

VARIATIONS OF Na/Cl RATIO IN HAWAIIAN
TRADE WIND RAIN SHOWERS

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ABSTRACT

Approximately four hundred rain samples were collected at twenty-three different altitudes along the Kulani Road and Saddle Road on the island of Hawaii during February, June and July, 1967. These samples were analyzed for Cl spectrophotometrically and for Na by flame photometry. Statistical treatment of the data from these samples shows a tendency for only a very slight increase in the Na/Cl ratios with altitude. This implies that Cl release from raindrops or the sea salt particles incorporated in the raindrops is not very significant from coastal regions to distances of 20-30 miles inland in Hawaii. The small Na/Cl ratio increase with altitude also sheds some light on the increase of I/Cl and Br/Cl ratios with altitude in Hawaiian rains found by Duce et al. (1965). These increases are apparently due to the gain of I and Br on the raindrop nuclei or on the raindrops themselves rather than the loss of Cl.

Approximately one hundred and fifty rain samples were also collected in a special collector which allowed rainfall intensity measurements to be made. These samples show a general inverse relationship between the rainfall intensity and the ionic sodium and chloride concentrations. However, the Na/Cl ratios do not appear to vary with the rainfall intensity. The lack of such a relationship suggests that any equilibrium between the gaseous Cl in the air and rain water is established very rapidly, if there is any such interaction at all.

The majority of the rain samples have Na/Cl ratios less than that of sea water. This excess of Cl raises the possibility of Cl enrichment with respect to Na when sea salt particles are ejected into the atmosphere by breaking bubbles at the air-sea interface.

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I. INTRODUCTION

The sodium/chloride ratio in precipitation samples has been investigated by several workers. Because ions in sea water have a rather constant ratio, the variations of Na/Cl in precipitation have caused speculation about the fate of atmospheric salt nuclei which are injected into the atmosphere from the ocean by breaking bubbles (Kientzler, et al., 1954; Moore and Mason, 1954). Rossby and Egner (1955) showed the Na/Cl ratio in Scandinavian rain samples increased as one went inland from the sea and coastal areas. A maximum was reached for rains in maritime air some distance from the coast. The ratio dropped in regions of marine air mass arriving by way of central or even southeastern Europe possibly because of collection of minute HCl droplets, and increased in precipitation from polar continental air masses possibly because of Na addition. This pattern has been explained by considering Cauer's (1949) hypothesis that chloride in the salt particles leaving the surface of the ocean could be oxidized to chlorine by ozone in the atmosphere. The chlorine in turn may react with water vapor and ultraviolet light to form HCl. The HCl then could be transported by wind as a gas or might form droplets which would normally be too small to serve as effective condensation nuclei. HCl could also be released from the sea salt particles by the acidification of the aerosol by dissolved SO_3 (Eriksson, 1960) or NO_2 (Robbins et al., 1959) due to the resultant lowering of the pH. The SO_3 is formed by the oxidation of SO_2 in the atmosphere. Depending on the general circulation, the precipitation falling from air masses near the coast contains various amounts of sodium chloride. As the air

travels further away from the coast most of the sodium chloride is used up. At this point the minute HCl droplets would come into play as condensation nuclei. When this occurs, the Na/Cl weight ratio would decrease below the 0.56 value of sea water. If the air continues along a continental trajectory without access to any source of chloride but is able to pick up small amount of continental sodium brought about by continental air masses, it is probable that the Na/Cl ratio of the precipitation would again increase.

The increase in the Na/Cl ratio in rain samples as one progresses inland from the coast was also observed in the United States by Junge and Werby (1958). They concluded that the major source of chloride was the ocean, and suggested that the increase of the Na/Cl ratio was caused by excess sodium from mineral dust. Brocas and Delwiche (1963) found the Na/Cl ratio in Antarctic snow and ice increased in the mountainous areas 300 km south of the coast. This was interpreted as due to a regional supply of non-marine Na from the land since the liberation of chlorine was not considered very likely because the solid state of precipitation above the Antarctic continent would make exchange reactions practically impossible.

During Project Shower, Ericksson (1957) collected rain samples at different altitudes on the island of Hawaii. Sodium and chloride analyses were performed on some of the samples. For the samples collected from Oct. 19 to Oct. 20, 1954, the Na/Cl ratios for samples collected at six altitudes from 1,325 feet to 5,550 feet did not show any particular trend with altitude. For the samples collected from Oct. 20 to Oct. 21, 1954, the Na/Cl ratios for samples collected at

five altitudes from 30 feet to 5,330 feet indicated a steady decrease from 0.56 to 0.36. The average Na/Cl ratio for the samples from these eleven altitudes was 0.50. Another eight rain samples with rainfall intensity measurements collected at Club 299 near Hilo had an average Na/Cl ratio of 0.60. Using Na as a reference the Hawaiian rains had a relative ionic composition different from sea water for several ions. There was an excess of Ca, Mg, K, SO₄ and, as seen above, sometimes chloride. Eriksson (1960) also reported that sulphur was enriched with respect to Na in sea salt particles compared to sea water.

Data on ionic enrichment at the air-sea interface was presented by Sugawara (1956). From such data, Komabayasi (1962) found that the logarithm of the enrichment coefficient of ions increases linearly with the logarithm of their ionic weights when compared with sea water. The enrichment coefficient was defined as the ratio of (M_1/Cl_1) to (M_2/Cl_2) where M stands for any ion, 1 refers to the ion concentration in the atmospheric sample, and 2 refers to the ion concentration in sea water. Na, Mg, K, Ca, CO₃, Sr and I followed this relation. Cl is of intermediate nature. The coefficient for Cl defined in this way is one. This value falls off from the general trend for the ionic weight of Cl. However, the Na coefficient is slightly less than one. This implies that there is a slight excess of Cl with respect to Na in atmospheric samples. Duce et al. (1963) showed that Br did not follow this relation. MacIntyre (1965) showed convincingly the existence of two types of phosphate enrichment corresponding to jet drops and film drops produced by bubbles breaking through a surface organic film.

Junge (1957) reported that approximately 50% of the chlorine

content in the Hawaiian atmosphere was present as a gas. This observation has been confirmed by Duce et al. (1965). The latter also found an increase of I/Cl and Br/Cl in Hawaiian precipitation with increasing altitude. From Junge and Werby's data (1958), the average coastal value of the Na/Cl ratio in precipitation is 0.60. Viewing this Na/Cl ratio of 0.60 and the 50% gaseous chlorine in the atmosphere, MacIntyre (1965) discussed the Na/Cl ratios in the following manner. The gaseous chlorine component presumably does not enter the atmosphere as a gas from the sea surface, but is expelled from aerosol particles due to chemical reactions in or on the particles in the atmosphere (Rossby and Egner, 1955). This means that the extra chlorine must enter the atmosphere in the small droplets ejected from the sea surface. For this to be true the Na/Cl ratio in these small droplets must be approximately half the value which is observed for the aerosol when it comes down in rain. That is, the Na/Cl ratio of the material leaving the sea surface must, under these assumptions, be $1/2 \times 0.60$, or 0.30. This is much lower than the sea water value of 0.56.

This low figure of 0.30 may be increased by noting that most aerosol particles smaller than 0.5μ escaped measurement in Duce's work (Duce, personal communication). These small particles may contain an appreciable fraction of the total chlorine, and their inclusion in the particulate fraction would reduce the 50% to perhaps 30%, increasing the Na/Cl ratio to 0.46 (assuming that the Na/Cl of the small particles is equal to 0.60 also). The ratio could be increased by finding another route for gaseous chlorine to enter the

atmosphere, or by finding continental contamination to be enriched in chlorine.

Oddie (1959) found a great deficiency of Cl in precipitation at Lerwick, Shetland. The nearest land mass to this island was Scotland. Since Mg, K, and Na were in nearly the same proportions as in sea water and continental contamination was not probable, he concluded Cl was released according to Cauer's hypothesis. However, Gorham and Cragg (1960) reported bog waters from the Falkland Islands were rich in sea spray. These bog water samples are similar to sea water and show an average Na/Cl ratio of 0.54. Moreover, Leeftang (1938) in Netherlands gave Na/Cl ratios from 0.53 to 0.45 for precipitation. These are average values over several years.

Mordy (1953) measured the nitrogen content in Oahu rains and found an approximate inverse relationship between rain intensity and nitrate and ammonia concentrations. Woodcock and Blanchard (1955) obtained a similar relationship between intensity and chloride concentration. Gorham (1958) showed a few rain samples with such inverse response for both sodium and chloride. Such behavior was expected because the more intense rain has fewer and larger raindrops (Blanchard and Spencer, 1957) to capture the limited number of salt particles in the air. In addition, at higher intensities there is more coalescence between the rain drops and the cloud drops. As the cloud drops are thought to be relatively pure water (Woodcock and Blanchard, 1957), the resulting drops from intense rain are diluted by the chloride free cloud droplets. The smaller drops would also be more seriously affected by evaporation on the way to the ground due to

their larger surface area to volume ratio. Nevertheless, there was no evidence to show any relationship between rainfall intensity and the Na/Cl ratio.

It can be seen that the Na/Cl ratio in rain water shows a definite trend to increase as one moves inland. Possible explanations for the increase in the Na/Cl ratio include addition of sodium from continental dust particles and volatilization of Cl from the sea salt nuclei which are incorporated into the rain drops. A smaller Na/Cl ratio than the sea water value of 0.56 may be accounted for by Cl enrichment with respect to sodium between the sea and air interface. The purpose of this investigation is to study the variations of the Na/Cl ratio with altitude, location, and rainfall intensity in tradewind showers in Hawaii. In Hawaii, local contamination of Na from soil particles will be at a minimum because of the short distance involved and the generally moist nature of the terrain. Thus, any variation observed in the Na/Cl ratio would most likely reflect loss or gain of Cl rather than Na. It is known that I/Cl and Br/Cl ratio in Hawaiian rains increase with increasing altitude (Duce et al. 1965). Since all three of the halogens have volatile species, it is difficult to determine whether or not the increase in the I/Cl ratio, for example, is due to addition of I or loss of Cl. This investigation would clarify the previous results concerning the I/Cl and Br/Cl ratios.

The relationship between rain intensity and Na/Cl ratio may also give valuable information regarding the interaction of the rain drops with any gaseous component of Cl present in the air. Generally,

higher rainfall intensity is associated with larger rain drop size, and the larger raindrops have a shorter residence time in the atmosphere than the smaller drops. Thus, if there is an equilibrium to be maintained between the Cl in solution in the rain drop and that in the gaseous phase in the atmosphere, the variation of the Na/Cl ratio with rain intensity may give an indication of the rate at which any exchange takes place with different size raindrops. For example, if the equilibrium is established very rapidly, no variation in the Na/Cl ratio with rainfall intensity should be observed.

II. EXPERIMENTAL METHODS

A. Sampling Procedure

1. Altitude Rain Samples

Rain water samples at different altitudes were collected on the Saddle Road and Kulani Road on the island of Hawaii during February, June, and July, 1967. The collection sites along the Kulani Road were operative only in February. Eighteen special rain gauges, made of pineapple cans and sprayed with lacquer, were distributed along each roadside at different altitudes and distances from the sea. The gauges were checked twice or more daily to collect rain samples or to rinse out the gauges with distilled water if no rain had occurred since the previous collection. The rain water was poured into polyethylene bottles which had been cleaned by washing with warm concentrated nitric acid and then rinsing twice with distilled water and once with distilled demineralized water. If the volume of rain water collected at a particular site was not sufficient for analysis, the sample was saved and additional rain from the same site was added during some later collection period. In some cases, when the sample was still not large enough, it was diluted to the proper volume with distilled demineralized water in the chloride analysis. Eighty-five samples were collected along the Kulani Road in February and three hundred and eight samples were collected along the Saddle Road during February, June and July. All these samples were collected between

1,750 feet and 5,100 feet.

2. Rainfall Intensity Samples

Rainfall intensity samples were collected in a conical stainless steel collector with a diameter of 80 cm. This collector, called the "scoop", is equipped with wiper-blades to assure complete drainage of the collector after each sample was collected. A square wooden cover (120x120 cm²) prevented any falling raindrops from getting into the scoop before sampling or between sample collections. This wooden cover was fitted with a handle and a piece of aluminum metal about two inches wide was attached along one of the edges. This piece of aluminum prevented any water from dripping into the scoop during the operation of covering and uncovering the scoop. Before sampling, the scoop was cleaned with distilled water, a polyethylene bottle was positioned below the outlet of the scoop, and the scoop was covered by the wooden cover. A stop-watch was started when the cover was removed from the scoop to collect a sample of rain. This stop-watch was stopped when enough rain had been collected and the cover was put on again. The volume of rain water collected was determined by weighing. In this manner it was possible to calculate the rainfall intensity from the volume, collector area, and time measurements. Fifty-five such samples were collected on the windward side of Oahu during two weeks in late March and early April. One hundred and twenty samples were collected in February, June and July on the island of Hawaii, primarily

along Saddle Road and near the radar pad at the University of Hawaii, Hilo campus. These rain samples were kept in the same type of polyethylene bottles as the altitude samples.

B. Analytical Procedure

1. Chloride Determination

The method and principle of the photometric determination of chloride in water was described in detail by D.M. Zall et al. (1956). The abstract of this paper reads as follows: "A method has been devised for the photometric determination of small amounts of chloride in water. The method is based on the displacement of thiocyanate from mercuric thiocyanate by chloride ion and the subsequent reaction of the liberated thiocyanate with ferric iron to form the colored complex $\text{Fe}(\text{SCN})^{++}$ which is measured either visually or in a spectrophotometer. Concentrations of chloride as low as 0.05 ppm can be determined." The reagents and procedure for Zall's method are as follows:

Reagents: Mercuric thiocyanate: saturated water solution (0.07%). Ferric perchlorate: dissolve 6 grams in 100 ml. of 4N perchloric acid. This reagent may also be prepared by dissolving 14.0 grams of pure iron wire in dilute nitric acid. Upon dissolution of the iron, add 120 ml. of perchloric acid and heat the solution until it fumes. Continue heating until the solution turns purple, then cool and

dilute to 1 liter.

Procedure: Place 10 ml. of sample in a 50-ml. volumetric flask, add 5 ml. of 60% perchloric acid, 1 ml. of mercuric thiocyanate, then 2 ml. of ferric perchlorate. Make up to volume and mix well. Allow to stand for 10 minutes, then read the transmittancy on a spectrophotometer at 460 m μ . The color can also be compared visually with suitably prepared standards.

This investigation has followed Zall's method rather closely. However, the following steps have been taken to improve the accuracy or speed in the present investigation.

- a. In the preparation of ferric perchlorate, 35 grams of iron wire was dissolved in 600 ml. dilute nitric acid. 300 ml. of 70% perchloric acid was added and the solution was heated until it fumed. The heating continued until the solution turned purple and some crystals of ferric perchlorate appeared. The solution was cooled, after which more crystals precipitated, and then was diluted to 2.5 liters and all the crystals dissolved. To this 2.5 liters of solution, 5 liters of 70% perchloric acid was added to make up the working ferric perchlorate solution. This 7.5 liters of ferric perchlorate solution was stored in a two-gallon polyethylene bottle.

Preparation of the ferric perchlorate in this way provided a large amount of homogeneous solution which served to eliminate possible variations when small portions of solutions are prepared at different times.

- b. Mercuric thiocyanate was prepared according to the original paper. A 1 liter saturated water solution of mercuric thiocyanate was made (0.07%).
- c. 15 ml. of mercuric thiocyanate was pipetted into a 100 ml. volumetric flask. This was made up to volume by addition of ferric perchlorate solution and mixed well. 7 ml. of this mixed mercuric thiocyanate and ferric perchlorate solution was pipetted into each of twelve 30 ml. volumetric flasks. These flasks were then made up to volume using standard chloride solutions or the rain samples being analyzed. All this was done within 20 minutes. If the rain sample was insufficient, i.e. it was less than 23 ml., a measured amount of distilled demineralized water was added to make the sample up to volume. Correction for such dilution was made in calculating the chloride concentration. Only twenty-five samples had to be diluted in all the chloride determinations.

The purpose of this step was to speed up the procedure by pipetting a mixed solution of mercuric thiocyanate and ferric perchlorate instead of pipetting them individually into the same 30 ml.

flask. However, it was found that the absorbance of a standard chloride solution was time dependent, depending on the length of time between the mixture of the mercuric thiocyanate and ferric perchlorate and the addition of standard or sample solution. The time dependence for chloride solutions of 35.5 ppm and 3.55 ppm is shown in Tables I-A and I-B. The absorbance within the first 20 minutes are rather constant, varying by about 1%. Consequently all the pipetting and addition of samples and standards in each run were done within 20 minutes after mixing the thiocyanate and ferric perchlorate.

- d. The flasks were brought into a room which was illuminated by red light and were allowed to stand for 15 minutes. The sample was transferred to a 10 cm. quartz cell and the absorbance was read on a Beckman DU spectrophotometer at 460 m μ .

The time dependence after the solution has been made up and is ready for absorbance measurement is not severe. The color takes about 5 minutes to develop and stays rather constant after that. However, the absorbance was found to be higher and more constant when the solution were prepared and kept under red light instead of being prepared and kept under the ordinary room lighting until absorbance measurements were made. This difference is shown in

Tables II-A and II-B. Another test investigated the variation of absorbances between a sample prepared and kept under red light and a sample prepared under ordinary light but kept under red light for fifteen minutes before absorbance measurement. Duplicate sets of samples were run. The pair prepared under red light had absorbances of 0.670 and 0.678. The pair prepared under ordinary light but kept under red light for fifteen minutes before absorbance measurement showed absorbances of 0.675 and 0.679. Since there was no significant differences observed, all the standards and samples during the chloride analyses were prepared under ordinary light but were kept under red light for fifteen minutes before absorbance measurements were made.

- e. A calibration curve was obtained by running several sets of chloride standards. This calibration curve is shown in Figs. 1-A and 1-B. The absorbance uncertainties are also indicated. It can be seen that there are higher uncertainties at lower concentrations. For each batch of analyses, ten rain samples and two standards were run. The two standards serve to show the deviation, if any, from the calibration curve in each run.

2. Sodium Determination

Sodium was determined in this investigation by flame

photometry. A Beckman model DU spectrophotometer with a flame attachment was used. Evaluation methods and operation procedures are outlined by Willard et al. (1965). A summary of the method follows.

The evaluation method used is called the direct-intensity method. With the flame burning properly and the monochromator set at 590 m μ , distilled demineralized water was introduced into the atomizer and the background emission was recorded. The most concentrated comparison standard was introduced and the sensitivity adjusted so that 100% transmittance was attained. The distilled demineralized water reading was rechecked and any necessary adjustments were made. Then several standards of lower concentration were introduced in turn and the respective transmittances were recorded. The standard transmittance readings were checked by introducing standards after each ten samples were run.

The instrument readings in percent transmittance were plotted against concentration in ppm to produce the calibration curve. Two such curves were employed. One was for sodium concentration in rain samples less than 1 ppm and another for sodium concentration in rain samples from 1 ppm to 10 ppm. These calibration curves are shown in Fig. 2 and Fig. 3. The uncertainties of the percent transmittance are also indicated. There are only a few rain samples with sodium content more than 10 ppm. These few were determined by using standards of 10 ppm and above to bracket the samples.

C. Standards and Precision

The chloride standard was prepared by dissolving 2.922 gram of dried c.p. sodium chloride in a 500 ml. volumetric flask. It was diluted to volume with distilled demineralized water. This master solution was 0.1N and was used to prepare ten standards from $5 \times 10^{-6} \text{N}$ (0.178 ppm chloride) to $10 \times 10^{-4} \text{N}$ (35.5 ppm chloride) by proper dilutions.

Similarly, a master solution containing 1,000 ppm of sodium was prepared by dissolving 2.542 gram of dried c.p. sodium chloride in one liter of solution. A set of sodium standards from 0.1 to 20 ppm was prepared by proper dilutions.

Distilled demineralized water was used to prepare both chloride and sodium standards. This water was concentrated about ten times in a clean bench to determine its sodium and chloride content. Six such runs showed the average chloride concentration to be 0.006 ± 0.003 ppm and the average sodium concentration to be 0.012 ± 0.003 ppm. Since the graphical calibration curves for chloride and sodium would not distinguish such small concentrations, no correction for sodium or chloride was attempted for the distilled demineralized water used.

The precision, in terms of absolute deviation, of the chloride analyses is shown in Table III. From 3.55 ppm and above, the concentration uncertainty is about ± 1.0 to $\pm 2.0\%$. The uncertainty increases below 3.55 ppm. It reaches $\pm 10.0\%$ at 0.178 ppm and 0.355 ppm. Small chloride magnitude and instrumental error may contribute to these higher uncertainties.

The precision, in terms of absolute deviation, of the sodium determinations is shown in Table IV and Table V. The concentration uncertainty ranges from $\pm 1.0\%$ at 5.0 ppm to $\pm 5.5\%$ at 0.1 ppm.

Since rain water is rather free from any appreciable amount of interference in chloride and sodium determinations, the uncertainties which occur should be a combination of operational and instrumental errors.

III. RESULTS AND DISCUSSION

The results of the analysis of the rain samples are given in Table VI. Samples designated D and B were collected along the Kulani Road and the Saddle Road respectively in February, 1967. The E samples were collected along the Saddle Road in June and July, 1967. The collection time interval of each sample is also given. The collection altitudes are rounded off to the nearest 50 feet. The uncertainties for the Na, Cl, and Na/Cl ratio values are estimated as described previously in the experimental section. Due to the long collection periods and the consequent partial evaporation of the rain samples, the Na and Cl concentrations observed are not representative of the true rain concentrations. However, it is believed that this evaporation does not affect the value of the Na/Cl ratio, which is the primary object of this investigation.

The Na/Cl ratios of the three hundred and ninety-three samples collected are plotted against collection altitude in Fig. 4 to Fig. 8. When several samples at the same altitude have identical Na/Cl ratios, they are represented by the symbols given in Figures 4 and 6. At any given altitude, the Na/Cl ratio varies from shower to shower. Nineteen samples show Na/Cl ratios equal to or greater than one. It is possible that these samples might have been contaminated in the series of processes from sample collection to analysis. They also could be caused by cold rains whose effect upon the Na/Cl ratio is still unknown. It is very possible that these values are real since there are many parameters which influence the chemical composition of a rain shower. A straight line is fitted to the three hundred and ninety-three

points in Fig. 4 by the least squares method. This line shows a tendency for the Na/Cl ratio to increase with altitude, increasing from about 0.53 at 1000 feet to 0.63 at 5000 feet. The extrapolation of this line gives a Na/Cl ratio at the sea surface of 0.51. In Fig. 5 the average value of the Na/Cl ratio at each altitude is computed and then a straight line is fitted to those points by the least squares method. The same trend is apparent here as in Fig. 4, except the slope is slightly less. The sea level extrapolation value of 0.53 is slightly higher than that in Fig. 4. Since the nineteen Na/Cl ratios with values equal to or greater one have a very great affect on the calculation of a straight line by the least squares method, another set of calculations was made ignoring these nineteen samples. Figs. 6 and 7 shows the results for the three hundred and seventy four remaining samples. For Fig. 6 the calculation was made using all three hundred and seventy four points, as in Fig. 4, and for Fig. 7 the average values at each altitude were used, as in Fig. 5. It can be seen that the lines in Fig. 6 and Fig. 7 are almost identical and are virtually horizontal. They both have a sea level extrapolation value for the Na/Cl ratio of 0.53 which increases to 0.57 at 5000 feet. A summary of figures 4, 5, 6, and 7 is given in Figure 8.

The straight lines in Figs. 4 and 5 indicate a trend for the Na/Cl ratio to increase with altitude. Without the nineteen exceptionally high Na/Cl ratios ($\text{Na/Cl} > 1.0$), Figs. 6 and 7 show essentially no change in the Na/Cl ratio with altitude. Of these nineteen samples with high Na/Cl ratios, all but two were collected during the periods 2-4 February and 17-18 June as shown in Table VII. During these

periods other samples also showed abnormally high Na/Cl ratios, and some of these are also given in Table VII. This might be the result of the prevailing weather condition with possible high level cold rain interference. Since the mechanism for the formation of high level cold rain and the warm trade wind showers are quite different, it is very possible that the chemical composition of the two types of rain will differ significantly. The possibility of cold rain interference in these samples is being investigated further.

If there is no addition of sodium to the sea salt particles or the raindrops themselves because of the moist Hawaiian terrain and the short distance between the sea coast and the collection sites, then the slight trend for the Na/Cl ratio to increase with increasing altitude must be caused by the release of Cl from sea salt particles or raindrops. However, the virtually horizontal line in Figs. 6 and 7 would indicate that there is extremely little Cl released from the sea surface to an altitude of 5000 feet on the island of Hawaii. Oddie (1959) concluded that there was Cl released in precipitation collected on Shetland. As mentioned previously this could occur by oxidation of chloride to chlorine (Cauer, 1949) or by the absorption of H_2SO_4 and subsequent release of HCl (Ericksson, 1960). On the other hand, Junge and Werby (1958) suggested the Na/Cl ratio increase over the continental United States was caused by the addition of continental dust particles rich in sodium. The result of the present altitude samples seems to indicate that there is no large amount of Cl release in warm rain on the island of Hawaii.

The Na/Cl ratio extrapolated to sea level in Figures 4, 5, 6, and

7 is about 0.51 to 0.53. This is lower than the sea water ratio of 0.56. Eriksson (1957) analyzed Hawaiian rain samples from eleven altitudes and found an average Na/Cl ratio of 0.50. This excess Cl in precipitation along with the considerable amount of gaseous Cl found by Junge (1957) and Duce et al. (1965) in the Hawaiian atmosphere raises the possibility of Cl enrichment with respect to sodium at the air-sea interface when sea salt particles are ejected into the atmosphere from the ocean by breaking bubbles. From aerosol, rain water and snow data Komabayasi (1962) showed very little Cl enrichment, but a distinct enrichment for sulfate. In addition, MacIntyre (1965) showed in laboratory studies that phosphate enrichment occurs in the particles formed from breaking bubbles. Thus, there is a good possibility that Cl is enriched with respect to sodium at the air-sea interface when sea salt particles are ejected into the air from the ocean.

Halogen concentrations and weight ratios for Hawaiian rain samples are reproduced in Figs. 9 through 13 (Duce et al., 1965). It can be seen that chlorine, bromine and iodine concentrations decrease with increasing altitude. However, the I/Cl and Br/Cl ratios both increase with altitude. In the present investigation, the Na/Cl ratios show only a very slight increase with altitude. This means the sodium concentration would follow the chlorine slope very closely in Figure 9, which implies that the I/Na and Br/Na ratios would increase with altitude. Since Na is not a volatile element, such ratio increases must be due to an increase in the I and Br either in the sea salt particles that are incorporated into the raindrops or in the

raindrops themselves as they move away from the coast. Thus, it follows that the I/Cl and Br/Cl ratio increases with altitude in the work of Duce et al. (1965) are due mainly to the increase of I and Br rather than the loss of Cl in Hawaiian rain water samples.

The results for the intensity rain samples are given in Table VIII. Samples C1 to C10 were collected in January, 1967 on the island of Hawaii. Samples C11 to C66 were collected on Oahu during late March and early April, 1967. Samples from B64 to B150 and C67 to C89 were collected on the island of Hawaii in June and July, 1967. Figs. 14 through 27 show the results of the analysis of these samples. The uncertainties for Na, Cl concentrations and Na/Cl ratio are also indicated unless the symbols themselves are larger than the uncertainty limits. These figures show the variations of sodium concentration, chloride concentration, rainfall intensity, and Na/Cl ratio with location in tradewind showers. The sea water value of the Na/Cl ratio (0.56) is shown as a horizontal broken line.

An inverse relation between rainfall intensity and ionic concentration is repeatedly observed. Figures 14, 15, 18, 22, 24, 26, and 27 are individual one cell showers that show that the concentrations of Na and Cl are high near the edge and then decrease to a minimum near the center of the shower before rising again to more near their original values. The low concentrations are accompanied by high rainfall intensity. This is also true for the rest of the intensity figures which have showers of more than one cell. Moreover, the individual cells in a rain shower or group of rain showers can be seen by the changes in concentration with intensity. It is not

necessary for the rain to stop to see the variations. For example, Figures 16, 17, 19, 20, 21, and 25 show rain situations where there are several cells or several showers very close together such that the rain does not stop. Nevertheless, these cells or showers can be easily distinguished chemically as well as from intensity measurements. Generally speaking, an intensity maximum is accompanied by a concentration minimum. These are in agreement with Woodcock and Blanchard's (1955) chloride data and Nordy's (1953) nitrogen data. Such an inverse relation has been explained (Nordy, 1953; Gorham, 1958) as follows: With a limited number of sea salt particles in a given volume of air, the same mass of these particles would be washed down by either light or intense rain in a given time if the wind speed is constant (Blanchard and Spencer (1957) showed an inverse relationship between the rain drop size and intensity in these shower rains). This would result in lower ionic concentration for more intense rainfall since the sea salt mass would be distributed in a larger volume of water. Statistically speaking, the more intense rainfall has more large raindrops to capture the limited number of sea salt particles.

Higher intensity also means there is more coalescence between raindrops and cloud drops. As the cloud drops are thought to be relatively pure water (Woodcock and Blanchard, 1955), the resulting drops from intense rain are diluted by the chloride free cloud droplets. In addition, smaller raindrops are more vulnerable to evaporation on their way to the ground due to their larger surface area to volume ratio. This evaporation would thus constitute another factor causing this small raindrop to have higher ionic concentrations.

In a given shower cell, the concentration minimum (e.g. Figs. 20, 21) may be explained as follows: As a shower passes over a stationary collection site, the initial raindrops come from the edge of the rain cloud. These correspond to low intensity rain samples with a large number of small rain drops (Blanchard and Spencer, 1957). Such samples would be collected at point A in Fig. 28. As the rain cloud continues to move, samples would be collected at point B of Fig. 28. This portion of the shower has high rainfall intensity with fewer and larger raindrops. Finally, as the trailing edge of the shower approaches the collection site, samples would be collected at point C of Fig. 28. It must be emphasized that the above discussion concerning the cause of the inverse relationship between rainfall intensity and ionic concentration is greatly oversimplified. Undoubtedly the actual situation is much more complicated and the whole question of the mechanism of the formation and growth of raindrops in warm rain showers is not well understood at the present time. However, it can be stated with certainty that high rainfall intensity is associated with fewer and larger raindrops and lower ionic concentrations. Similarly, low rainfall intensity is associated with smaller and more raindrops and higher ionic concentrations.

If there is an equilibrium between the Cl^- in the raindrops and the gaseous component of Cl present in the atmosphere, any variation in the Na/Cl ratio with rainfall intensity might indicate the rate at which any equilibrium is established between the various sized raindrops and the gaseous Cl. If the equilibrium is attained in an interval shorter than the residence time of the largest raindrops,

which have a shorter atmospheric residence time than the smaller drops, there should be no variation of the Na/Cl ratio with respect to rainfall intensity. From the intensity data, there is no apparent pattern between the rainfall intensity and Na/Cl ratio. In fact, the ratios are rather constant in all the showers in spite of great changes in the intensities. Thus, it appears that either there is no interaction between the raindrops and the gaseous component of Cl in the air or that such an interaction establishes an equilibrium very rapidly. The time for such establishment of this equilibrium would be even shorter than the residence time of the largest raindrops.

The majority of the Na/Cl ratios in these intensity samples have values less than the 0.56 value of sea water. One possible explanation for this could be that the procedure used in this investigation systemically lowers the Na/Cl ratio. This was checked by determining in triplicate the Na/Cl ratio in sea water after suitable dilution by this procedure. The analyses gave three identical Na/Cl ratio value of 0.54. As the Na/Cl ratio in sea water may vary slightly in different locations, this value of 0.54 does not indicate for certain how good the procedure is. Nevertheless, it supports the contention that the low Na/Cl ratios in the intensity and altitude samples are reliable. As mentioned previously, excess Cl might be due to ionic fractionation enrichment of chloride.

TABLE I-A. TIME DEPENDENCE ON MIXING OF $\text{Hg}(\text{SCN})_2$ AND $\text{Fe}(\text{ClO}_4)_3$ WITH A 35.5 ppm CHLORIDE SOLUTION

Elapsed time before being made up to volume in minutes	4	6	11	16	21	31	41	51	94	108
Absorbance	1.827	1.865	1.868	1.882	1.854	1.872	1.745	1.745	1.565	1.458

TABLE I-B. TIME DEPENDENCE ON MIXING OF $\text{Hg}(\text{SCN})_2$ AND $\text{Fe}(\text{ClO}_4)_3$ WITH A 3.55 ppm CHLORIDE SOLUTION

Elapsed time before being made up to volume in minutes	3	5	10	15	20	25	30	40	50	60
Absorbance	.740	.738	.735	.736	.734	.730	.725	.716	.702	.682

TABLE II-A. TIME DEPENDENCE UNDER ORDINARY ROOM LIGHTING FOR 0.710 ppm CHLORIDE SOLUTION

Time in minutes	3	7	10	16	24	27	35	41	45	51	71
Absorbance	.941	.941	.941	.932	.922	.928	.920	.923	.930	.931	.912

TABLE II-B. TIME DEPENDENCE UNDER RED LIGHT FOR 0.710 ppm CHLORIDE SOLUTION

Time in minutes	2	6	10	14	18	22	28	35	43	52	64
Absorbance	.960	.962	.964	.965	.968	.968	.968	.967	.968	.968	.968

TABLE III. PRECISION OF CHLORIDE ANALYSES

Chloride Concentration ppm	Absorbance							Mean	Absorbance Percent Uncertainty	Concentration Percent Uncertainty
0.178	.147	.139	.150	.157	.143	.154	.138	.147±.006	±4.0	±10.0
0.355	.211	.200	.182	.184	.207	.188	.186	.194±.010	±5.2	±10.0
0.710	.279	.275	.283	.277	.276			.278±.003	±1.1	± 3.0
1.07	.367	.371	.341	.343	.363	.362		.359±.010	±2.8	± 5.1
1.78	.481	.461	.486	.481	.462	.463		.472±.010	±2.1	± 5.6
3.55	.663	.682	.672	.675				.673±.006	±1.0	± 1.4
7.10	.943	.931	.947	.926				.937±.008	±1.0	± 2.1
10.6	1.121	1.140	1.136	1.134				1.133±.006	±1.0	± 1.0
17.8	1.379	1.402	1.377	1.359				1.379±.011	±1.0	± 1.4
55.5	1.763	1.800	1.775	1.768				1.776±.012	±1.0	± 2.2

TABLE IV. PRECISION OF SODIUM ANALYSES TO 1 ppm

Na. Concentration ppm	Percent Transmittance						Mean	Percent Transmittance Uncertainty	Concentration Percent Uncertainty
demineralized water	9.5	11.0	10.3	9.0	11.8	9.0	10.1± .9		
0.1	20.8	21.3	20.3	21.9	21.8	20.7	21.1± .5	±2.4	±5.5
0.2	29.2	29.8	29.4	29.3	32.3	28.9	29.8± .8	±2.7	±4.3
0.3	40.7	39.5	37.3	34.9	40.8	41.3	39.1±2.0	±5.1	±3.4
0.5	58.4	60.0	61.2	61.2	64.2	58.8	60.6±1.6	±2.6	±3.4
1.0	100.5	101.5	101.5	108.2	110.2	104.5	104.4±3.2	±3.1	±3.4

TABLE V. PRECISION OF SODIUM ANALYSES BETWEEN 1 AND 10 ppm

Na Concentration ppm	Percent Transmittance				Mean	Percent Transmittance Uncertainty	Concentration Percent Uncertainty
demineralized water	1.0	1.1	0.9	1.1	1.0± .1		
1.0	12.1	12.2	11.7	11.9	12.0± .2	1.7	±3.4
2.0	22.6	22.5	22.0	22.0	22.3± .3	1.3	±1.5
3.0	33.6	33.4	32.7	32.5	33.0± .5	1.5	±1.7
5.0	54.0	52.9	52.3	52.7	53.0± .5	1.0	±1.0
10.0	107.5	101.0	100.5	99.5	102.1±2.7	2.6	±2.7

TABLE VI. ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl	
(All D samples were collected along Kulani Road and all B and E samples were collected along Saddle Road)	1750	D1	2 Feb 1530-0923 Feb 3	10.0 ±.3	15.1 ±.2	.66±.02
	D24	4 Feb 1400-1720	1.49±.04	2.85±.06	.52±.02	
	D42	5 Feb 1045-1525	5.29±.05	7.12±.14	.74±.02	
	D68	5 Feb 1525-0935 Feb 6	.47±.02	.80±.03	.59±.03	
	B1	2 Feb 1760-2210	5.72±.06	10.1 ±.1	.57±.01	
	B12	2 Feb 2210-0800	6.08±.06	9.10±.09	.67±.01	
	B62	5 Feb 1020-1510 Feb 6	2.17±.03	3.91±.08	.55±.01	
	E1	17 Jun 1500-1924	.30±.01	.65±.03	.46±.02	
	E19	17 Jun 1924-2106	.19±.01	.34±.03	.56±.06	
	E21	17 Jun 2106-2323	.34±.01	.70±.02	.49±.02	
	E34	17 Jun 2323-0142 Jun 18	2.48±.04	4.53±.08	.55±.02	
	E50	19 Jun 1834-1920 Jun 20	.36±.01	.98±.05	.37±.02	
	E68	20 Jun 1920-2330 Jun 20	1.34±.04	2.56±.12	.52±.03	
	E80	20 Jun 2330-0143 Jun 21	3.03±.05	5.10±.10	.59±.02	
	E89	21 Jun 2043-0623 Jun 22	2.33±.03	4.40±.09	.53±.01	
	E99	22 Jun 0623-1804	2.85±.05	5.40±.11	.53±.01	
	E128	23 Jun 1802-0034 Jun 24	2.14±.03	4.07±.06	.53±.01	
	E129	24 Jun 0034-0701	1.16±.03	1.97±.10	.59±.03	
	E152	24 Jun 0701-0905	1.85±.03	3.35±.05	.55±.01	
	E153	24 Jun 0905-1032 Jun 25	5.38±.05	11.2 ±.1	.48±.01	
E207	26 Jun 1912-2027 Jun 27	1.96±.03	3.34±.05	.59±.01		
E208	29 Jun 1625-0632 Jun 30	.42±.01	1.22±.06	.34±.02		
1900	D2	2 Feb 1535-0925 Feb 3	6.24±.06	10.4 ±.1	.60±.01	
	D41	4 Feb 1402-1045 Feb 5	.85±.03	1.79±.11	.47±.03	
	D43	5 Feb 1045-1530	3.38±.06	6.10±.12	.55±.02	
	D69	5 Feb 1530-0945 Feb 6	.45±.02	.91±.4	.49±.03	
	B2	2 Feb 1725-2215	3.85±.04	6.95±.14	.55±.01	
	B13	2 Feb 2215-0705 Feb 3	4.05±.04	6.96±.14	.58±.01	
	4 Feb 1415-2215					

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	B48	5 Feb 1025-2150	1.20±.04	2.39±.06	.50±.02
	E2	17 Jun 1502-1928	.30±.01	.65±.03	.46±.02
	E20	17 Jun 1928-2101	.15±.01	.22±.02	.68±.08
	E22	17 Jun 2101-2329	.27±.01	.57±.03	.47±.03
	E35	17 Jun 2329-0146 Jun 18	.23±.01	.39±.04	.58±.07
	E51	19 Jun 1836-1925 Jun 20	.52±.02	1.10±.05	.47±.03
	E69	20 Jun 1925-2335 Jun 20	.78±.03	1.50±.08	.52±.03
	E81	20 Jun 2335-0143 Jun 21	2.60±.05	4.48±.09	.58±.02
	E90	21 Jun 2046-0627 Jun 22	2.43±.04	4.55±.09	.53±.01
	E110	23 Jun 0745-1800	2.42±.04	4.55±.09	.53±.01
	E111	23 Jun 1800-2300	1.20±.04	2.20±.11	.54±.03
	E130	23 Jun 2300-0709 Jun 24	.81±.03	1.41±.07	.57±.04
	E151	24 Jun 0709-0902	1.71±.04	3.12±.12	.55±.03
	E171	24 Jun 0902-1210 Jun 25	5.15±.05	9.60±.10	.54±.01
	E206	26 Jun 1909-2023 Jun 27	1.55±.04	2.94±.12	.53±.02
	E225	29 Jun 1622-0744 Jun 30	.38±.01	.90±.04	.42±.02
2050	D3	2 Feb 1540-0930 Feb 3	3.91±.06	7.32±.15	.53±.01
	D25	4 Feb 1405-1725	.84±.03	1.41±.07	.60±.02
	D44	5 Feb 1050-1535	2.07±.03	4.02±.06	.57±.02
	D55	5 Feb 1535-1705	1.91±.03	5.13±.10	.37±.01
	D70	5 Feb 1705-0945	.22±.01	.42±.04	.52±.06
2150	D4	2 Feb 1545-0935 Feb 3	3.39±.05	5.62±.10	.60±.02
	D26	4 Feb 1410-1730	.61±.02	1.17±.06	.52±.03
	D45	5 Feb 1055-1540	2.13±.03	3.94±.08	.54±.01
	D56	5 Feb 1540-1710	2.71±.04	5.38±.10	.50±.01
	D71	5 Feb 1710-0950 Feb 6	.34±.01	.52±.03	.65±.04
	B3	2 Feb 1720-2220	3.10±.05	5.65±.10	.55±.02

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	B32	4 Feb 1420-2225	2.67±.04	5.30±.10	.50±.01
	B49	5 Feb 1630-2155	1.20±.04	2.35±.07	.51±.02
	E3	17 Jun 1506-1932	.26±.01	.54±.04	.48±.04
	E23	17 Jun 1932-2335	.16±.01	.33±.03	.48±.06
	E36	17 Jun 2335-0150 Jun 18	1.99±.03	3.47±.06	.57±.02
	E52	19 Jun 1838-1930 Jun 20	.63±.02	1.39±.07	.45±.03
	E70	20 Jun 1930-2339 Jun 20	.70±.02	1.33±.07	.53±.03
	E82	20 Jun 2339-0132 Jun 21	1.80±.03	3.14±.06	.57±.02
	E91	21 Jun 2049-0631 Jun 22	2.25±.03	4.40±.08	.51±.01
	E101	22 Jun 0631-1756 Jun 23	2.00±.03	3.94±.08	.51±.01
	E112	23 Jun 1756-2305	1.21±.04	2.33±.07	.52±.02
	E131	23 Jun 2305-0712 Jun 24	.67±.02	1.24±.07	.54±.03
	E150	24 Jun 0712-0858	1.69±.03	3.31±.06	.51±.01
	E170	24 Jun 0858-1206 Jun 25	4.88±.05	9.95±.10	.49±.01
	E205	26 Jun 1907-2021 Jun 27	1.28±.04	2.60±.08	.49±.02
	E223	29 Jun 1521-0742 Jun 30	.68±.02	1.40±.07	.47±.03
2250	D5	2 Feb 1550-0940 Feb 3	2.84±.05	4.60±.09	.62±.02
	D27	4 Feb 1415-1735	1.10±.04	2.08±.08	.53±.03
	D46	5 Feb 1100-1545	1.73±.03	3.06±.09	.56±.02
	D57	5 Feb 1545-1715	1.78±.03	3.49±.05	.51±.01
	D72	5 Feb 1715-0955 Feb 6	.46±.02	.82±.03	.56±.03
	B4	2 Feb 1715-2225	2.10±.03	3.60±.05	.58±.01
	B33	4 Feb 1425-2230	1.15±.04	2.47±.04	.46±.02
	B50	5 Feb 1935-2230	1.39±.04	2.84±.09	.49±.02
	E4	17 Jun 1510-1937	.37±.01	.66±.05	.56±.04
	E24	17 Jun 1937-0135 Jun 18	.32±.01	.69±.05	.46±.03
	E40	18 Jun 0135-0831	1.21±.04	3.00±.06	.40±.01
		22 Jun 0635-0735 Jun 23			
	E53	19 Jun 1841-1935	1.08±.03	2.07±.10	.52±.03

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	E71	20 Jun 1935-2343 Jun 20	.62±.02	1.19±.06	.52±.03
	E83	20 Jun 2343-0128 Jun 21	1.21±.04	2.41±.12	.50±.03
	E88	21 Jun 0913-2055	1.26±.04	2.82±.12	.45±.03
	E92	21 Jun 2055-0635 Jun 22	1.31±.04	2.66±.11	.49±.03
	E113	23 Jun 0753-2308	2.30±.04	4.35±.08	.53±.01
	E132	23 Jun 2308-0716 Jun 24	.77±.02	1.40±.07	.55±.03
	E149	24 Jun 0716-0854	1.24±.04	2.38±.07	.52±.02
	E169	24 Jun 0854-1203 Jun 25	5.00±.05	11.4 ±.1	.44±.01
	E204	26 Jun 1904-2018 Jun 27	1.43±.04	2.86±.12	.50±.02
	E224	29 Jun 1514-0739 Jun 30	.58±.02	1.28±.06	.45±.03
2400	D6	2 Feb 1555-0945 Feb 3	3.80±.05	4.32±.08	.88±.02
	D28	4 Feb 1420-1740	1.11±.04	2.05±.08	.54±.03
	D47	5 Feb 1105-1554	1.23±.04	1.98±.08	.62±.03
	D58	5 Feb 1550-1720	1.53±.04	2.64±.08	.58±.03
	D73	5 Feb 1720-1000 Feb 3	.57±.02	.87±.03	.66±.03
	B5	2 Feb 1711-2230	2.80±.05	4.07±.08	.69±.02
	B34	4 Feb 1430-2235	.69±.02	1.10±.05	.63±.03
	B51	5 Feb 1040-2205	2.03±.03	3.71±.05	.55±.01
	E5	17 Jun 1517-1941	1.00±.03	.46±.04	2.17±.20
	E25	17 Jun 1941-2346	.15±.01	.18±.02	.83±.10
	E37	17 Jun 2346-0156 Jun 18	.55±.02	.93±.05	.59±.03
	E41	18 Jun 0156-0835	1.72±.05	3.36±.06	.51±.01
		21 Jun 0123-0918			
		22 Jun 0641-0758 Jun 23			
	E54	19 Jun 1843-1939 Jun 20	.51±.02	1.00±.05	.51±.03
	E72	20 Jun 1939-2347	.38±.01	.72±.02	.53±.02
	E84	20 Jun 2347-0123 Jun 21	.48±.01	.86±.04	.56±.03
	E93	21 Jun 2200-0641 Jun 22	.93±.03	2.06±.08	.45±.02

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	E114	23 Jun 0758-2313	2.35±.04	4.65±.09	.50±.01
	E133	23 Jun 2313-0720 Jun 24	.81±.03	1.52±.08	.53±.03
	E148	24 Jun 0720-0850	.46±.01	.87±.04	.53±.03
	E154	24 Jun 0850-1040 Jun 25	4.11±.05	7.80±.14	.53±.01
	E203	26 Jun 1902-2015 Jun 27	.94±.03	1.92±.10	.49±.03
	E222	29 Jun 1510-0736 Jun 30	.47±.01	1.10±.05	.42±.02
2600	D7	2 Feb 1600-1630 Feb 3	5.95±.07	5.80±.12	1.02±.02
		3 Feb 2305-1425 Feb 4			
	D29	4 Feb 1425-1745	1.41±.05	2.10±.08	.67±.03
	D48	5 Feb 1110-1555	2.63±.05	3.60±.05	.73±.02
	D59	5 Feb 1555-1725	2.10±.04	3.45±.05	.61±.01
	D74	5 Feb 1725-1005 Feb 6	1.69±.04	1.94±.08	.87±.03
2700	D8	2 Feb 1605-1635 Feb 3	2.09±.03	3.88±.07	.54±.01
	D19	3 Feb 2310-1430 Feb 4	1.40±.04	2.56±.08	.55±.02
	D30	4 Feb 1430-1750	1.04±.03	2.12±.08	.49±.02
	D49	5 Feb 1115-1600	1.55±.04	2.99±.06	.52±.02
	D60	5 Feb 1600-1730	1.50±.04	2.89±.06	.52±.02
	D75	5 Feb 1730-1010 Feb 6	.77±.02	1.60±.08	.48±.03
	B6	2 Feb 1705-2235	4.00±.07	5.33±.10	.75±.02
	B16	3 Feb 1600-2300	5.84±.07	6.35±.13	.92±.02
	B35	4 Feb 1435-2240	1.05±.03	1.62±.08	.65±.04
	B52	5 Feb 1045-2210	1.85±.04	2.96±.06	.62±.02
	E6	17 Jun 1522-1945	1.30±.04	1.24±.07	1.05±.06
	E26	17 Jun 1945-2354	.47±.01	.52±.04	.90±.07
	E38	17 Jun 2354-0200 Jun 18	.59±.02	.80±.03	.74±.04
	E42	18 Jun 0200-0840	1.65±.04	2.85±.08	.58±.02
		20 Jun 2352-0924 Jun 21			
	E55	19 Jun 1845-1944 Jun 20	.78±.02	1.28±.06	.61±.04

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	E73	20 Jun 1944-2352	.43±.01	.57±.04	.75±.05
	E94	21 Jun 2102-0645 Jun 22	.87±.02	1.92±.08	.45±.20
	E115	23 Jun 0803-2318	1.87±.03	3.62±.05	.52±.01
	E134	23 Jun 2318-0725 Jun 24	1.39±.04	3.82±.06	.36±.01
	E147	24 Jun 0725-0845	.30±.01	.69±.02	.43±.02
	E155	24 Jun 0845-1044 Jun 25	3.40±.06	6.56±.13	.52±.01
	E202	26 Jun 1900-2011 Jun 27	.54±.02	1.09±.05	.50±.03
	E221	29 Jun 1430-0733 Jun 30	.30±.01	.75±.02	.40±.02
	E232	9 Jul 1822-1758 Jul 10	.30±.01	.62±.02	.48±.02
2850	D9	3 Feb 1005-1640	1.13±.04	1.67±.09	.68±.04
	D20	3 Feb 2315-1435 Feb 4	.84±.02	1.69±.09	.50±.03
	D31	4 Feb 1435-1755	.67±.02	1.38±.07	.48±.03
	D50	5 Feb 1120-1605	1.55±.05	2.86±.08	.54±.02
	D61	5 Feb 1605-1735	1.39±.04	2.66±.07	.52±.02
	D76	5 Feb 1735-1015 Feb 6	1.58±.04	2.30±.07	.69±.03
2950	D10	3 Feb 1010-1645	3.00±.05	3.93±.08	.76±.02
		5 Feb 1125-1740			
	D21	3 Feb 2320-1440 Feb 4	1.45±.04	2.06±.08	.70±.04
	D32	4 Feb 1440-1800	1.31±.04	2.29±.08	.57±.02
	D77	5 Feb 1740-1020 Feb 6	3.00±.05	5.50±.10	.54±.01
	B7	2 Feb 1700-2240	4.70±.05	4.26±.08	1.10±.02
	B17	3 Feb 1610-2315	2.80±.05	3.27±.07	.86±.02
	B36	4 Feb 1440-2245	1.39±.04	1.29±.06	1.08±.06
	B53	5 Feb 1050-2215	1.51±.04	2.21±.05	.68±.03
	E7	17 Jun 1527-1949	.89±.03	.66±.02	1.35±.06
	E27	17 Jun 1949-2400	.22±.01	.25±.02	.88±.10
	E39	17 Jun 2400-0205 Jun 18	.29±.01	.50±.04	.58±.05

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	E43	18 Jun 0205-0844	1.26±.04	1.36±.07	.93±.05
		20 Jun 2357-0930 Jun 21			
	E56	19 Jun 1848-1948 Jun 20	.50±.02	.77±.02	.65±.03
	E74	20 Jun 1948-2357	.26±.01	.41±.04	.63±.07
	E95	21 Jun 2106-0650 Jun 22	.49±.02	.88±.04	.56±.03
	E103	22 Jun 0650-0809 June 23	2.57±.04	4.95±.10	.52±.01
		23 Jun 2322-0731 Jun 24			
	E116	23 Jun 1707-2322	1.84±.03	3.13±.04	.59±.01
	E146	24 Jun 0731-0837	.34±.01	.70±.02	.48±.02
	E156	24 Jun 0837-1048 Jun 25	2.77±.05	4.77±.10	.58±.02
	E190	26 Jun 1858-1928 Jun 27	.43±.01	.87±.04	.49±.02
	E220	29 Jun 1319-0731 Jun 30	.24±.01	.61±.03	.39±.02
	E233	9 Jul 1908-1802 Jul 10	.28±.01	.58±.03	.48±.03
3100	D11	3 Feb 1015-1445 Feb 4	1.30±.04	2.23±.09	.58±.03
	D33	4 Feb 1445-1805	1.39±.04	2.85±.08	.49±.02
	D51	5 Feb 1130-1615	1.66±.04	3.10±.06	.54±.02
	D62	5 Feb 1615-1745	1.21±.04	2.13±.08	.56±.03
	D78	5 Feb 1745-1025 Feb 6	1.35±.04	2.83±.08	.48±.02
	B8	2 Feb 1655-1615 Feb 3	1.93±.03	5.78±.12	.33±.01
	B18	2 Feb 1615-2320	.67±.02	1.18±.06	.57±.03
	B37	4 Feb 1445-2250	.58±.02	1.12±.06	.52±.03
	B54	5 Feb 1055-2220	.74±.02	1.63±.08	.45±.03
	E8	17 Jun 1532-1953	.16±.01	.26±.03	.62±.07
	E29	17 Jun 1953-0014 Jun 18	.11±.01	.062±.007	1.77±.26
	E44	18 Jun 0014-0848	.13±.01	.24±.02	.54±.08
	E57	19 Jun 1851-1952 Jun 20	.20±.01	.50±.04	.40±.04
	E75	20 Jun 1952-2400	.09±.01	.19±.02	.47±.07
	E85	20 Jun 2400-1020 Jun 21	.19±.01	.33±.03	.58±.06

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	E96	21 Jun 2110-0653 Jun 22	.30±.01	.61±.04	.49±.04
	E104	22 Jun 0653-0813 June 23	2.39±.04	4.30±.08	.56±.02
		23 Jun 2327-0735 Jun 24			
	E117	23 Jun 1709-2327 June 23	1.81±.04	3.48±.05	.52±.01
	E145	24 Jun 0735-0834	.30±.01	.66±.04	.45±.03
	E157	24 Jun 0834-1051 Jun 25	2.26±.04	4.27±.08	.53±.02
	E191	26 Jun 1856-1931 Jun 27	.34±.01	.70±.02	.49±.02
	E219	29 Jun 1322-0729 Jun 30	.19±.01	.34±.03	.56±.06
	E234	9 Jul 1910-1804 Jul 10	.19±.01	.37±.04	.51±.06
3250	D12	3 Feb 1020-2330	.95±.03	1.57±.08	.60±.03
	D22	3 Feb 2330-1450 Feb 4	1.15±.04	2.13±.08	.54±.03
		5 Feb 1620-1750			
	D34	4 Feb 1450-1810	1.49±.04	2.90±.08	.51±.02
	D52	5 Feb 1135-1620	.81±.03	1.76±.09	.46±.03
	D79	5 Feb 1750-1030 Feb 6	.70±.02	1.51±.08	.46±.03
	B9	2 Feb 1650-1620 Feb 3	2.40±.04	4.50±.09	.53±.01
	B19	3 Feb 1620-2325	.49±.01	.83±.03	.59±.03
	B38	4 Feb 1450-2255	.62±.02	1.36±.07	.46±.03
	B55	5 Feb 1100-2225	.56±.02	1.25±.06	.45±.03
	E9	17 Jun 1536-1957	.12±.01	.22±.02	.54±.08
	E28	17 Jun 1957-0007 Jun 18	.042±.002	.065±.007	.65±.10
	E45	18 Jun 0007-0851	.062±.004	.12±.01	.52±.08
	E58	19 Jun 1853-1956 Jun 20	.20±.01	.47±.04	.43±.05
	E76	20 Jun 1956-0008 Jun 21	.12±.01	.17±.02	.70±.10
	E86	21 Jun 0008-0937	.20±.01	.39±.04	.51±.06
		21 Jun 2113-0657 Jun 22			
	E105	22 Jun 0657-0819 Jun 23	2.39±.04	4.82±.09	.50±.01
		23 Jun 2331-0741 Jun 24			

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	E118	23 Jun 1711-2331	1.82±.04	3.47±.05	.52±.01
	E144	24 Jun 0741-0830	.24±.01	.62±.03	.39±.02
	E158	24 Jun 0830-1055 Jun 25	2.06±.03	3.65±.05	.56±.01
	E192	26 Jun 1854-1933 Jun 27	.31±.01	.72±.02	.43±.02
	E209	29 Jun 1324-0647 Jun 30	.18±.01	.36±.04	.50±.06
	E235	9 Jul 1912-1806 Jul 10	.23±.01	.32±.03	.72±.08
3350	D13	3 Feb 1025-2335	.98±.03	2.09±.08	.47±.02
	D23	3 Feb 2335-1455 Feb 4	2.17±.04	3.97±.08	.55±.02
	D35	4 Feb 1455-1815	1.72±.04	3.69±.05	.47±.01
	D53	5 Feb 1140-1625	.75±.02	1.66±.08	.45±.02
	D80	5 Feb 1755-1035	.53±.02	1.21±.06	.44±.03
3450	D14	3 Feb 1030-1505 Feb 4	3.40±.06	4.58±.09	.74±.02
	D36	4 Feb 1500-1820	2.24±.04	4.22±.09	.53±.02
	D54	5 Feb 1145-1630	.91±.03	1.74±.08	.52±.03
	D63	5 Feb 1630-1800	.78±.03	1.40±.07	.56±.03
	D81	5 Feb 1800-1040 Feb 6	.86±.03	1.80±.09	.48±.03
	B10	2 Feb 1645-1625 Feb 3	3.99±.06	7.35±.15	.54±.01
	B20	3 Feb 1625-2330	.62±.02	1.10±.05	.56±.03
	B39	4 Feb 1445-1045 Feb 5	.79±.03	1.54±.08	.51±.03
	B56	5 Feb 1105-2230	.46±.01	.98±.05	.47±.02
	E10	17 Jun 1539-2000	.15±.01	.35±.04	.44±.05
	E30	17 Jun 2000-0026 Jun 18	.053±.004	.13±.01	.41±.06
	E46	18 Jun 0026-0855	.08±.005	.17±.02	.47±.07
	E59	19 Jun 1854-1959 Jun 20	.16±.01	.42±.04	.38±.04
	E77	20 Jun 1959-0941 Jun 21	.26±.01	.34±.04	.76±.08
	E97	21 Jun 2115-0701 Jun 22	.24±.01	.50±.04	.48±.04
	E106	22 Jun 0701-0821 Jun 23	3.00±.05	5.65±.11	.53±.01
		23 Jun 2334-0745 Jun 24			

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (Ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	E119	23 Jun 1712-2334	1.82±.03	3.48±.05	.52±.01
	E143	24 Jun 0745-0826	1.72±.03	4.29±.08	.40±.01
	E159	24 Jun 0826-1057 Jun 25	2.06±.03	3.78±.08	.54±.01
	E172	25 Jun 1057-1205 Jun 26	1.88±.03	3.40±.05	.55±.01
	E189	26 Jun 1205-1852	.84±.03	1.77±.09	.47±.03
	E193	26 Jun 1852-1935 Jun 27	.30±.01	.62±.04	.48±.04
	E210	29 Jun 1340-0650 Jun 30	.19±.01	.42±.04	.45±.05
	E236	9 Jul 1913-1808	.13±.01	.40±.04	.32±.05
3600	D15	3 Feb 1035-2345	1.30±.04	2.25±.09	.58±.03
	D37	4 Feb 1505-1825	1.83±.03	3.80±.08	.48±.01
	D64	5 Feb 1635-1805	.58±.02	1.26±.06	.46±.03
	D82	5 Feb 1805-1045 Feb 6	.39±.01	.86±.04	.45±.03
	B11	2 Feb 1640-1630 Feb 3	5.34±.06	5.33±.11	1.00±.02
		3 Feb 2340-1440 Feb 4			
	B21	3 Feb 1630-2340	1.09±.03	1.39±.07	.78±.05
	B40	4 Feb 1500-2300	1.01±.03	1.40±.07	.72±.04
	B63	5 Feb 1100-1545 Feb 6	1.82±.04	2.09±.10	.87±.05
	E11	17 Jun 1547-2004	.42±.01	.48±.03	.88±.06
	E31	17 Jun 2004-0032 Jun 18	.22±.01	.26±.03	.85±.09
	E47	18 Jun 0032-0859	.56±.02	.67±.03	.84±.03
		20 Jun 2004-0018 Jun 21			
	E60	19 Jun 1857-2004 Jun 20	.23±.01	.54±.03	.42±.02
	E78	30 Jun 0654-0850	.38±.01	.71±.02	.54±.02
	E87	21 Jun 0018-0945 Jun 21	.65±.02	1.11±.06	.58±.04
		21 Jun 2118-0705 Jun 22			
	E120	23 Jun 1714-2338	2.00±.03	3.80±.05	.53±.01
	E135	23 Jun 2338-0748 Jun 24	1.50±.04	3.40±.05	.44±.01
	E160	24 Jun 0748-1100 Jun 25	1.56±.04	2.95±.06	.53±.02

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	E173	25 Jun 1100-1208 Jun 26	1.72±.04	3.14±.06	.55±.02
	E188	26 Jun 1208-1850	.68±.02	1.23±.06	.55±.03
	E194	26 Jun 1850-1937 Jun 27	.78±.01	.54±.03	.52±.03
	E211	29 Jun 1353-0654 Jun 30	.15±.01	.26±.03	.58±.06
	E237	9 Jul 1915-1810 Jul 10	.15±.01	.45±.04	.33±.04
3750	D16	3 Feb 1045-2350	1.22±.04	1.68±.09	.73±.04
		5 Feb 1150-1635			
	D38	4 Feb 1510-1830	1.56±.04	3.10±.05	.50±.01
	D65	5 Feb 1640-1810	.52±.01	1.13±.06	.46±.03
	D85	5 Feb 1810-1050 Feb 6	.27±.01	.49±.04	.55±.05
	B14	3 Feb 0740-1635	2.65±.04	3.97±.07	.67±.02
		3 Feb 2352-1445 Feb 4			
	B22	3 Feb 1635-2350	1.00±.03	1.34±.07	.75±.04
	B41	4 Feb 1505-2305	.96±.03	1.51±.08	.64±.04
	B57	5 Feb 1115-2240	.75±.03	1.41±.07	.53±.03
	E12	17 Jun 1645-2009	.66±.02	.60±.03	1.10±.06
	E32	17 Jun 2009-0038 Jun 18	.29±.01	.44±.04	.66±.07
	E48	18 Jun 0038-0904	1.89±.03	2.68±.08	.70±.02
		20 Jun 2008-0950 Jun 21			
	E61	19 Jun 1859-2008 Jun 20	.34±.01	.60±.03	.57±.03
	E79	30 Jun 0657-0856	.35±.01	.80±.03	.44±.02
	E98	21 Jun 2122-0829 Jun 23	1.98±.03	3.86±.07	.51±.01
	E121	23 Jun 1715-2343 Jun 23	1.70±.03	3.35±.05	.51±.01
	E136	23 Jun 2343-0752 Jun 24	1.69±.03	3.26±.05	.52±.01
	E161	24 Jun 0752-1103 Jun 25	1.46±.04	2.70±.08	.54±.02
	E174	25 Jun 1103-1211 Jun 26	1.26±.04	2.54±.07	.50±.02
	E187	26 Jun 1211-1848	.59±.02	.98±.05	.55±.03
	E195	26 Jun 1848-1940 Jun 27	.33±.01	.48±.04	.69±.06

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	E212	29 Jun 1355-0657 Jun 30	.15±.01	.45±.04	.33±.03
	E238	9 Jul 1918-1812 Jul 10	.13±.01	.28±.03	.46±.05
3900	B23	3 Feb 1640-2355	.53±.02	.69±.02	.77±.04
	B42	4 Feb 1510-2310	.66±.02	1.16±.06	.57±.03
	B58	5 Feb 1120-2245	1.15±.04	1.69±.09	.68±.04
	E13	17 Jun 1640-2013	.65±.02	.50±.04	1.30±.10
	E33	17 Jun 2013-0044 Jun 18	.31±.01	.33±.03	.94±.10
	E49	18 Jun 0044-0908	1.07±.03	2.28±.10	.47±.03
		20 Jun 2013-0032 Jun 21			
	E62	19 Jun 1901-2013 Jun 20	.41±.01	.47±.04	.87±.07
	E100	30 Jun 0700-2145	.32±.01	.72±.02	.44±.02
	E122	23 Jun 1717-2348	1.60±.04	2.97±.07	.54±.02
	E137	23 Jun 2348-0756 Jun 24	1.69±.04	3.30±.05	.51±.01
	E162	24 Jun 0756-1105 Jun 25	1.23±.04	2.60±.07	.47±.01
	E175	25 Jun 1105-1213 Jun 26	1.30±.04	2.60±.07	.50±.01
	E186	26 Jun 1213-1846	.54±.02	.94±.05	.57±.03
	E196	26 Jun 1846-1943 Jun 27	.20±.01	.35±.04	.57±.06
	E213	29 Jun 1417-0700 Jun 30	.17±.01	.34±.03	.50±.06
	E239	9 Jul 1919-1815 Jul 10	.14±.01	.29±.03	.48±.05
4050	D17	3 Feb 1045-2355	1.08±.03	1.34±.06	.80±.04
	D39	4 Feb 1515-1835	1.32±.04	2.27±.09	.58±.03
	D66	5 Feb 1645-1815	.46±.02	.92±.05	.50±.03
	D84	5 Feb 1815-1055 Feb 6	.32±.01	.68±.02	.47±.02
4200	B24	3 Feb 1645-2400	.59±.02	.56±.03	1.05±.06
	B43	4 Feb 1515-2315	.60±.02	.84±.03	.71±.03
	B59	5 Feb 1125-2255	1.40±.04	2.08±.08	.67±.03

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	E14	17 Jun 1632-0050 Jun 18	1.53±.04	.84±.03	1.82±.08
	E63	19 Jun 1903-0038 Jun 21	.91±.03	.87±.04	1.04±.06
	E102	30 Jun 0704-2150	.40±.01	.84±.03	.48±.02
	E123	23 Jun 1719-2353	1.33±.04	2.62±.10	.51±.02
	E138	23 Jun 2353-0800 Jun 24	2.42±.04	4.53±.09	.53±.01
	E162	24 Jun 0800-1109 Jun 25	1.23±.04	2.32±.09	.53±.03
	E176	25 Jun 1109-1216 Jun 26	1.62±.04	3.82±.08	.42±.01
	E185	26 Jun 1216-1843	.45±.02	.78±.03	.58±.03
	E197	26 Jun 1843-1945 Jun 27	.20±.01	.31±.03	.64±.07
	E214	29 Jun 1359-0704 Jun 30	.19±.01	.46±.04	.42±.05
	E227	2 Jul 1518-0858 Jul 4	.36±.01	.66±.03	.54±.03
	E240	9 Jul 1922-1817 Jul 10	.14±.01	.31±.03	.45±.05
	E245	10 Jul 1817-1744 Jul 11	.76±.03	1.45±.07	.52±.03
4400	D18	3 Feb 1050-2400	.84±.03	.93±.05	.90±.05
	D40	4 Feb 1520-1840	.70±.02	1.26±.06	.56±.03
	D67	5 Feb 1650-1820	.50±.02	.73±.02	.68±.03
	D85	5 Feb 1820-1100 Feb 6	.50±.02	1.25±.06	.40±.02
	B25	3 Feb 1650-0005 Feb 4	1.10±.04	.85±.03	1.29±.06
	B44	4 Feb 1520-2320	1.18±.04	1.72±.08	.69±.04
	B60	5 Feb 1130-2300	1.70±.04	1.96±.10	.87±.05
	E15	17 Jun 1625-0056 Jun 18	1.51±.04	.96±.05	1.57±.09
	E64	19 Jun 1906-0045 Jun 21	.95±.03	1.26±.06	.75±.04
	E107	30 Jun 0708-2155	.37±.01	.57±.04	.65±.05
	E124	23 Jun 1722-2359	1.03±.03	1.99±.08	.52±.03
	E139	23 Jun 2359-0803 Jun 24	2.20±.04	4.12±.08	.53±.02
	E164	24 Jun 0803-1112 Jun 25	.87±.03	1.61±.08	.54±.03
	E177	25 Jun 1112-1219 Jun 26	1.46±.04	2.82±.06	.52±.02
	E184	26 Jun 1219-1840	.36±.01	.62±.03	.58±.03

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	E198	26 Jun 1840-1947 Jun 27	.84±.03	1.47±.07	.57±.03
	E215	29 Jun 1402-0708 Jun 30	.19±.01	.26±.03	.73±.08
	E228	2 Jul 1521-0901 Jul 4	.46±.02	.79±.03	.58±.03
	E241	9 Jul 1925-1820 Jul 10	.10±.007	.26±.03	.38±.06
	E246	10 Jul 1820-1746 Jul 11	.84±.03	1.58±.08	.53±.03
4600	B30	3 Feb 1652-1505 Feb 4	2.79±.05	2.29±.07	1.22±.05
		5 Feb 1135-1600 Feb 6			
	B45	4 Feb 1525-2325	.64±.02	1.06±.05	.60±.03
	E16	17 Jun 1621-0100 Jun 18	.76±.03	.83±.03	.92±.05
	E65	19 Jun 1908-2028 Jun 20	.62±.02	.75±.02	.83±.03
	E108	30 Jun 0710-2158	.43±.01	.80±.03	.54±.02
	E125	23 Jun 1724-0005 Jun 24	.97±.03	1.97±.08	.49±.02
	E140	24 Jun 0005-0806	2.15±.04	4.35±.08	.49±.01
	E165	24 Jun 0806-1115 Jun 25	.93±.03	1.81±.09	.51±.03
	E178	25 Jun 1115-1222 Jun 26	1.16±.04	2.57±.07	.45±.02
	E183	26 Jun 1222-1838	.31±.01	.61±.03	.51±.03
	E199	26 Jun 1838-1951 Jun 27	.08±.006	.28±.03	.29±.04
	E216	29 Jun 1404-0710 Jun 30	.09±.006	.20±.02	.45±.07
	E229	2 Jul 1523-0903 Jul 4	.55±.02	1.01±.05	.54±.03
	E242	9 Jul 1927-1822 Jul 10	.13±.01	.24±.02	.54±.06
	E247	10 Jul 1822-1748 Jul 11	.84±.03	1.67±.08	.50±.03
4800	B26	3 Feb 1655-0015 Feb 4	.86±.03	.86±.03	1.00±.04
	B46	4 Feb 1530-2330	.62±.02	1.09±.05	.57±.03
	B61	5 Feb 1140-2310	.89±.03	1.33±.06	.67±.04
	E17	17 Jun 1617-0105 Jun 18	.87±.03	.95±.05	.92±.05
	E66	19 Jun 1910-2031 Jun 20	1.12±.04	1.05±.05	1.07±.06
	E109	30 Jun 0713-2202	.60±.02	1.05±.05	.57±.03

TABLE VI. (Continued) ALTITUDE RAIN SAMPLES

Altitude (ft.) and Road	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
	E126	23 Jun 1725-0007 Jun 24	.76±.03	1.31±.06	.58±.04
	E141	24 Jun 0007-0809	1.93±.03	3.70±.05	.52±.01
	E166	24 Jun 0809-1118 Jun 25	.52±.02	1.24±.06	.42±.03
	E179	25 Jun 1118-1225 Jun 26	.98±.03	2.16±.09	.45±.02
	E182	26 Jun 1225-1836	.27±.01	.48±.04	.56±.05
	E200	26 Jun 1836-1953 Jun 27	.10±.007	.24±.02	.42±.06
	E217	29 Jun 1406-0713 Jun 30	.07±.005	.16±.02	.44±.06
	E230	2 Jul 1526-0905 Jul 4	.53±.02	.93±.05	.57±.03
	E243	9 Jul 1929-1824 Jul 10	.13±.01	.27±.03	.48±.05
	E248	10 Jul 1824-1750 Jul 11	.71±.02	1.26±.06	.56±.03
5100	B27	3 Feb 1700-0020 Feb 4	.96±.03	.57±.03	1.68±.10
	B31	4 Feb 0020-1510	1.33±.04	2.59±.10	.51±.02
	B47	4 Feb 1535-2335	.78±.03	.62±.03	.79±.05
	E18	17 Jun 1610-0110 Jun 18	.58±.02	.61±.02	.95±.04
	E67	19 Jun 1912-2036 Jun 20	.49±.02	.92±.05	.53±.03
	E127	23 Jun 1728-0012 Jun 24	.55±.02	.92±.05	.60±.04
	E142	24 Jun 0012-0815	1.69±.04	3.43±.05	.49±.02
	E167	24 Jun 0815-1122 Jun 25	.55±.02	1.06±.05	.52±.03
	E168	24 Jun 0815-1122 Jun 25	.55±.02	1.08±.05	.51±.03
	E180	25 Jun 1122-1228 Jun 26	.70±.03	1.57±.08	.44±.03
	E181	26 Jun 1228-1834	.28±.01	.55±.04	.51±.04
	E201	26 Jun 1834-1956 Jun 27	.06±.004	.22±.02	.27±.04
	E218	29 Jun 1409-0716 Jun 30	.10±.007	.10±.02	.50±.07
	E231	2 Jul 1528-0908 Jul 4	.30±.01	.54±.04	.56±.04
	E244	9 Jul 1934-1827 Jul 10	.08±.006	.20±.02	.40±.06
	E249	10 Jul 1827-1752 Jul 11	.47±.02	.98±.05	.48±.03

TABLE VII. SOME SAMPLES WITH EXCEPTIONALLY HIGH Na/Cl RATIOS

Altitude	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
2400	E5	17 Jun 1517-1941	1.00±.03	.46±.02	2.17±.1
2600	D7	2 Feb 1600-1630 Feb 3 3 Feb 2305-1425 Feb 4	5.95±.07	5.80±.06	1.02±.02
2700	E6	17 Jun 1522-1945	1.30±.04	1.24±.03	1.05±.04
2950	B7	2 Feb 1700-2240	4.75±.05	4.26±.04	1.10±.01
	B36	4 Feb 1440-2245	1.39±.04	1.29±.03	1.08±.04
	E7	17 Jun 1527-1949	.89±.03	.66±.01	1.35±.04
3100	E29	17 Jun 1953-0014 Jun 18	.11±.01	.062±.005	1.77±.15
3600	B11	2 Feb 1640-1630 Feb 3 3 Feb 2340-1440 Feb 4	5.34±.06	5.33±.05	1.00±.01
3750	E12	17 Jun 1645-2009	.66±.02	.60±.01	1.10±.03
3900	E13	17 Jun 1640-2013	.65±.02	.50±.02	1.30±.06
4200	B24	3 Feb 1645-2400	.59±.02	.56±.02	1.05±.04
	E14	17 Jun 1632-0050 Jun 18	1.53±.04	.84±.02	1.82±.05
	E63	19 Jun 1903-0038 Jun 21	.91±.03	.87±.02	1.04±.03
4400	B25	3 Feb 1650-0005 Feb 4	1.10±.04	.85±.02	1.29±.05
	E15	17 Jun 1625-0056 Jun 18	1.51±.04	.96±.03	1.57±.06
4600	B30	3 Feb 1652-1505 Feb 4 5 Feb 1135-1600 Feb 6	2.79±.05	2.29±.05	1.22±.03

TABLE VII. (Continued) SOME SAMPLES WITH EXCEPTIONALLY HIGH Na/Cl RATIOS

Altitude	Sample No.	Collection Time Interval	Na (ppm)	Cl (ppm)	Na/Cl
4800	E16	17 Jun 1621-0100 Jun 18	.76±.03	.83±.02	.92±.04
	B26	3 Feb 1655-0015 Feb 4	.86±.03	.86±.02	1.00±.04
	E17	17 Jun 1617-0105 Jun 18	.87±.03	.95±.03	.92±.04
	E66	19 Jun 1910-2031 Jun 20	1.12±.04	1.05±.03	1.07±.05
5100	B27	3 Feb 1700-0020 Feb 4	.96±.03	.57±.02	1.68±.03
	E18	17 Jun 1610-0110 Jun 18	.58±.02	.61±.01	.95±.03

TABLE VIII. INTENSITY RAIN SAMPLES

Date, Location and Remarks	Sample No.	Start of Sample Collection HST	Collection Time in Minutes and Seconds	Intensity mm/hr	Na (ppm)	Cl (ppm)	Na/Cl
June 24, 1967 Radar Pad, Hilo Elev. 250 ft.	B64	1049:00	3:05	1.6	12.1 ±.4	25.3 ±.5	.48±.02
	B65	1054:00	0:50	12.6	6.20±.07	12.9 ±.2	.48±.01
	B66	1055:00	1:25	6.3	5.70±.06	12.0 ±.2	.48±.01
	B67	1056:50	0:40	17.5	2.62±.04	5.04±.10	.52±.01
	B68	1058:00	0:50	12.6	2.72±.04	5.42±.11	.50±.01
	B69	1059:35	1:35	4.9	3.08±.05	5.80±.12	.53±.01
	B70	1101:20	2:00	4.3	3.53±.06	6.75±.15	.52±.02
	B71	1103:50	5:00	1.3	5.84±.06	12.0 ±.2	.49±.01
June 24, 1967 Saddle Road 2700 ft. off 1556:30	B72	1554:15	2:15	2.2	1.81±.06	3.40±.05	.53±.02
June 26, 1967 In town, Hilo 300 ft.	B73	1009:50	1:20	5.5	4.85±.05	9.53±.10	.51±.01
	B74	1011:40	0:45	14.9	2.22±.03	4.32±.07	.51±.01
	B75	1012:40	0:45	11.4	1.61±.04	3.28±.06	.49±.02
	B76	1013:35	1:10	7.8	1.31±.04	2.85±.06	.46±.02
	B77	1015:30	1:40	1.7	1.43±.04	3.43±.06	.42±.02
Same location as above	B78	1024:40	0:32	18.4	1.90±.03	3.78±.06	.50±.01
	B79	1025:35	0:40	19.9	1.49±.04	3.12±.06	.48±.02
	B80	1027:00	0:42	13.0	1.76±.03	3.53±.05	.50±.01
	B81	1028:15	0:43	14.4	1.45±.04	2.88±.06	.50±.02
	B82	1029:30	1:00	9.4	1.37±.04	3.10±.06	.44±.02
	B83	1030:55	0:55	9.4	.85±.03	1.85±.10	.46±.03
	B84	1032:20	1:00	9.0	.50±.02	1.08±.05	.46±.03
	B85	1033:45	1:10	1.8	.61±.02	1.40±.07	.44±.03
End of RW							

TABLE VIII. (Continued) INTENSITY RAIN SAMPLES

Date, Location and Remarks	Sample No.	Start of Sample Collection HST	Collection Time in Minutes and Seconds	Intensity mm/hr	Na (ppm)	Cl (ppm)	Na/Cl
June 27, 1967 Saddle Road 2700 ft. RW imbedded in general orographic rain	B86	1830:20	1:30	5.3	2.50±.04	4.82±.10	.52±.02
	B87	1832:20	0:40	12.6	.74±.03	1.52±.08	.49±.03
	B88	1833:25	0:50	10.0	.48±.02	.93±.05	.52±.03
	B89	1834:40	0:58	8.7	.40±.01	.79±.03	.51±.02
	B90	1836:00	0:52	9.2	.42±.01	.69±.03	.61±.03
	B91	1837:15	0:42	13.4	.13±.01	.24±.02	.54±.07
	B92	1838:20	0:48	10.4	.10±.007	.20±.02	.50±.06
	B93	1839:27	1:27	4.2	.076±.005	.18±.02	.42±.05
	B94	1841:12	1:51	6.6	.088±.006	.16±.02	.55±.07
	B95	1843:30	2:70	4.3	.15±.01	.35±.04	.43±.05
New Rain Showers Start of new RW	B96	1846:30	2:30	5.2	.19±.01	.44±.04	.43±.05
	B97	1849:40	1:27	9.2	.17±.01	.46±.04	.37±.05
	B98	1852:15	1:52	7.3	.17±.01	.42±.04	.40±.05
	B99	1856:30	1:03	5.1	.24±.01	.53±.04	.45±.04
	B100	1856:05	2:15	3.4	.25±.01	.68±.03	.37±.02
	B101	1901:30	2:50	3.3	.34±.01	.73±.03	.46±.02
	B102	1904:40	1:18	9.2	.32±.01	.66±.03	.48±.02
	B103	1906:15	0:50	14.1	.24±.01	.52±.04	.46±.05
	B104	1907:30	0:45	17.0	.24±.01	.54±.04	.44±.04
	B105	1908:55	1:07	11.5	.15±.01	.34±.03	.44±.06
End of RW	B106	1910:25	2:00	5.3	.22±.01	.53±.04	.42±.04
	B107	1912:50	2:30	4.1	.28±.01	.67±.03	.42±.02
June 29, 1967 Saddle Road 3400 ft. End of RW at high intensity	B108	1330:20	3:56	2.3	.23±.01	.47±.03	.49±.03
	B109	1334:45	4:00	2.1	.07±.005	.15±.02	.47±.05
	B110	1339:30	3:32	3.1	.057±.004	.083±.01	.69±.10
	B111	1343:50	2:15	4.3	.047±.004	.084±.01	.56±.10

TABLE VIII. (Continued) INTENSITY RAIN SAMPLES

Date, Location and Remarks	Sample No.	Start of Sample Collection HST	Collection Time in Minutes and Seconds	Intensity mm/hr	Na (ppm)	Cl (ppm)	Na/Cl
June 29, 1967 Saddle Road 2600 ft.	B112	1441:00	4:20	1.3	.25±.01	.52±.04	.48±.04
	B113	1445:45	1:33	5.8	.17±.01	.35±.04	.48±.06
	B114	1447:45	1:17	7.1	.16±.01	.31±.04	.52±.06
	B115	1449:20	3:32	1.8	.25±.01	.52±.04	.48±.04
	B116	1453:30	4:33	1.8	.22±.01	.49±.03	.45±.04
	B117	1458:30	5:48	0.81	.36±.01	.80±.03	.45±.02
	End of RW						
June 29, 1967 Saddle Road 2300 ft.	B118	1559:25	7:32	0.51	1.69±.04	3.67±.05	.46±.01
	B119	1607:00	5:47	0.57	1.26±.04	2.92±.09	.43±.02
Only two samples low intensity							
June 30, 1967 Saddle Road 2700 ft.	B120	1604:40	3:25	2.4	1.00±.03	2.12±.10	.47±.03
	B121	1608:30	1:17	5.8	.90±.03	1.60±.08	.56±.03
	B122	1610:10	0:52	10.8	.96±.03	1.75±.09	.55±.03
	B123	1611:18	0:43	14.8	.48±.02	.86±.04	.58±.04
	B124	1612:20	0:41	15.7	.42±.01	.76±.02	.55±.03
	B125	1613:30	1:06	9.4	.35±.01	.70±.02	.50±.02
	B126	1614:55	1:15	7.0	.27±.01	.62±.03	.44±.03
	B127	1616:25	1:55	6.2	.41±.01	.79±.03	.52±.03
	B128	1618:40	2:38	4.6	.40±.01	.82±.03	.49±.02
	B129	1621:40	1:53	6.0	.40±.01	.80±.03	.50±.02
	B130	1623:55	3:35	2.5	.51±.02	.93±.04	.55±.03
	B131	1627:55	2:39	3.7	.47±.02	.88±.04	.53±.03
	B132	1630:55	2:00	5.0	.46±.02	.86±.04	.53±.03
	B133	1633:20	1:02	11.3	.44±.01	.81±.04	.54±.03
	B134	1634:40	1:03	11.4	.38±.01	.74±.02	.51±.02

TABLE VIII. (Continued) INTENSITY RAIN SAMPLES

Date, Location and Remarks	Sample No.	Start of Sample Collection HST	Collection Time in Minutes and Seconds	Intensity mm/hr	Na (ppm)	Cl (ppm)	Na/Cl
	B135	1636:05	0:33	20.0	.34±.01	.64±.03	.53±.03
	B136	1636:55	0:39	18.8	.49±.02	.82±.03	.60±.03
	B137	1637:50	0:50	14.3	.56±.02	.90±.04	.62±.04
	B138	1639:08	1:31	5.0	.64±.02	1.06±.05	.60±.04
	B139	1641:00	2:43	3.7	.82±.03	1.52±.09	.54±.04
Intensity Increase	B140	1644:05	1:30	7.9	.69±.02	1.35±.07	.51±.03
	B141	1646:05	0:58	11.2	1.04±.03	1.74±.09	.60±.04
	B142	1647:30	1:05	11.4	1.15±.04	2.08±.10	.55±.03
	B143	1649:00	1:11	9.4	1.31±.04	2.41±.12	.54±.03
End of RW	B144	1650:50	4:00	2.6	1.80±.04	3.29±.06	.55±.02
July 3, 1967	B145	1039:00	1:10	8.7	2.75±.05	5.30±.10	.52±.01
Near Airport, Hilo	B146	1040:30	0:52	11.0	1.73±.04	3.35±.05	.52±.02
	B147	1041:40	0:58	10.9	1.55±.04	3.10±.04	.50±.02
	B148	1042:50	1:10	8.7	1.95±.04	3.75±.05	.52±.01
Intensity increase	B149	1044:20	0:41	18.5	1.60±.04	3.04±.04	.53±.01
dropped sample lost about 20 m	B150	1045:20	2:10	3.5	3.02±.05	5.50±.10	.55±.02
Jan. 30, 1967	C1	1641:25	2:15	6.8	1.66±.04	3.39±.05	.49±.01
Saddle Road	C2	1644:30	1:40	7.6	1.88±.04	3.43±.05	.55±.01
2500 ft.	C3	1646:40	3:05	5.0	2.30±.05	5.67±.10	.40±.01
	C4	1651:00	4:13	2.9	2.86±.05	5.48±.10	.52±.01
	C5	1656:00	5:30	1.7	3.76±.06	6.76±.12	.56±.02
	C6	1705:25	10:05	0.84	4.38±.05	6.86±.12	.64±.01
	C7	1721:45	15:00	0.48	4.12±.05	6.83±.12	.60±.01

TABLE VIII. (Continued) INTENSITY RAIN SAMPLES

Date, Location and Remarks	Sample No.	Start of Sample Collection HST	Collection Time in Minutes and Seconds	Intensity mm/hr				
					Na (ppm)	Cl (ppm)	Na/Cl	
Saddle Road 2700 ft. Bad Sample spilled	C8	1754:30	3:30	3.1	1.02±.03	2.11±.07	.48±.02	
	C9	1758:45						3:00
	C10	1809:45	7:00	1.2	1.54±.04	3.03±.09	.51±.02	
(hour only)								
March 27, 1967 Kahana Bay, Oahu	C11	1205	2:10	6.7	23.3 ±.4	40.6 ±.8	.58±.02	
	C13	1210	1:35	7.8	22.6 ±.4	40.4 ±.8	.56±.02	
	C14	1214	2:30	3.7	23.4 ±.4	40.4 ±.8	.58±.02	
	C15	1217	4:08	2.1	28.4 ±.5	48.6 ±1.0	.58±.02	
	C16	1222	2:12	3.8	25.0 ±.5	45.0 ±.9	.55±.02	
	C17	1225	5:23	1.7	28.5 ±.5	48.6 ±1.0	.58±.02	
	C18	1233	3:48	2.3	28.0 ±.5	45.2 ±.9	.62±.02	
	RW stopped New light rain	C19	1238	8:12	1.2	30.7 ±.5	49.5 ±1.0	.62±.02
	C20	1242	8:55	1.2	30.5 ±.5	52.8 ±1.1	.58±.02	
	C21	1257	1:08	8.3	22.6 ±.4	40.2 ±.8	.56±.02	
	C22	1300	2:13	4.5	21.6 ±.4	40.4 ±.8	.54±.02	
RW stopped	C23	1303	2:14	4.4	23.9 ±.4	40.4 ±.8	.59±.02	
	C24	2306	2:15	4.2	22.4 ±.4	40.2 ±.8	.36±.02	
	C25	2309	8:45	1.0	26.5 ±.5	42.9 ±.8	.62±.02	
March 30, 1967 Kahana Bay, Oahu Kahuku, Oahu Hauula, Oahu Some spilled	C26	1520	1:30	7.2	5.06±.05	1.28 ±.09	.54±.01	
	C27	1720	3:00	1.9	4.90±.05	11.8 ±.1	.42±.01	
	C28	1825	0:29	9.0	27.4 ±.5	52.8 ±1.1	.52±.01	
	C29	1828	1:10	11.4	20.3 ±.4	40.2 ±.8	.50±.02	
	C30	1830	2:00	4.8	9.63±.3	40.2 ±.8	.48±.02	
	C31	1833	4:05	2.0	7.26±.2	14.6 ±.2	.50±.02	

TABLE VIII. (Continued) INTENSITY RAIN SAMPLES

Date, Location and Remarks	Sample No.	Start of Sample Collection HST	Collection Time in Minutes and Seconds	Intensity mm/hr	Na (ppm)	Cl (ppm)	Na/Cl
March 31, 1967	C32	1600	2:00	4.7	7.40±.2	14.2 ±.2	.52±.02
Hauula, Oahu	C33	1604	0:50	12.3	6.09±.07	12.4 ±.2	.49±.01
	C34	1606	1:38	5.3	5.15±.05	10.6 ±.1	.49±.01
	C35	1608	0:32	23.7	2.17±.03	3.61±.06	.60±.01
	C36	1609	0:20	44.3	1.12±.04	2.02±.10	.55±.04
	C37	1610	0:37	15.5	1.67±.04	3.29±.06	.51±.02
RW stopped	C38	1611	3:25	0.84	4.50±.05	9.09±.09	.50±.01
	C39	1615	8:00	1.3	8.01±.2	17.0 ±.3	.47±.01
About 1/2 mile up Wailehua Road, Oahu	C40	1710	2:38	5.6	4.58±.05	8.90±.09	.51±.01
	C41		C41 to C58	87	3.02±.05	5.67±.10	.53±.01
	C42		No individual measurement	66	1.01±.03	2.05±.10	.49±.03
	C43			72	.88±.03	1.68±.08	.52±.03
C41 to C58 are from a very intense RW. 18 samples collected in about 6 minutes; about half of total rain collected RW. Stopped with no tailing at 1718. No time measured. Intensities are only estimates.	C44		Very intense	76	.70±.02	1.36±.07	.51±.03
	C45		rain water.	51	.64±.02	1.26±.06	.51±.03
	C46			60	.46±.02	.89±.04	.52±.03
	C47			60	.33±.01	.61±.02	.54±.03
	C48			60	.36±.01	.65±.03	.55±.03
	C49			68	.50±.02	1.03±.05	.48±.03
	C50			72	.35±.01	.69±.02	.51±.02
	C51			73	.46±.02	.91±.04	.50±.03
	C52			73	.72±.02	1.45±.07	.50±.03
	C53			68	.58±.02	1.17±.06	.50±.03
	C54			84	.28±.01	.53±.04	.53±.04
	C55			92	.37±.01	.72±.02	.51±.02
	C56			59	.96±.03	1.80±.09	.53±.03
	C57			50	1.75±.04	3.20±.06	.55±.02
	C58	1718		45	2.32±.04	4.29±.08	.54±.02

TABLE VIII. (Continued) INTENSITY RAIN SAMPLES

Date, Location and Remarks	Sample No.	Start of	Collection Time	Intensity mm/hr	Na(ppm)	Cl(ppm)	Na/Cl
		Sample Collection HST	in Minutes and Seconds				
April 1, 1967	C59	0750	1:29	5.8	5.38±.06	10.5 ±.1	.51±.01
Sugar Mill Rain	C60	0752	1:04	9.2	2.85±.05	5.37±.10	.53±.01
Windward, Oahu RW stopped	C61	0753	2:35	0.84	4.05±.06	9.31±.09	.44±.01
Kaaawa, Oahu	C62	0950	4:00	1.2	15.0 ±.3	27.0 ±.5	.56±.02
	C63	1012	1:30	5.5	17.5 ±.3	31.2 ±.6	.56±.02
	C64	1014	1:37	4.5	15.5 ±.3	27.6 ±.5	.56±.02
	C65	1018	3:20	0.85	14.1 ±.2	28.4 ±.6	.50±.01
	C66	1022	2:31	2.1	11.1 ±.1	20.9 ±.4	.53±.01
July 7, 1967	C67	1424:10	2:37	3.0	5.66±.06	11.4 ±.1	.50±.01
Radar Pad	C68	1427:00	1:30	6.4	2.55±.04	4.67±.1	.55±.01
Hilo	C69	1429:00	0:30	22.7	1.64±.04	3.18±.04	.52±.02
Elev. 250 ft.	C70	1429:45	1:08	114.0	.87±.03	1.44±.07	.60±.04
	C71	1430:55	0:07	85.4	.35±.01	.61±.03	.57±.03
	C72	1432:00	0:07	90.3	.30±.01	.55±.03	.54±.04
	C73	1433:05	0:09	101.0	.20±.01	.37±.04	.54±.06
	C74	1434:10	0:10	88.3	.17±.01	.34±.03	.50±.06
	C75	1435:10	0:07	114.0	.21±.01	.38±.04	.55±.06
	C76	1435:55	0:18	42.4	.25±.01	.45±.04	.56±.06
	C77	1437:00	0:31	22.6	.40±.01	.84±.03	.48±.02
	C78	1438:35	0:20	38.4	.26±.01	.60±.03	.43±.03
	C79	1439:30	0:40	22.6	.34±.01	.70±.02	.48±.02
	C80	1440:52	0:40	17.3	1.36±.04	3.84±.05	.35±.01
End of RW	C81	1442:10	3:05	2.6	2.46±.04	4.70±.10	.52±.01

TABLE VIII. (Continued) INTENSITY RAIN SAMPLES

Date, Location and Remarks	Sample No.	Start of Sample Collection HST	Collection Time in Minutes and Seconds	Intensity mm/hr	Na (ppm)	Cl (ppm)	Na/Cl
New RW	C82	1602:30	4:30	2.4	5.75±.06	11.8 ±.1	.49±.01
	C83	1607:30	1:55	5.4	2.28±.04	4.43±.10	.51±.01
	C84	1610:00	4:00	2.5	2.55±.04	4.65±.10	.55±.01
	C85	1614:25	6:20	1.2	4.12±.05	8.20±.16	.50±.01
July 21, 1967 Hilo, Elev. 300 ft.	C86	1003:45	5:35	1.5	2.87±.05	5.50±.10	.52±.01
	C87	1009:55	4:00	2.4	.72±.03	1.48±.07	.49±.03
	C88	1014:25	5:55	3.0	.31±.01	.84±.03	.37±.02
	C89	1019:15	4:35	1.9	.46±.02	1.01±.05	.46±.03

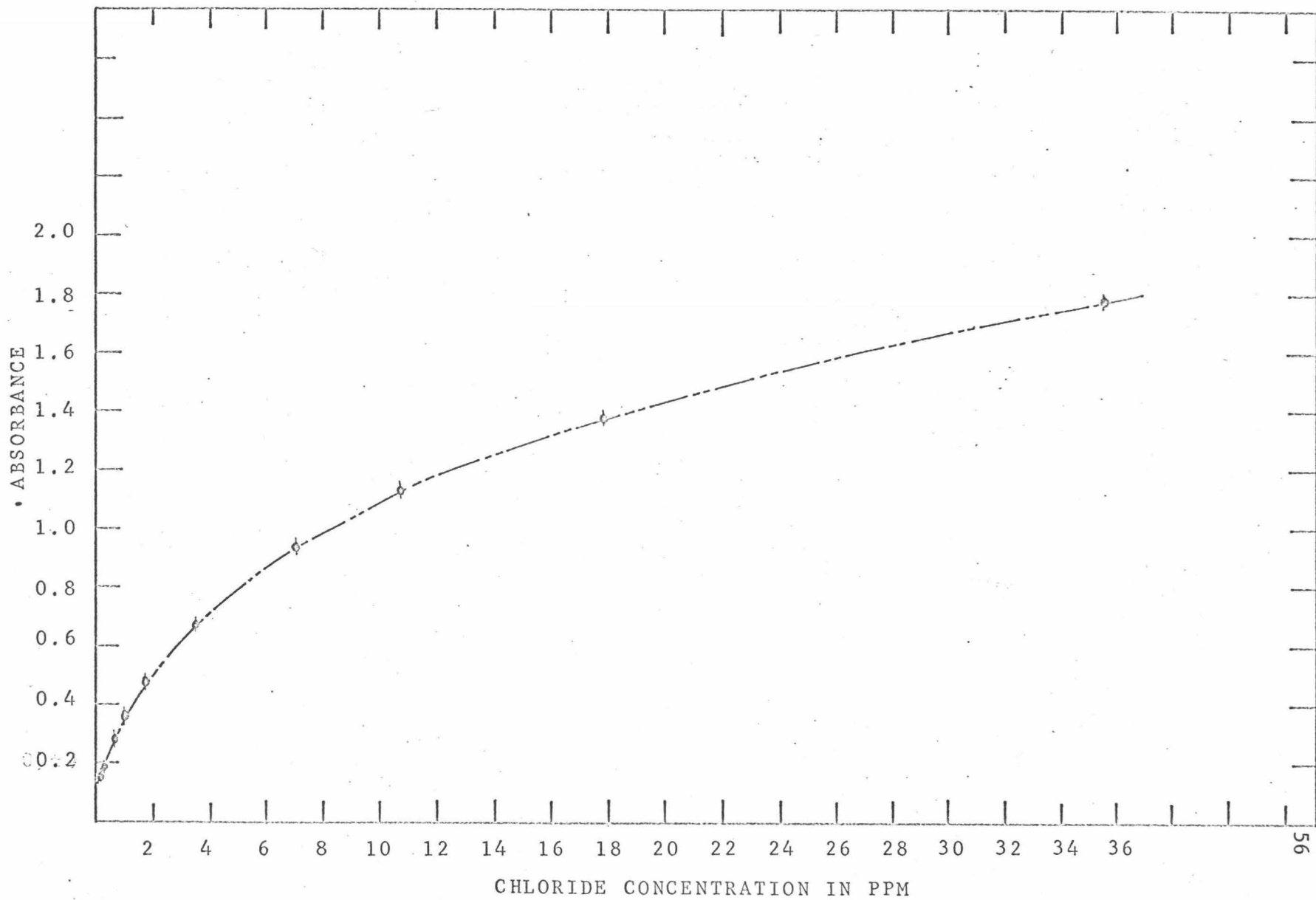


FIG. 1A CALIBRATION CURVE FOR CHLORIDE DETERMINATION

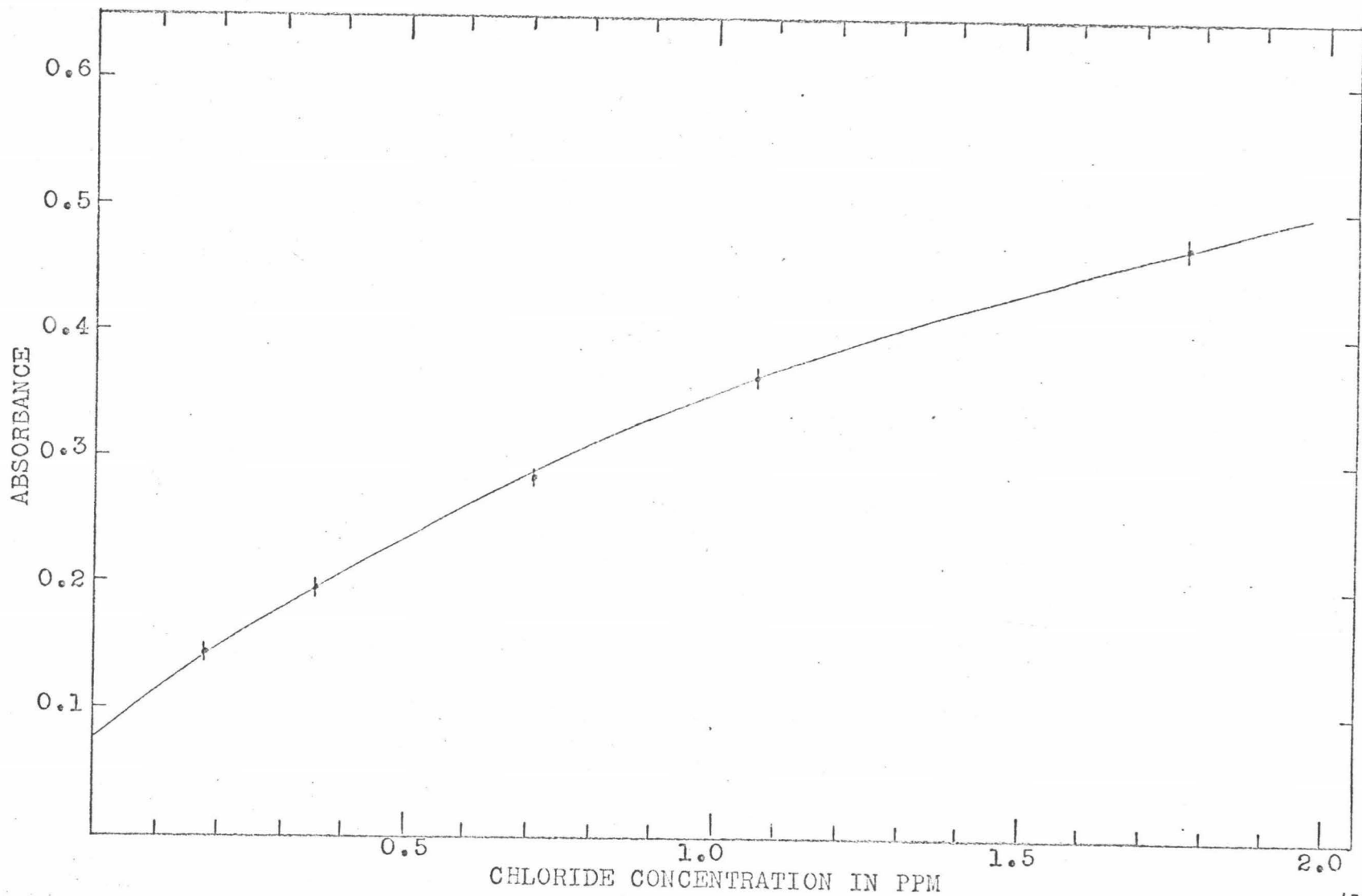


FIG. 1B EXPLODED CALIBRATION CURVE FOR CHLORIDE TO 2 PPM

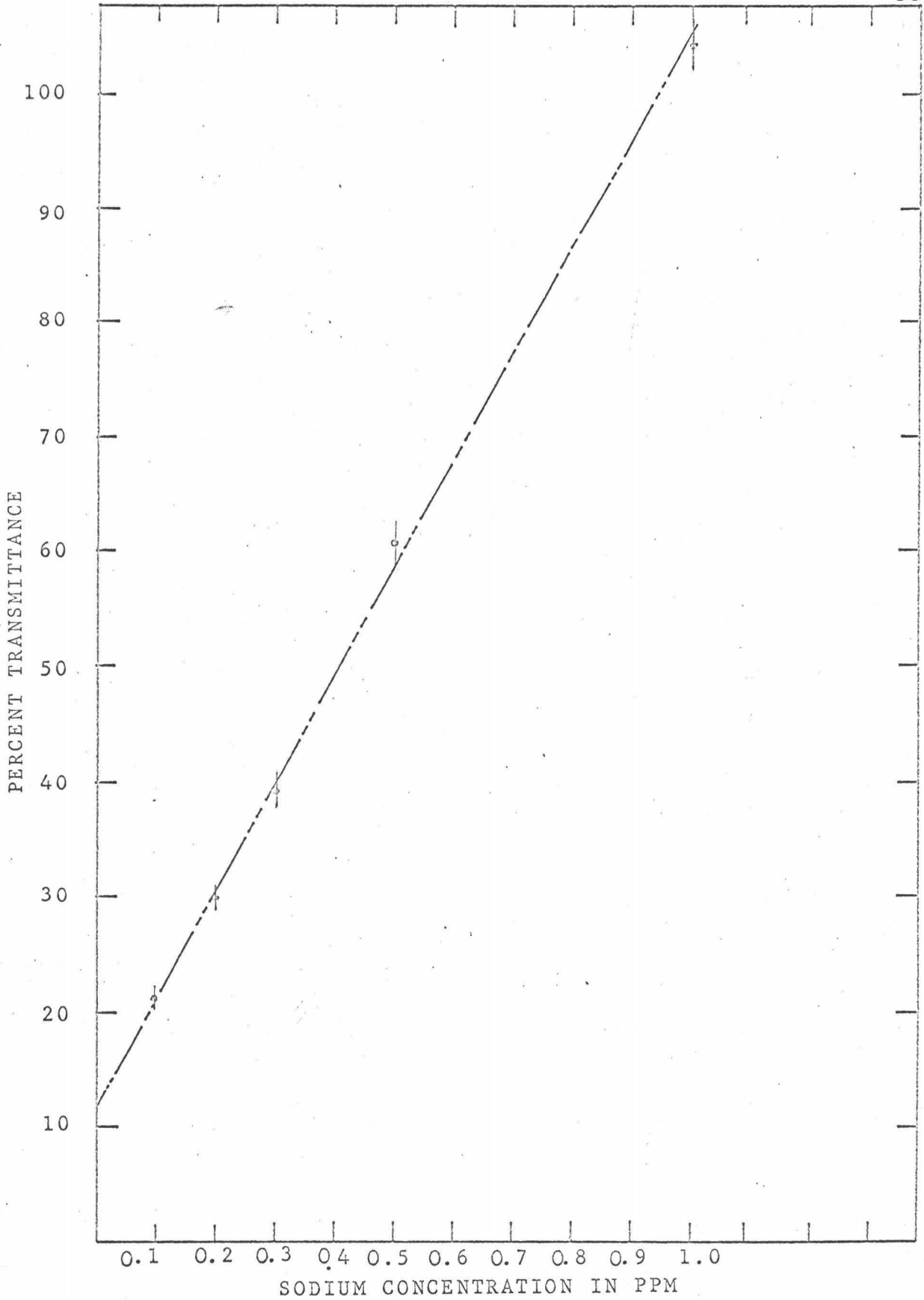


FIG. 2 CALIBRATION CURVE FOR SODIUM TO 1 PPM

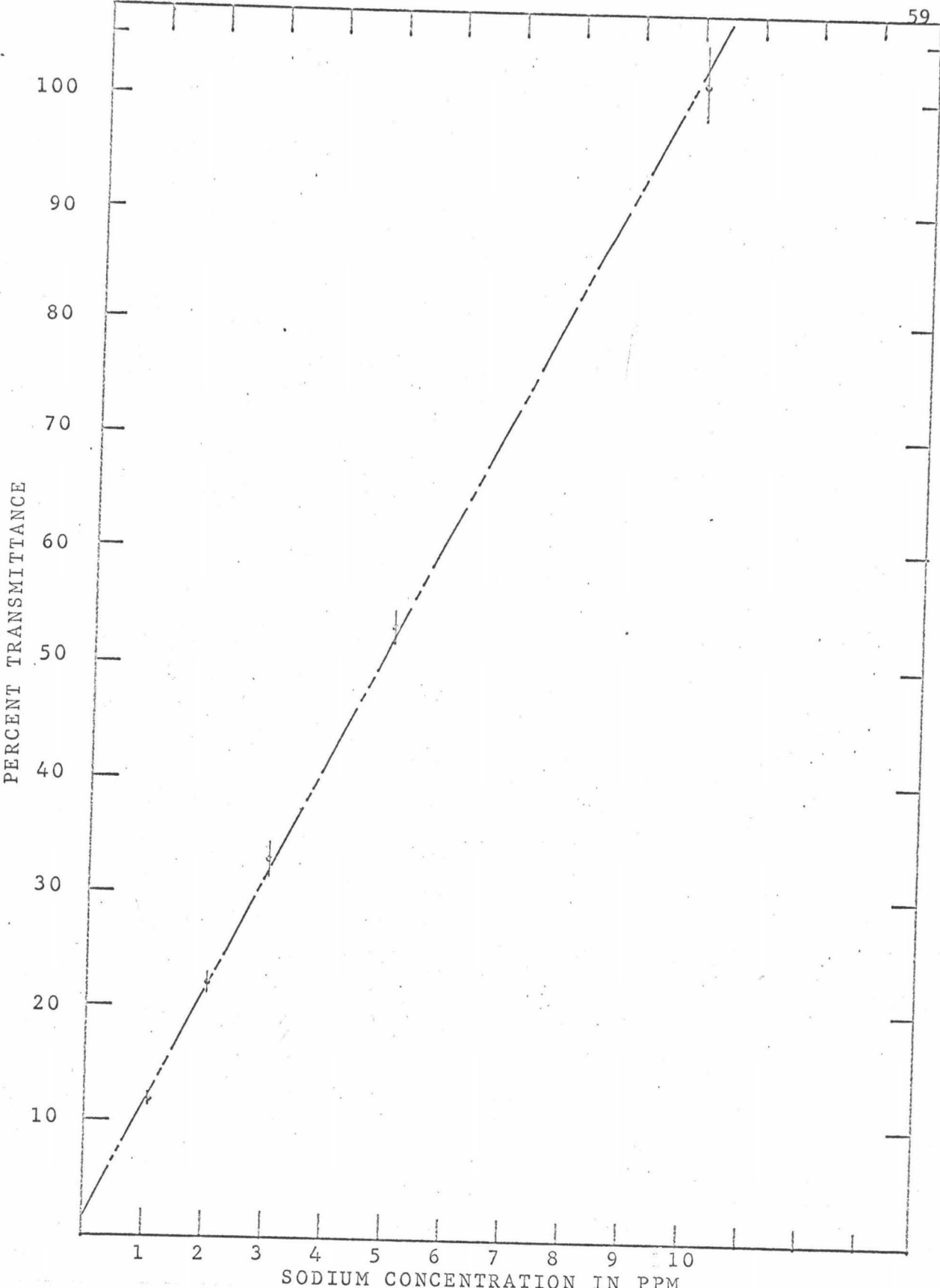


FIG.3 CALIBRATION CURVE FOR SODIUM BETWEEN 1 PPM AND 10 PPM

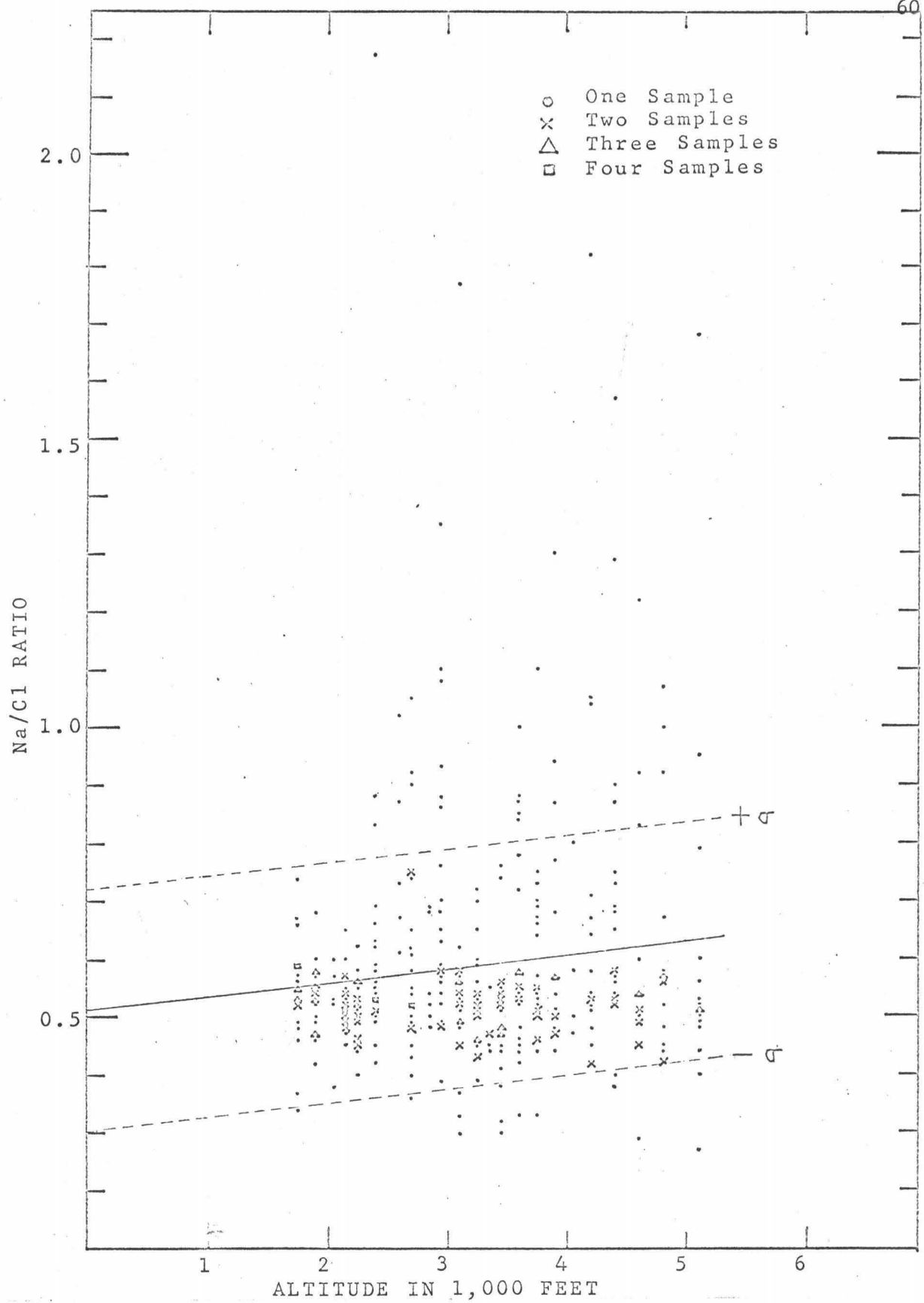


FIG.4 Na/Cl RATIO VS. ALTITUDE, STRAIGHT LINE FITTED BY LEAST SQUARES METHOD

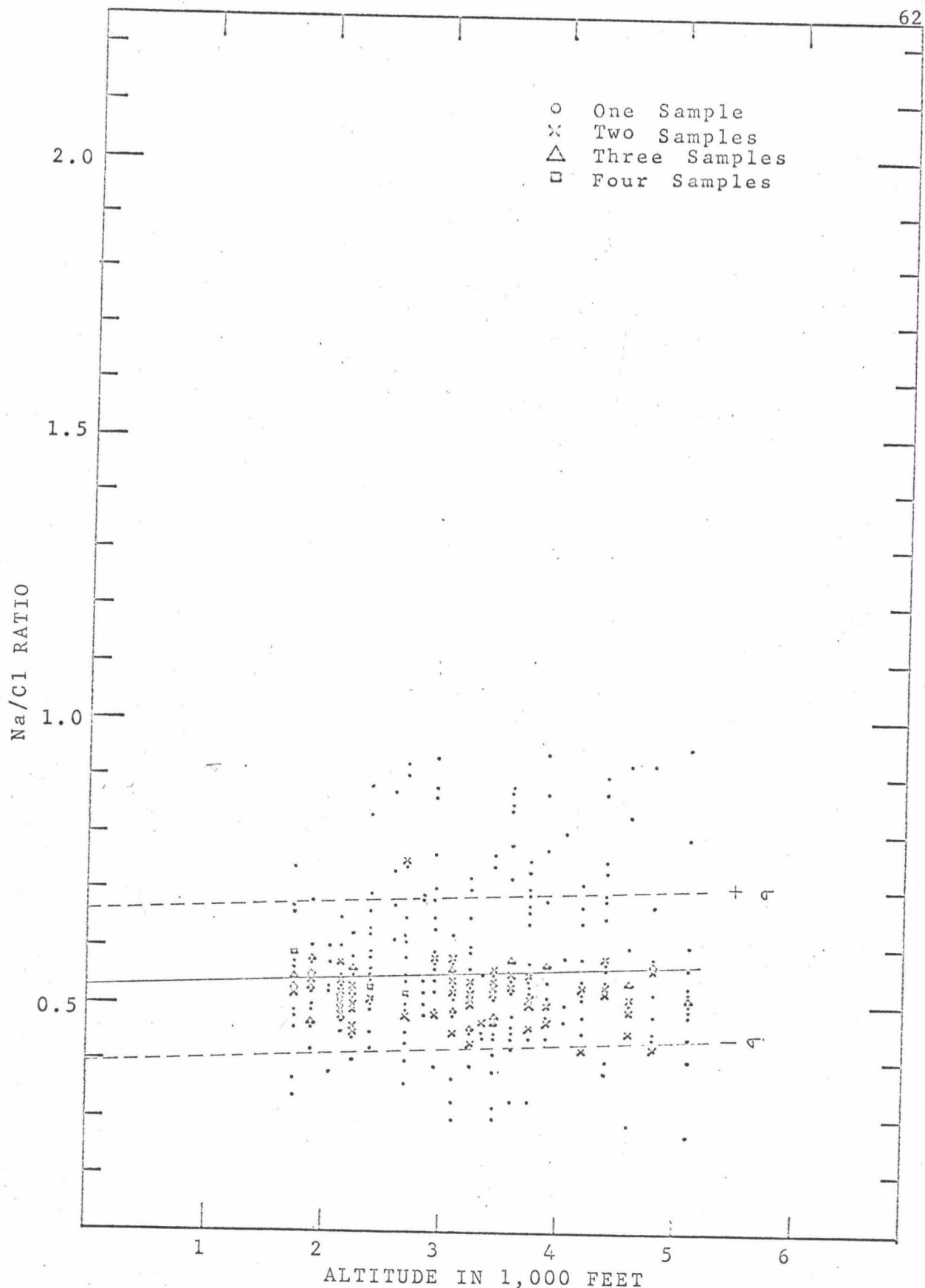


FIG.6 Na/Cl RATIO VS. ALTITUDE, STRAIGHT LINE FITTED BY LEAST SQUARES METHOD WITHOUT RATIOS EQUAL TO OR GREATER THAN ONE

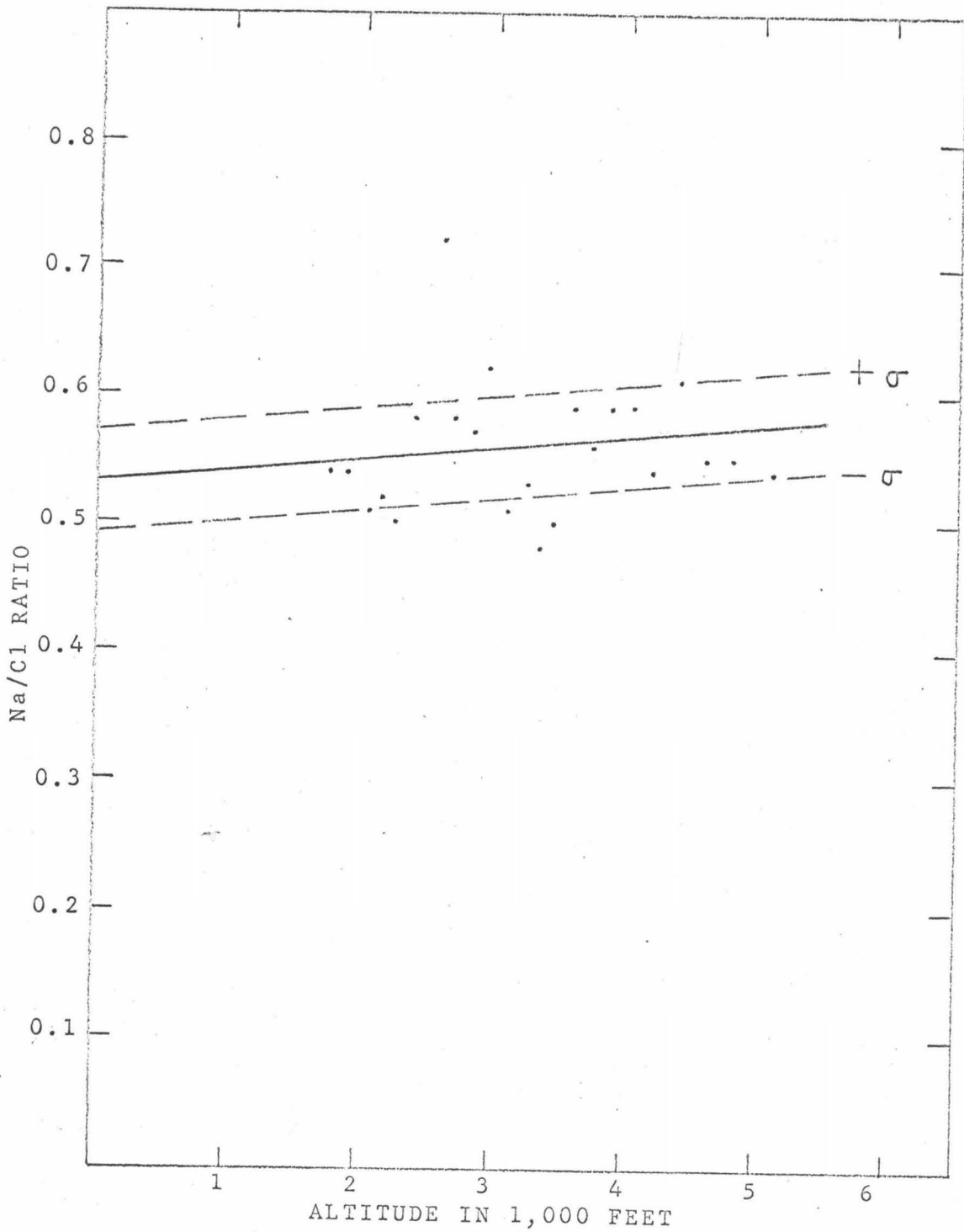


FIG.7 Na/Cl RATIO VS. ALTITUDE, STRAIGHT LINE FITTED BY LEAST SQUARES METHOD TO THE AVERAGE RATIO AT EACH ALTITUDE WITHOUT RATIOS EQUAL TO OR GREATER THAN ONE

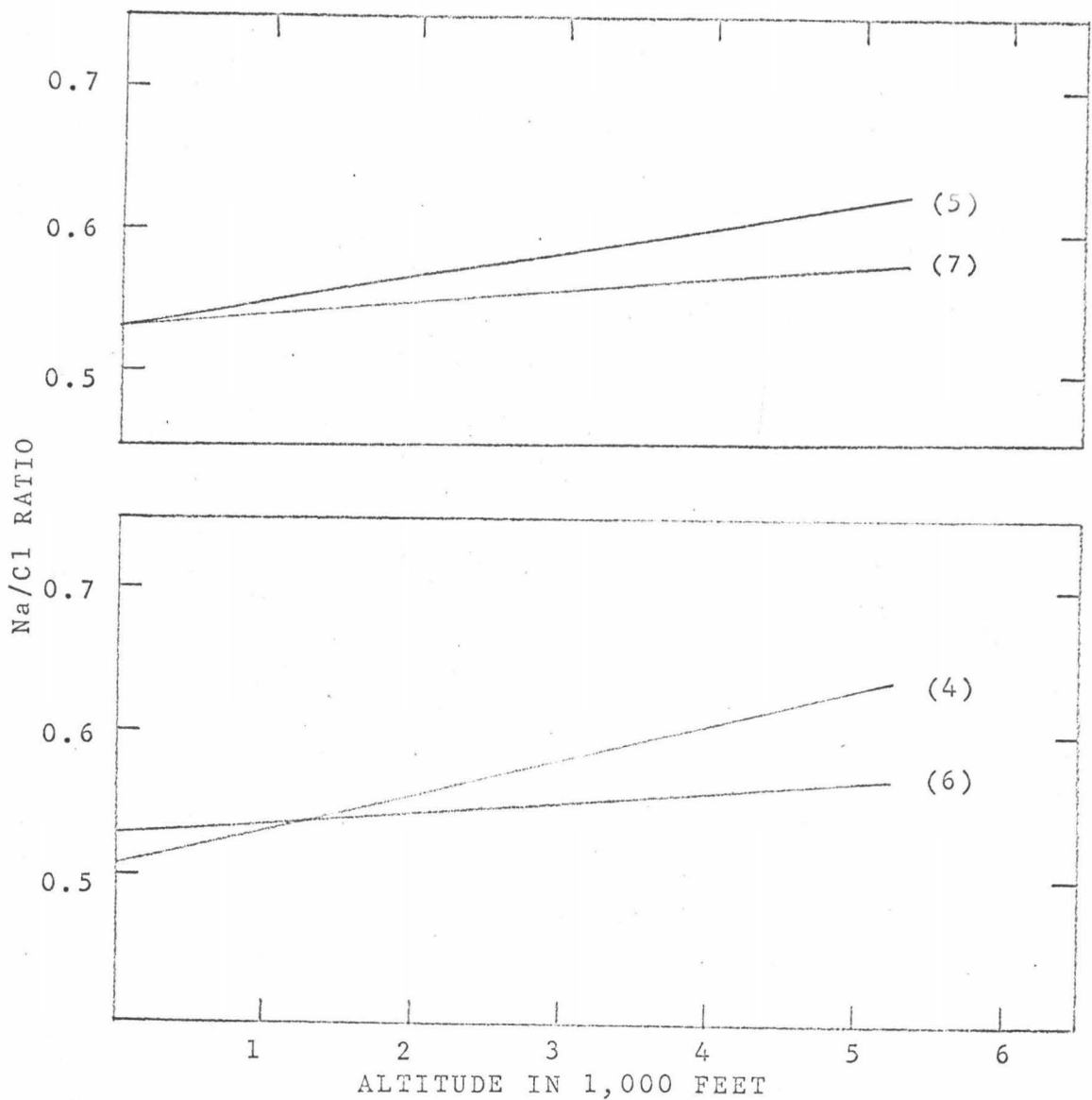
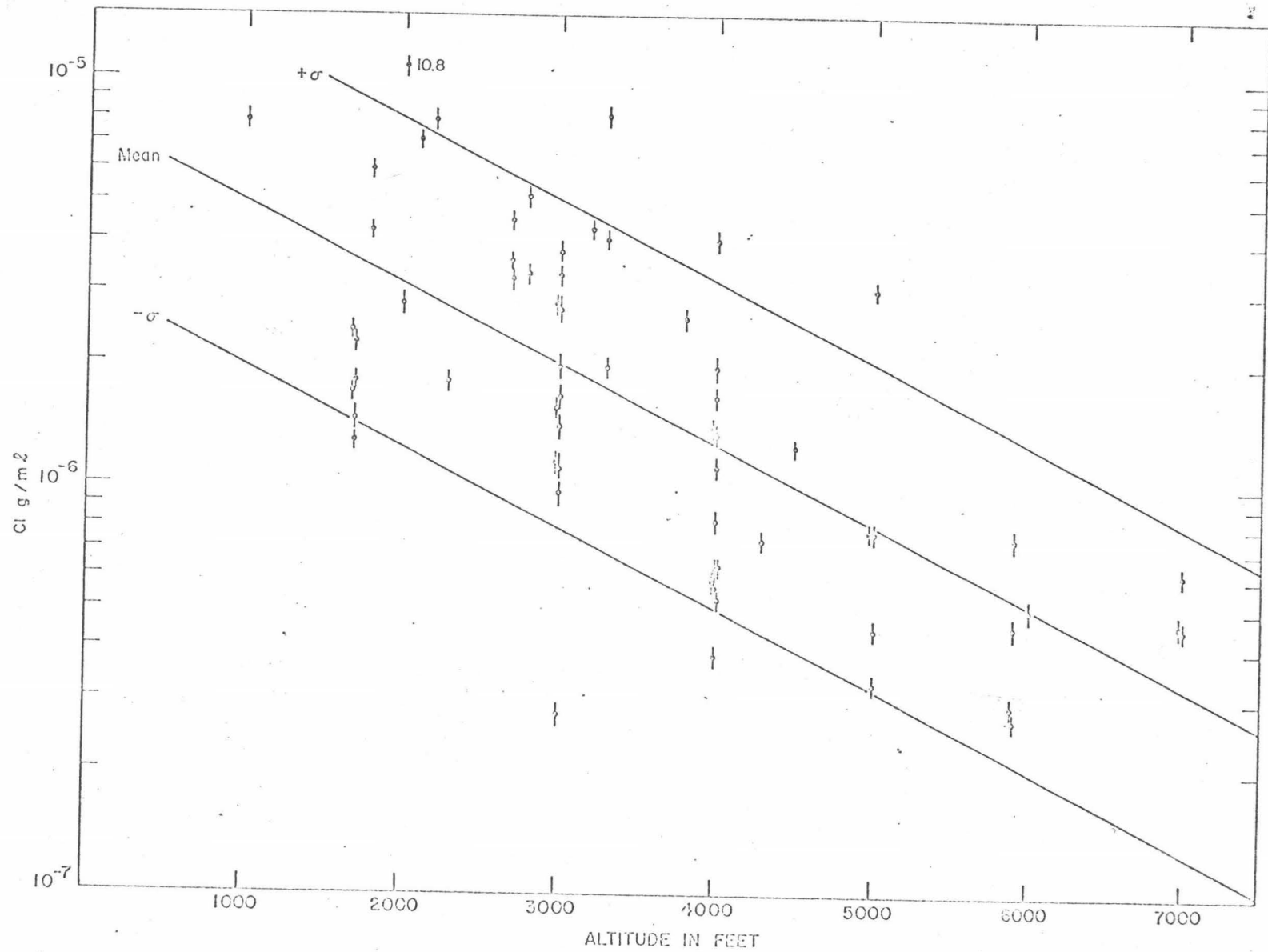
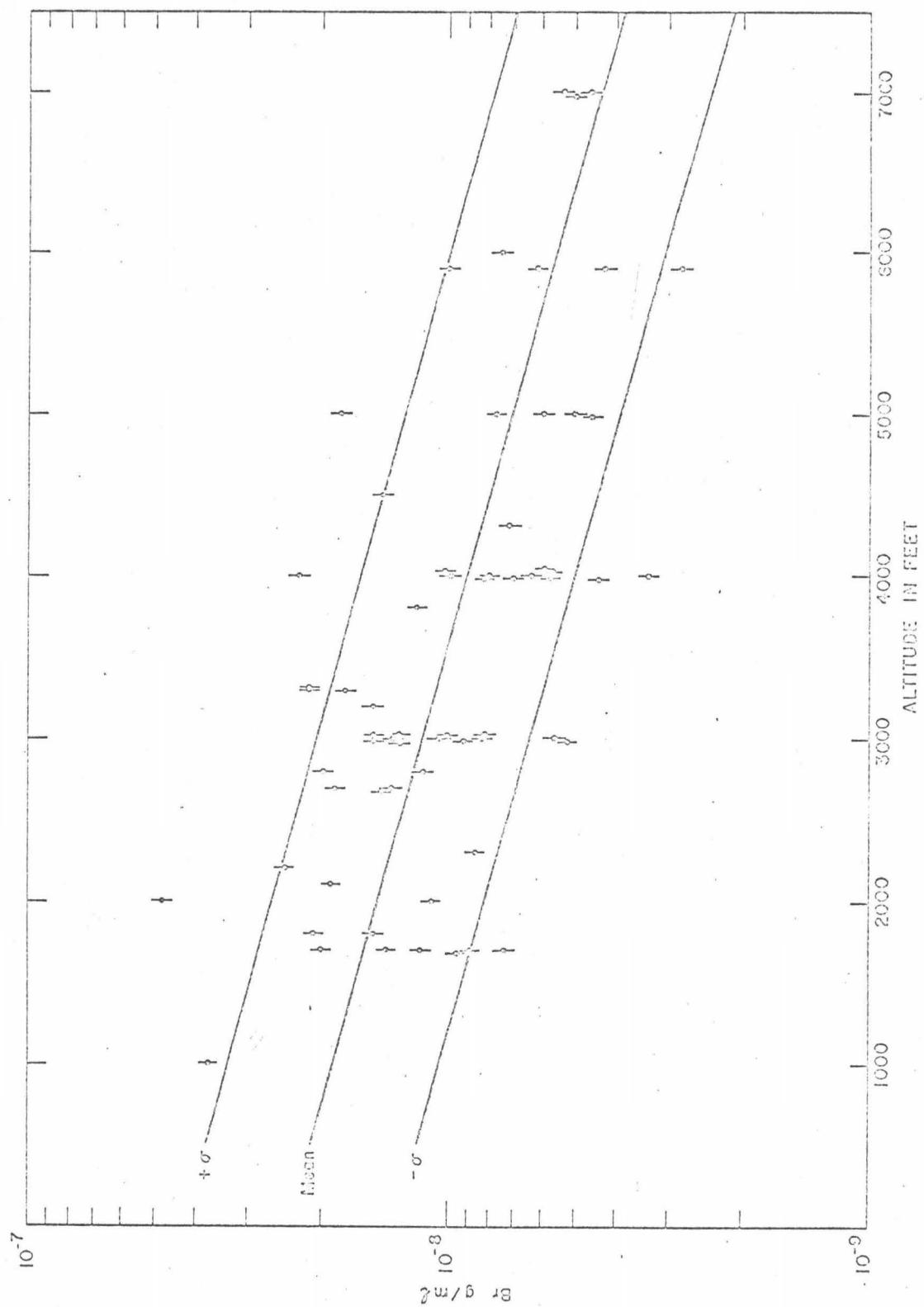


FIG.8 -SUMMARY OF Na/Cl RATIO VS. ALTITUDE

- (4) STRAIGHT LINE FITTED BY LEAST SQUARES METHOD TO ALL POINTS
- (5) STRAIGHT LINE FITTED BY LEAST SQUARES METHOD TO THE AVERAGE RATIO AT EACH ALTITUDE
- (6) STRAIGHT LINE FITTED BY LEAST SQUARES METHOD TO ALL POINTS WITHOUT RATIOS EQUAL TO OR GREATER THAN ONE
- (7) STRAIGHT LINE FITTED BY LEAST SQUARES METHOD TO THE AVERAGE RATIO AT EACH ALTITUDE WITHOUT RATIOS EQUAL TO OR GREATER THAN ONE

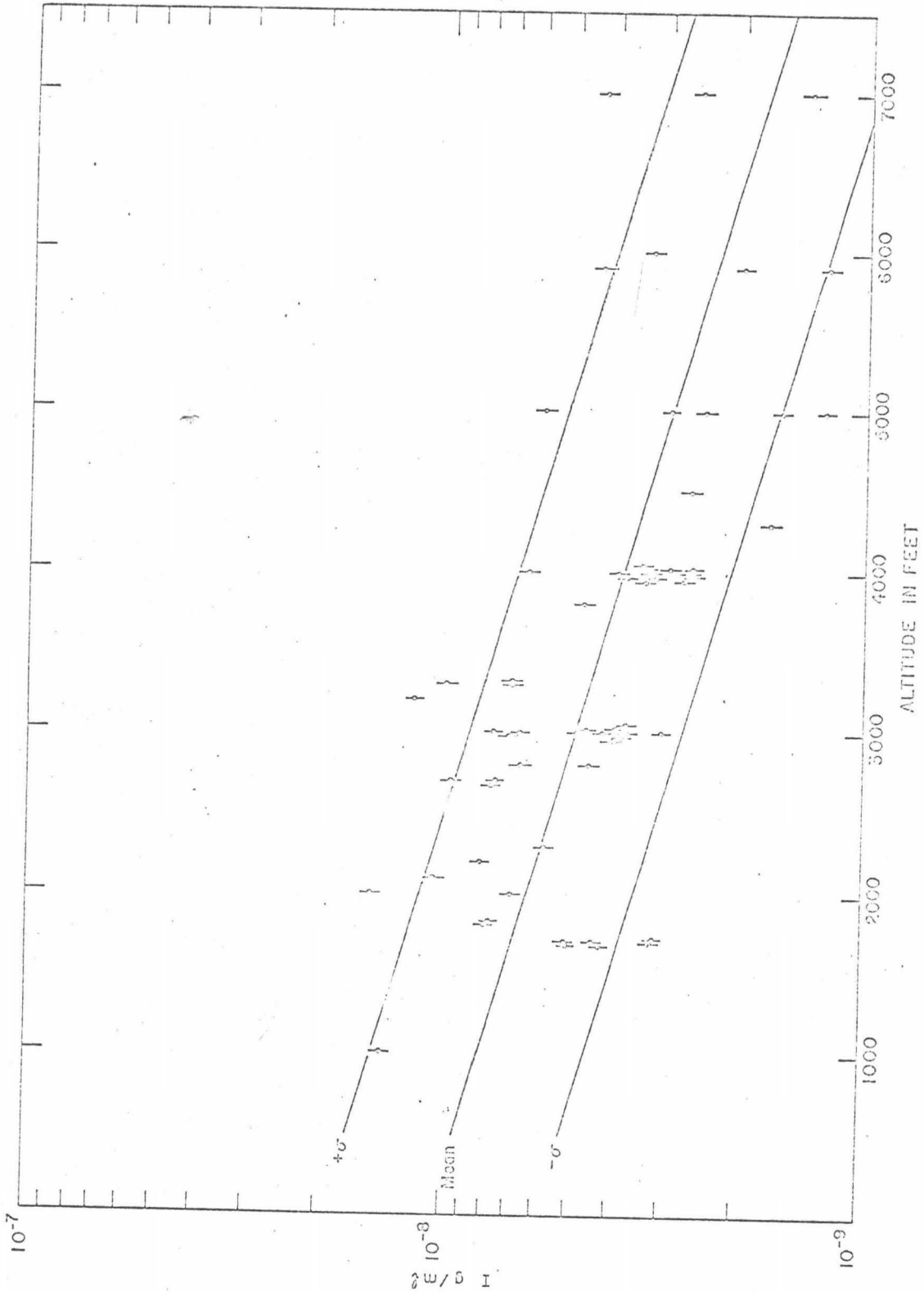


HAWAIIAN RAIN SAMPLES-Cl CONCENTRATION VS. ALTITUDE
 FIG. 9 (FROM DUCE ET AL., 1965)

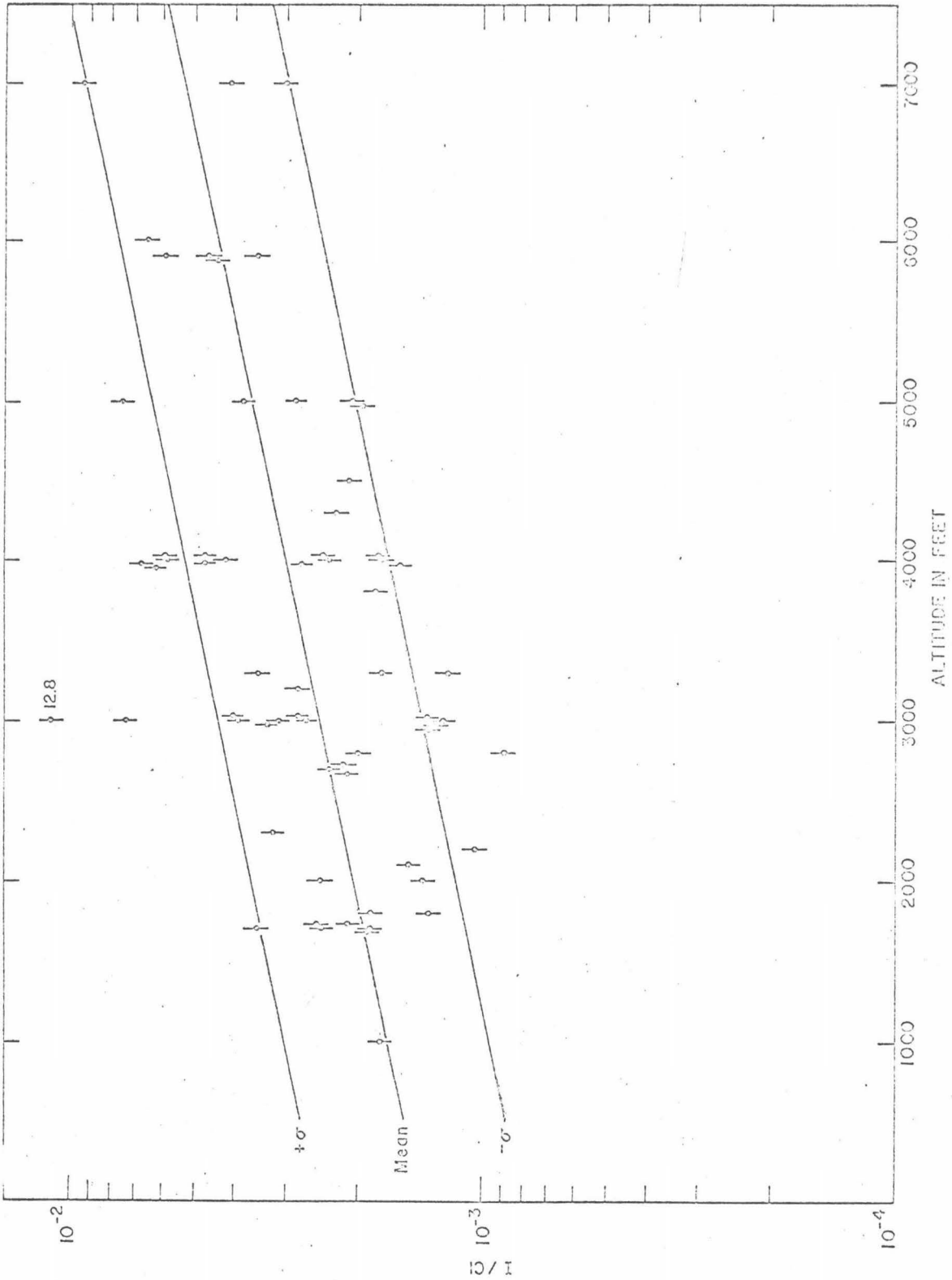


HAWAIIAN RAIN SAMPLES--Br CONCENTRATION VS. ALTITUDE

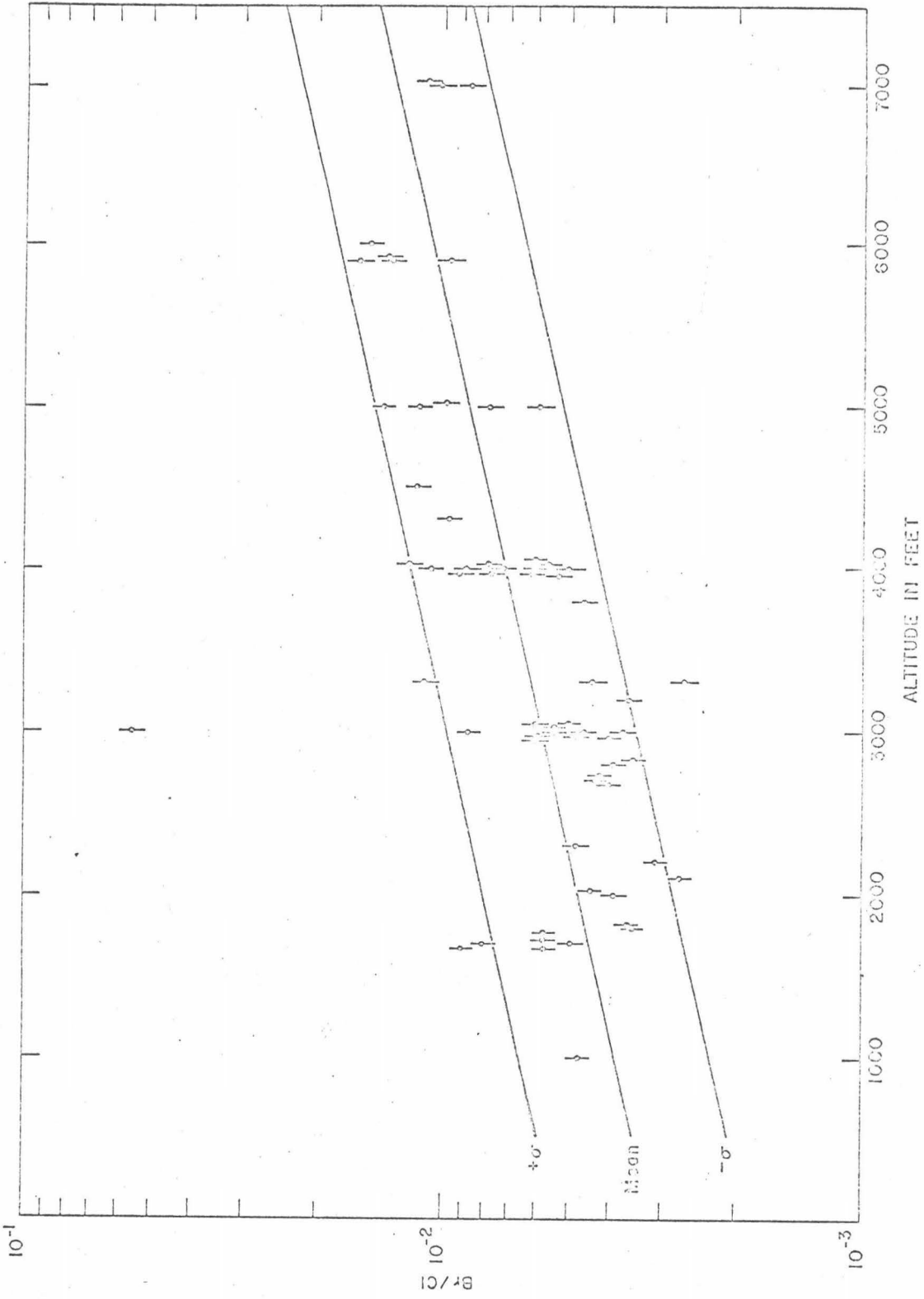
FIG. 10 (FROM DUCE ET AL., 1965)



HAWAIIAN RAIN SAMPLES - I CONCENTRATION VS. ALTITUDE
FIG. 11 (FROM DUCE ET AL., 1965)



HAWAIIAN RAIN SAMPLES - I/CI RATIO VS. ALTITUDE
FIG. 12 (FROM DUCE ET AL., 1965)



HAWAIIAN RAIN SAMPLES - Br/Cl RATIO VS. ALTITUDE

FIG. 13 (FROM DUCE ET AL., 1965)

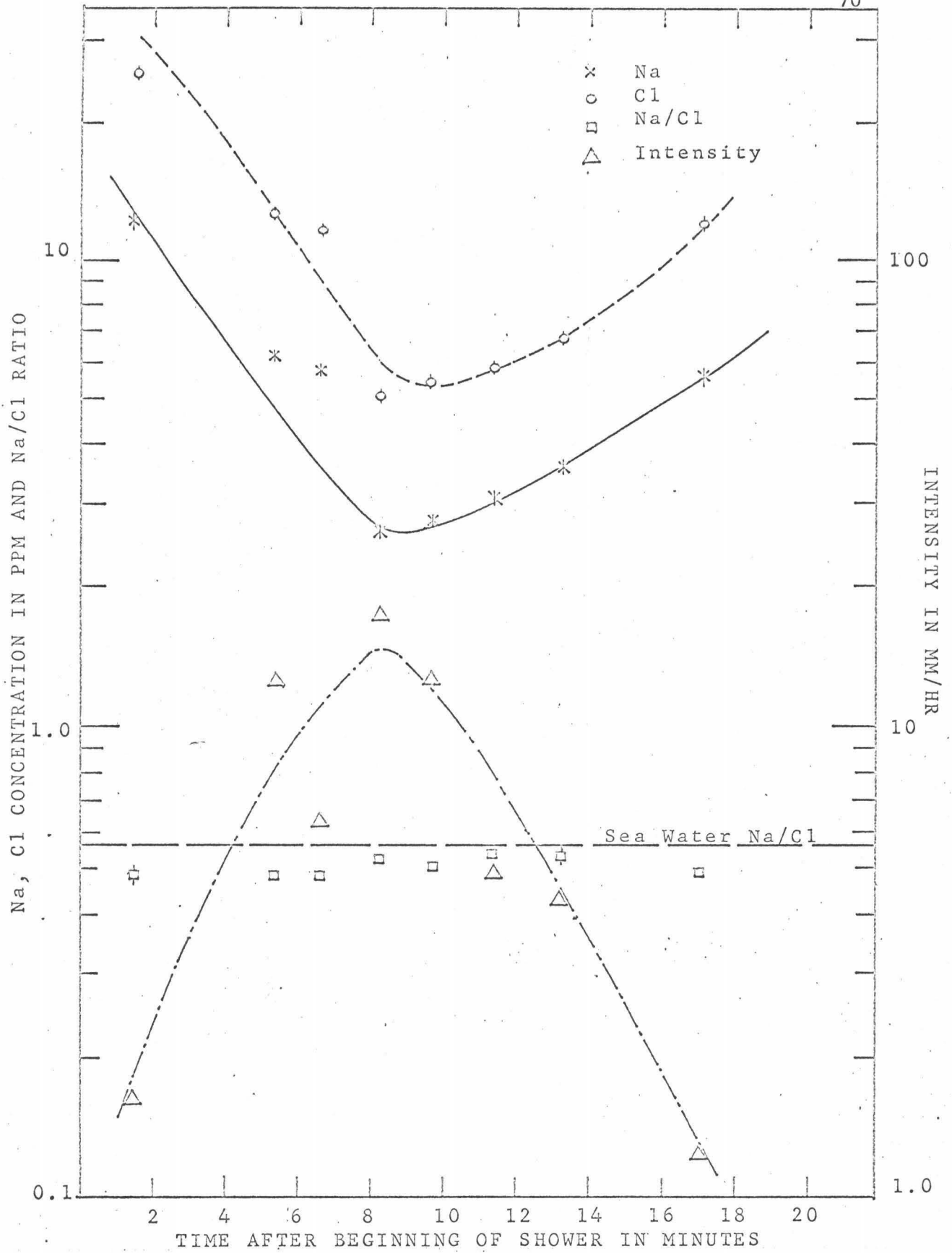


FIG.14 RAIN SAMPLES B64 TO B71, COLLECTED JUNE 24, 1967 AT THE RADAR PAD, HILO, ELEV. 250 FEET

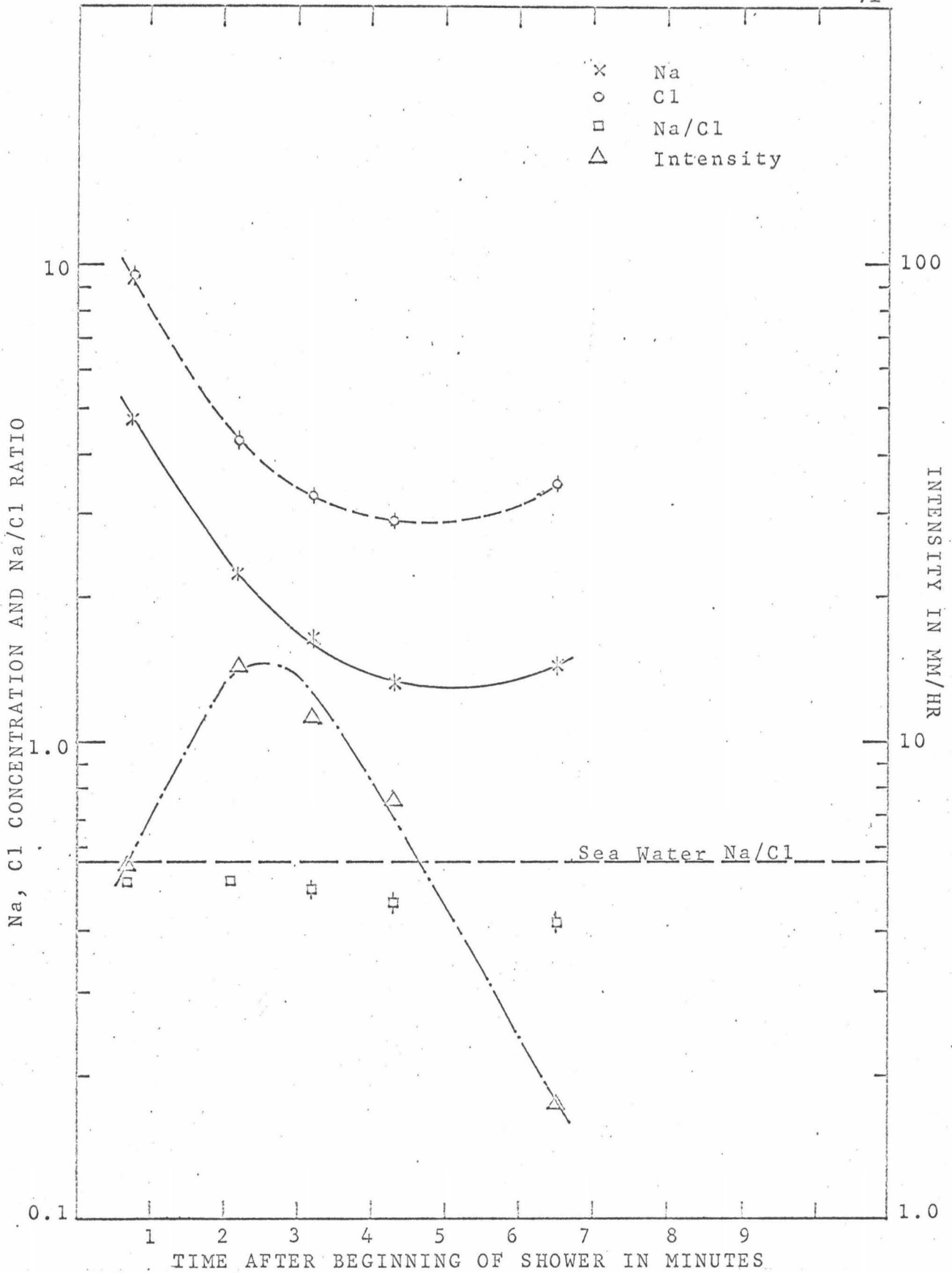


FIG.15 RAIN SAMPLES B73 TO B77, COLLECTED JUNE 26, 1967 IN HILO, ELEV. 300 FEET

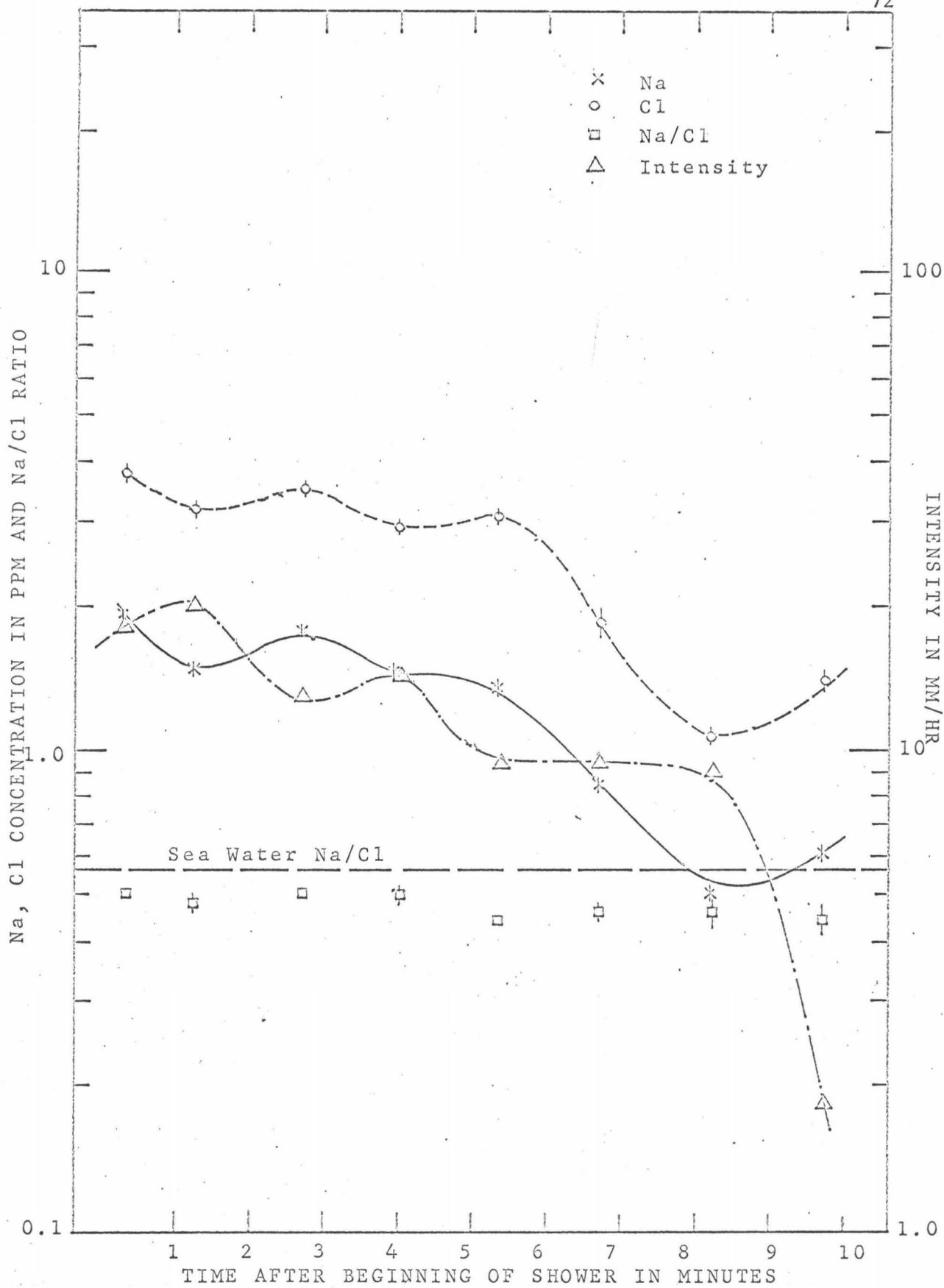


FIG.16 RAIN SAMPLES B78 TO B85, COLLECTED JUNE 26, 1967
IN HILO, ELEV. 300 FEET

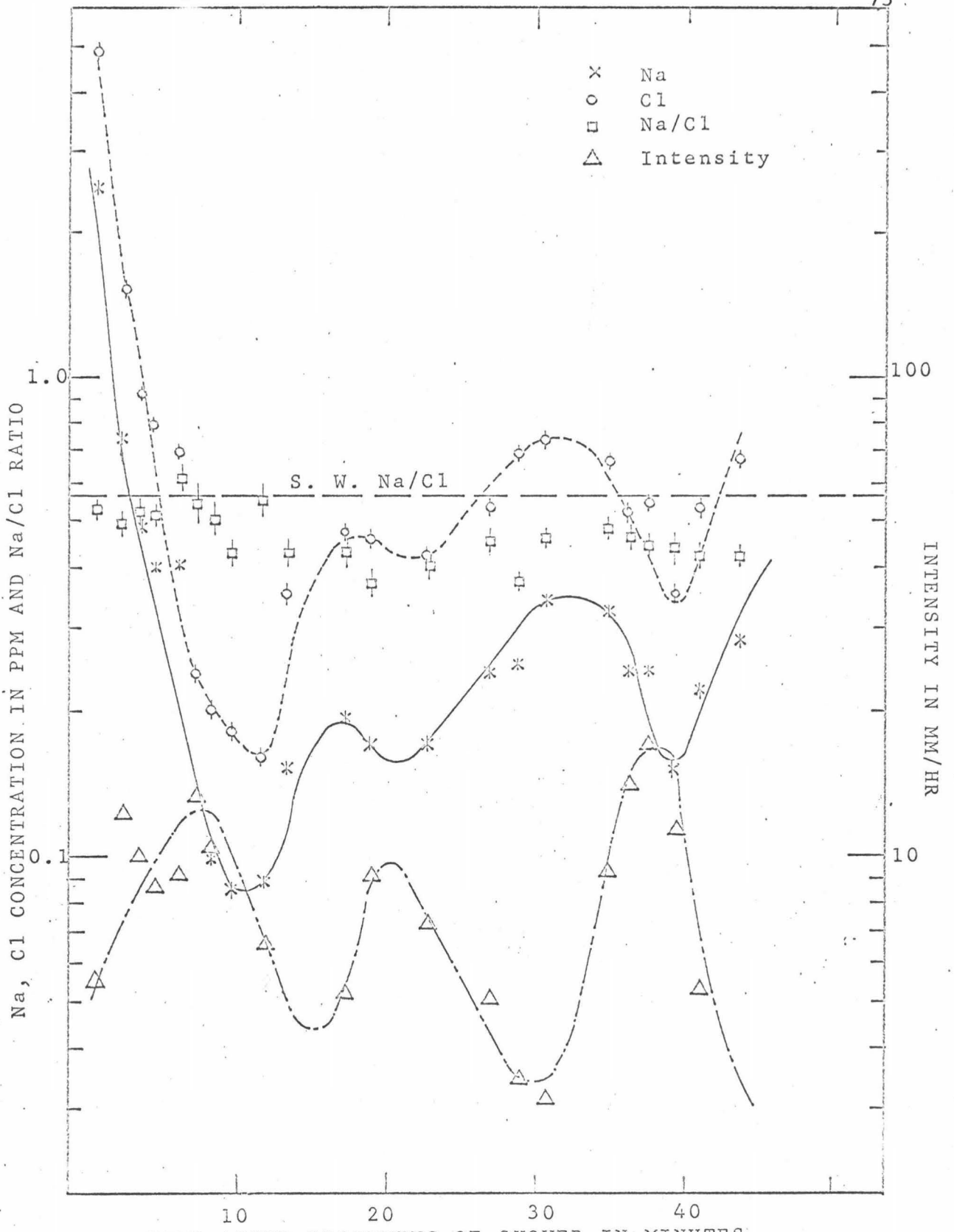


FIG.17 RAIN SAMPLES B86 TO B107, COLLECTED JUNE 27, 1967 AT 2,700 FEET, SADDLE ROAD

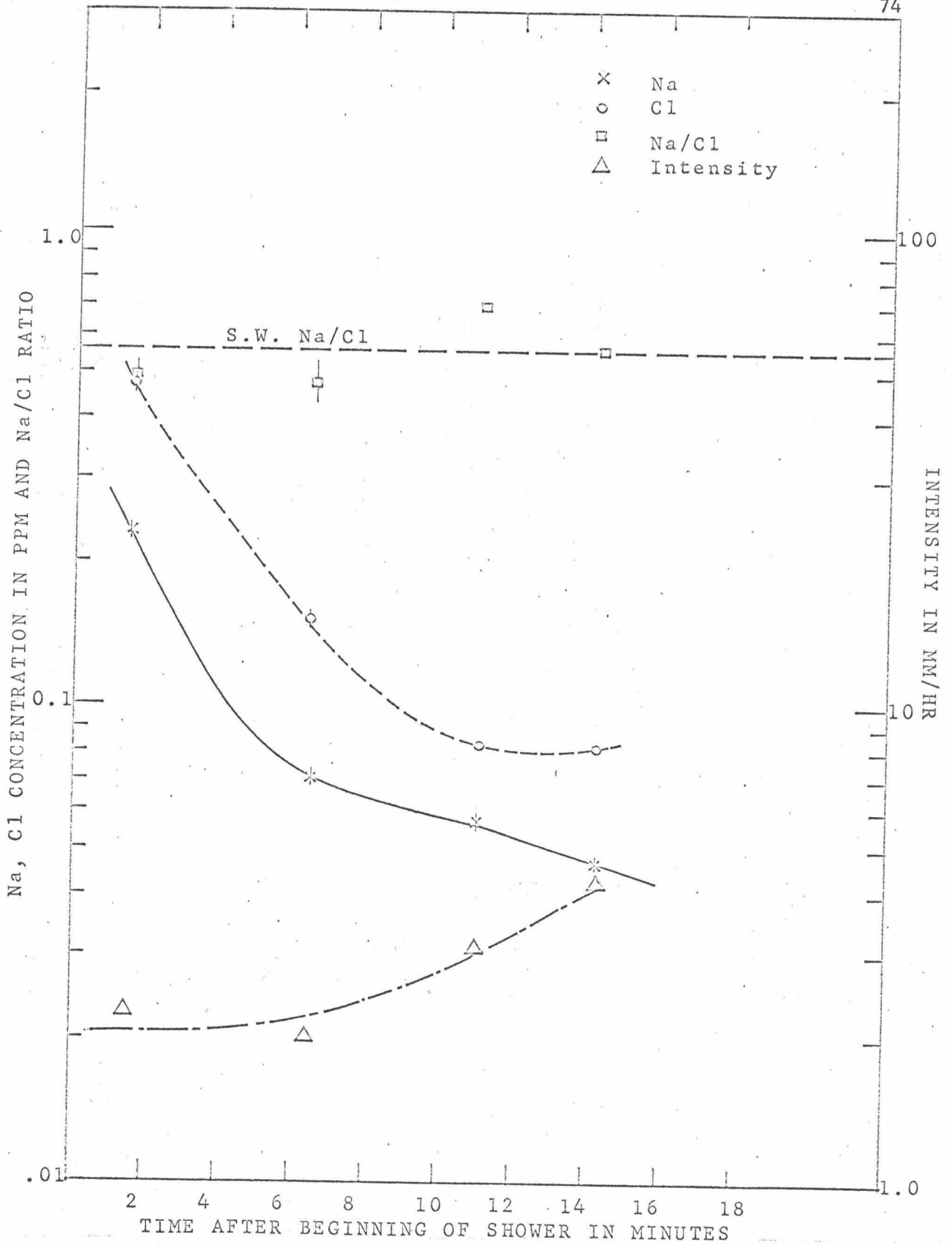


FIG.18 RAIN SAMPLES B108 TO B111, COLLECTED JUNE 29, 1967 AT 3,400 FEET, SADDLE ROAD

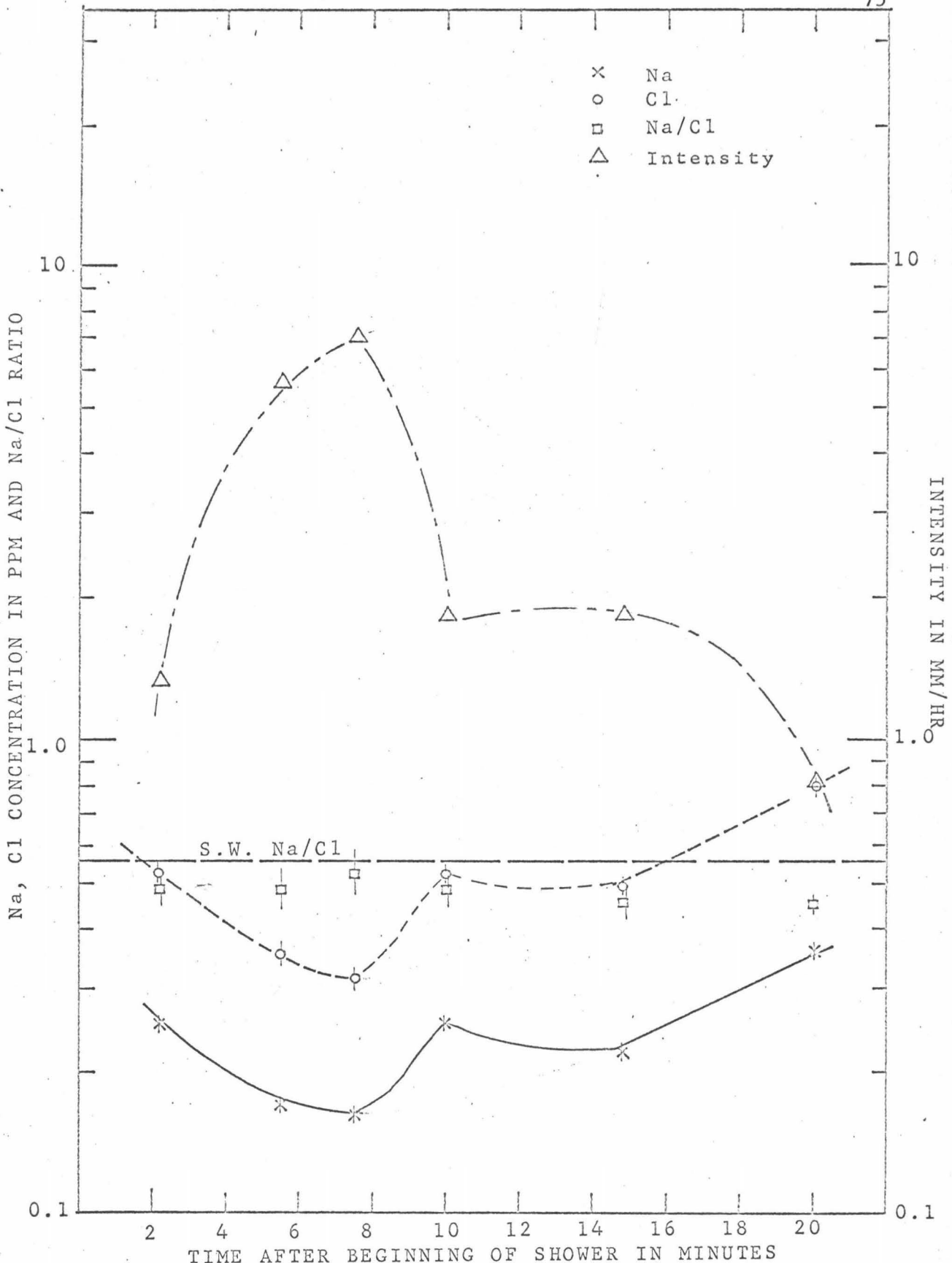


FIG.19 RAIN SAMPLES B112 TO B117, COLLECTED JUNE 29, 1967 AT 2,600 FEET, SADDLE ROAD

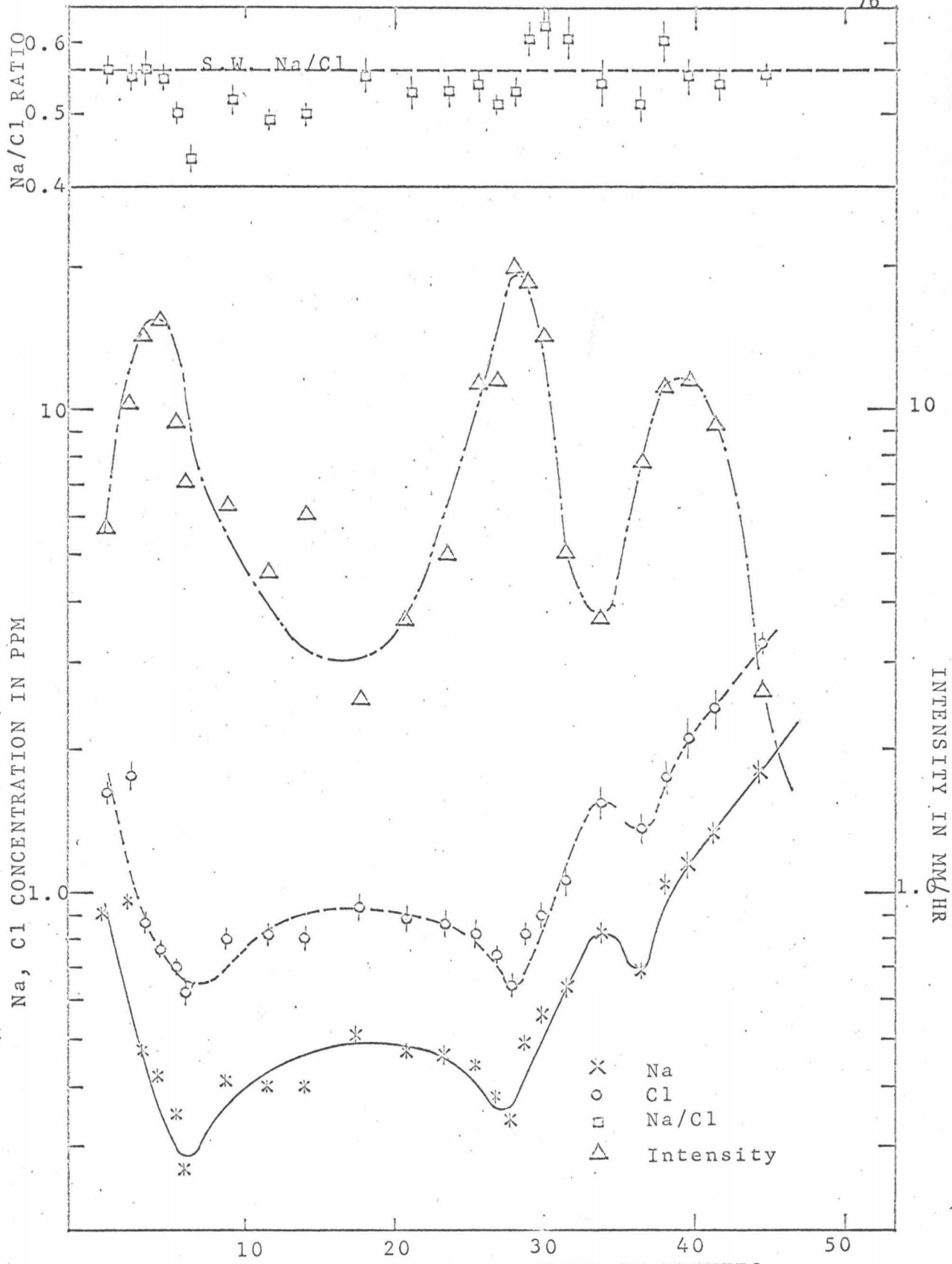


FIG.20 RAIN SAMPLES B121 TO B144, COLLECTED JUNE 30, 1967 AT 2,700 FEET, SADDLE ROAD

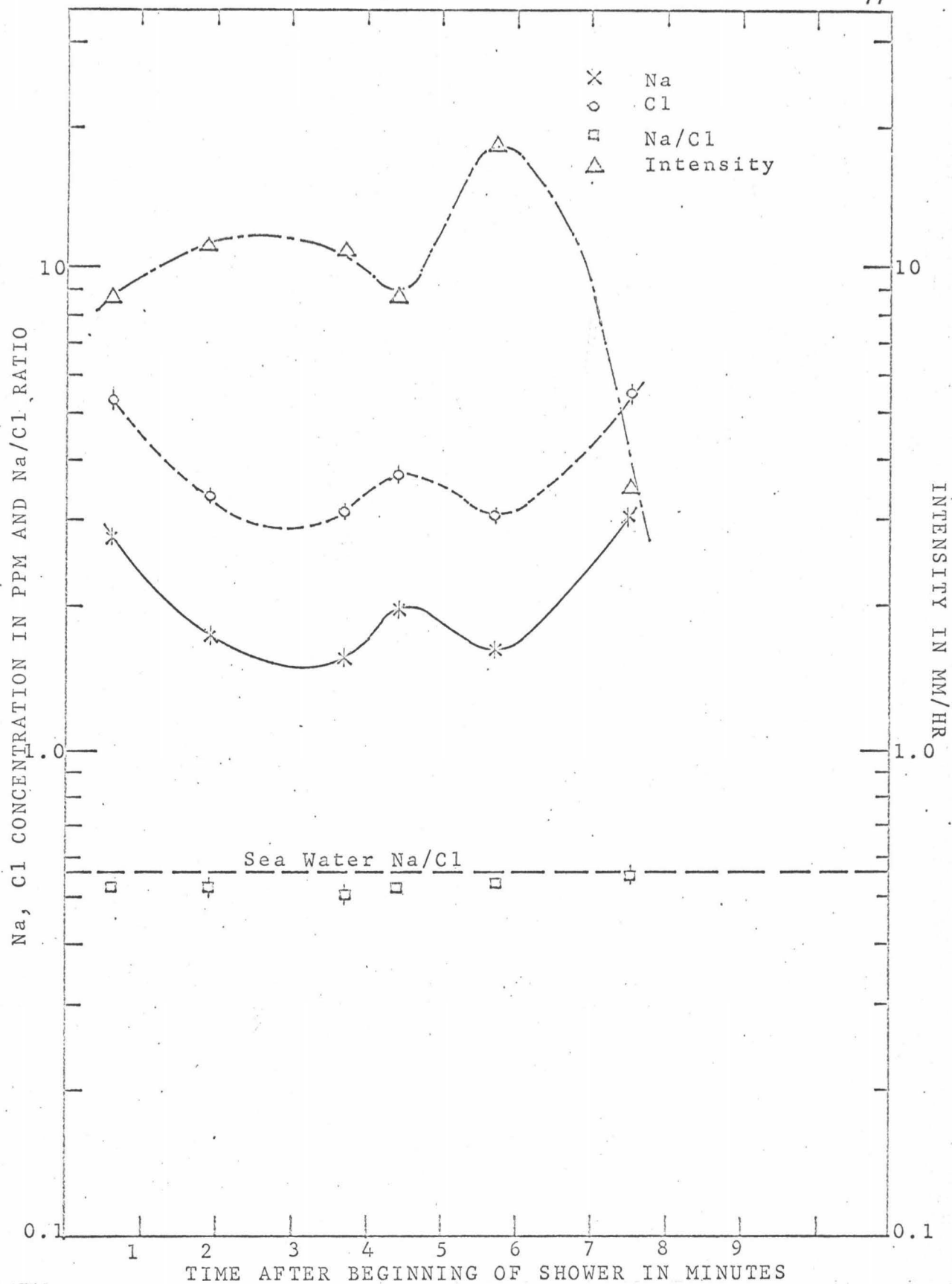


FIG.21 RAIN SAMPLES B145 TO B150, COLLECTED JULY 3, 1967
NEAR THE AIRPORT, HILO

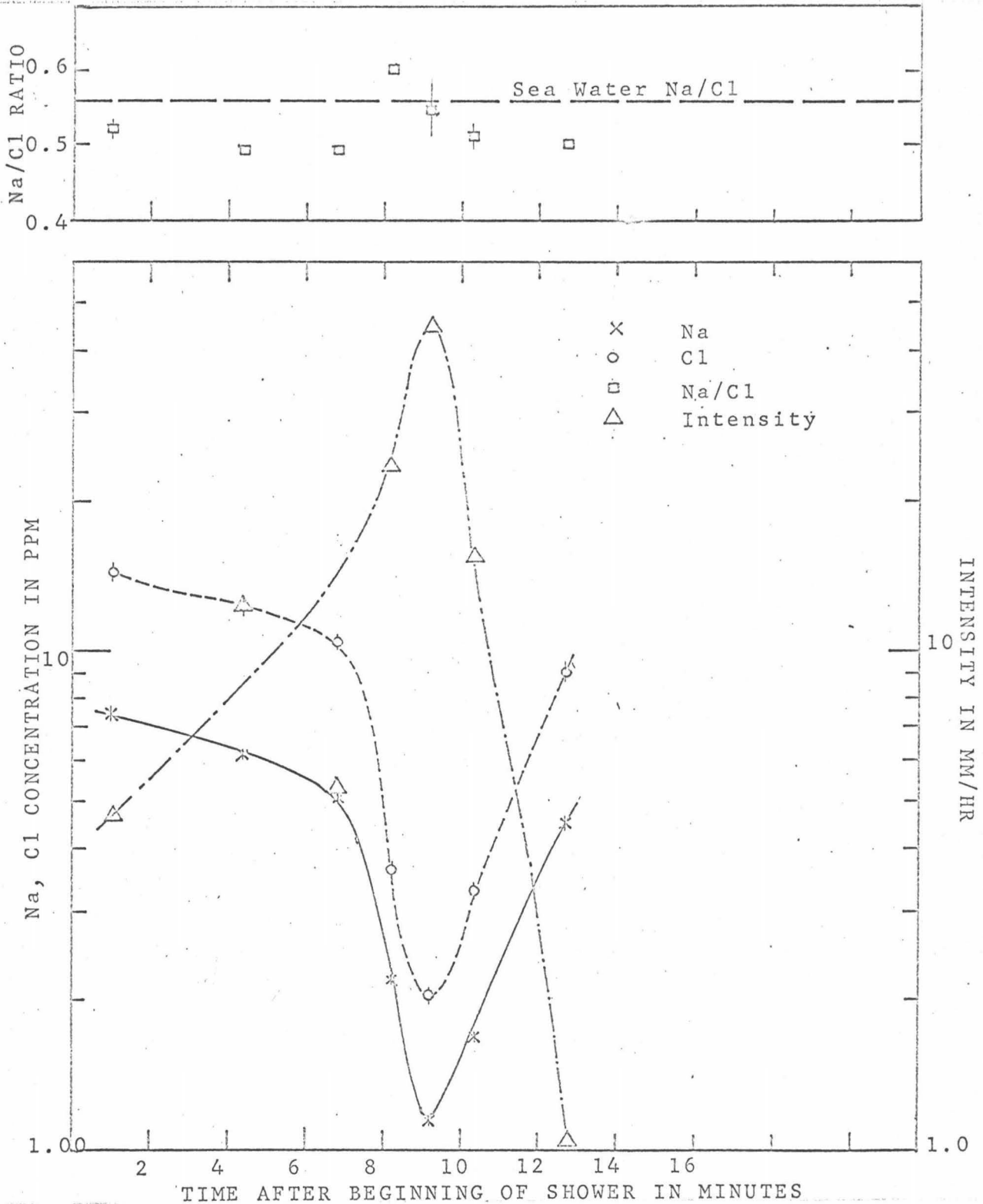


FIG.22 RAIN SAMPLES C32 TO C38, COLLECTED MARCH 31, 1967 ON WINDWARD SIDE OF OAHU AT SEA LEVEL

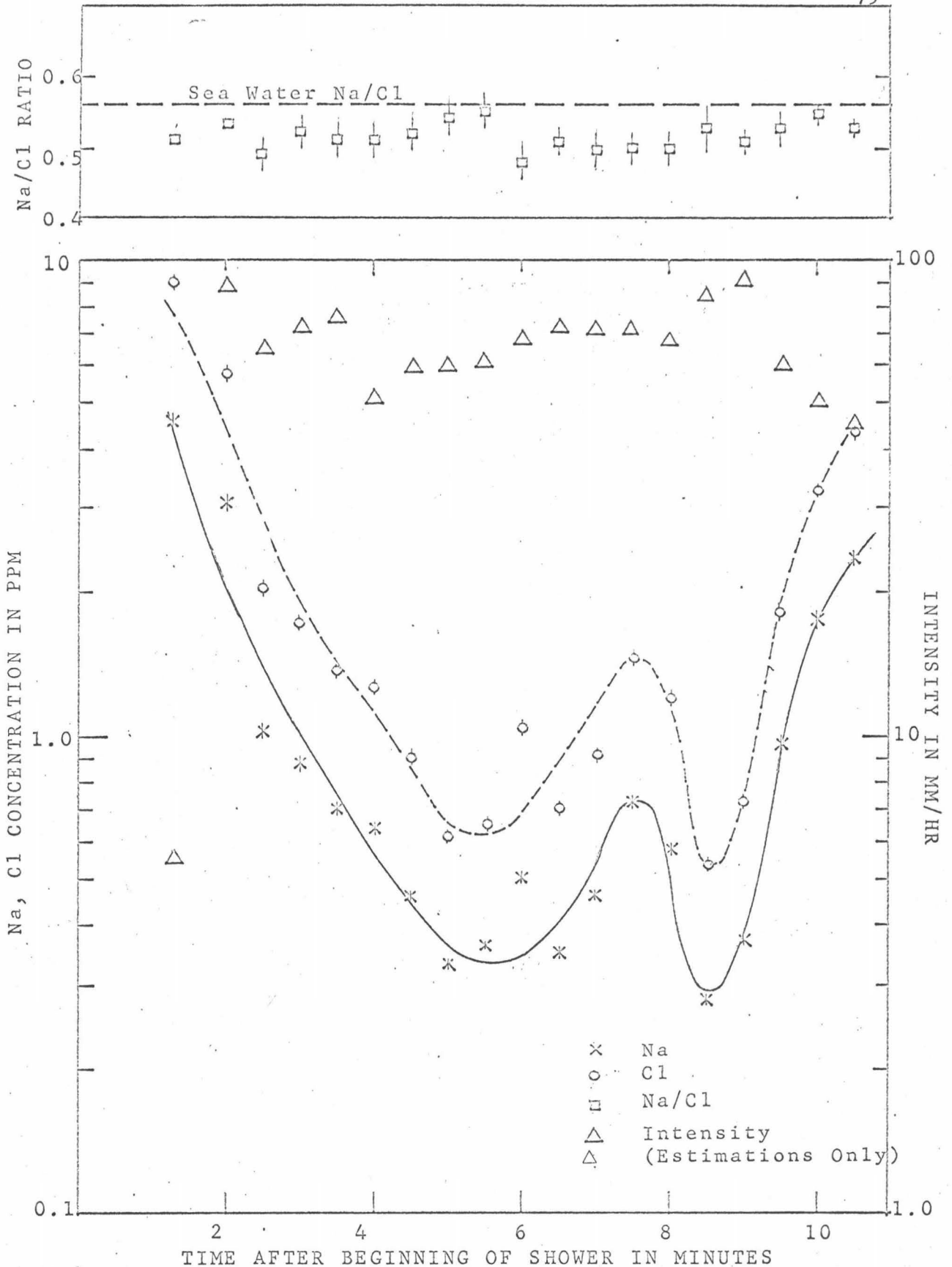


FIG.23 RAIN SAMPLES C40 TO C58, COLLECTED MARCH 31, 1967 ON WINDWARD SIDE OF OAHU AT SEA LEVEL

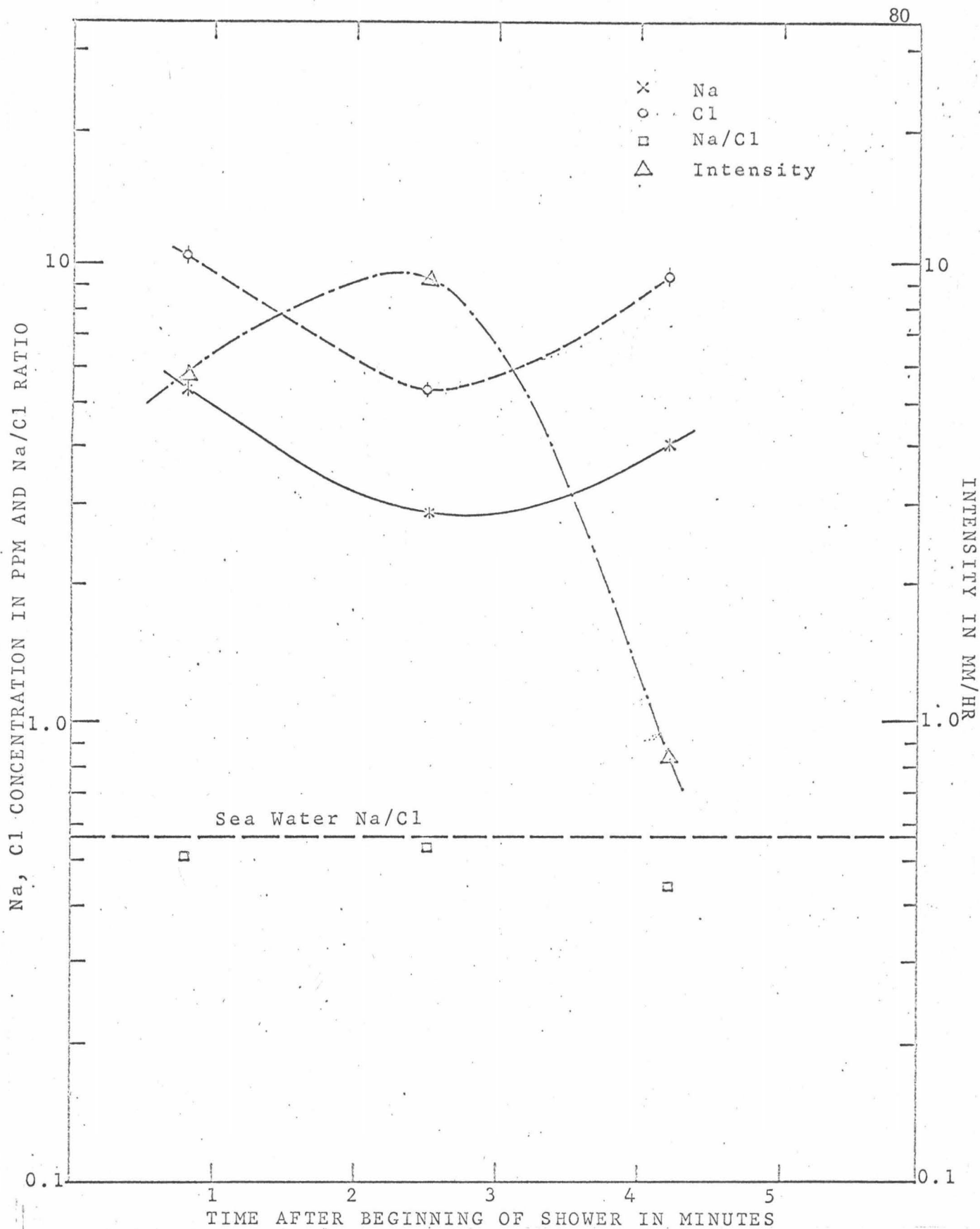


FIG.24 RAIN SAMPLES C59 TO C61, COLLECTED APRIL 1, 1967 ON WINDWARD SIDE OF OAHU AT SEA LEVEL

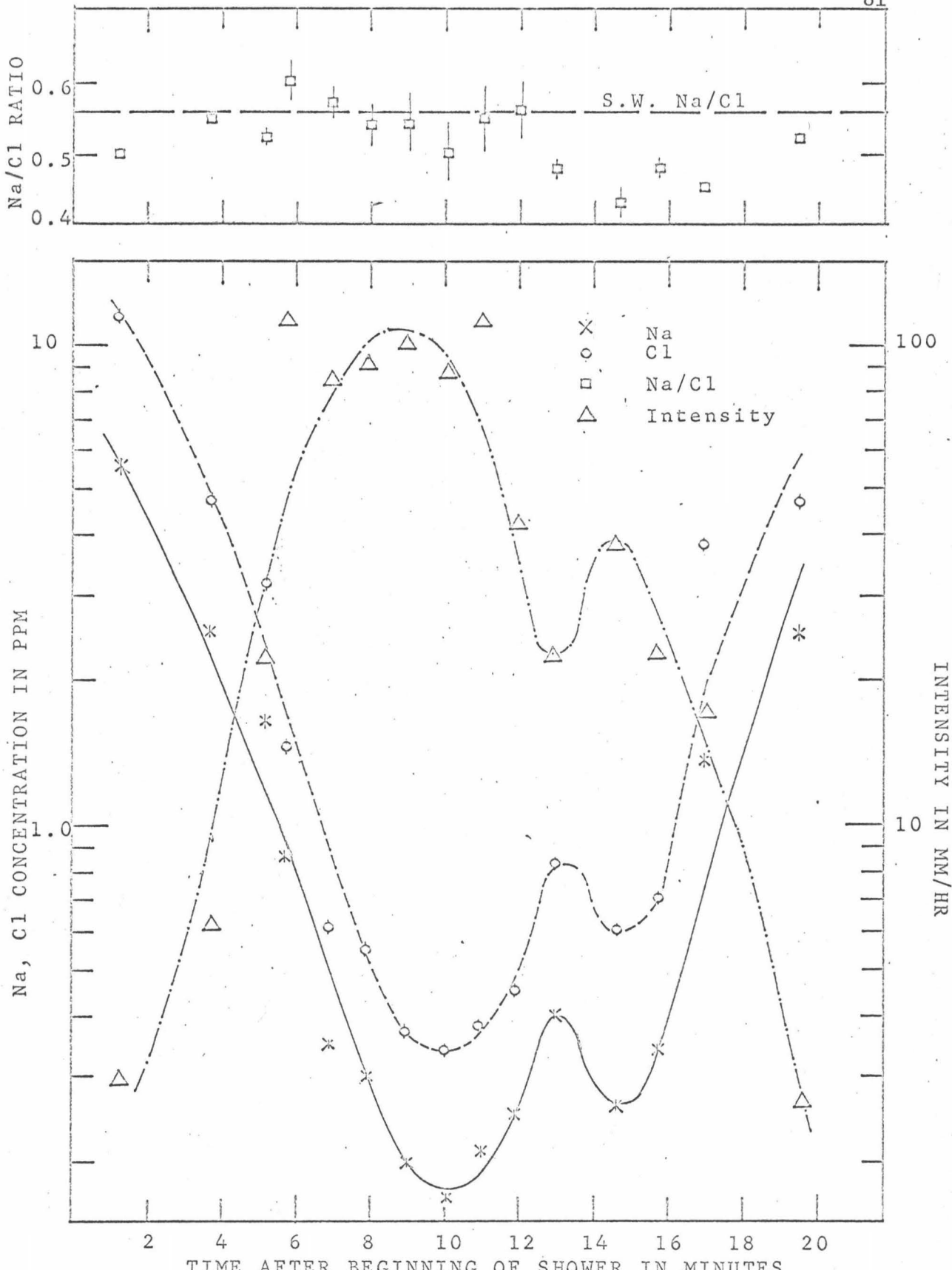


FIG.25 RAIN SAMPLES C67 TO C81, COLLECTED JULY 7, 1967 AT THE RADAR PAD, HILO, ELEV. 250 FEET

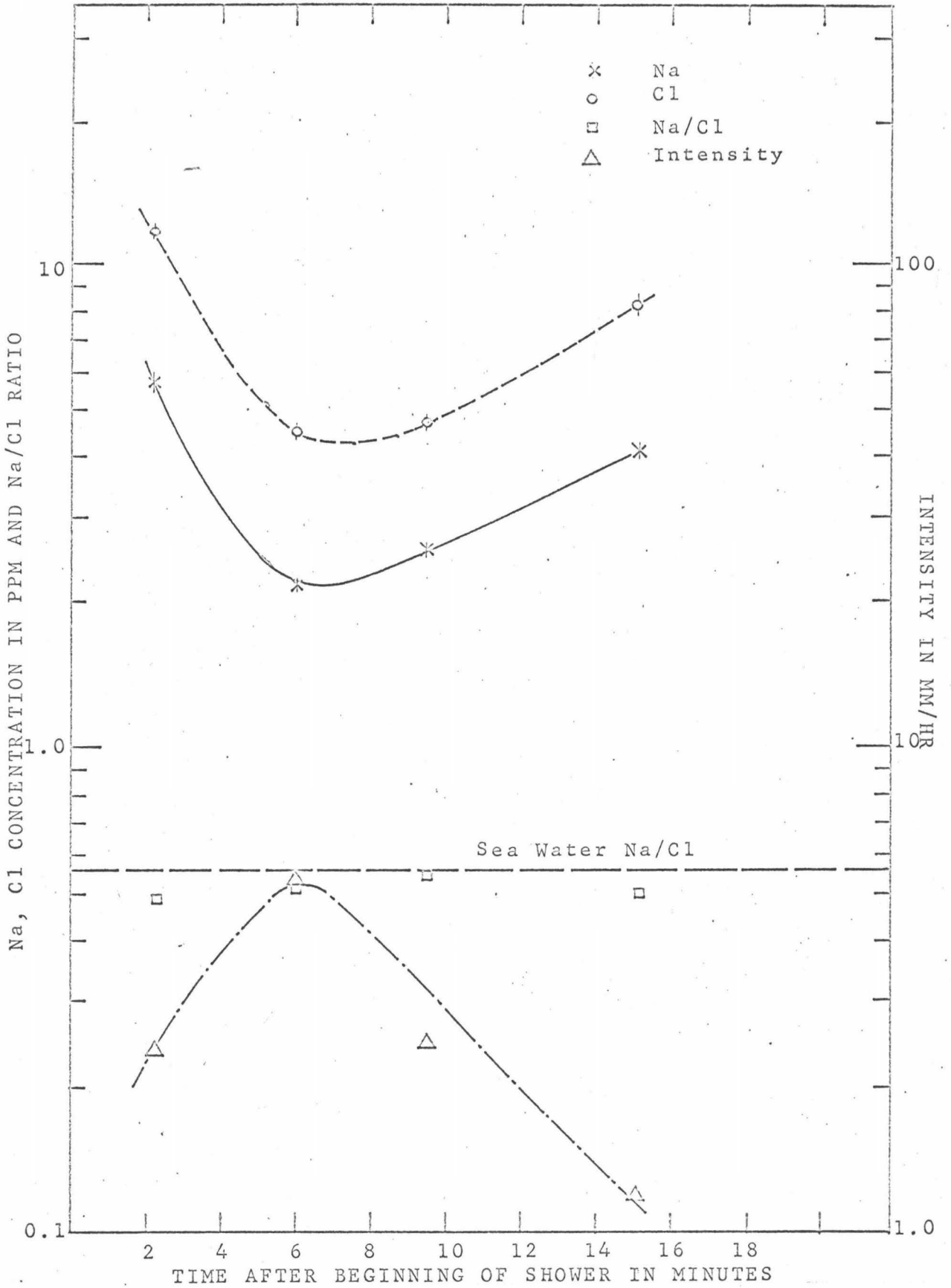


FIG. 26 RAIN SAMPLES C82 TO C85, COLLECTED JULY 7, 1967
AT THE RADAR PAD, HILO, ELEV. 250 FEET

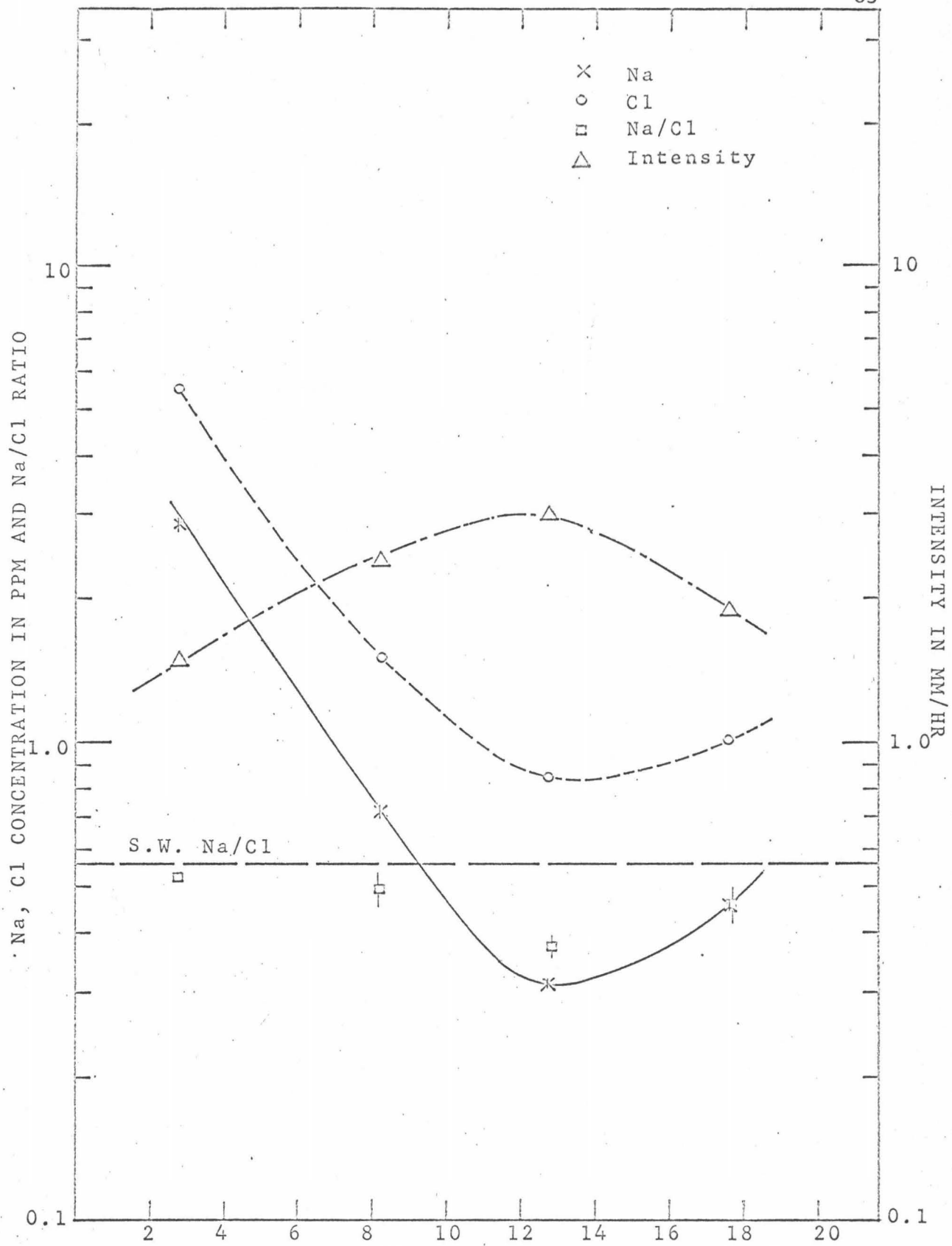


FIG.27 RAIN SAMPLES C86 TO C89, COLLECTED JULY 21, 1967 IN HILO, ELEV. 300 FEET

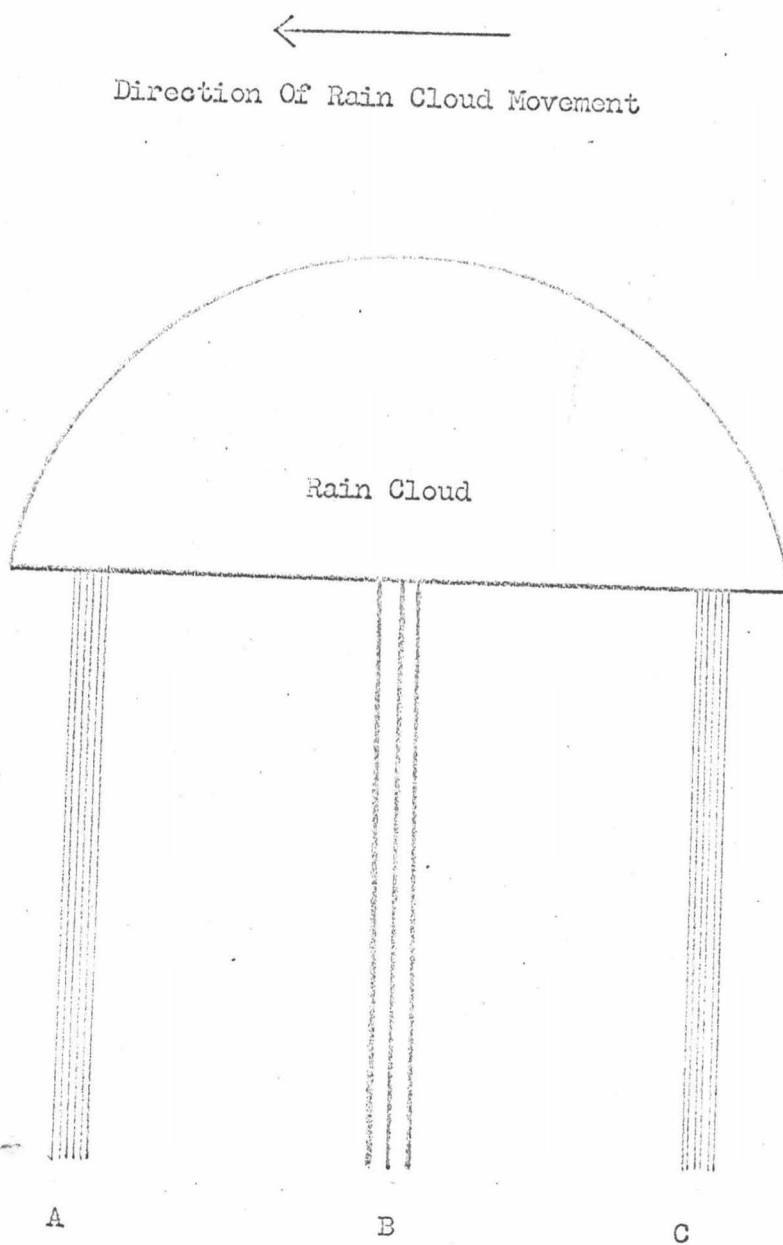


FIG. 28 GENERAL RAINFALL INTENSITY OF A SHOWER CELL

A, C ARE POINTS NEAR CLOUD EDGE AND HAVE LOW RAINFALL INTENSITY WITH A LARGE NUMBER OF SMALL RAINDROPS

B IS THE REGION NEAR CLOUD CENTER AND HAS HIGH RAINFALL INTENSITY WITH FEWER AND LARGER RAINDROPS

IV. CONCLUSIONS

The Na/Cl ratios for Hawaiian trade wind showers show very little if any increase with altitude. Because of the moist Hawaiian terrain and the short distances involved, addition of sodium from land to the rain samples is not likely. Thus, the very slight increase of Na/Cl ratio with altitude found in this investigation indicates little Cl is released from the rain or from the sea salt particles as the air mass moves inland away from the coast in Hawaii. This would imply that Cl release from raindrops or the sea salt particles incorporated in the raindrops is not very significant in rain falls from the coastal regions to regions further inland in Hawaii.

I/Cl and Br/Cl ratios in Hawaiian rains were found to increase with altitude by Duce et al. (1965). The small variations of the Na/Cl ratios with altitude found in this investigation would indicate that the variation in the I/Cl and Br/Cl ratios were primarily due to changes in the I and Br concentrations on the particles or in the raindrops, not release of Cl.

The sodium and chloride concentrations are inversely proportional to rainfall intensity, an intensity maximum being accompanied by a concentration minimum. This may be due partly to the fact that smaller raindrops are more vulnerable to evaporation on their way to the ground. In addition, at high rainfall intensities the available salt per unit volume of air must be distributed to a larger volume of rain water. Higher rainfall intensity is also related to more clean cloud drop coalescence resulting in concentration dilution.

In spite of such regular trends for the ionic concentrations, the Na/Cl ratios do not appear to show any dependence on the rainfall intensity. They are generally constant even for great changes in rainfall intensities. If there is any interaction between the gaseous Cl in the atmosphere and rain water, equilibrium must be established very rapidly. The time involved would be less than the residence time of the largest raindrops, which have the shortest residence time in the atmosphere.

Finally, the majority of the altitude and intensity rain water samples have Na/Cl ratios less than that of sea water. Since industrial or other local sources of Cl contamination are very unlikely and the addition of Na is considered to be negligible, the excess Cl in the rainwater may be due to Cl enrichment when the sea salt particles are formed at the sea surface by breaking bubbles. However, further laboratory investigation of bubble bursting in sea water is needed to explore this possibility of Cl enrichment with respect to Na in atmospheric sea salt particles.

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