/Working period	11.19 m/day
302.25 m/Working days	13.14 m/day
302.25 m/Drilling period	15.11 m/day
302.25 m/Net drilling days	18.89 m/day
Total workers/302.25 m (incl. Road repairs)	1.01 man/m
Total workers/302.25 m (excl. Road repairs)	0.71 man/m
Total drilling workers/302.25m (incl. Road reparis)	0.81 man/m
Total drilling workers/302.25m (excl. Road repairs)	0.51 man/m

Inserting casing pipe

Pipe size & inserted length (m)	Inserted length / Drilling length × 100%	Recovery of casing pipe (%)
HW.C.P.: 2.25	0.7	100
BW.C.P.: 260.25	86.1	100

Drilling length by each size (m)

Bit size	115 mm	NQ	BQ
Drilling length	2.25	258.00	42.00
Core length	1.65	245.79	41.25

Remarks: * Waiting for water and road repairing.

Table VIII-11 Summary of Drilling Results: DDH-M2 (Mina la Morena)

Item	Working period	Number of days	Actual working days	Repairing days	No. working days	Total number of workers
Preparation	16th Aug.'78∿18th Aug.'78	3	3	0	0	36
Drilling	19th Aug.'78∿ 8th Sep.'78	21	17	0	4*	146
Dismounting	9th Sep.'78	1	1	0	0	11
Total	16th Aug.'78∿ 9th Sep.'78	25	21	0	4	193

Drilling length, etc.			
Planned length	212.5 m	Over-burden	0 m
Increase or decrease in length	+89.7 m	Core length	277.90m
Length drilled	302.20 m	Core recovery	91.96%

Core recovery for each 100m section		
Depth of hole	Section	Total
0∿100.25 m	96.36 %	96.36 %
100.25∿200.95 m	86.84 %	91.59 %
200.95∿302.20 m	92.69 %	91.96 %

Working time				
Drilling	Drilling	93h30m	50.5 %	41.2 %
Drilling	Hoisting & lowering rod, casing	59h00m	31.9 %	26.0 %
Drilling	Repairing	3h00m	1.6 %	1.3 %
Drilling	Others	29h30m	16.0 %	13.0 %
Drilling	Sub total	185h00m	100.0 %	81.5 %
Preparation		25h00m		11.0 %
Dismounting		9h00m		4.0 %
Others		8h00m		3.5 %
Total		227h00m		100.0 %

Drilling efficiency	
302.20 m/Working period	12.09 m/day
302.20 m/Working days	14.39 m/day
302.20 m/Drilling period	14.39 m/day
302.20 m/Net drilling days	17.78 m/day
Total workers/302.20 m	0.64 man/m
Total workers/ m (excl. Road Repairs)	man/m
Total drilling workers/302.20m	0.48 man/m
Total drilling workers/ m (excl. Road Repairs)	man/m

Inserting casing pipe: Pipe size & inserted length (m)	Inserted length / Drilling length × 100%	Recovery of casing pipe (%)
HW.C.P.: 0.6	0.2	100
BW.C.P.: 130.15	43	100

Drilling length by each size (m)			
Bit size	115 mm	NQ	BQ
Drilling length	0.6	132.55	169.05
Core length	0.6	119.00	158.30

Remarks: * Waiting for decision of increase in drilling length.

Table VIII-12 Summary of Drilling Results: DDH-M3 (Mina la Morena)

Item	Working period	Number of days	Actual working days	Repairing days	No. working days	Total number of workers: excl. Repairs	Total number of workers: incl. Repairs
Preparation	10th Sep.'78∿11th Sep.'78	2	2	0	0	16	16
Drilling	12th Sep.'78∿24th Sep.'78	13	9	4	0	77	112
Dismounting	25th Sep.'78	1	1	0	0	9	9
Total	10th Sep.'78∿25th Sep.'78	16	12	4	0	102	137

Drilling length, etc.

Planned length	212.5 m	Overburden	5.5m
Increase or decrease in length	-0.25 m	Core length	206.40m
Length drilled	212.25 m	Core recovery	97.24%

Core recovery for each 100m section

Depth of hole	Section	Total
0∿109.95 m	97.0 %	97.0 %
109.95∿212.25 m	97.6 %	97.2 %

Working time

Drilling	Drilling	68^h30^m	35.5 %	31.1 %
	Hoisting & lowering rod, casing	30^h00^m	15.6 %	31.6 %
	Repairing	71^h00^m	36.8 %	32.3 %
	Others	23^h30^m	12.1 %	10.7 %
	Sub total	193^h00^m	100.0 %	87.7 %
Preparation		18^h00^m		8.2 %
Dismounting		9^h00^m		4.1 %
Others				%
Total		220^h00^m		100.0 %

Drilling efficiency

212.25 m/Working period	13.27 m/day
212.25 m/Working days	17.69 m/day
212.25 m/Drilling period	16.33 m/day
212.25 m/Net drilling days	23.58 m/day
Total workers/ 212.25m (incl. Repairs)	0.65 man/m
Total workers/ 212.25m (excl. Repairs)	0.48 man/m
Total drilling workers/212.25m (incl. Repairs)	0.53 man/m
Total drilling workers/212.25m (excl. Repairs)	0.36 man/m

Inserting casing pipe

Pipe size & inserted length (m)	Inserted length / Drilling length x 100%	Recovery of casing pipe (%)
HW.C.P.: 5.80	2.7	100
NW.C.P.: 153.30	72.0	100

Drilling length by each size (m)

Bit size	115 mm	NQ
Drilling length	5.80 m	206.45 m
Core length	5.80 m	200.60 m

Remarks:

Table VIII-13 Summary of Drilling Results: DDH-M4 (Mina la Morena)

Item	Working period	Number of days	Actual working days	Repairing days	No. working days	Total number of workers
Preparation	26th Sep.'78∿27th Sep.'78	2	2	0	0	16
Drilling	28th Sep.'78∿ 3rd Oct.'78	6	6	0	0	52
Dismounting	4th Oct.'78∿ 5th Oct.'78	2	2	0	0	18
Total	26th Sep.'78∿ 5th Oct.'78	10	10	0	0	86

Drilling length, etc.			
Planned length	212.5 m	Over-burden	5.90m
Increase or decrease in length	-9.25 m	Core length	203.15m
Length drilled	203.25 m	Core recovery	99.95%

Core recovery for each 100m section		
Depth of hole	Section	Total
0∿106.55 m	99.9 %	99.9 %
106.55∿203.25m	100.0 %	99.9 %

Working time				
Drilling	Drilling	$52^{h}30^{m}$	62.5 %	44.5 %
	Hoisting & lowering rod, casing	$16^{h}30^{m}$	19.6 %	14.0 %
	Repairing	–	–	–
	Others	$15^{h}00^{m}$	17.9 %	12.7 %
	Sub total	$84^{h}00^{m}$	100.0 %	71.2 %
Preparation		$18^{h}00^{m}$		15.3 %
Dismounting		$16^{h}00^{m}$		13.5 %
Others		–		%
Total		$118^{h}00^{m}$		100.0 %

Drilling efficiency	
203.25 m/Working period	20.33 m/day
203.25 m/Working days	20.33 m/day
203.25 m/Drilling period	33.88 m/day
203.25 m/Net drilling days	33.88 m/day
Total workers/203.25 m	0.42 man/m
Total workers/ m (excl. Repairs)	man/m
Total drilling workers/203.25 m	0.26 man/m
Total drilling workers/ m (excl. Repairs)	man/m

Inserting casing pipe		
Pipe size & inserted length (m)	Inserted length / Drilling length x 100%	Recovery of casing pipe (%)
NW.C.P.: 5.90	2.9	100

Drilling length by each size (m)		
Bit size	115 mm	NQ
Drilling length	5.90 m	197.35 m
Core length	5.90 m	197.25 m

Remarks:

Table VIII-14 Summary of Drilling Results: DDH-M5 (Mina la Morena)

Item	Working period	Number of days	Actual working days	Repairing days	No. working days	Total number of workers
Preparation	6th Oct.'78~7th Oct.'78	2	2	0	0	16
Drilling	8th Oct.'78~15th Oct.'78	8	8	0	0	72
Dismounting	16th Oct.'78~19th Oct.'78	4	4	0	0	30
Total	6th Oct.'78~19th Oct.'78	14	14	0	0	118

Drilling length, etc.			
Planned length	212.5 m	Over-burden	1.90m
Increase or decrease in length	+17.5 m	Core length	208.45m
Length drilled	220.95m	Core recovery	94.34%

Core recovery for each 100m section		
Depth of hole	Section	Total
0~105.75 m	97.0 %	97.0 %
105.75~220.95 m	91.9 %	94.3 %

Working time				
Drilling	Drilling	72^h00^m	52.0%	41.9 %
Drilling	Hoisting & lowering rod, casing	26^h00^m	21.0%	15.1 %
Drilling	Repairing	-	-	-
Drilling	Others	26^h00^m	21.0%	15.1 %
Drilling	Sub total	124^h00^m	100.0%	72.1 %
Preparation		19^h00^m		11.0 %
Dismounting		29^h00^m		16.9 %
Others		-		- %
Total		172^h00^m		100.0 %

Drilling efficiency	
220.95 m/Working period	20.09 m/day
220.95 m/Working days	20.09 m/day
220.95 m/Drilling period	27.62 m/day
220.95 m/Net drilling days	27.62 m/day
Total workers/ 220.95m	0.53 man/m
Total workers/ m (excl. Repairs)	man/m
Total drilling workers/220.95m	0.33 man/m
Total drilling workers/ m (excl. Repairs)	man/m

Inserting casing pipe		
Pipe size & inserted length (m)	Inserted length / Drilling length x 100%	Recovery of casing pipe (%)
115mm C.P.: 1.90	0.9	100

Drilling length by each size (m)		
Bit size	115 mm	NQ
Drilling length	1.90 m	219.05 m
Core length	1.90 m	206.55 m

Remarks:

In this time, HQ-WL was additionally supplied to make assurance of the drilling. It was however, scarcely used because the drilling could be carried out mainly by the use of NQ-WL.

Limestone is the main rock to be drilled in this area which is developed by open fissures, that caused rapid loss of circulation water very often. At first, attempt was m de to prevent lost circulation, but the water was lost every several centimeters to several tens centimeters. At last, the drilling was continued under the lost circulation intact to avoid the delay of the work by waiting time for the cement concretion. Under such conditions, bentonite mud water was scarcely used, in turn the fresh water was used flowing down without returning. The drilling under the condition of lost water lowered the drill rate and caused the damages of diamond bit such as burning, and breaking by falling down of inner tube.

VIII.3 Summary

VIII.3.1 Drilling Results

(1) Puerto Rico area

Based on the findings of the Phase II survey, diamond drilling was carried out at three promising sites in the Las Norias fault zone located in the Puerto Rico area.

As a result the geological features of the Las Norias fault and the surroundings were clarified as follows:

These three holes were drilled from the west side of the fault line, penetrated the Las Noria fault and reached the basement or the Cretaceous basal conglomerate of this area. From the location of the Las Norias fault on the surface and its depth in the drill holes, it was found that the fault dipped at 40 to 60° to the west. It was also discovered that the Las Norias fault was accompanied with a group of reverse faults making the repetition of strata, and that the fractured zones associated with these faults were on a large scale.

The effects of mineralization in these three drill holes were generally weak, but the mineralized zones as listed in Table VIII-15 were recognized in DDH-2.

Table VIII-15 Mineralized Zones in DDH-2

Depth (m)	Thickness (m)	Ag g/t	Cu ppm	Pb ppm	Zn ppm	Remarks
56.55 ~ 56.62 56.76 ~ 56.80	0.12	1.7	23	1042	8355	Oxide vein
57.35 ~ 58.35	1.00	2.9	23	1250	9375	Fractured zone with swarm of veinlets
58.95 ~ 59.20	0.25	16.1	34	2292	21875	Oxide vein
131.65 ~313.85	0.20	17.6	500	1042	43750	Oxide vein

These mineralized zones consist of veins filled with calcite and iron oxide accompanied with oxidized lead and zinc minerals. Since primary sulfide ore minerals are hardly found in the zones, the grade of primary ores is unknown. Analytical results for examining the mineralization show rather high lead and zinc contents in and around the Las Norias fault zone. This is one of the evidences of the role played by the Las Norias fault in the structural control of the mineralization in this area.

(2) Mina la Morena area

Each borehole consisted primarily of limestone beds interbedded partly with marl. In all the boreholes except DDH-M4, rocks were heavily recrystallized, and in some cases it was difficult to presume their origin.

However, the drill hole geology corresponded well on the whole to the surface geology, and thus the drilling work contributed in a large measure toward shedding light on the stratigraphical and structural investigation.

Structurally, in DDH-M1, DDH-M2, and DDH-M3, the occurrence of conspicuous fractured zones around Kau III units was confirmed. It also been known that the concealed intrusive rock body whose occurrence had been predicted occurs at an unexpectedly great depth.

It has been confirmed that the thermal metamorphic zones consist mainly of recrystallized limestone and that large porphyroblastic garnet, wollastonite and hedenbergite occur in some parts of the skarn mineral-bearing recrystallized zones. This will contribute largely toward presumption of the conditions of metamorphism.

In DDH-M1, DDH-M2, DDH-M3 and DDH-M5, ore bodies of relatively high grade were encountered, which contributed largely on exploration of the mineralized zones in this area. In DDH-M2 and DDH-M5, primary sulfide ores were locally distributed, and this is an important contribution toward the elucidation of the nature of mineralization.

In DDH-M4 which was drilled for the purpose of investigation into the IP anomalies, carbonaceous limestone and marl were found, and concluded to be the cause of IP anomalies.

VIII.3.2 Consideration

The drilling operation in Puerto Rico area in Phase III incurred a lot of delay in the progress arising from the difficulties in the protection of caved bore holes caused by unfavorable geological conditions. For the drilling operation in Mina la Morena area planned in Phase IV, additional equipment were prepared and the works were improved from the experience in the previous phase, which resulted in the satisfactory result in drill efficiency and in core recovery.

The considerations are made here on the problems of the drilling works as follows:

(1) Wire line method

The drilling in Phase III was planned to drill on the basis of NQ-WL and BQ-WL, which revealed that the casing program was not sufficient to meet the unfavorable conditions in the holes.

In Phase IV, HQ-WL was added but without full use of it because of the different geological conditions compared with that of the Puerto Rico area. However, from the experience of these surveys, it was made clear that the preparation of rather sufficient equipment is decidely advantageous in exploration in the ground of unknown geology.

The use of wire line system has shown a favorable result for the present time. However, in the case of drilling under the condition of lost circulation, it betrayed a mechanical weak point to break the bit which is at the lowest end of the core barrel by passing through of the inner tube which had fallen as the result of vibration.

(2) Cementation

It is the most perfect measure to insert casing pipe for the protection of the bore hole. However, it is the common practice to extend a stage of casing as deep as possible by protecting the hole with cementation for reason of the casing program. The effect of cementation as a protection measure for such zones as fracture, lost water in the face of frequent appearance of the formation of lost circulation, and clay has an important effect on the progress of the drill works. In Puerto Rico area, although the schedule was delayed greatly in order to pass through the fracture zones and clay zones, the hole was sunk to the depth as initially planned by repetition of cementation. While in Mina la Morena area, without getting favorable result of preventing the drilling was yet continued, eliminating the obstacles caused by rod vibration and burning of bit, making the lost water intact. As the result, the lowering of the drill efficiency was prevented.

(3) Rationalization of preparatory and ancillary works

In this drill program, the problems such as securing drill water, procurement of equipment and materials, and the construction of the access road had been indicated from the beginning. Setting aside the questions in 1977, the preparatory work by CRM in 1978 made good progress, especially in construction of the access road, which resulted in rapid removal of the drill machineries between the holes. Moreover, the construction of the base camp close to the drill site greatly contributed to raise the efficiency of the drilling.

PART IX CONCLUSION AND RECOMMENDATION

CONCLUSION AND RECOMMENDATION

After the comprehensive investigation on the survey results up to the third phase, evaluation was made on various kinds of mineralization found in the district, and eight areas were selected as targets for further investigation. The order of priority of these areas are as follows:

1st rank : Thermal metamorphic zone around Mina la Diana in the Mina la Morena area.

2nd rank : Thermal metamorphic zone around Mina el Volcan in the El Volcan area.

3rd rank : Geochemical anomaly zone near Mina la Morena.

4th rank : Pneumatolytic to hydrothermal alteration zone extending from Mina Libertad to the Noria del Picacho dome in the Sierra de Cruces area.

5th rank : Lower part of silicified zone near Mina Collan in the El Volcan area.

6th rank : Northern and southern plunges of the Santa Elena anticline in the Sierra de Cruces area, and geochmeical anomalies found about 3 km south of Mina Santa Elena.

7th rank : Mineralized zone 500 m to the south-southwest of Mina Venos in the Puerto Rico area.

8th rank : Geochemical anomaly zone in the Sierra del Carmen area.

In accordance with this order, the thermal metamorphic zone around Mina la Diana in the Mina la Morena area which had been ranked first, was surveyed in Phase IV.

As the result of the survey, silver-bearing copper deposits were discovered. The occurrence of this type of deposits seems uncommon in this district from metallogenic point of view.

The ore deposits mainly consist of a group of veins of high temperature hydrothermal type, but manto or irregular massive deposits are found in some parts of the area.

The size of a unit ore vein is several tens centimeters to several meters in width and several tens meters to several hundred meters in length. The grade of ores is in the order of about 1 g/T Au, several tens to several hundred g/T Ag, and several % Cu. Pb and Zn contents are as low as 0.0n and 0.n percent respectively.

The ore deposits are localized in the northeast-trending fault fracture zones in the recrystallized zone of limestone of the Aurora formation, within which the principal deposits are distributed in the central part, eastern part, and northeastern part of the recrystallized zone.

Although the ore deposits so far confirmed might not be too much excellent in size and grade, from the fact that these deposits tend to be predominantly developed in the depths and that the Cupido formation is the most favorable ore horizon in this district, it is considered that the future exploration should be directed to the confirmation of the extention of main mineralized zones to the horizon of the Cupido formation.

For this purpose, it is required that the drilling is to be planned to reach the depth of 600 m to 800 m from the surface.

It will be also recommended to reexamine the areas of 2nd to 4th rank, if the exploration of this 1st-ranked area results in success.

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