2–2–3 Measurement of Radon Concentration

A hole of 60 cm depth is drilled with a hand-auger and an etch cup (made of Terradex) is buried bottoms up in the hole and covered (Fig. II–2–10).

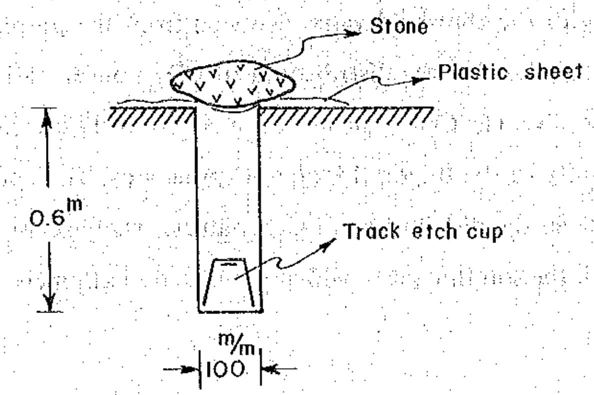

Fig. II–2–10 Planting of Track Etch Cup

After about 3 weeks, the cup is retrieved and sent to Terradex for track etch count. The corrected values (Table II–2–1) correspond to the number of tracks in 30 days for a 1 mm^2 area. Fig. II–2–11 shows the frequency distribution of the logarithm of radon concentration (in tracks per mm^2 per 30 days). The distribution is very regular and the probability curve (Fig. II–2–12) gives a threshold value of 1.6 corresponding to 39.8 tracks per 30 days per 1 mm^2.

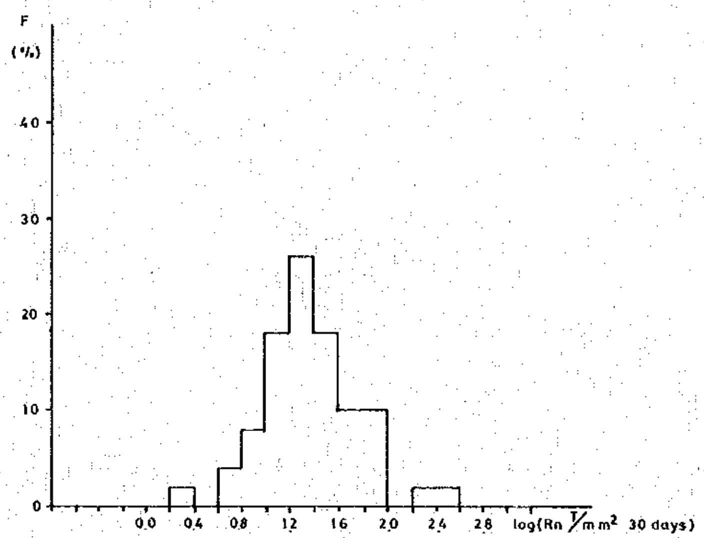

Fig. II–2–11 Frequency of Diagram of Rn Gas Concentration

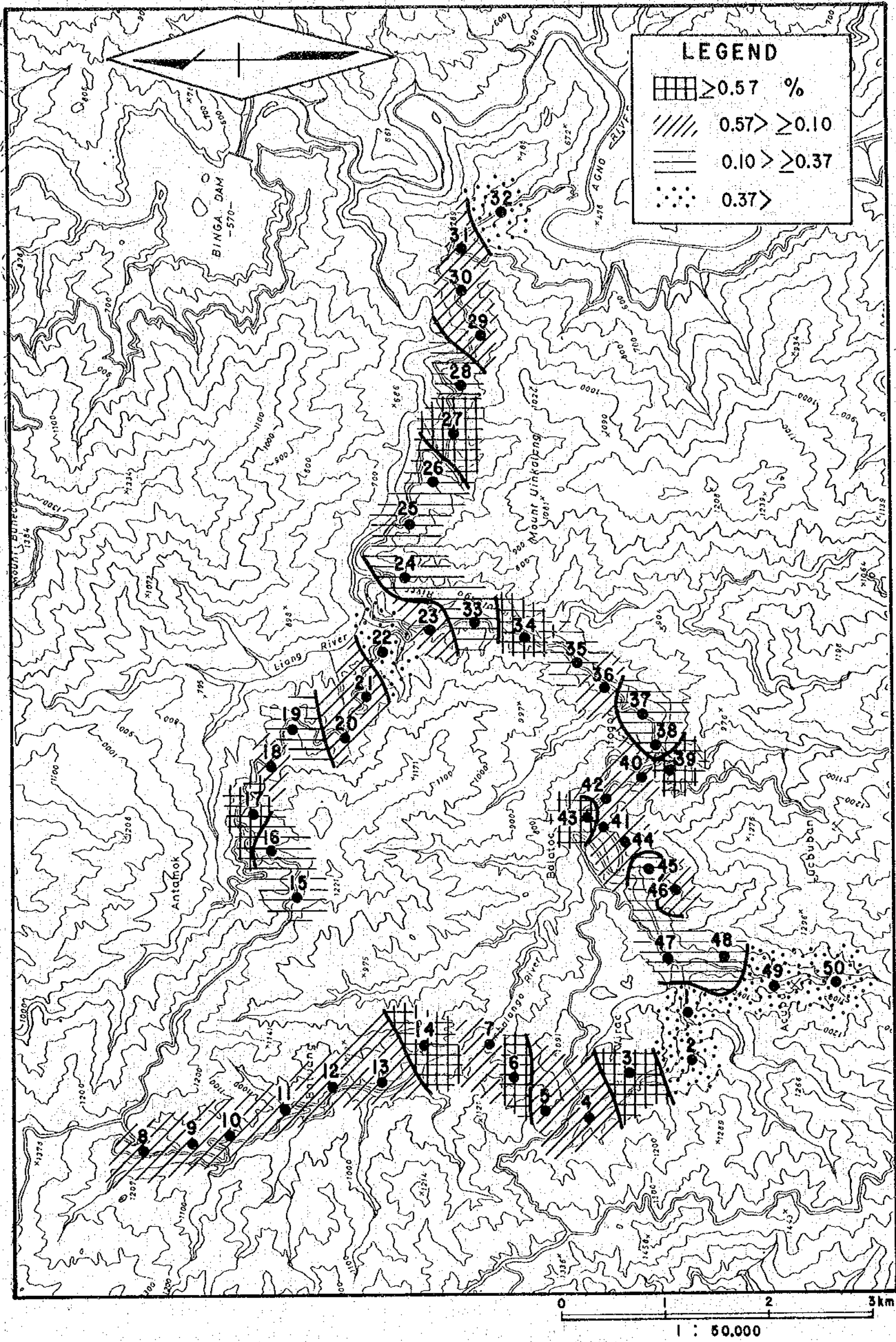

Fig. II–2–9 Distribution Map of CO_2 Gas Concentration

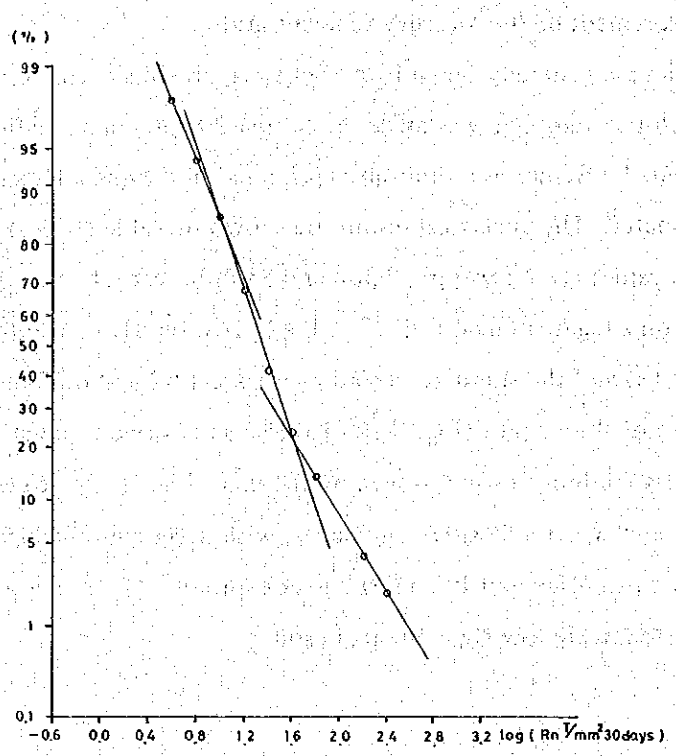

Fig. II–2–12 Probability Plot of Rn Gas Concentration

The mean value ($\bar{x}$) and standard deviation (v) obtained from the frequency diagram (Fig. II–2–11) are 1.37 and 0.38 respectively. The map of radon concentration (Fig. II–2–13) has been drawn using $\bar{x}$, $\bar{x}$±v and $\bar{x}$–2v as limits. It shows a large domain of relatively high/radon concentration from the Itogon Bridge hot spring to Acupan Mine. But the most striking feature of the radon distribution is a large positive anomaly in the vicinity of Batuang which corresponds geologically to the presence of andesite and granodiorite-porphyry. The outlined anomaly thus reflects this geological difference rather than the presence of geothermal fluids at depth. On the other hand, a large negative anomaly appears in the northeastern part of the field which corresponds geologically to intermediate and basic eruptive rocks.

2–2–4 Measurement of the Mercury Concentration

Soil samples are generally taken from the A_1 layer. But as the soils of the surveyed area are poorly developed sampling was made in the first 20–30 cm excluding the A_0 layer. The analysis was made by flameless atomic absorption method using a Hiranuma HG-1 type mercury concentration meter. The analytical results are shown in Table II–2–1. The maximum, minimum and mean values are 4,385 ppb, 9 ppb and 83 ppb, respectively. As shown by the frequency diagram drawn on a logarithmical scale (Fig. II–2–14), the Hg concentrations fall in two groups. The mean value ($\bar{x}$) and the standard deviation (v) are 1.92 and 0.65 respectively on the logarithmic scale. The probability plot (Fig. II–2–15) also shows two populations of Hg values. The distribution of Hg content in soil is drawn on the map (Fig. II–2–16) with the limit concentrations of $\bar{x}$, $\bar{x}$±v and $\bar{x}$–2v. Positive anomalies, with a Hg content higher than $\bar{x}$+v (2.57), occur around Acupan Mine and Itogon Bridge hot springs. The northeastern part of the area however, shows relatively low Hg contents in soil.

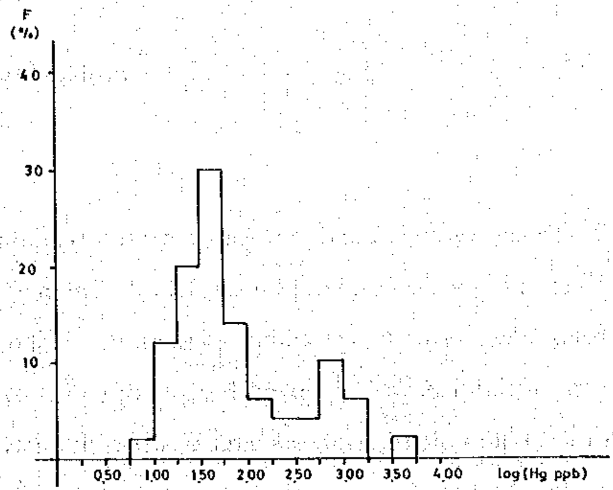

Fig. II–2–14 Frequency Diagram of Hg Contents in Soil

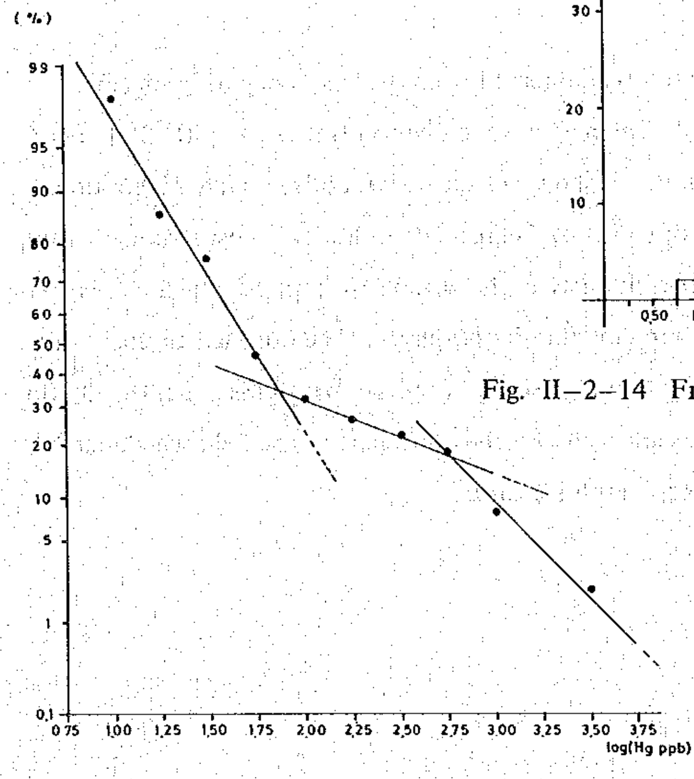

Fig. II–2–15 Probability Plot of Hg Contents in Soil

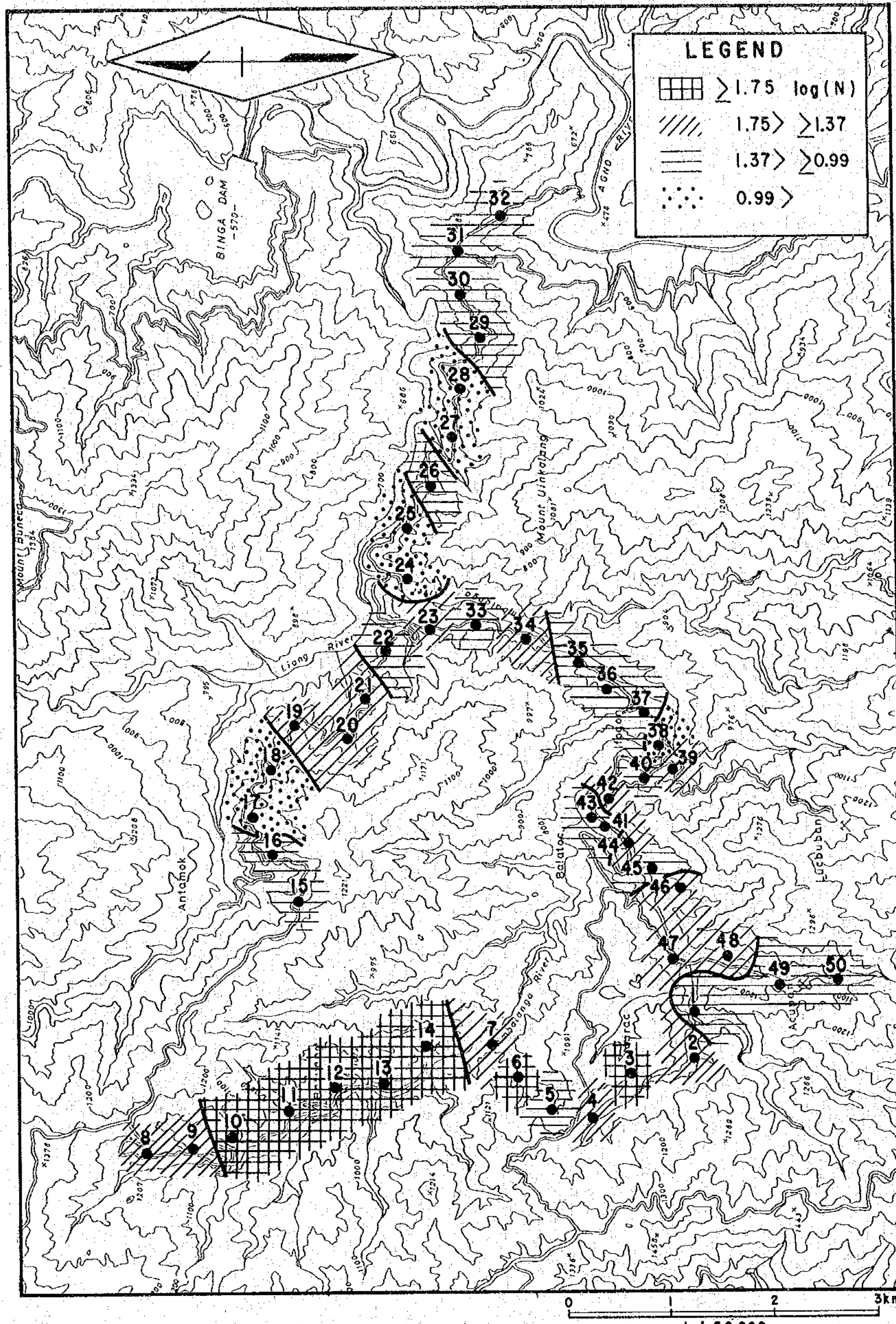

Fig. II–2–13 Distribution Map of Rn Gas Concentration

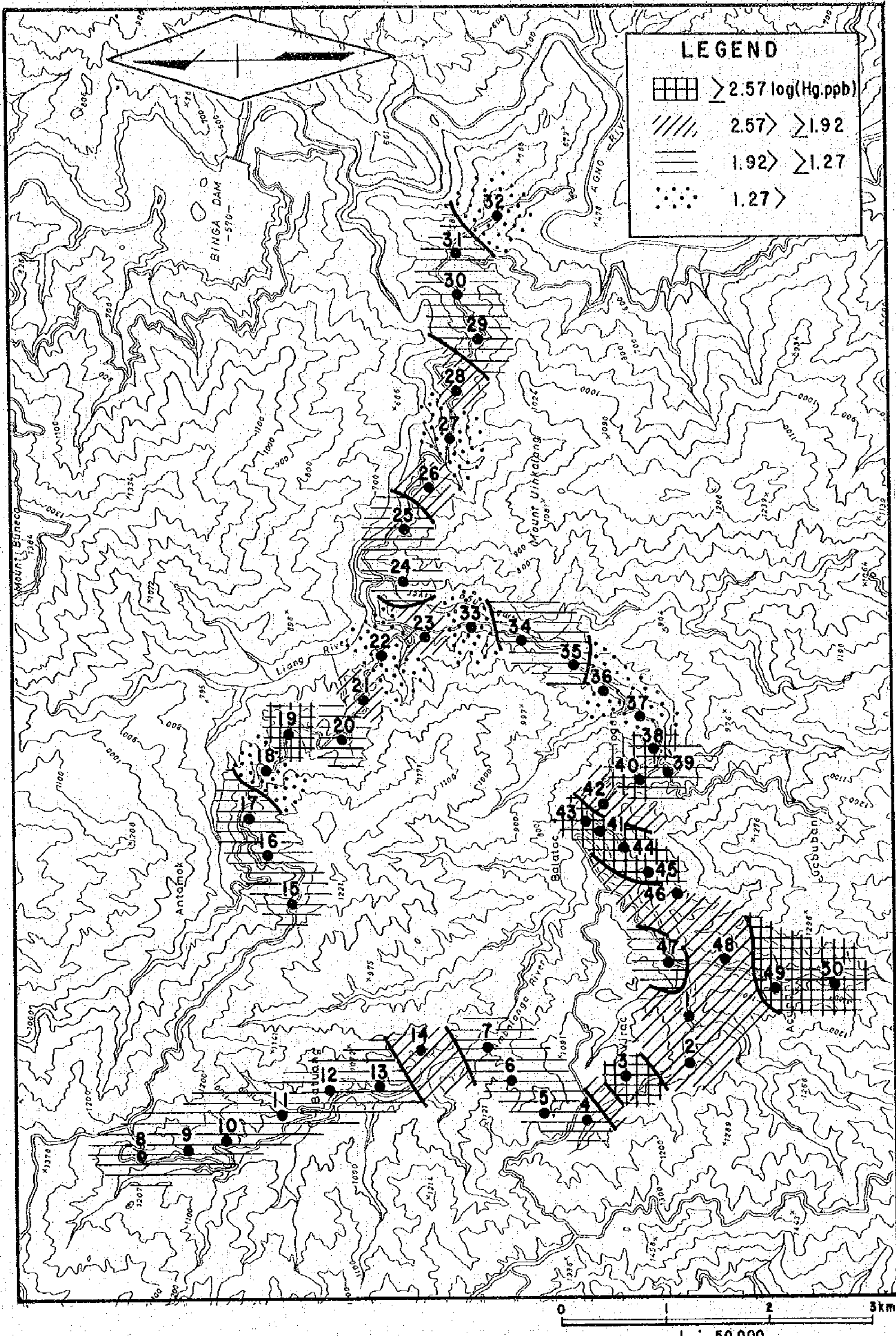

Fig. II–2–16 Distribution Map of Hg Contents in Soil

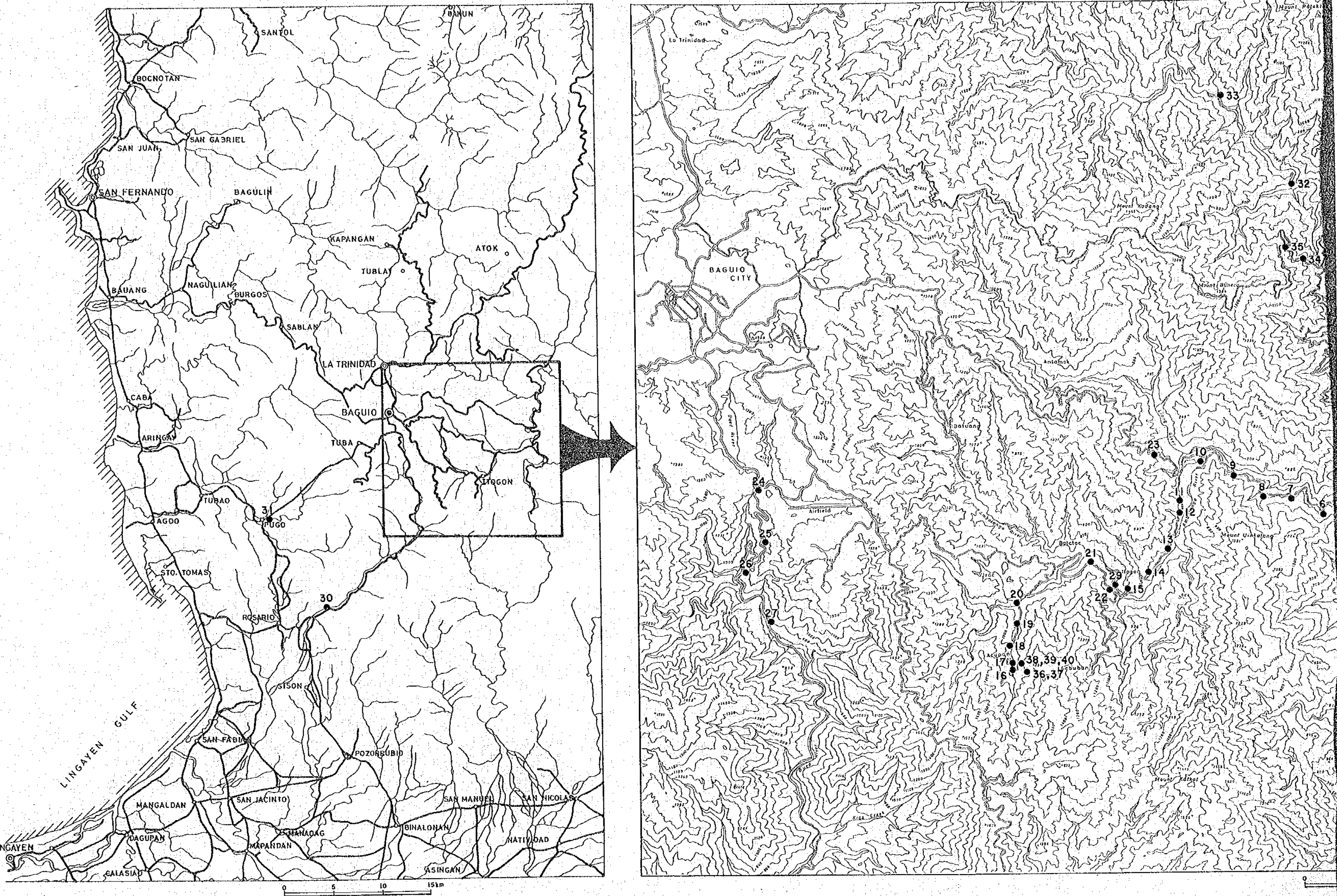

Fig. Ⅱ-2-17 Location Map of Rock Samples for Hg Analy

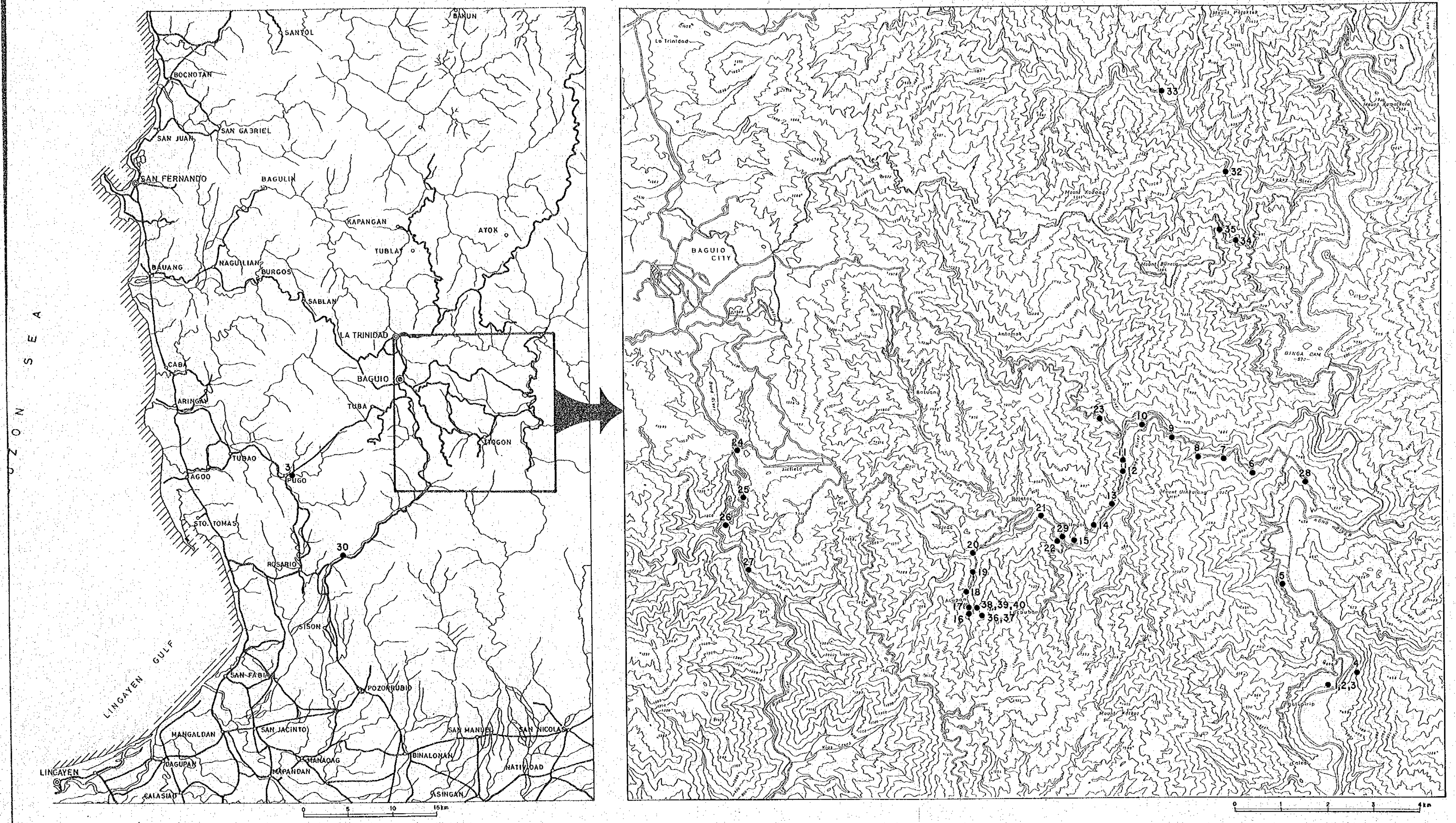

Fig. II-2-17 Location Map of Rock Samples for Hg Analysis

Table II–2–2 shows whether a given sample analyzed for mercury is altered or fresh. Sampling locations are shown on Fig. II–2–17. With reference to Table II–2–2, the following are the average Hg content of host-rocks of hot springs;

Dalupirip : 25 ppb (mean of no. 1, 2 and 3)

Itogon : 1,078 ppb (no. 29)

Klondyke : 19 ppb (no. 30)

Pugo : 269 ppb (no. 31)

Laboy : 21 ppb (mean of no. 32 and 33)

Acupan : 156 (mean of no. 36, 37, 38, 39 & 40).

It can be noted from the above data that host rocks from the Itogon Bridge and Pugo hot springs and from Acupan Mine show particularly high mercury contents. The frequency

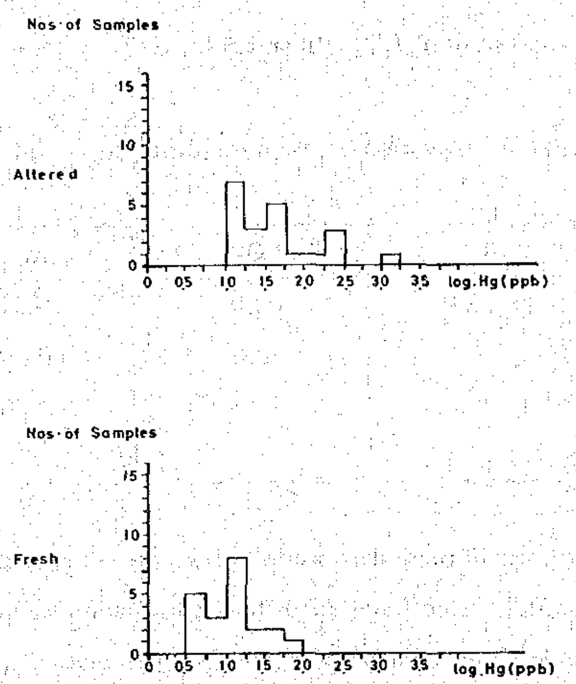

Fig. II–2–18 Histograms for Hg Contents in Rocks diagrams of mercury contents of altered samples on one and of unaltered ones on the other, are shown on a logarithmic scale in Fig. II–2–18. The minimum duplication appears on both diagrams between 1.00 and 1.25, but in most cases the Hg content is higher in altered samples than in fresh ones. It is not sure whether this alteration is linked with the hydrothermal alteration associated with the gold mineralization in the area, or whether it is connected with the hot spring alteration. For the time being, we can consider it to be related to the post-mineralization hot spring activity. As a matter of fact, relatively high Hg content (43 and 34 ppb) in no. 21 and 22 are found at Itogon Bridge even in altered rocks that are not the hot spring host rocks, whereas, in the Acupan Mine, rocks that underwent strong mineralization-alteration (shown by abundant pyrite and chalcopyrite) have relatively low Hg contents (12–24 ppb, no. 16 to 20). This is also the case for sample no. 14 from Ambalanga River. On the other hand, the host rocks of some hot springs, for example the Laboy River hot spring, show low Hg contents. This reveals that the geothermal fluids perhaps did not always cause an enrichment in mercury.

2–2–5 Factor Analysis of T, CO_2, Rn and Hg in Soil

The coefficients of correlation between the different parameters are as follows:

	T	CO_2	Rn	Hg
T	1.00	–0.20	0.24	0.19
CO_2		1.00	0.29	–0.18
Rn			1.00	0.07
Hg				1.00

The number of sets of these data seems to be quite small to allow statistical considerations. The correlation coefficients between the different parameters are characteristically very samll, too. However, the degree of connection of the four parameters may be tested using, for convenience sake, the following criteria:

0.7 to 1.0 (–0.7 to –1.0): rather strong connection

0.4 to 0.7 (–0.4 to –0.7): good connection

0.2 to 0.4 (–0.2 to –0.4): slight connection

0.0 to 0.2 (–0.0 to –0.2): really no connection

As the radon (Rn) content shows correlation of 0.24 and 0.29 with temperature (T) and carbon dioxide (CO_2) content respectively, there are slight connections between Rn and T and

Table II-2-2 Analytical Data Sheet of Rock Samples for Hg Analysis

Sample No.	Location	Geological formation	Rock name	Alteration	Hg contents (ppb)	Remarks
1	Dalupirip	Pugo	andesitic meta-volcanics fine grained, schistose	deep green, altered hydrothermally, Py. diss.	37	host rock for discharging hot spring
2	″	″	″	silicified strongly, quartz vein rich.	27	″
3	″	″	″	altered hydrothermally, calcite vein rich.	12	″
4	″	″	andesitic vol. breccia	quartz and calcite vein rich.	5	
5	″	Aguno batholith	hornblende diorite	fresh, although hb. is altered to chlo. partialy.	10	
6	along S. Liang	Pugo	meta-sediments of coarse basic pyroclastics	fresh, dark gray in colour.	7	
7	″	″	meta-sediments of fine basic pyroclastics	fresh, deep gray in colour.	40	
8	″	Basement	green schist	fresh.	5	
9	″	″	meta-sediments of basic pyroclastics	fresh, although Py. imp. imp.	12	
10	″	″	actinolite schist	silicified strongly.	45	
11	along S. Ambalanga	Aguno batholith	hornblende diorite	fresh.	29	
12	″	″	″	fresh, although hb. is altered to chlo. and Py. diss. weakly	14	
13	″	″	″	fresh. no Py. and hb. is fresh.	12	
14	″	″	″	altered by ore mineralization. hb. is altered to chlo. & bio.	10	
15	″	″	quartz diorite	fresh, although hb. is altered to chlo. partially. no Py.	10	
16	Acupan	Balatoc plug	dacite	altered by mineralization. calcite, Py, Cp. rish. hb. is fresh.	12	
17	″	Aguno batholith	quartz diorite	altered. Py. & Cp. rich. hb. is altered to chlo. & bio. partialy.	24	
18	″	″	hornblende quartz diorite	altered. Py. diss. & stringer rich. hb. is altered to actinolite.	12	
19	″	″	hornblende diorite	altered. Py. stringer rich. hb. is altered to chlo.	14	
20	″	″	″	altered. much Py. stringer & dss., hb. is altered to chlo.	14	
21	Itogon	Zig. Em.	andesitic lapilli toff	altered. argillied.	43	
22	″		andesite dyke	altered. chloritized & quartz veined. much Py. stringer & diss.	34	
23	Antamok	Aguno batholith	hornblende diorite	fresh, Py. diss. weakly and bearing malachite.	7	
24	Kennon Rd.	Klondyke	auto-brecciated andesite	fresh. grayish green in colour. chlo. & calcite rich.	5	
25	″	″	andesitic tuff breccia	fresh. deep green in colour. chlo. & calcite rich.	24	
26	″		diorite	fresh. hb. is altered to chlo. partialy.	7	
27	″	Klondyke	andesitic coarse tuff	fresh. calcite rich.	5	
28	along S. Liang	Pugo	chlorite schist	fresh. calcite veinlet network and bearing malachite.	5	
29	Itogon	Balatoc plug	dacite breccia	altered. Py. diss. with calcite veinlet network.	1078	host rock for discharging hot spring
30	Klondyke	Klondyke	tuffaceous sandstone	fresh. dark gray in colour.	19	″
31	Pugo hot-spring	Rosario	″	altered. chloritized and much Py. diss.	269	″
32	Laboy	Aguno batholith	hornblende quartz diorite	altered to white. calcite veinlet rich.	17	″
33	″	″	″	altered. hb. is altered to chlo. & epi., calcite & Py. rich.	24	″
34	″	″	hornblende diorite	fresh. greenish gray. hb. is black in colour. no Py.	12	
35	″	″	micro hornblende diorite	fresh. grayish green. hb. is fresh. no Py.	19	
36	Acupan		diorite	silicified strongly. hb. is altered to chlo., Py. diss.	161	host rock for discharging hot spring
37	″		andesite	silicified strongly.	82	″
38	″	Balitoc plug	dacite breccia (fine)	altered. pale green. chlo. & calcite rich.	190	″
39	″	″	″ (coarse)	altered. pale green chlo. & calcite rich	48	″
40	″	″	″ (older)	altered. pale green. chlo. & calcite rich	298	″

between Rn and CO_2. There is also a slight negative correlation between T and CO_2 content. However, there is really no correlation between Rn content and Hg content. Using the four variables: T, CO_2 and Rn content in soil air, and Hg content in soil, a principal factor analysis can be made although the number of parameters and sets of data are both small. Nevertheless, the factor analysis, within the range covered by the data, allows examination of the advantages and problems of the different methods used in the geochemical exploration.

The Pearson integrated correlation factors are obtained from the raw data, and the following results are derived after the Varimax rotation for factor loading (See also the geographical representation on Fig. II–2–19).

	first factor	second factor
T	0.530	0.120
CO_2	–0.349	0.491
Rn	0.202	0.572
Hg	0.400	–0.049

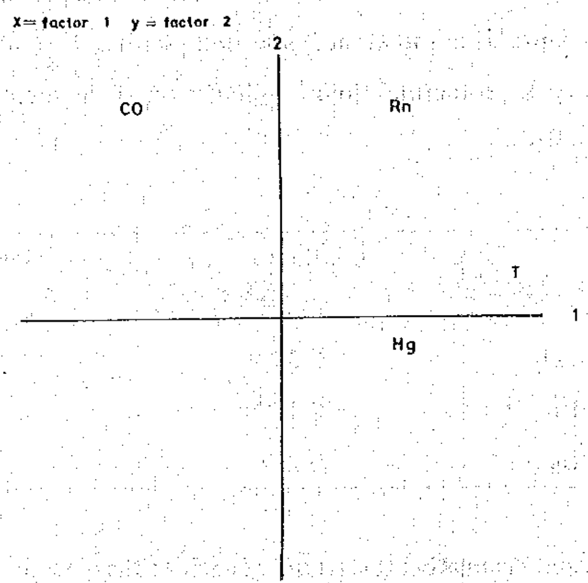

Fig. II–2–19 Factor Loading for Variables

This shows the T and the Hg content as first factors, and the CO_2 and Rn content in soil air as second. The contribution of the factors are similar (0.604 for the first factor and 0.585

for the second), and this may be expalined by the general dilution of the values taken by each variable. However, analysis of each variable yields the following communalities:

T	0.296
CO_2	0.363
Rn	0.368
Hg	0.162

All these values are small, especially those concerning the T and the Hg content. This means that there is a strong influence of some peculiarity outside the first and second factors, as previously seen in the examination of the degree of connection of one variable with respect to the others. In conclusion, judging from the factor analysis of the 50 sets of four variables used in the survey, there may be some doubts about the efficacy of some of these factors as exploration indices. Conversely speaking, the positive or negative correlation between the different variables probably become inexplicit because the geothermal manifestations at the surface are not very strong.

As regards the significance of this factor analysis, although many problems remain unsolved, the T and the Hg content apparently act as first factors and, as the distribution maps of these two parameters (Fig. II–2–5 and II–2–16) shows a good correlation with hot springs, we may say that these reflect the movements of geothermal fluids at depth. On the other hand, since the CO_2 and Rn contents in soil air act as second factors, these parameters do not seem to be related to the activity of geothermal fluids. Calculation of the factor weights of each parameter yields the following results:

	first factor	second factor
T	0.387	0.091
CO_2	−0.274	0.376
Rn	0.167	0.443
Hg	0.271	−0.031

Using these data, and calculating the scores of each of these factors for every measurement point, the distribution maps of Fig. II–2–20 and II–2–21 showing factor scores are obtained.

Without forgetting the limitations already pointed out earlier, it may be inferred that the first factor corresponds to the activity of geothermal fluids, and the second one to the presence around Batuang of andesites and granodioritic porphyries.

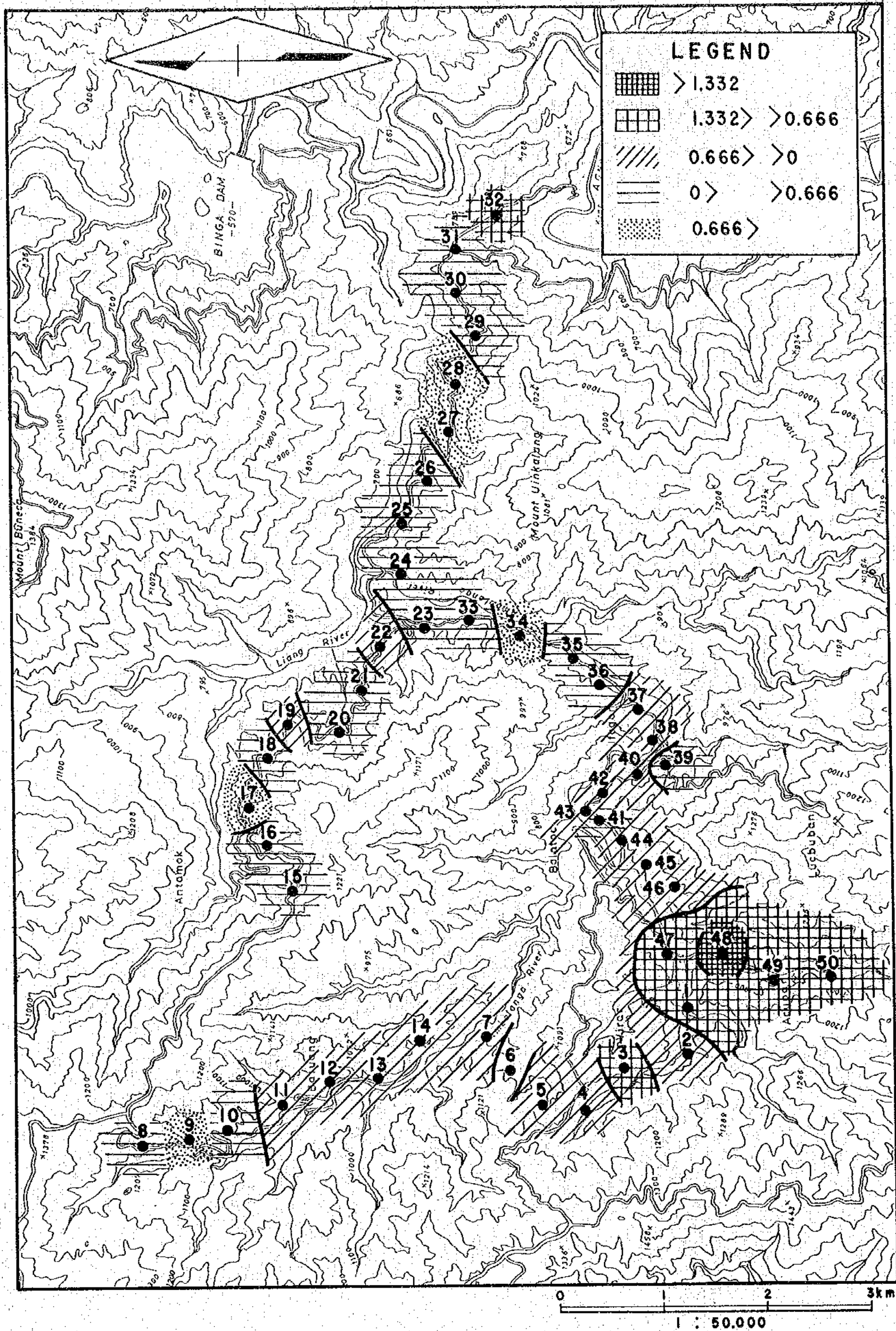

Fig. II–2–20 Distribution Map of Factor Score (Factor–1)

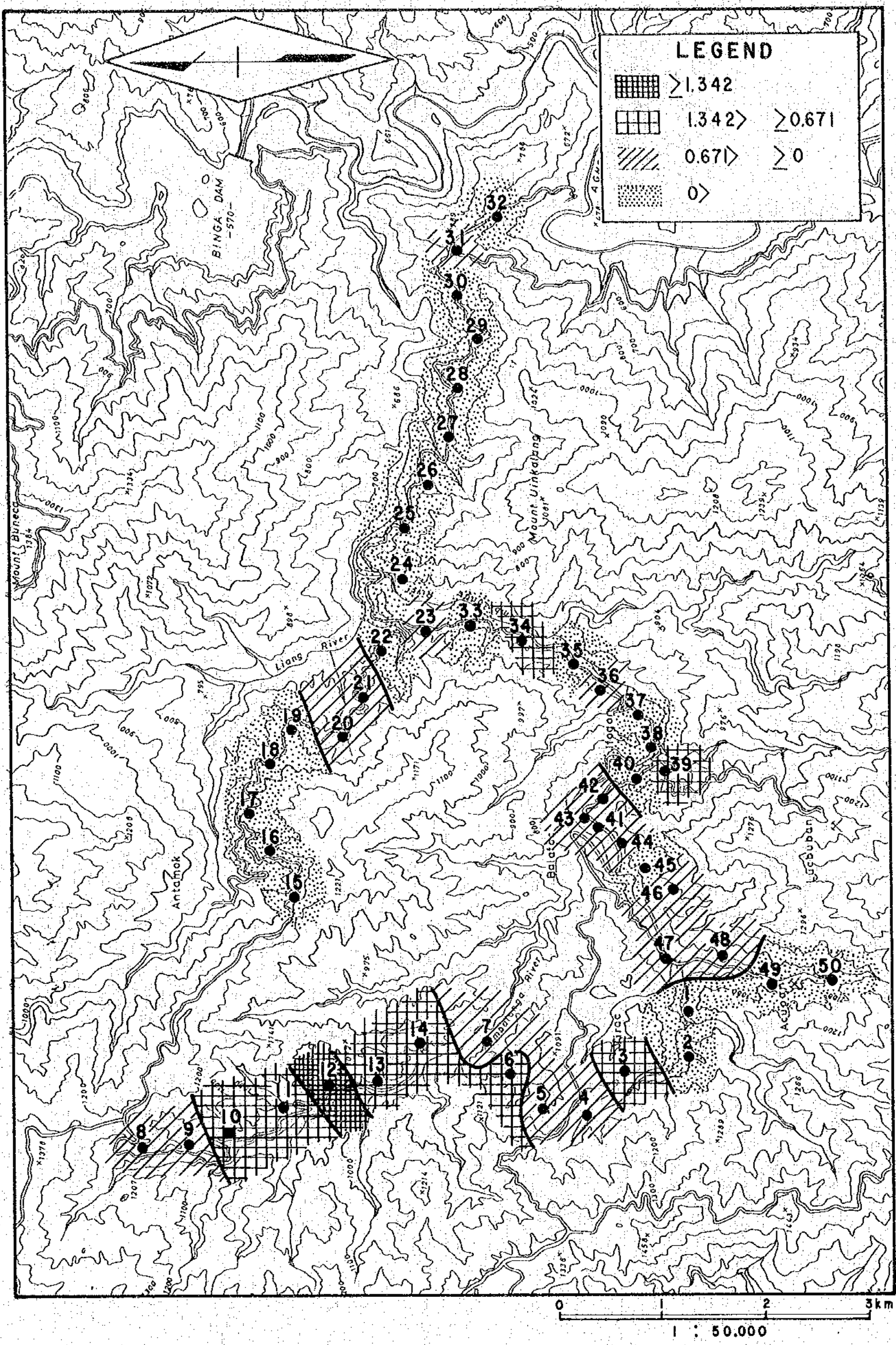

Fig. II–2–21 Distribution Map of Factor Score (Factor–2)

2–2–6 Measurement of T, CO_2, Rn and Hg in Soil

Of the four parameters considered in the geochemical exploration at one meter depth, the temperature and the mercury content in soil reflect the activity of geothermal fluids, whereas the other two variables which do not seem to be directly linked with the activity, reflect geological differences. Concerning the connection between mercury content and mineralization, the relation is not very clear between gold-silver mineralization and mercury content. However, within the limits of the sampling method, may be disregarded any relation between mercury content and copper mineralization. It is generally observed that for copper and gold-silver mineralizations occuring in a given area at a given period of time, the gold-silver stage, in many cases, postdated the copper mineralization. The mercury enrichment, likewise probably occur in the later stage of a given series of geothermal fluid activity. The reason for this may be the evolution of the chemical characteristics of the associated intrusive and extrusive rocks. In any case the distribution of mercury contents reflect the whole activity of geothermal waters accumulated at depth over a long period of time.

Carbon dioxide and radon contents, which were measured at intervals of about 500 m reflect geological differences rather than geothermal fluid activity. It is possible, however, that other correlations will appear if the intervals between sampling points will be reduced and the superficies of the surveyed area be reflected.

Unfortunately, the activity of underground geothermal fluids does not act very strongly on the four parameters measured at the surface. This causes limitations on the effectiveness of these parameters with regards to the understanding of underground processess. For interpretative investigation of movements of hydrothermal fluids at depth, measurements not only of the first factor, namely the temperature and the mercury content, but also the carbon dioxide and radon concentrations should be made. However, concerning the measurement of carbon dioxide content, as the soils of the surveyed area are poorly developed, it is difficult to obtain at each point the same condition for measurement of the gas concentration, and it is perhaps sufficient, for this geochemical exploration at one meter depth, to measure the temperature, the mercury content in soil and the radon concentration.

2–3 Geochemical Survey of the Hot Spring Water

During this survey, 10 hot spring water samples were taken from seven (7) locations: Dalupirip, Itogon, Klondyke, Asin, Pugo, Laboy and Acupan mines. Gas samples were also taken from exhalations. Chemical and isotopic analyses were done on the water samples. The locations of the hot spring are shown in Figure II–2–22; and summary is given in Table II–2–3.

2–3–1 The Source Regions of Hot Springs

The Dalupirip hot spring ascends from within the boulders below the Agno River. The source area measures approximately 6m x 7m where three (3) horizontal pipes were constructed within cubicles for drainage of the hot spring. The sampled water was taken from the drainage pipe having the highest temperature (42.5°C). The total discharge was observed to be 150 l/min., temperature ranges from 37.2°C to 42.5°C and field pH of 5.5. Found under the sedimentary pebbles along the Agno River are green andesitic altered pyroclastic rocks, which suffered strong pyritization and silicification but no bleaching was observed. Many quartz veins and calcite veinlets were also observed as well as white crystals of gypsum and green crystals of iron sulfate.

Itogon hot spring is located at 150 m to 300 m above Itogon bridge. The host rock could be the Balatoc plug or the andesites that intrude it. There are three main springs in the area where temperature ranges from 41.3°C to 89.5°C, pH 6.5 to 7.5, and discharge at approximately 10 l/min. Two samples were taken from the springs having the highest temperatures. The host rock, where spring water discharges along its joint surfaces, suffered grey green alteration with calcite veinlets. Besides gypsum and iron sulfates, there are also large amounts of calcite sinters. Hot spring gas bubbles were observed at the spring with the highest temperature. Of the 87 ml of the gas collected, only 0.05 ml contained H_2S while 86.95 ml contained CO_2.

Klondyke hot spring is located near downstream of Bued River. The host rocks consist of andesitic pyroclastic and conglomeratic formations. Numerous calcite veins were also observed. The hot waters probably discharges along a NE–SW trending fault zone and along the associated joint surfaces. Temperature ranges from 44°C to 49°C and pH is 7.5. White to yellow precipitates of acicular sulfur crystals are locally observed. Collection of gas bubbles were done using gas detection tube and showed that CO_2 concentration is less than 0.05% and H_2S is below detection limit.

Asin hot spring is located at approximately 10 km from the city of Baguio. The locality was reconstructed so that the thermal discharge flow to a 4m x 8m area of the fluvial sediments and accumulates into a pond-like reservoir, thus no discharge rate was taken. Measured temperature is 73.8°C and pH is 8.0. Gas bubbles in the pond were collected and analyzed using gas detector and showed that CO_2 and H_2S concentration are below detection limit, i.e. less than 0.05% and 0.005%, respectively. No precipitates of sulfur were observed.

Pugo hot spring is located at the left bank of the Pugo River. The fluid discharges at two locations from within sedimentary fluvial sand. Temperature is from 35.3°C to 36.3°C while

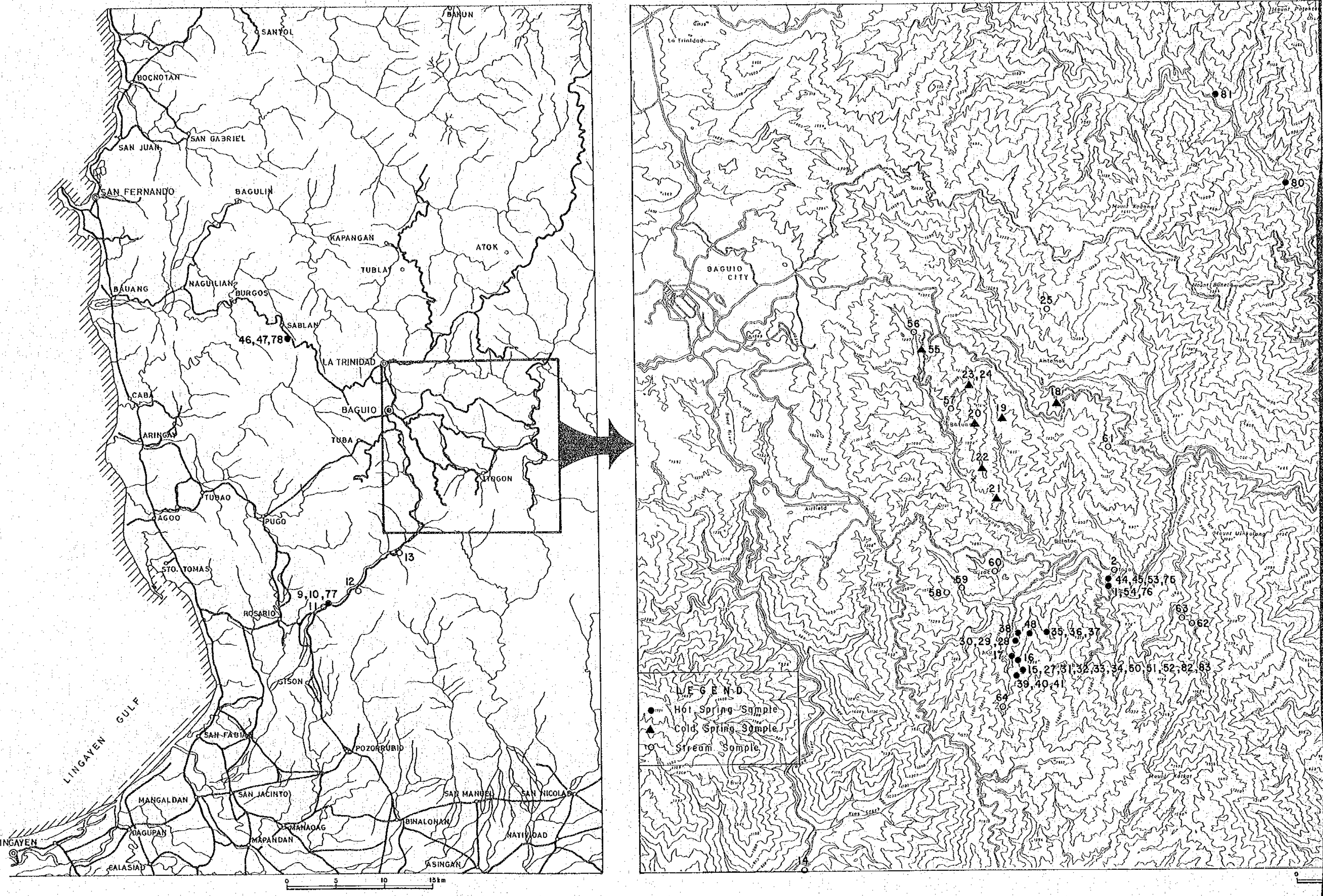

Fig. II-2-22 Location Map of Spring Water Samples

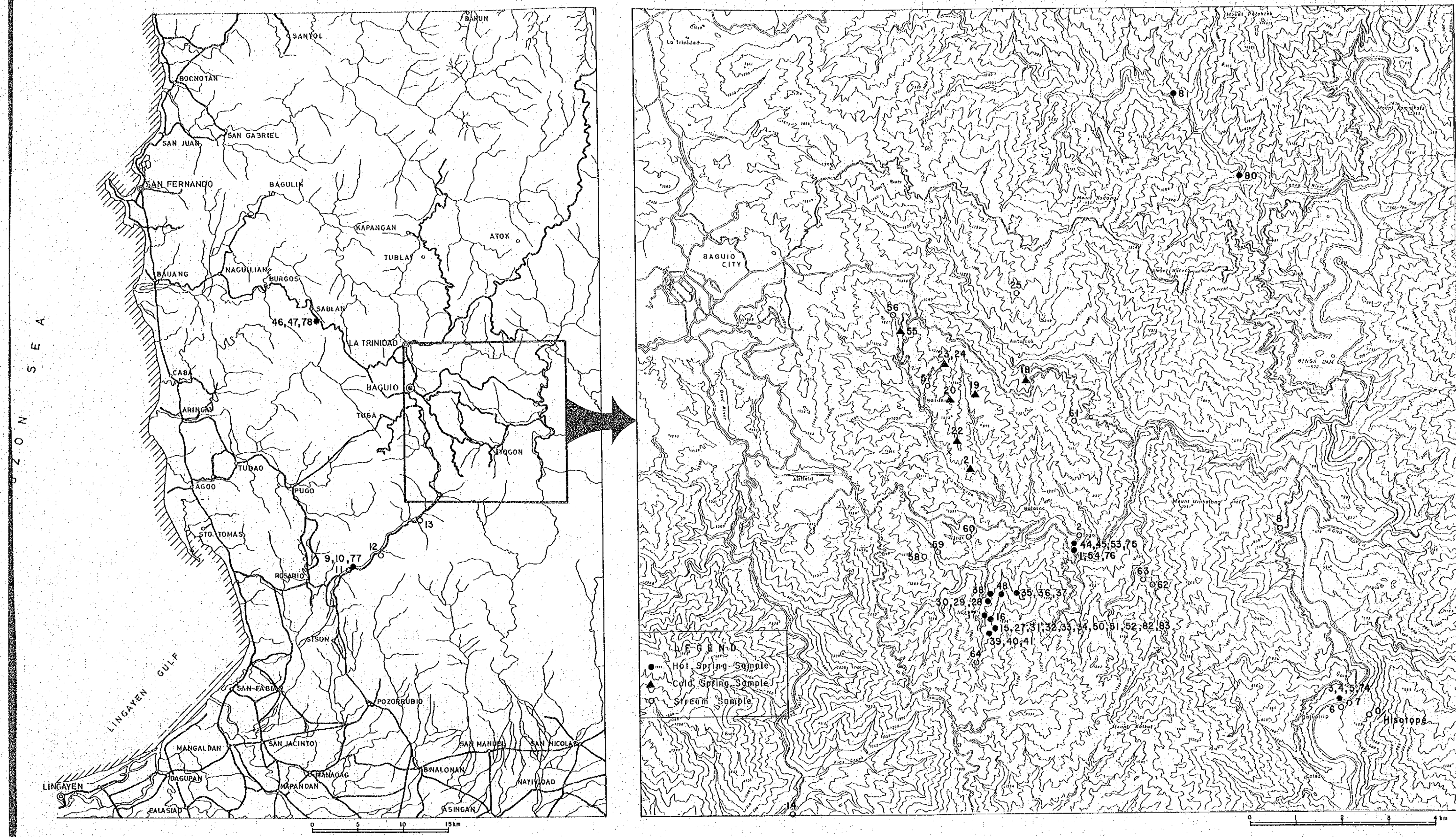

Fig. II-2-22 Location Map of Spring Water Samples

Table II–2–3 List of Spring Water Samples

SAMPLE CODE	HOT SPRING LOCATION	ELEVATION M. a.s.l.	TEMPERATURE (°C)	pH	DISCHARGE VOL. (L/min.)	%V GAS		DEPOSIT	COUNTRY ROCK/GEOLOGY
						CO_2	H_2S		
DA	Dalupirip	420	42.5	5.5	> 50	–	–	calcite & quartz vein. $CaSO_4$ & $FeSO_4$ films	gravels on Pugo formation
IT–1	Itogon	680	89.5	7.5	5	99.94	0.06	calcite veinlet, calcite sinter, gypsum-like crystals, $FeSO_4$	Balatoc Plug
IT–2			62.2	7.5	5	–	–		along the contact between lower Balatoc Plug and overlying deteric
KL	Klondyke	240	49.5	7.5	10	<0.05	<0.005	calcite vein	andesitic tuffaceous sandstone (Rosario Formation)
AS	Asin	260	73.8	8.0	not sure	<0.05	<0.005	none	gravels
PU	Pugo	80	36.3	7.0	5–6	<0.05	<0.005	none	gravels on tuffaceous sandstone (Rosario formation)
LA–1	Laboy	660	47.5	7.0	10	–	–	calcite thin veinlet along jointing	hb. qtz diorite
LA–2		700	47.5	7.0	15	–	–	calcite epidote veinlet;	granite
BA–1	Balatoc (Acupan Mine)	Acupan mine 3300 level (519m)	81.0	7.5	25	–	–	gypsum and calcite vein	diorite
BA–2		3150 level (565m)	62.1	8.0	60–80	?	?		andesite

Table II–2–4 Analytical Data Sheet for Spring Water Samples

No.	1		2		3		4		5		6		7		8		9		10		11	
Location	Itogon		Itogon		Dalupirip		Dalupirip		Dalupirip		Dalupirip		Dalupirip		Labeien		Klondykes		Klondykes		Klondykes	
Code	E1		E3		E4		E5		E6		E7		E8		E9		E10		E11		E12	
Sampling Date	3, June, '82		3, June, '82		3, June, '82		3, June, '82		3, June, '82		3, June, '82		3, June, '82		3, June, '82		4, June, '82		4, June, '82		4, June, '82	
T(°C)	50.5		27.0		44.0		41.0		43.0		22.0		21.0		23.5		39.0		45.0		24.0	
pH	7.43		7.64		7.10		7.08		6.78		7.60		7.50		7.93		7.43		7.78		7.48	
Conductivity (μ℧/cm)	2,348		1,701		1,361		1,429		1,361		201		315		199		2,025		2,348		451	
Discharge(ℓ/min)					7~8		4		7~8						7.5		1.5		3			
Chemi. Ana	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ
Na^+	416	18.095	84.0	3.654	200	8.699	208	9.047	200	8.699	8.00	0.348	12.5	0.544	6.50	0.283	304	13.223	388	16.877	8.50	0.370
K^+	65.0	1.662	14.0	0.358	5.60	0.143	6.00	0.153	5.50	0.141	tr	–	1.50	0.038	tr	–	2.40	0.061	2.30	0.059	3.90	0.100
Ca^{2+}	98.0	4.890	309	15.419	87.0	4.341	94.0	4.691	96.0	4.790	28.0	1.397	38.0	1.896	29.0	1.447	116	5.788	132	6.587	76.0	3.792
Mg^{2+}	9.00	0.741	16.3	1.341	10.7	0.880	8.70	0.716	11.3	0.930	5.60	0.461	7.20	0.592	4.40	0.362	1.50	0.123	tr	–	7.07	0.582
Cl^-	145	4.090	104	2.933	45.4	1.281	47.2	1.331	43.8	1.235	4.17	0.118	19.2	0.542	4.08	0.115	486	13.708	597	16.839	7.09	0.200
SO_4^{2-}	586	12.201	758	15.782	588	12.243	639	13.305	586	12.201	5.50	0.115	67.8	1.412	8.25	0.172	296	6.163	340	7.079	123	2.561
HCO_3^-	660	10.817	47.0	0.770	6.10	0.100	8.54	0.140	7.32	0.120	87.8	1.439	62.2	1.019	97.6	1.600	30.5	0.500	40.2	0.659	70.2	1.151
CO_3^{2-}																						
H_2CO_3																						
Li	2.10		tr	–	tr	–	tr	–	tr	–							tr	–	tr	–		
As																						
B	9.63	0.891	tr	–	tr	–	tr	–	tr	–							2.38	0.220	3.95	0.365	tr	–
SiO_2	299	4.976	49.3	0.821	50.5	0.840	46.9	0.781	50.1	0.834	29.2	0.486	21.2	0.353	52.8	0.879	39.1	0.651	39.6	0.659	30.1	0.501
NH_4^+																						
T.S.M.(mg/ℓ)	2,287.6		1,381.6		993.3		1,058.3		1,000.0		168.3		229.6		202.6		1,277.9		1,543.0		325.9	
Alkalinity																						
Acidity																						
Remarks	hot spring		stream water		hot spring		hot spring		hot spring		stream water		stream water		cold spring		hot spring		hot spring		stream water	
Reference	B.E.D. (9/Aug/82)		do		do		do		do		do		do		do		do		do		do	

No.	12		13		14		15		16		17		18		19		20		21		22	
Location	Kennon Rd.		Kennon Rd.		Kennon Rd.		Acupan		Acupan		Acupan		Antamok		Antamok		Antamok		Batuang		Batuang	
Code	E13		E14		E15		E16		E17		E18		E19		E20		E21		E22		E23	
Sampling Date	4, June, '82		4, June, '82		4, June, '82		5, June, '82		5, June,'82		5, June, '82		7, June, '82		7, June, '82		7, June, '82		7, June, '82		7, June, '82	
T (°C)	21.0		23.0		19.0		62.0		85.0		80.0		19.0		20.0		18.0		18.5		19.0	
pH	7.62		7.76		7.28		7.99		7.95		6.88		7.07		6.20		6.78		6.62		6.73	
Conductivity (μʊ/cm)	134		374		515		4,932		4,514		4,839		875		1,805		1,656		121		137	
Discharge(ℓ/min)							5						10		10		10					
Chemi. Ana.	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ
Na^+	7.00	0.304	6.00	0.261	6.05	0.263	939	40.844	830	36.103	949	41.279	7.50	0.326	17.0	0.739	13.2	0.574	9.20	0.400	8.24	0.358
K^+	0.28	0.007	2.90	0.074	1.46	0.037	156	3.990	134	3.427	162	4.143	1.0	0.026	3.24	0.083	4.24	0.108	0.30	0.008	0.30	0.008
Ca^{2+}	16.8	0.838	55.9	2.789	84.8	4.232	130	6.487	45.6	2.275	54.4	2.715	151	7.535	425	21.208	310	15.469	7.20	0.359	6.40	0.319
Mg^{2+}	2.20	0.181	6.53	0.537	8.50	0.699	8.80	0.724	8.38	0.690	2.00	0.165	24.2	1.991	27.0	2.222	63.0	5.184	4.20	0.346	6.25	0.514
Cl^-	9.93	0.280	9.93	0.280	13.0	0.367	1,302	36.725	1,223	34.496	1,257	35.455	18.9	0.533	14.2	0.401	8.86	0.250	6.20	0.175	4.73	0.133
SO_4^{2-}	7.00	0.146	91.9	1.913	194	4.039	366	7.621	351	7.308	305	6.350	319	6.642	1,241	25.839	1,006	20.946	3.57	0.074	36.7	0.764
HCO_3^-	29.9	0.490	12.2	0.200	28.7	0.470	352	5.769	122	1.999	515	8.440	210	3.442	40.9	0.670	85.8	1.406	72.6	1.190	35.0	0.574
CO_3^{2-}																						
H_2CO_3																						
Li							4.60		4.50		5.10											
As																						
B							35.6	3.293	38.1	3.525	43.9	4.061										
SiO_2	23.4	0.389	44.6	0.742	19.7	0.328	137	2.280	206	3.429	182	3.029	27.7	0.461	37.4	0.622	44.6	0.742	37.0	0.616	40.3	0.671
NH_4^+																						
T.S.M.(mg/ℓ)	96.5		230.0		356.2		3,426.4		2,958.1		3,470.3		759.3		1,805.7		1,535.7		140.3		137.9	
Alkalinity																						
Acidity																						
Remarks	stream water		stream water		stream water		hot spring 3,350L		hot spring 3,300L		hot spring 3,150L		cold spring 400L		cold spring 400L		cold spring 400L		cold spring		cold spring	
Reference	B.E.D. (9/Aug/82)		do		do		do		do		do		do		do		do		do		do	

No.	23		24		25		26		27		28	
Location	Batuang		Batuang		Antemok		Antemok		Acupan		Acupan	
Code	E24		E25		E26		Antamok		Benquet-1		Benquet-2	
Sampling Date	7, June, '82		7, June, '82		9, June, '82				19, Aug., '77		18, Aug., '77	
T (°C)	19.0		18.0		17.5		37.0		79.5		99	
pH	5.51		5.30		6.79		3.35		7.84		8.36	
Conductivity ($\mu\mho$/cm)	518		647		258		4,653					
Discharge(ℓ/min)	1		0.5		20				40			
Chemi. Ana.	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ
Na^+	12.6	0.548	14.8	0.644	5.10	0.222	360	15.659	866	37.669	1,245	54.154
K^+	0.61	0.016	0.73	0.019	0.60	0.015	22.3	0.570	117	2.992	178	4.553
Ca^{2+}	40.0	1.996	49.6	2.475	32.0	1.597	580	28.942	121	6.038	195	9.731
Mg^{2+}	28.8	2.370	39.0	3.209	7.75	0.638	94.0	7.735	5.4	0.444	0.3	0.025
Cl^-	7.09	0.200	2.95	0.083	2.36	0.067	613	17.290	1,202	33.904	1,550	43.720
SO_4^{2-}	230	4.789	247	5.143	52	1.083	2,199	45.786	392	8.162	332	6.913
HCO_3^-	16.5	0.270	22.4	0.367	83.9	1.375			157	2.573	278	4.556
CO_3^{2-}									2	0.067	10	0.333
H_2CO_3									6	0.097	3	0.048
Li							2.40		4.2		7.0	
As												
B							10.60	0.981	47	4.348	68	6.290
SiO_2	34.1	0.568	39.0	0.649	21.8	0.363	47.6	0.792	177	2.946	295	4.910
NH_4^+												
T.S.M.(mg/ℓ)	369.7		415.5		205.5		3,926.5		3,092.4		4,154.3	
Alkalinity												
Acidity												
Remarks	cold spring		cold spring		stream water		hot spring 1,850L		hot spring 3,300L		hot spring 3,150L	
Reference	B.E.D. (9/Aug/82)		do		do		do		KRTA (Sep/77)		do	

No.	29		30		31		32		33	
Location	Acupan		Acupan		Acupan		Acupan		Acupan	
Code	Benquet-3		Benquet-4		Benquet-5		Benquet-6		Benquet-7	
Sampling Date	19, Aug., '77		19, Aug., '77		18, Aug., '77		19, Aug., '77		19, Aug., '77	
T (°C)	80		72.5		64.5		55		73	
pH	–		8.12		8.05		7.80		7.25	
Conductivity ($\mu\mho$/cm)										
Discharge(ℓ/min)	50		2~3				20		60	
Chemi. Ana.	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ
Na^+	1,077	46.846	990	43.062	856	37.234	37	1.609	41	1.783
K^+	158	4.041	138	3.530	122	3.120	3.9	0.100	4.7	0.120
Ca^{2+}	57	2.844	67	3.343	210	10.479	438	21.856	408	20.359
Mg^{2+}	2.0	0.165	2.2	0.181	8.3	0.683	11.2	0.922	8.5	0.699
Cl^-	1,405	39.630	1,248	35.202	1,260	35.540	7	0.197	12	0.338
SO_4^{2-}	540	11.243	495	10.306	410	8.537	1,440	29.983	1,420	29.566
HCO_3^-	–	–	198	3.245	336	5.507	87	1.426	85	1.393
CO_3^{2-}	–	–	4	0.133	5	0.167	1	0.033	0	0.000
H_2CO_3	–	–	4	0.064	8	0.129	3	0.048	10	0.161
Li	5.9		5.6		4.6		0.05		0.07	
As										
B	55	5.088	57	5.273	47	4.348	<0.05	0.005	0.96	0.089
SiO_2	236	3.928	206	3.429	167	2.779	26	0.433	28	0.466
NH_4^+										
T.S.M.(mg/ℓ)	3,530.0		3,409.2		3,429.3		2,054.2		2,018.2	
Alkalinity										
Acidity										
Remarks	hot spring 3,150L		hot spring 3,150L		hot spring 3,150L		hot spring 3,150L		hot spring 3,150L	
Reference	do		do		do		do		do	

No.	34		35		36		37		38		39	
Location	Acupan		Acupan		Acupan		Acupan		Acupan		Acupan	
Code	Benquet-8		Benquet-9		Benquet-10		Benquet-11		Benquet-12		Benquet-13	
Sampling Date	19, Qug., '77		20, Aug., '77		20, Aug., '77		20, Aug., '77		20, Aug., '77		20, Aug., '77	
T (°C)	57		65		52		97		63		51.5	
pH	7.25		8.23		7.89		–		7.57		7.04	
Conductivity (μυ/cm)												
Discharge(ℓ/min)	5		15		10		<1				8	
Chemi. Ana.	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ
Na^+	23	1.000	845	36.755	942	40.974	1,041	45.281	85	3.697	32	1.392
K^+	3.3	0.084	118	3.018	124	3.172	139	3.555	7.2	0.184	2.2	0.056
Ca^{2+}	425	21.208	50	2.495	98	4.890	119	5.938	312	15.569	505	25.200
Mg^{2+}	12.0	0.987	1.7	0.140	7.0	0.576	1.3	0.107	2.9	0.239	11.0	0.905
Cl^-	8	0.226	935	26.373	1,142	32.212	1,360	38.361	12	0.338	6	0.169
SO_4^{2-}	1,400	29.150	740	15.408	622	12.951	488	10.161	1,000	20.821	1,520	31.648
HCO_3^-	173	2.835	188	3.081	266	4.360	–		72	1.180	259	4.245
CO_3^{2-}	0	0.000	5	0.167	3	0.100	–		1	0.033	0	0.000
H_2CO_3	21	0.339	3	0.048	8	0.129	–		4	0.064	58	0.935
Li	0.05		4.4		4.7		5.2		0.10		0.07	
As												
B	<0.05	0.005	31	2.868	45	4.163	55	5.088	0.05	0.005	<0.05	0.005
SiO^2	26	0.433	140	2.330	153	2.546	177	2.946	46	0.766	36	0.599
NH_4^+												
T.S.M.(mg/ℓ)	2,091.4		3,056.7		3,410.0		3,380.3		1,542.2		2,429.3	
Alkalinity												
Acidity												
Remarks	hot spring 3,150L		hot spring 2,900L		hot spring 2,900L		hot spring 2,900L		hot spring 2,900L		hot spring 2,900L	
Reference	KRTA (Sep./77)		do		do		do		do		do	

No.	40		41		42		43		44	
Location	Acupan		Acupan		Acupan		Acupan		Itogon	
Code	Benquet-14		Benquet-15		Benquet-16		Benquet-17		Benquet-18	
Sampling Date	20, Aug., '77		20, Aug., '77		20, Aug., '77		20, Aug., '77		19, Aug., '77	
T (°C)	–		45		24		43		94	
pH	7.61		7.75		–		–		7.47	
Conductivity (μυ/cm)										
Discharge(ℓ/min)			50		200		20,000		5	
Chemi. Ana.	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ
Na^+	42	1.827	44	1.914	18	0.783	124	5.394	570	24.793
K^+	2.8	0.072	3.0	0.077	1.7	0.043	15	0.384	81	2.072
Ca^{2+}	592	29.541	550	27.445	274	13.673	445	22.206	86	4.291
Mg^{2+}	3.4	0.280	3.8	0.313	12.9	1.062	15.9	1.308	4.0	0.329
Cl^-	7	0.197	10	0.282	<5	0.141	151	4.259	397	11.198
SO_4^{2-}	1,500	31.232	1,475	30.711	770	16.032	1,185	24.673	655	13.638
HCO_3^-	195	3.196	192	3.147	–	–	–	–	473	7.752
CO_3^{2-}	2	0.067	2	0.067	–	–	–	–	2	0.067
H_2CO_3	10	0.161	6	0.097	–	–	–	–	38	0.613
Li	0.05		0.07		0.05		0.61		3.0	
As										
B	0.32	0.030	<0.05	0.005	<0.05	0.005	7.8	0.722	24	2.220
SiO^2	34	0.566	32	0.533	30	0.499	32	0.533	137	2.280
NH_4^+										
T.S.M.(mg/ℓ)	2,388.5		2,317.9		1,111.7		1,975.7		2,467.0	
Alkalinity										
Acidity										
Remarks	hot spring 2,900L		hot spring 2,900L		mine drainage 1,500L		mine drainage 2,000L		hot spring	
Reference	do		do		do		do		do	

No.	45		46		47		48		49		50	
Location	Itogon		Asin		Asin		Acupan		Acupan		Acupan	
Code	Benquet-19		Benquet-20		Benquet-21		BED-1		BED-2		BED-3	
Sampling Date	19, Aug., '77		21, Aug., '77		21, Aug., '77		25, Oct., '78		25, Oct., '78		25, Oct., '78	
T (°C)	85		70		41		96		87		61	
pH	7.37		8.78		7.43		8.5		6.8		8.8	
Conductivity (μ℧/cm)							4,115		–		4,478	
Discharge(ℓ/min)					2.5		60		<6		30	
Chemi. Ana.	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ
Na^+	355	15.441	523	22.749	122	5.307	783	34.058	–	–	775	33.710
K^+	56	1.432	11	0.281	1.7	0.043	125	3.197	–	–	88.2	2.256
Ca^{2+}	152	7.585	222	11.078	64	3.194	12.2	0.609	–	–	234	11.677
Mg^{2+}	16.0	1.317	N.D.	0.000	5.0	0.411	1.5	0.123	–	–	10	0.823
Cl^-	233	6.572	835	23.552	200	5.641	984	27.755	–	–	1,440	40.617
SO_4^{2-}	670	13.950	475	9.890	108	2.249	407	8.474	–	–	449	9.349
HCO_3^-	347	5.687	26	0.426	170	2.786	382	6.261	–	–	292	4.786
CO_3^{2-}	0	0.000	2	0.067	0	0.000						
H_2CO_3	34	0.548	0	0.000	21	0.339						
Li	1.8		0.2		0.1		3.36		–	–	4.11	
As							2.25		–	–	2.50	
B	9.5	0.879	9.5	0.879	3.3	0.305	38.9	3.599	–	–	40.9	3.784
SiO_2	103	1.714	32	0.533	32	0.533	267	4.444	–	–	210	3.495
NH_4^+							0.05		0.38		0.046	
T.S.M.(mg/ℓ)	1,975.5		2,135.5		727.0		3,000.6				3,539.1	
Alkalinity												
Acidity												
Remarks	hot spring		hot spring		hot spring		hot spring 2,900L		hot spring 3,150L		hot spring 3,150L	
Reference	KRTA (Sep./77)		do		do		BED-ELC (Feb./79)		do		do	

No.	51		52		53		54		55	
Location	Acupan		Acupan		Itogon		Itogon		Batuang	
Code	BED-4		BED-5		BED-6		BED-7		BED-8	
Sampling Date	25, Oct., '78		25, Oct., '78		25, Oct., '78		25, Oct., '78		26, Oct., '78	
T (°C)	59		79		86		75		20	
pH	7.8		7.7		6.3		6.0		2.7	
Conductivity (μ℧/cm)	1,757		4,267		1,470		2,323		638	
Discharge(ℓ/min)	very low		40		20		10		30	
Chemi. Ana.	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	m.eq/ℓ	
Na^+	187	8.134	750	32.623	183	7.960	376	16.355	8.67	0.377
K^+	18.5	0.473	88.2	2.256	36.1	0.923	62.2	1.591	0.57	0.015
Ca^{2+}	226	11.277	85.7	4.276	103	5.140	54.3	2.710	47.4	2.365
Mg^{2+}	2.63	0.216	7.31	0.602	17.2	1.415	7.81	0.643	16.6	1.366
Cl^-	204	5.754	1,110	31.309	417	11.762	191	5.387	24.2	0.683
SO_4^{2-}	584	12.160	272	5.663	560	11.660	481	10.015	447	9.307
HCO_3^-	126	2.065	168	2.753	244	3.999	387	6.343	–	–
CO_3^{2-}										
H_2CO_3										
Li	0.48		4.55		1.28		2.50		–	–
As	–		4.0		0.4		1.0		–	–
B	5.26	0.487	41.8	3.867	3.57	0.330	13.7	1.267	–	–
SiO_2	118	1.964	244	4.061	172	2.863	195	3.245	81.3	1.353
NH_4^+	0.035		0.031		0.042		0.036		0.040	
T.S.M.(mg/ℓ)	1,471.4		2,767.0		1,735.9		1,768.0		625.7	
Alkalinity										
Acidity										
Remarks	hot spring 3,150L		hot spring 3,300L		hot spring		hot spring		cold spring	
Reference	do		do		do		do		do	

No.	56		57		58		59		60		61		62		63		64		65		56	
Location	Batuang		Batuang		Virac		Virac		Virac		Balinguay		Itogon		Itogon		Acupan		Acupan		Acupan	
Code	BED-9		BED-10		BED-11		BED-12		BED-13		BED-14		BED-15		BED-16		BED-17		76-B-3		76-B-4	
Sampling Date	26, Oct., '78		26, Oct., '78		26, Oct., '78		26, Oct., '78		26, Oct., '78		30, Oct., '78		1, Nov., '78		1, Nov., '78		31, Oct., '78					
T (°C)	20		19.5		20		20		20		20		20		20		20		63.7		46.1	
pH	3.9		4.2		7.3		8.2		8.0		8.0		7.4		7.4		7.2					
Conductivity (μʊ/cm)	532		247		275		224		183		279		104		134		870					
Discharge(ℓ/min)			6,000		600		6,000		6,000		300		400		400		500					
Chemi. Ana.	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ
Na^+	10.0	0.435	7.33	0.319	4.0	0.174	4.67	0.203	6.33	0.275	5.67	0.247	2.67	0.116	2.67	0.116	7.50	0.326	1,360	59.156	25	1.087
K^+	0.86	0.022	0.43	0.011	0.29	0.007	0.43	0.011	0.29	0.007	0.43	0.011	0.14	0.004	0.29	0.007	1.43	0.037	200	5.115	4.0	0.102
Ca^{2+}	12.7	0.634	13.0	0.649	42.6	2.126	30.4	1.517	20.0	0.998	47.8	2.385	19.6	0.978	23.5	1.173	220	10.978	30.5	1.522	489	24.401
Mg^{2+}	8.75	0.720	9.31	0.766	5.88	0.484	9.69	0.797	7.63	0.628	8.13	0.669	1.88	0.155	2.81	0.231	20	1.646	1.83	0.151	4.43	0.365
Cl^-	24.2	0.683	27.8	0.784	3.55	0.100	4.43	0.125	3.55	0.100	3.55	0.100	3.90	0.110	4.14	0.117	6.50	0.183	1,720	48.515	3	0.085
SO_4^{2-}	284	5.913	115	2.394	86.6	1.803	50.9	1.060	33.3	0.693	25.3	0.527	5.89	0.123	18.5	0.385	469	9.765	394	8.204	1,210	25.194
HCO_3^-	–	–	–	–	71.6	1.173	80.8	1.324	77.1	1.264	145	2.376	69.8	1.144	734	12.030	126	2.065	394	6.457	150	2.458
CO_3^{2-}																						
H_2CO_3																						
Li	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	6.75		<0.01	
As	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–				
B	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	5.88	0.544	<0.1	0.009
SiO_2	74	1.232	59	0.982	24.2	0.403	27.4	0.456	42.1	0.701	49.6	0.826	45.8	0.762	23.1	0.384	27.2	0.453	372	6.191	40.7	0.677
NH_4^+	0.040		0.050		0.015		0.140		0.015													
T.S.M.(mg/ℓ) Alkalinity Acidity	414.5		231.7		238.7		208.7		190.3		285.5		149.7		809.0		877.6		4,478.2		1,726.2	
Remarks	stream water		stream water		stream water		stream water		stream water		stream water		stream water		stream water		stream water		hot spring 3,150L		hot spring 2,600L	
Reference	BED-ELC (Feb./79)		do		do		do		do		do		do		do		do		Sawkins F.J. et. al., (1979)		do	

No.	67		68		69		70		71		72		73		74		75		76		77	
Location	Acupan		Itogon		Antamok		Antomok		Antomok		Acupan		Acupan		Dalupirip		Itogon		Itogon		Klondyke	
Code	76-B-5		76-B-11		76-B-12		76-B-14		76-B-15		76-B-26		76-B-27		DA		IT-1		IT-2		KL	
Sampling Date															24, Sep., '82		24, Sep., '82		29, Sep., '82		25, Sep., '82	
T (°C)	46.1		87.9		51.7		40.6		46.1		61.1		Cold		42.5		89.5		62.2		49.5	
pH															7.90		7.68		7.79		8.36	
Conductivity (μʊ/cm)																						
Discharge(ℓ/min)															50							
Chemi. Ana.	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ
Na^+	30	1.305	620	26.968	1,620	70.465	167	7.264	120	5.220	920	40.017	8.3	0.361	71.0	3.088	267.0	11.614	332.0	14.441	397.0	17.268
K^+	4.3	0.110	8.6	0.220	107	2.737	6.1	0.156	4	0.102	110	2.813	2	0.051	2.8	0.072	43.8	1.120	53.5	1.368	2.8	0.072
Ca^{2+}	509	25.399	13.2	0.659	565	28.194	1,000	49.900	753	37.575	77	3.842	79	3.942	19.9	0.993	90.6	4.521	134.0	6.687	124.0	6.188
Mg^{2+}	4.25	0.350	8.3	0.683	92.0	7.570	20.5	1.687	19.1	1.572	14.1	1.160	12	0.987	2.8	0.230	12.6	1.037	14.2	1.168	0.2	0.016
Cl^-	4.4	0.124	516	14.554	1,890	53.310	828	23.355	302	8.518	1,270	35.822	3	0.085	7.0	0.197	55.0	1.551	64.0	1.805	555.0	15.655
SO_4^{2-}	1,370	28.525	480	9.994	1,660	34.563	1,360	28.317	1,240	25.818	87	1.811	168	3.498	125.0	2.603	600.0	12.493	600.0	12.493	355.0	7.392
HCO_3^-	162	2.655	522	8.555	886	14.521	590	9.670	798	13.079	470	7.703	110	1.803	98.0	1.606	294.0	4.818	600.0	9.833	17.0	0.279
CO_3^{2-}															0.0	0.000	0.0	0.000	0.0	0.000	0.6	0.020
H_2CO_3															0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000
Li	< 0.01		2.80		1.05		0.40		0.5		4.0		< 0.01		< 0.1		1.4		2.0		< 0.1	
As																						
B	0.12	0.011	2.35	0.217	4.83	0.447	0.64	0.059	0.52	0.046	3.95	0.370	< 0.1	0.009	0.3	0.028	4.5	0.416	5.9	0.546	4.9	0.453
SiO_2	42	0.699	191	3.179	143	2.380	82.3	1.370	69.5	1.157	254	4.227	24.8	0.413	39.0	0.649	178.0	2.963	151.0	2.513	88.3	1.470
NH_4^+																						
T.S.M.(mg/ℓ)	2,126.1		2,361.5		6,967.8		4,054.5		3,306.1		3,206.1		407.2		345		1,436		1,686		1,548	
Alkalinity															1.60		4.80		9.80		0.20	
Acidity															0.10		0.20		0.30		0.00	
Remarks	hot spring 2,600L		hot spring		hot spring 1,850L		hot spring 1,850L		hot spring 1,550L		hot spring 3,150L		cold spring 1,500L		hot spring		hot spring		hot spring		hot spring	
Reference	Sawkins F.J. et al (1979)		do		do		do		do		do		do		BED-JICA (1982)		do		do		do	

No.	78		79		80		81		82		83											
Location	Asin		Pugo		Laboy		Laboy		Acupan		Acupan											
Code	AS		PU		LA-1		LA-2		BA-1		BA-2											
Sampling Date	25, Sep., '82		26, Sep., '82		27, Sep., '82		27, Sep., '82		28, Sep., '82													
T (°C)	73.8		36.3		47.5		47.5		81.0		62.1											
pH	8.64		7.93		8.02		8.40		8.10		8.21											
Conductivity (μʊ/cm)																						
Discharge(ℓ/min)	not sure		5		10		15		25		60~80											
Chemi. Ana.	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ	mg/ℓ	m.eq/ℓ
Na^+	525.0	22.836	570.0	24.793	162.0	7.047	145.0	6.307	892.0	38.799	942.0	40.974										
K^+	12.0	0.307	3.0	0.077	2.8	0.072	1.6	0.041	129.0	3.299	145.0	3.709										
Ca^{2+}	243.0	12.126	277.0	13.822	241.0	12.026	257.0	12.824	41.9	2.091	146.0	7.285										
Mg^{2+}	0.1	0.008	0.1	0.008	0.8	0.066	0.1	0.008	5.0	0.411	5.4	0.444										
Cl^-	763.0	21.521	1,200.0	33.848	6.0	0.169	6.0	0.169	1,280.0	36.104	1,270.0	35.822										
SO_4^{2-}	217.0	4.518	2.0	0.042	930.0	19.364	910.0	18.947	385.0	8.016	420.0	8.745										
HCO_3^-	10.0	0.164	24.0	0.393	27.0	0.443	13.0	0.213	19.0	0.311	541.0	8.867										
CO_3^{2-}	9.6	0.320	0.0	0.000	0.0	0.000	0.6	0.020	0.0	0.000	0.0	0.000										
H_2CO_3	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000										
Li	0.1		<0.1		<0.1		<0.1		5.2		5.5											
As																						
B	9.1	0.842	5.1	0.472	0.1	0.009	0.1	0.009	39.5	3.654	42.9	3.969										
SiO_2	113.0	1.881	12.0	0.200	215.0	3.578	194.0	3.229	388.0	6.458	374.0	6.225										
NH_4^+																						
T.S.M.(mg/ℓ)	2,427		2,598		1,563		1,465		3,396		3,748											
Alkalinity	0.50		0.40		0.50		0.20		3.20		8.90											
Acidity	0.00		0.10		0.10		0.00		0.30		0.10											
Remarks	hot spring		hot spring		hot spring		hot spring		hot spring 3,300L		hot spring 3,150L											
Reference	BED-JICA (1982)		do		do		do		do		do											

pH is from 5.5 to 7.0. Total discharge is estimated at about 10 to 15 l/min. The water samples was taken from a well-like reservoir where hot spring gas bubbles were observed. The detection tube shows that this gas contains less than 0.05% CO_2 and less than 0.005% H_2S. The rocks outcropping in the bottom of the river at 6 to 7 meters beneath the hot spring are middle grained pyroclastic sandstones, which are chloritized and pyritized.

There are three occurrences of hot springs in the Laboy River. One at upstream, one at downstream, and one 100 m above the downstream. Near the upstream and downstream, the water discharges along the joint surfaces of an amphibole-bearing quartz-diorite which suffered a general silicification with transformation of amphibole into epidote or chlorite and development of numerous calcite veinlets. The pyritization is particularly strong in the host rocks of the upstream hot spring. For each of these two hot springs, the discharge is around 15 l/min, temperature range is 47.5 to 48.6°C while pH is 7.0. No gas bubbling was observed in the area. However, the rocks around are covered by a relatively thick deposit of white crystals of gypsum. At about 100 m upstream from the downstream spring, hot water discharges from the pebbles of the bottom of the river and mix with the river water. Temperature is 38.5°C, pH is 7.0 and discharges at a few l/min.

Hot waters are emitted at several places in the galleries of Acupan Mine. Water sampling was done at levels 3,300 and 3,150. For sample at 3,300 level, the discharge was running down a concrete channel after its springing from a drilling hole. Temperature is 81.0°C, pH is 7.5 and discharge rate is 25 l/min. Ambient temperature was 66°C. Geologically, the area consists of dioritic rocks intruded by andesitic dykes. The pale green amphibole is altered to chlorite; the rocks are strongly pyritized and silicified. On the ventilation pipes, which are in contact with the gallery walls, a large amount of white crystal resembling gypsum has deposited. At the 3,150 level, the fluid also discharges from a drilling hole but flows directly to the bottom of the gallery, where it was sampled. The andesite is particularly silicified in this area. Discharge rate is 60 to 80 l/min, temperature is 62.1°C, and pH is 8.0. Ambient temperature was 62.0°C. At this level, gas is also emitted together with the hot water but sampling was impossible due to extreme heat which made breathing difficult.

2–3–2 Chemical Composition of the Hot Spring Waters

The results obtained on the samples collected during this survey are shown on Table II–2–4 together with those reported by B.E.D. (Aug. 9, 1982), KRTA (Sept. 1977), B.E.D.-E.L.C. (Feb. 1979) and F. J. Sawkins et. al. (1979). The sampling locations of the present survey are shown on Fig. II–2–22.

Key-diagrams of the chemical compositions of the hot spring waters are shown on Fig. II–2–23 for Acupan and Asin hot springs, on Fig. II–2–24 for Itogon, Antamok, Dalupirip, Laboy, Klondyke and Pugo hot springs and on Fig. II–2–25 for stream waters and cold waters. On the basis of these key diagrams, the following characteristics were obtained for the hot springs of the different areas:

Acupan Mine: Two types of water composition can be distinguished: the Cl^- type, which is rich in chloride ions, and the SO_4^{2-} type, rich in sulfate ions. This difference in anionic composition affects the cation proportions of the waters such that the Cl^- type is rich in Na^+ and K^+, and the SO_4^{2-} type is rich in Ca^{2+}. A close relationship between this chemical difference and the space distribution of the springs was found, i.e. the Cl^- type waters are restricted to the Balatoc plug and the SO_4^{2-} type waters are distributed outside the plug (Fig. II–2–26).

Itogon: As regards the proportion of anions, the $SO_4^{2-}/HCO_3^- + CO_3^{2-}$ ratio fluctuates around 3/2 and the Cl^- from 0 to 50%. For the cations, $Na^+ + K^+$ accounts for 60% to 100%, the rest being Ca^{2+} and very small concentrations of Mg^{2+}. The anionic composition is similar to that of the SO_4^{2-} type of Acupan Mine but since the $Na^+ + K^+$ concentrations are high, the waters are also similar to the Cl^- type. The Itogon hot spring waters may thus be considered as waters of the Cl^- type of Acupan Mine correlatively enriched in SO_4^{2-} and $HCO_3^- + CO_3^{2-}$ (Fig. II–2–24).

Antamok: Most of the waters have SO_4^{2-} as dominant anion and Ca^{2+} as dominant cation, thus resembling the SO_4^{2-} type of Acupan Mine. Sample no. 69 (76–B–12), however, is rich in Cl^- and $Na^+ + K^+$ and thus similar to the Cl type waters of Acupan Mine. This sample was taken from the 1,980 level.

Laboy: Only two samples were analyzed, but in both cases, SO_4^{2-} is the dominant anion and Ca^{2+} is the dominant cation; Na^+ and K^+ are absent. Both samples clearly belong to the SO_4^{2-} type of Acupan Mine (Fig. II–2–24).

Dalupirip: The principal anion is SO_4^{2-}, with small amounts of $HCO_3^- + CO_3^{2-}$, while the principal cations are $Na^+ + K^+$. This composition is similar to that of the Itogon spring waters (Fig. II–2–24).

Asin, Klondyke and Pugo: All these samples have Cl^- rich and $Na^+ + K^+$ rich compositions.

As shown in Fig. II–2–25, the stream waters and cold waters have Cl^- as anion and $Ca^{2+} + Mg^{2+}$ as cations.

The chemical compositions of hot spring waters may thus be classified according to the relative proportions of the anions SO_4^{2-}, Cl^- and $CO_3^{2-} + HCO_3^-$ on one hand and the cations $Na^+ + K^+$, Mg^{2+} and Ca^{2+} on the other.

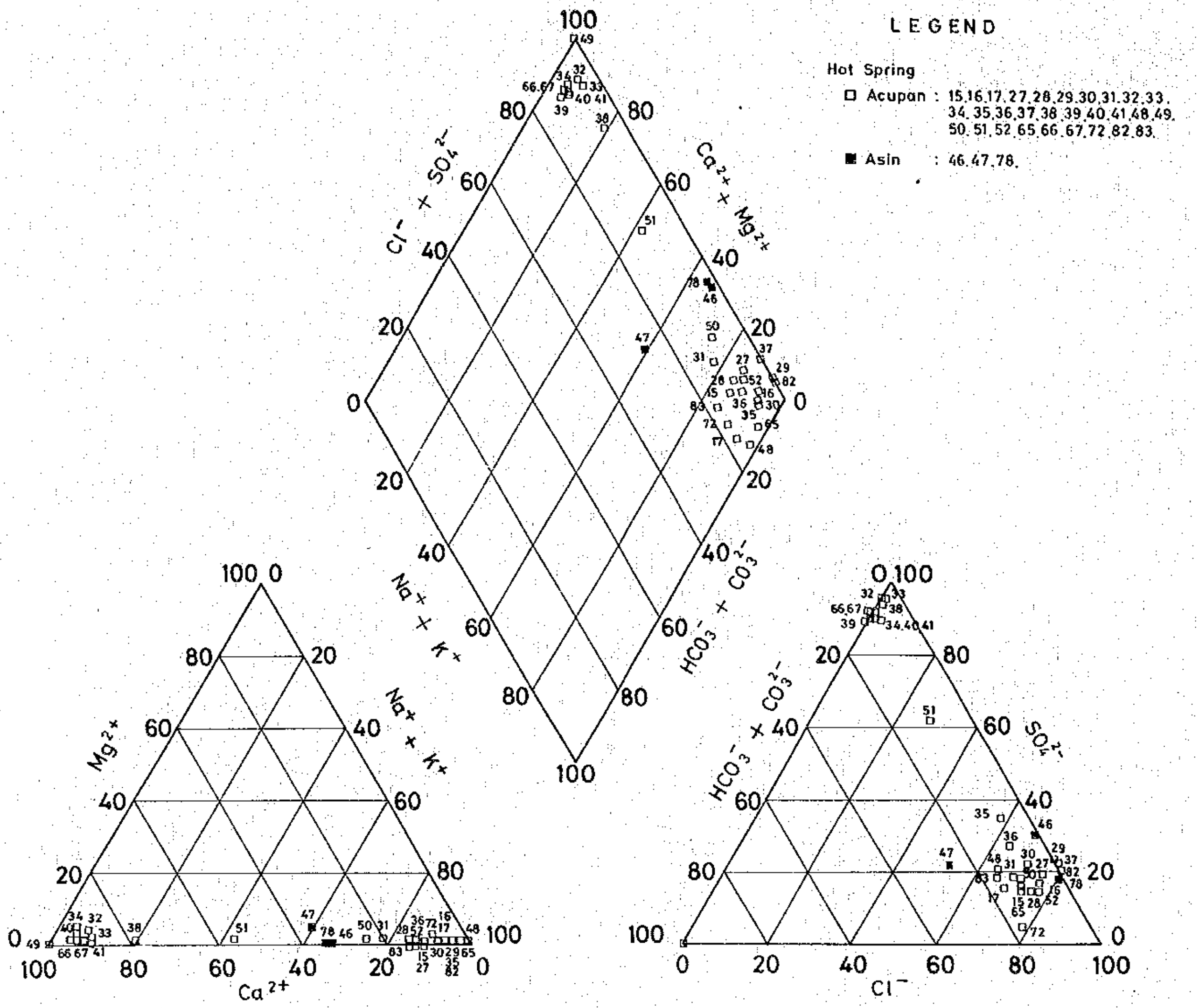

Fig. II–2–23 Key-Diagram for Acupan and Asin Hot Spring

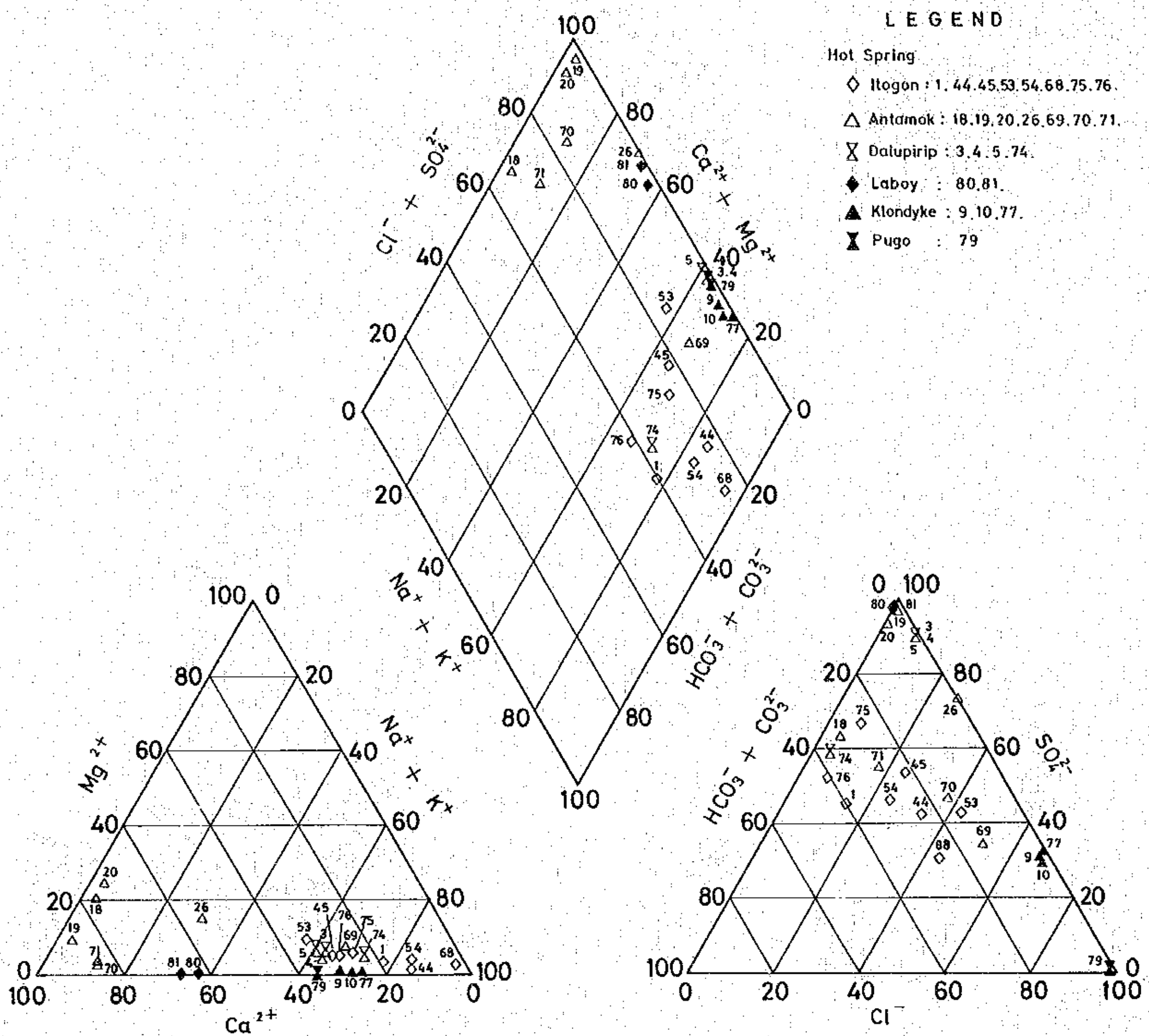

Fig. II–2–24 Key-Diagram for Itogon, Antamok, Dalupirip, Laoby, Klondyke and Pugo Hot Spring

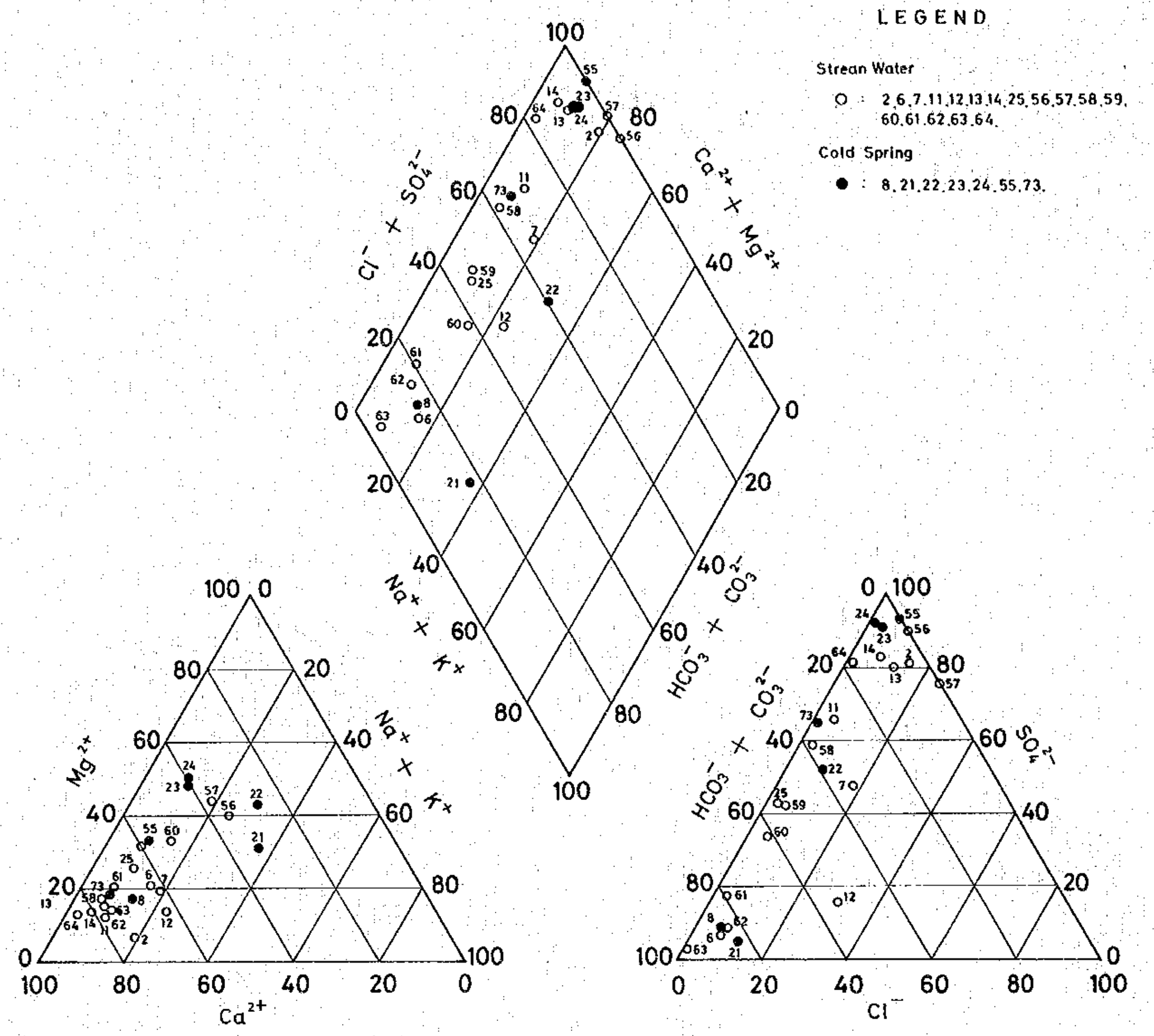

Fig. II—2—25 Key-Diagram for Stream Water and Cold Spring

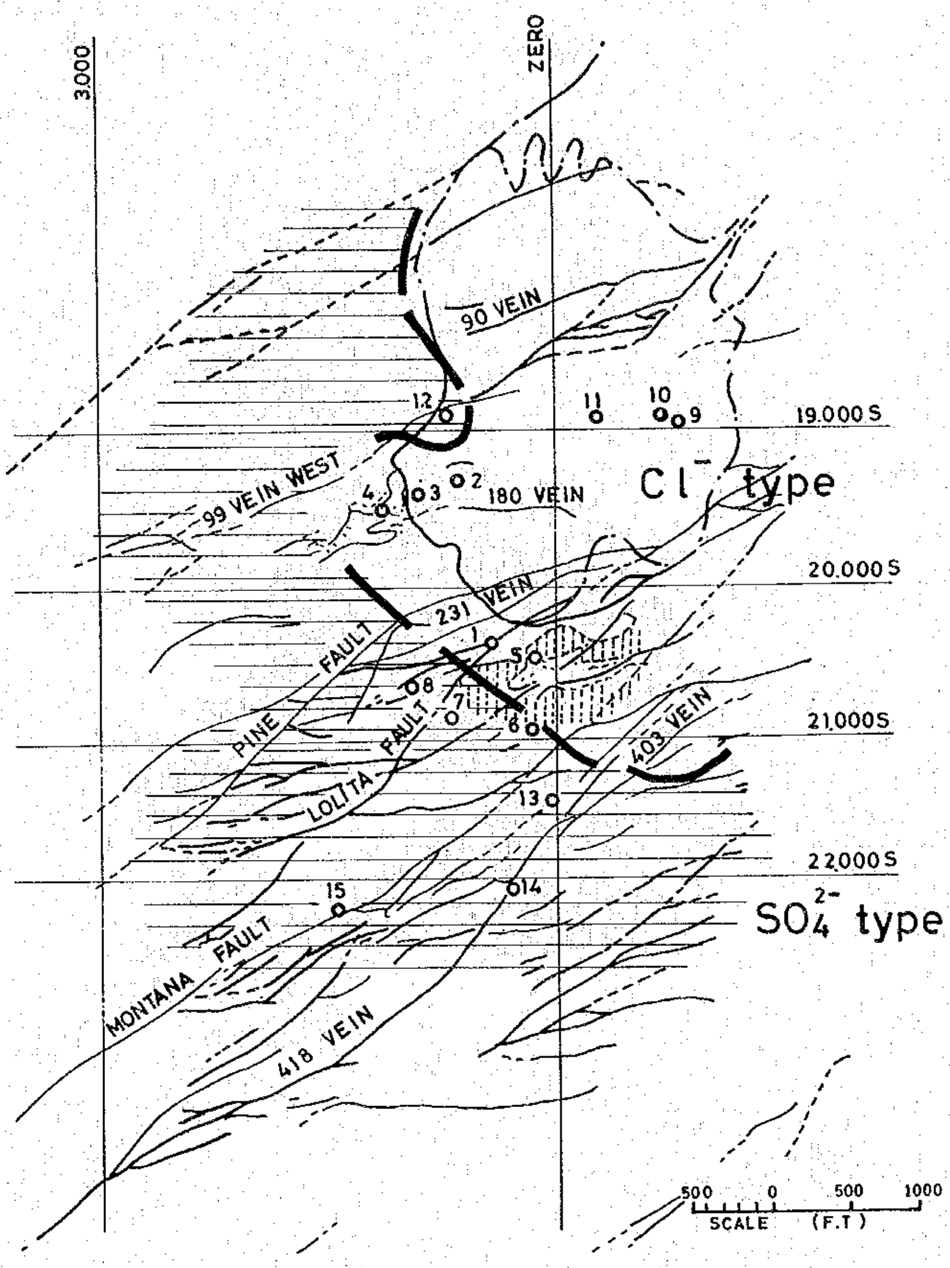

Fig. II–2–26 Chemical Zoning of Spring Water Samples at Acupan Mine