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Radiative Transfer Modeling Applied to Sea Water Constituent Determination

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Kenneth H. Faller

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Kenneth H. Faller

NATIONAL SPACE TECHNOLOGY LABORATORIES
Bay St. Louis, Mississippi

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By Kenneth H. Faller
National Space Technology Laboratories
Earth Resources Laboratory

INTRODUCTION

Electromagnetic radiation from the sea contains information about some of the sea-water constituents. In the microwave region of the spectrum the emissivity of the sea surface is determined partially by its conductivity; consequently, the microwave radiation emitted by the sea can be used to infer its salinity. Infrared radiation emitted by the sea is proportional to the surface water thermodynamic temperature. Optical radiation from the sea is influenced by pigments dissolved in the water and contained in discrete organisms suspended in the sea. It is influenced by both pigmented and unpigmented particles, whether organic or inorganic.

This report addresses the problem of extracting the information concerning these pigments and particulates from the optical properties of the sea, the properties which determine characteristics of the light that a remote sensor will detect and measure. The ultimate goal of this research is to determine the constituents of sea water from remotely measured spectra of upwelling light. It is a part of the overall NASA Earth Resources Laboratory's objective to develop techniques for remotely sensing information that is useful in the management of natural resources.

Two basic phenomena determine the optical properties of the sea: absorption and scattering. Dissolved pigments of both terrestrial or marine origin selectively absorb light as a function of wavelength, as does pure water itself. Interpretation of the absorbance of sea water is complicated by the presence of many compounds that absorb light in the visible region of the spectrum. Most particles in the sea scatter light in a manner which is not strongly affected by wavelength, although scattering from pigmented particles, such as phytoplankton, does exhibit significant wavelength dependence. The scattering effect of sea water is determined by the distribution of sizes and refractive indicies of the particles as well as the absorption spectra of pigments they contain. Because of the many variables involved, exact analytical results are highly unlikely. However, through the judicious application of physical approximations and statistical modeling, it is possible to develop a good description of the constituents of sea water from its optical properties.

This document is a progress report documenting the status of research at the NASA National Space Technology Laboratories, Earth Resources Laboratory (ERL).

THEORY

Radiative Transfer

The spectrum of upwelling radiance from the sea surface may be related to the incident radiation through exact radiative transfer theory or one of several approximations to it. The approach taken is to adapt the quasi-single scattering approximation proposed by Gordon (1973) and developed by McCluney (1974).

Light entering the sea undergoes reflection and refraction as described by Fresnel's equations. For light incident at an angle θ_a (relative to the surface normal), these may be cast into the following forms:

$$E_l = E_{0l} T_l(\theta_a) = E_l \frac{4 \cos \theta_a \sqrt{n^2 - \sin^2 \theta_a}}{\cos \theta_a + \sqrt{n^2 - \sin^2 \theta_a}} \quad (1a)$$

$$E_r = E_{0r} T_r(\theta_a) = E_r \frac{4n^2 \cos \theta_a \sqrt{n^2 - \sin^2 \theta_a}}{n^2 \cos \theta_a + \sqrt{n^2 - \sin^2 \theta_a}} \quad (1b)$$

The subscripts r and l represent, respectively, polarization perpendicular and parallel to the scattering plane. These relations apply to a flat surface element, and, for the present analysis, it is assumed that the entire sea surface is flat.

The light reaching depth z with the same directional properties as the incident radiation is attenuated by absorption and scattering. Because the natural systems to which the analysis is to be applied are characterized by strong forward scattering, the author adapted for this work the quasi-single scattering approximation, which considers light scattered in the forward hemisphere to be scattered at 0°; i.e., in the exact direction of original propagation. Thus, the attenuation of downwelling light by the scattering process is represented by the factor $\exp[-kz\sec\theta]$ where θ is the angle between the incident radiation within the medium and the vertical and

$$k = C_{abs} + \int_0^{2\pi}\int_{\pi/2}^{\pi} \beta(\tau)\sin\tau\, d\tau\, d\phi \tag{2}$$

Here, $\beta(\tau)$ is the volume scattering function of the medium and C_{abs} is the total absorption cross section. Both terms include the effects of pure water itself plus the effects of suspended particles; the latter term also includes the effects of pigments in solution.

The present analysis neglects light reaching the sea surface from the sky and considers only direct sunlight. The sunlight is essentially plane-parallel unpolarized irradiance, E_o. The radiant intensity scattered upward from a volume element dv at depth z and measured just beneath the surface is

$$\begin{aligned} dN^{+}(\theta',\phi') = \tfrac{1}{2}n^2\, E_0 \left[T_1\beta_1(\tau) + T_r\beta_r(\tau)\right] \\ \exp\left[-(\sec\theta + \sec\theta')\int_0^z C(z')dz'\right] \cos\theta\,\sin\theta\, d\theta\, d\phi \end{aligned} \tag{3}$$

where θ' is the angle between direction of propagation of the scattered light relative to the vertical, θ' is the angle between this direction and the plane defined by the sun, the volume element and the vertical, and

$$\cos\tau = \cos\theta\cos\theta' + \sin\phi\sin\phi'\sin\theta\sin\theta' + \cos\phi\cos\phi'\sin\theta\sin\theta' \tag{4}$$

For an infinitely deep sea, equation (3) may be integrated over depth to give

$$dN^{+}(\theta',\phi') = E_0\tfrac{1}{2}n^2 \frac{1}{C(\sec\theta + \sec\theta')} T_1\beta_1(\tau) + T_r\beta_r(\tau) \cos\theta\,\sin\theta\, d\theta\, d\phi \tag{5}$$

Where N^{+} is the radiance scattered along the ray defined by θ', ϕ' from the water column. After an additional transmission through the sea-air interface and transmission through the atmosphere, it is this radiance that is measured by a remote sensor.

Absorption

This analysis is based on the assumption that the total absorption cross section, C_{abs}, is the sum of three elements: the actual absorption of light by pigments contained in suspended particles, absorption by pigments dissolved in the water, and absorption by pure water. The first element is an intrinsic part of the scattering phenomenon and will be discussed later under scattering. Dissolved pigments, generally classed as Gelbstoff, absorb according to Beer's law, so that the product of the specific absorbance and concentration of each individual compound at each wavelength may be summed to give the absorbance of the collection of compounds at that wavelength. These materials have terrestrial and marine sources, and may be decay products of pigments contained by once living plants or excreted by living phytoplankton.

Scattering

The volume scattering function, β, of the bulk medium is the sum of the volume scattering function of pure sea water, and the scattering by each of the individual particles suspended therein. It is a function of the number of particles, the size of the particles, the index of refraction of the particles relative to the medium, the internal structure of the particles if they are non-homogeneous, and the pigmentation of the particles. Adopted here is the assumption that the particles in the sea can be grouped into discrete classes with each class having a representative refractive index, size distribution, internal structure and pigmentation, as has been assumed by Zaneveld et al. (1974). So that the individual particle scattering properties can be computed using Mie scattering theory, the author further assumes that all the particles are spherical. Although this assumption undoubtedly introduces error, without it the problem is virtually unworkable. The volume scattering function for scattering at angle τ may then be written as

$$\beta(\tau) = \sum_j M_j \sum_i f_j(d_i)\beta_{ij}(\tau) + \beta_w(\tau)$$

where M is the concentration of particles of type j, $f_j(d_i)$ is the normalized size distribution of type j, and $\beta_{ij}(\tau)$ is the individual particle scattering function for type j, diameter d_i, and angle τ as computed according to Mie theory. Further, $\beta_W(\tau)$ is the Rayleigh scattering from the pure water computed according to Morel (1974).

Mie scattering theory as described by Van de Hulst (1957) is directly applicable to the computation of scattering by homogeneous spheres. This theory has been extended by Kerker (1969) to apply to scattering by non-homogeneous spheres composed of concentric spherical shells, and, in this expanded form, it has been applied by Mueller (1973) to compute the scattering properties of a hypothetical spherical diatom composed of three layers; the innermost being the unpigmented vacuole, the intermediate shell being a pigment-bearing pseudochloroplast, and the outer shell being the unpigmented frustule. The absorption spectrum of the pigment enters into the scattering by introducing a non-zero imaginary component of the index of refraction which appears explicitly in the Mie computation, and causes pigment-bearing particles to have a non-zero absorption cross section. Attenuation by unpigmented particles is restricted to scattering, while pigmented particles absorb some energy and thus attenuate by both scattering and absorption mechanisms.

EXPERIMENTAL DESIGN

Experimental work was planned to provide the basic data required by the theory previously outlined relating the constituents of sea water to the spectrum of light upwelling in the sea and then to test it. The first element of the theory to be tested was the synthesis of the bulk scattering from five classes of hypothetical particles. Additional research was being conducted to isolate the dissolved organic pigments found in the coastal waters of the northern Gulf of Mexico so their specific absorption spectra could be determined for inclusion in the radiative transfer model, but these data were not available at the time of this writing. A preliminary absorption spectrum was developed from organic material extracted from sea water and used initially in the radiative transfer model. The radiative transfer model was tested with measurements of the upwelling light spectrum made by Earth Resources Laboratory (ERL) using the preliminary data and using the absorption spectrum of one sample of filtered sea water relative to distilled water.

Dissolved Pigment Analysis

Three different approaches have been taken to isolate the dissolved organic components of sea water. The first is the extraction technique using organic solvents as described by Copin and Barbier (1971), and the second is an absorption technique utilizing reverse phase high-pressure liquid chromatography (HPLC). The third approach was to precipitate most of the organic material of interest by addition of methanol, then to apply the HPLC analysis.

Sea water samples were collected for the analysis of dissolved organic substances at sampling stations located in the northern Gulf of Mexico and its coastal environs as indicated in Table I. The water samples were filtered with a 0.4-μm filter immediately after collection. The samples were stored in glass bottles under refrigeration. All glassware was scrupulously cleaned before use to minimize contamination.

To perform the extraction, the sea water was acidified to pH 2 with concentrated hydrochloric acid. Pesticide analysis grade ethyl acetate was then added in the proportions of 500 ml per liter of sea water and agitated for 15 minutes. After separation, the ethyl acetate was evaporated in a flash distillation apparatus which included a liquid-nitrogen cooled trap where the solvent was recovered. The organic material remaining after evaporation of the solvent was redissolved in ethyl acetate to separate it from the inorganic salts. The solvent was again evaporated in a tared flask, and the mass of organic material extracted from the sea water was then determined.

TABLE I. EXPERIMENT DATA SAMPLING STATIONS

Station	Latitude, North	Longitude, West	Radiance	Data Acquisition Scattering	Supporting	Gelbstoff
1	30°12.7'	89°01.5'	X[a]	X	X	
2	29°58.5'	88°38.5'	X	X	X	
3	29°53.0'	88°32.5'	X	X	X	
4	30°13.5'	88°32.5'	X	X	X	X
5	29°54.5'	88°32.0'	X	X	X	X
7	30°19.7'	87°10.2'	X	X	X	X
8	30°19.7'	87°10.2'	X	X	X	
9	30°00.5'	86°57.7'	X	X	X	X
10	30°11.2'	89°09.5'	X	X	X	
11	30°11.2'	89°09.5'	X	X	X	X
12	29°59.0'	88°43.7'	X	X	X	X
13	29°56.5'	88°24.2'	X	X	X	X
20	28°49.3'	89°33.0'	X		X	
21	29°01.6'	89°42.6'	X		X	
33	28°39.0'	83°05.0'	(1)[b]	X	(3)[d]	
34	29°38.0'	84°01.0'	(1)	X	(3)	
35	30°08.0'	88°16.0'	(1)	X	(3)	
37	28°42.0'	89°50.0'	(1)	X	(3)	
41	30°05.0'	88°42.2'	X	X	X	X
42	30°12.7'	89°01.5'	X	X	X	X
43	30°12.5'	87°31.2'	X	X	X	X
44	29°57.5'	87°16.2'	X	X	X	X
45	30°19.7'	87°10.2'	X	X	X	X
51	27°20.0'	92°22.0'	(2)[c]	X	(4)[e]	
52	28°49.0'	94°45.0'	(2)	X	(4)	
53	27°39.9'	96°29.6'	(2)	X	(4)	
54	28°50.4'	89°29.4'	(2)	X	(4)	
55	29°58.1'	88°01.1'	(2)	X	(4)	
56	28°29.0'	90°18.5'	(2)	X	(4)	
57	27°51.0'	92°55.4'	(2)	X	(4)	
58	28°25.0'	95°55.9'	(2)	X	(4)	
59	29°35.6'	93°51.0'	(2)	X	(4)	
60	29°41.1'	93°23.2'		X	(4)	
61	29°13.0'	92°24.0'		X	(4)	
62	28°46.2'	92°16.7'		X	(4)	

LEGEND:
a. X = ERL
b. (1) = Scripps Visibility Lab, Researcher cruise
c. (2) = Scripps Visibility Lab, Gyre cruise
d. (3) = NOAA/AOML and Bigelow Labs
e. (4) = ERL, Texas A&M, Bigelow Labs

Portions of the organic material extracted from the sea water were subjected to thin layer plate and gravity flow liquid partition chromatography. Additional high pressure liquid chromatographic separations were performed on some of the extracts. The column used was the μ BONDAPAK C_{18} from Waters Associates, Inc. and was operated at pressures from 400 to 1000 psi. The nominal plate count for this reverse phase column is 2700. Solvent systems used were 100% methanol; 90% methanol, 10% water; and 80% methanol, 20% water. Three detectors were used after the column; a universal refractive index meter and absorption detectors at 254 and 365 nm.

The same column was used to extract the organic substances directly from the sea water. For this isolation procedure, the sea water was filtered with a 0.3-μm glass filter and 200 ml was passed through the column at about 900 psi. The water leaving the column was collected in 10 ml aliquots for which visible/ultraviolet spectra were recorded on a Cary-17 spectrometer. After the sea water had been passed through the column, 300 ml distilled water was used to wash inorganic salts from the column. The organic material which had been absorbed on the column was finally eluted with ethanol or methanol; the solvent was collected in 5 to 10 ml aliquots and analyzed spectrophotometrically. The column was then cleaned with tetrahydrofuran, methanol and distilled water before further use. Because some of the results were very perplexing and it appeared that some contamination of the column might be interfering with the analysis, a special cleaning procedure specified by the column manufacturer was carried out. This procedure consisted of successively pumping 100 ml distilled water, 300 ml methanol, 100 ml dimethylformamide, 300 ml methanol and 100 ml distilled water through the column. Sea water was again processed after the cleaning and the organics eluted. The eluted materials were chromatographed on the same column with a solvent of 80% methanol, 20% water. Analysis is continuing to separate and isolate the pigments from these fractions.

The third approach to separating the organic solutes from the sea water was to cause them to precipitate by the addition of an alcohol. Prior to injection of a sea water sample on the column with a methanol/water solvent, a small sample was tested to determine whether inorganic salts would be precipitated on the column. Such an occurrence would very likely damage the column. It was found that some carbonates and a large portion of the organics were precipitated. Sea water samples were then mixed with two parts methanol for each part sea water and filtered. Visible and ultraviolet absorption spectra were recorded before and after precipitation. Because organic material was being removed from the solution, further analysis was performed on the precipitate. Ethanol was also found to cause the formation of a precipitate, but not as much as caused by the methanol.

The sea water samples that had been treated with methanol were injected on the reverse phase column after filtration. Both 365- and 254-nm detectors were used. The solvent system was 8:2 methanol/water.

Scattering Analysis

Samples were taken at various stations in the coastal waters of Louisiana, Mississippi and Florida as indicated in Table I. The samples were analyzed with a slightly modified Bryce-Phoenix light scattering photometer to measure the light scattered at 10° intervals from 20° to 130°. The sample was illuminated by light from a mercury lamp with emission lines at 436, 546, and 578 nm selected by appropriate filters. The illumination was polarized either parallel (l) or perpendicular (r) to the scattering plane. The instrument had been calibrated using suspensions of polystyrene or polyvinyl toluene spheres of known radius, for which the volume scattering functions had been calculated using Mie scattering theory. The sea water samples were analyzed with a Coulter counter to determine the particle size distribution and concentration. Also, 50 μm and 200 μm aperture tubes were used for some of the samples, and 15 μm, 70 μm, and 200 μm aperture tubes were used for later samples. Concentrations of pigments were also determined.

A scattering model based on equation (6) was developed. Five classes of particles were included, four of which are homogeneous and have refractive indices of 1.05, 1.075, 1.15 and 1.20 (relative to water) and a fifth particle that corresponds to Mueller's (1973) hypothetical three-layered diatom. The first two classes of particles are organic, having indices of refraction relative to air of 1.40 and 1.44. They correspond to bacteria and fragments of micro- and macro-plants. The second two are inorganic and have indices of refraction relative to air of 1.54 and 1.60. The most common minerals, including silica and alumina, have refractive indices near 1.54, while others, such as montmorillonite, have indices near 1.60. The vacuole of the diatom was assigned a refractive index of 1.05 (relative to water) and the frustule was assigned 1.064, based on data published in Lewin (1962). The problem of assigning a refractive index to the pseudochloroplast is compounded by the fact that the index is a complex number, the imaginary part of which varies greatly with wavelength. Mueller used published estimates of the concentration of chlorophyll-a and -c, carotenoids, and xanthophylls with their specific absorption spectra as determined in vitro. For this model, in-vivo absorption measurements on cultures of several different diatoms (Farmer, 1977)* were used with the Mie scattering computation to determine, through an iterative least-squares error analysis, the wavelength-dependent values of the imaginary part of the refractive index, with the real part assumed to be 1.05. Farmer measured the absorbtivity of cultures of various types of phytoplankton using a Cary-17 spectrometer with a diffuser placed behind the sample cells of both the reference and sample beams. He therefore collected light that had been scattered in the forward

*Farmer, Frank. Personal Communication

direction and measured as absorbance only the true absorbance and backscatterance. The radiative transfer equation can be adapted to compute the absorbtivity of the cell as

$$A = P\,Q_{ext} - P\pi \int_0^{\alpha} \beta_l(\theta) + \beta_r(\theta) \quad \sin\theta\, d\theta$$

where $A = \ln T$, T is the transmissivity of the culture in reciprocal meters, P is the concentration of phytoplankton in cells/m^3, β_l and β_r are the scattering functions for the individual cells computed using the three-layered spherical model and extended Mie scattering theory and α is the maximum angle for which scattered light is collected by the diffuser. Computing the chlorophyll-a content of the individual cell from the resulting refractive index yielded a value of 2×10^{-10} mg/cell, a value considerably less than 1 to 50×10^{-9} expected for oceanic areas. The imaginary part of the refractive index of the pseudochloroplast was scaled to match Mueller's model at the long wavelength chlorophyll-a absorption peak (although it occurs at 667.5 nm in his data and 680 nm in Farmer's) and at 600 nm. This gives a chlorophyll-a content of 10^{-9} mg/cell. Table II lists the imaginary part of the refractive index of the pseudochloroplast at 20-nm intervals from 380 to 700 nm.

Individual scattering functions were computed at 1° intervals for each of the homogeneous particle types for radii ranging from 0.025 μm to 56.750 μm, and for diatoms having radii ranging from 2 to 18.375 μm. Absorption cross sections were also computed for the diatoms. Computations were made at wavelengths from 380 nm to 700 nm at 200-nm intervals. When data were required at other wavelengths, linear interpolation was used. Two different size distribution forms are used. The distribution of the inorganics is assumed to be hyperbolic, as suggested by Bader (1970) for the entire family of marine particles. This distribution is expressed by the relation $dP = P^{-\gamma} dD$, where P is the population and D is the diameter. Because of the physical processes involved in the determination of particle size, the nature of the organic detrital material, and the fact that living organisms such as bacteria contribute to the number of organic particles, a peaked size distribution was selected for the unpigmented organic particles and the phytoplankton. Diermendjian (1969) suggests a modified gamma distribution of the form $dP = b_1 D^{\alpha} \exp(-b_2 D)$, where

$$b_1 = \frac{\gamma^{b_2} \; (\alpha + 1)/\gamma}{\Gamma\left(\frac{\alpha + 1}{\gamma}\right)}$$

$$b_2 = \frac{\alpha}{\gamma^{D_M}{}^{\gamma}}$$

and D_M is the mode diameter.

TABLE II. PSEUDOCHLOROPLAST PROPERTIES

Wavelength, nm	Imaginary part of refractive index
380	0.02748
400	0.02950
420	0.03494
440	0.04162
460	0.03903
480	0.03209
500	0.02938
520	0.02222
540	0.01785
560	0.01223
580	0.007777
600	0.006700
620	0.007256
640	0.007867
660	0.01159
680	0.04100
700	0.009768

A computer program was written that relates the measured volume scattering function of sea water samples to the individual particle scattering through the scattering model. This program performs a least-squares error analysis to determine a series of parameters that define the population and size distribution of the model particles that give the best fit of the computed volume scattering function to the actual measurements. The technique is a combination of an algorithm that linearizes the fitting function and a gradient search algorithm. The former algorithm gives a rapid convergence to the solution from points already nearby, whereas the latter algorithm is ideally suited for approaching a minimum error from far away. The algorithm as described by Bevington (1969) was implemented for interactive use on the Univac 1108 Demand Terminal System of the Marshall Space Flight Center at the Slidell Computer Complex.

In-situ volume scattering measurements published by Kullenberg (1968) were analyzed using this technique. The beta-meter measurements made in the Sargasso Sea were the first processed. After completing analysis of these data, in-vitro measurements made by ERL were processed. These data represent a wide variety of marine conditions in the Gulf of Mexico, from the clear blue water offshore to the turbid waters of coastal estuaries.

Upwelling Light Spectrum

A modified United Detector Technology spectroradiometer was used to measure the spectrum of upwelling and downwelling radiation in the water column. It was configured to measure upwelling radiance from a solid angle of approximately 0.154 steradians and downwelling irradiance from the entire hemisphere using a cosine collector. Data were collected at the locations listed in Table I, coordinated with the other sampling efforts. The spectra were measured just beneath the surface, at 1/3, 2/3 and 1 secchi depth continuously for 1 minute and then averaged. The radiance or irradiance values differing from the mean at each wavelength by more than two standard deviations were discarded to eliminate problems resulting from focusing by waves, a phenomenon that could distort the shape of the spectra. The calibrated data were sampled at 20-nm intervals and entered into a data base of spectra.

The radiative transfer model was implemented on a Univac 1108 computer. Equation (3) was integrated, yielding

$$N^{+}(z) = \tfrac{1}{2}E_{z}\,\mathcal{Z}\int_{0}^{\xi/2}\int_{0}^{2\pi}\frac{R(\theta')}{R}\left[T_{1}\beta_{r}(\tau) + T_{r}\beta_{r}(\tau)\right] \tag{6}$$

$$\cos\theta'\,\sin\theta'\,d\phi'\,d\theta' + N^{+}(Z-\Delta Z)\,\exp(-C\,\Delta Z)$$

where

$$\mathcal{Z} = \frac{1 - \exp[-(\sec\theta + 1)C\,\Delta Z]}{C(\sec\theta + 1)}$$

$$\overline{R} = \left[\int_0^{\xi}\int_0^{2\pi} R(\eta)\ \sin\eta\ \cos\eta\ d\phi\ d\eta\right]^{-1}$$

$$C = \gamma G + C_s + C_w$$

and C_s is the absorbance and backscattering of particulates, γ and G are, respectively, the specific absorbance and concentration of Gelbstoffe, and C_W is the absorbance of pure water as published by Morel and Prieur (1977). Further, R is the responsivity of the instrument as a function of zenith angle, and the other terms are as defined earlier. The refractive index of the medium does not appear because all of the radiometer optics are behind a glass flat in air, so the radiance measurement is in air. The field of view is, however, corrected for the change of refraction index.

The radiative transfer equation was formulated in terms of the same particle size distribution functions and individual particle scattering properties used in the volume scattering function analysis, with the additional Gelbstoffe concentration for use in a least-square error analysis of upwelling radiance. The computer program was written in such a manner that upwelling radiance was assumed to originate in a uniform infinitely deep sea or from a finite uniform layer. For the latter case, the program subtracts from the measurement of upwelling radiance at the top of the layer the upwelling radiance measured at the bottom of the layer, corrected for attenuation using Beer's law, and the diffuse attenuation coefficient computed from the quasi-single scattering approximation. The program computes the distribution parameters and concentrations for each of the five particle types and the concentration of Gelbstoffe that results in the best match between the computed and measured upwelling light spectra. Because good values for the specific absorbance of Gelbstoffe were not available, most of the spectral analyses were performed with the absorbance of the filtered sea water from the surface at Station 12. Therefore, the concentrations of Gelbstoffe reported in the results section of this report are, in fact, the concentration relative to Station 12. This assumes that the absorption spectrum is uniform, although it is quite possible that the continuing analysis of the dissolved organics will reveal multiple pigments (with different absorption spectra) appearing in varying proportions.

RESULTS

Absorption

The concentration of organic matter in the various sea water samples which were extracted with ethyl acetate ranged from 0.33 to 2.35 mg/l, assuming constant extraction efficiency. The lowest values were found in the offshore waters of the Gulf of Mexico while the higher concentrations were found in the Mississippi Sound. The absorption spectra of the extracts were all very similar, with exponentially increasing absorption at shorter wavelengths. Absorption is negligible from 700 to about 580 nm, at which point it begins to rise exponentially to 360 nm, the limit of analysis performed on most samples. Only one peak was observed in the visible absorption spectrum of any of the samples; and that sample is believed to have been contaminated.

It appears that an important component is being lost during the process of evaporating the solvent used to extract the organics. The solvent collected in the cold trap was consistently colored yellow; however, it has not been determined whether the colored compounds were contamination from the evaporator system or were actually being evaporated from the extract, although extensive cleaning of the system did not eliminate the substance.

Thin-layer chromatography was used for preliminary analysis of the extract. The best separations on thin-layer plates were achieved with silica gel having no fluorescent indicator and near neutral pH. With a 6:2:1 butanol/acetic-acid/water solvent system, three spots were resolved over a continuous streak of material. With a 7:3 acetone/water solvent, three distinct spots were found. Good separations were also obtained with silicic acid instant thin-layer medium. The silicic acid is embeded in a fibrous glass support with no binders. Three or four spots were formed by developing with pure ethanol, 1:1 chloroform/methanol and 9:1 acetone/water. In general, it appeared that there were four classes of compounds, all of which were basic or neutral. Although it appears that there are some nonpolar components, the greatest portion having visible absorption is polar.

The results of the liquid partition chromatography were negative, in that it was impossible to clearly separate the components which absorbed in the visible portion of the spectrum. Using a solvent system of 9:1 acetone/water, there was virtually no movement of the sample on the column, but when the solvent was changed to 8:2 acetone/water, the sample appeared to separate into two components. After most of the sample was taken off the column, the absorbance of the material being eluted began to increase, but no distinct band of material could be identified. Serious trailing of the sample on the column thus prevented a clear separation of visible absorbing components. This is consistent with the report by Copin et al. (1971) that with various absorbants and solvent systems, he found only smears on the thin layer plates when working with the pigment found dissolved in the sea water.

The high-pressure liquid chromatographic technique offered more promising results. The detector, operating at 254 nm, indicated that as many as 24 components may be separated from the extract. One particular sample had 20 components indicated by the 254-nm detector, but only three or possibly four indicated by the 365-nm detector. The refractive index indicator consistently showed two or three components.

Because the visible absorption of the extract appears to be the result of the fringe of ultraviolet absorption bands, the detector operating at 365 nm, which is very close to the visible, will indicate the compounds of greatest interest to this investigation. With strong absorption at 365 nm, a compound would probably have some absorption in the visible portion of the spectrum. The 365-nm detector indicates that trailing is present even with this high-pressure reverse-phase chromatographic technique. It does appear, however, that these components, which are the true yellow substances, may be separated from most of the non-pigment components using this technique.

Separations performed on extracts from four samples were very consistent. Based on retention time, six components common to all four samples were identified. The relative proportions of these components appear to vary significantly from sample to sample and they may not be pure compounds, but groups of closely related substances.

The separations performed on the sea water itself showed two clearly defined but not totally resolved components followed by a trail similar to that observed with the extract at 365 nm. The sample had components that were detected by the 365-nm detector at 4.9 and 5.1 minutes, whereas the extract had one or more components at about 3.8 minutes and at 5.0 minutes. The later component was not completely resolved from the former and may have been composed of two substances, and the retention time by the column for the two samples are within the accuracy of the experiment. Thus, one may conclude that one of the components which contributes to the visible absorption of the sea water was not precipitated (the 5-minute component), while the extract contained an additional component, apparently in significant concentration, that was removed from the sea water by the precipitation.

Scattering

The results of selected analyses of the volume scattering function measurements are presented in graphical form in Appendix A. These graphs show the measured volume scattering function as points and the best-fit predicted theoretical scattering function as continuous lines. Both polarizations are shown on the same graph for the samples processed at ERL, whereas only the unpolarized measurements were available for the Sargasso Sea data taken from the literature and hence only unpolarized data are shown.

In general, the agreement between the best-fit model prediction and the measurements is quite good. The prediction for the Sargasso Sea data is within the experimental error for the measurements, and the predictions for the data taken by ERL are generally near the estimated experimental error. The predicted curves for some data sets are not as smooth and regular as the measurements, indicating that, although the error in the fitting is not great, there is a basic discrepancy in the analysis. The analyses of Stations 43 and 44 are good examples of this problem. The greatest difficulty in the curve fitting process seems to be in matching the computed curve with the measurements at angles greater than 110° (in the backscattering direction). It appears that the irregularities in the shapes of the computed curves arise from attempting to match the backscattering curves, as much greater regularity results from discounting the error due to the backscattering points. It should be observed that some irregularities do appear in the measurements themselves. For example, the Station 9 data have a local maximum at about 100°, a maximum that is matched in the predicted curve. This can also be noted in the data from Station 13.

The true test of the analysis is the comparison of the predicted particle size distributions with those measured with the Coulter counter. Appendix B contains the graphical comparisons between the Coulter counter measurements (the points) and the predicted distributions (the continuous lines). It can be seen that some show excellent agreement over many orders of magnitude while others are not very good.

The inconsistency results, it is believed, from the fact that it is very difficult to identify the true minimum in the error function defined by the deviation between the prediction and the measurements of the volume scattering function and to distinguish it from the many local minima that exist in the error function. The computer program requires a first estimate of the concentrations of each particle type and their distribution parameters. A good estimate results in rapid convergence to the minimum, whereas a poor estimate leaves the analysis wandering among local minima in the error function. Experience in working with the data results in improved estimation of the starting values, but with the work reported here being completed on a tightly limited schedule, full advantage could not be taken of this learning process. Experimentation with various combinations of starting parameters could not be extensive, and similar starting values, with few exceptions, were used for all samples processed. This undoubtedly biased the analysis results, preventing the computer program from finding the truly optimum distributions.

Another factor that must be considered in explaining the error is the limitation of the theoretical scattering calculations to spherical particles of only five refractive indices. Simulation of scattering by distributions of particles of varying refractive index showed that features such as a local maximum in the backcattering direction shifted as the refractive index changed. Failure to match perfectly this feature in the Station 9 data probably results from a slight mismatch in the predicted and actual index of refraction of the dominant particle types. The less-than-desirable match between prediction and measurement at angles greater than 110° may result from the requirement for the initial calculations of individual particle scattering properties that all particles be spherical.

Upwelling Spectrum

The results of the least-squares-error analysis of the radiative transfer model with the measurements of upwelling light spectra are presented in graphical form in Appendix C. Agreement in general is quite good, with the predicted maximum usually falling at the same wavelength as the measured maximum. Prediction and measurement are closest in the range of 460 to 640 nm, probably the most important range for remote sensing applications.

Problems occur in the short wavelength region of the spectrum, below 460, and between 660 and 680 nm. It is believed the former problem results from not having the proper absorption spectrum for the dissolved organic pigments. This hypothesis could be tested when the final result of the Gelbstoffe analysis is available. The second problem, in the red region of the spectrum, is apparent only in some very clear water data sets. It appears that fluorescence of chlorophyll in the suspended phytoplankton causes shorter wavelength radiation to be converted to the long wavelength radiation. This is most obvious at Station 9, where the transmissivity at 436 nm was 95% per meter and the Secchi extinction depth was 26 meters. The radiative transfer model as implemented does not include fluorescence, but could be easily modified to incorporate the effects of chlorophyll fluorescence if the requisite efficiency factors were available.

A further problem is evident when the theoretical diffuse attenuation coefficient is plotted as a function of wavelength with the experimental values determined from the downwelling irradiance spectra measured at sea (Appendix D). Although agreement is good on some measurements, the theoretical attenuation curve is higher than the measured curve. This is consistent with the comparison of the predicted particle size distributions with the Coulter counter measurements (Appendix E). The predicted curves are generally an order of magnitude higher than the measurements. The problem may be related to the problem noted with the agreement between the predicted and measured volume scattering functions in the backward direction. In the discussion of the scattering analysis, it was noted that the predicted curve was lower than the measurements at 120° and beyond. With the upwelling radiance originating in backscattering, underestimation of individual particle backscattering would require an overestimation of the particle concentration. This, in turn, would explain the increased attenuation across the spectrum and the disagreement with the Coulter counter measurements.

Another factor that should be considered is the time that elapsed between the in-situ spectral measurements and the Coulter counter measurements that were made in the laboratory days after the sample collection. It is commonly agreed that the particle size distribution is seriously affected by the sampling process and by storage.

It should be noted here that only a very limited period of time was available for working with the radiative transfer model after the computer program appeared to begin functioning. During that time, several errors were found in the implementation of the model. It is therefore possible that computer programming errors may still exist in the software and therefore the results of the data analyses may not yet represent a true demonstration of the theoretical model.

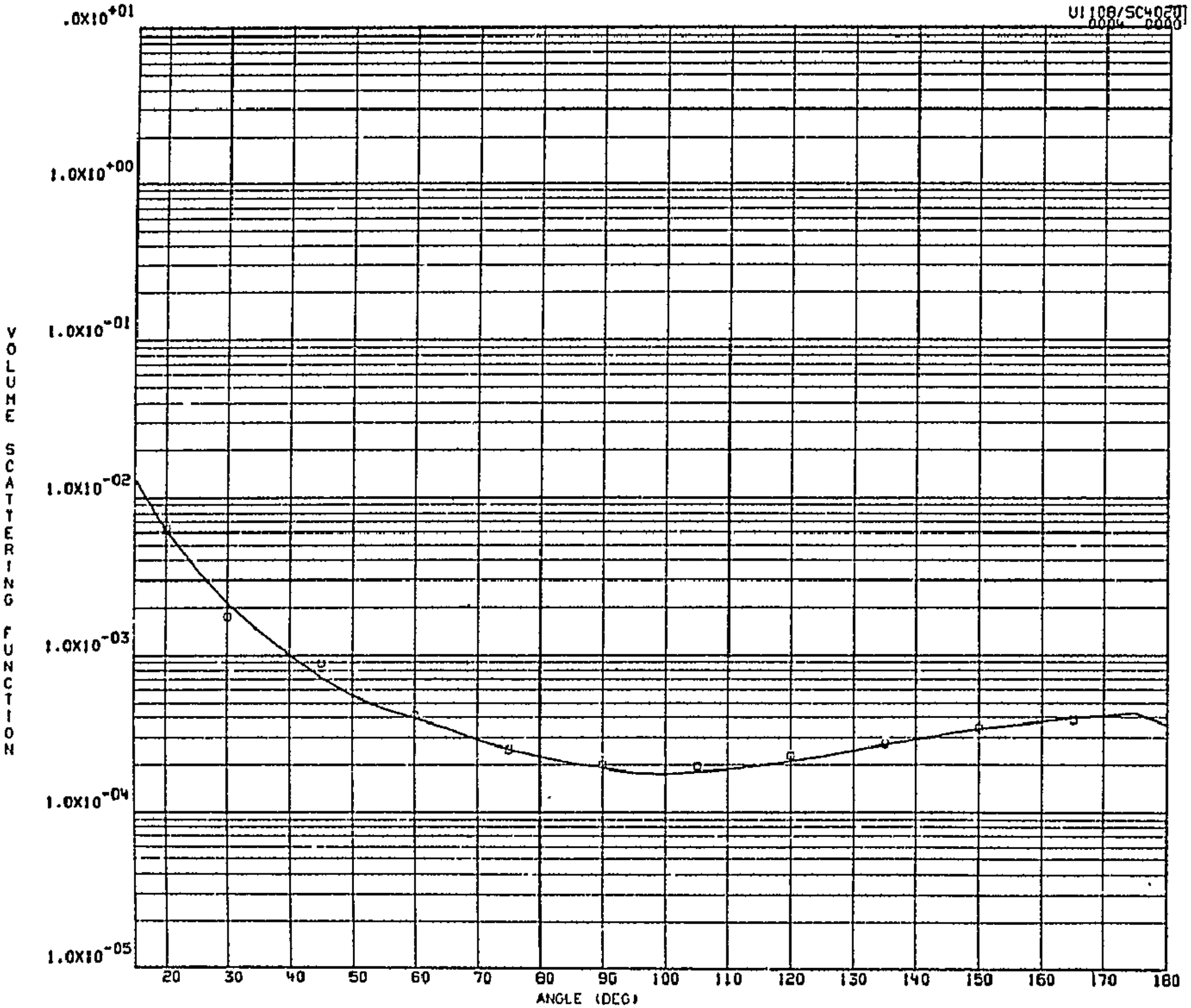
CONCLUSION

The results of the application of the volume scattering function model to the data collected in the Gulf of Mexico and its environs indicate that one can reasonably predict the size distribution of the concentrations of particles found in the sea from measurements of the volume scattering function. Furthermore, with the volume scattering function model and knowledge of the absorption spectra of dissolved pigments, the radiative transfer model can compute a distribution of particle sizes and indices of refraction and concentration of dissolved pigments that give an upwelling light spectrum that closely matches measurements of that spectrum at sea. There appears to be a systematic deviation between the concentration of particles required to give the model predicted spectrum and the concentration actually measured from samples taken at the location and time of the spectral measurements. However, because the error appears systematic, the model calculations could be calibrated to permit accurate computation of the sea water constituents from the upwelling light spectrum.

National Space Technology Laboratories
National Aeronautics and Space Administration
NSTL Station, Mississippi 39529 November 13, 1979

APPENDIX A

VOLUME SCATTERING FUNCTION



WAVELENGTH 460 NM

CHI SQUARE = 2.40×10^{-02}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$2.218 \times 10^{+03}$	$2.669 \times 10^{+01}$	5.363×10^{-03}	$2.467 \times 10^{+00}$	3.398×10^{-02}
MODE DIAM			1.22	0.23	4.36
ALPHA			6.00	6.00	6.00
GAMMA	5.63	3.81	0.30	0.39	0.81

SARGASSO SEA

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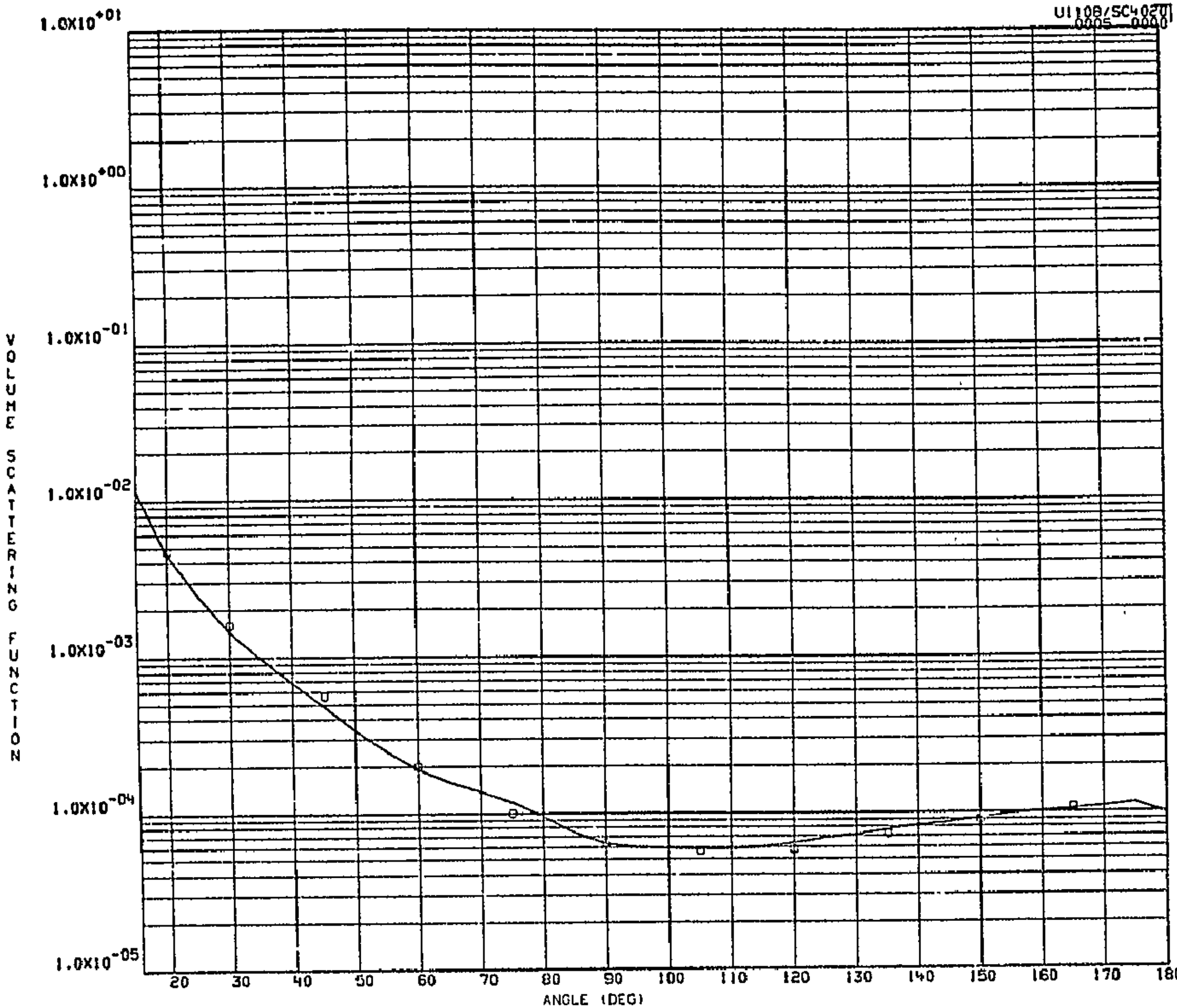
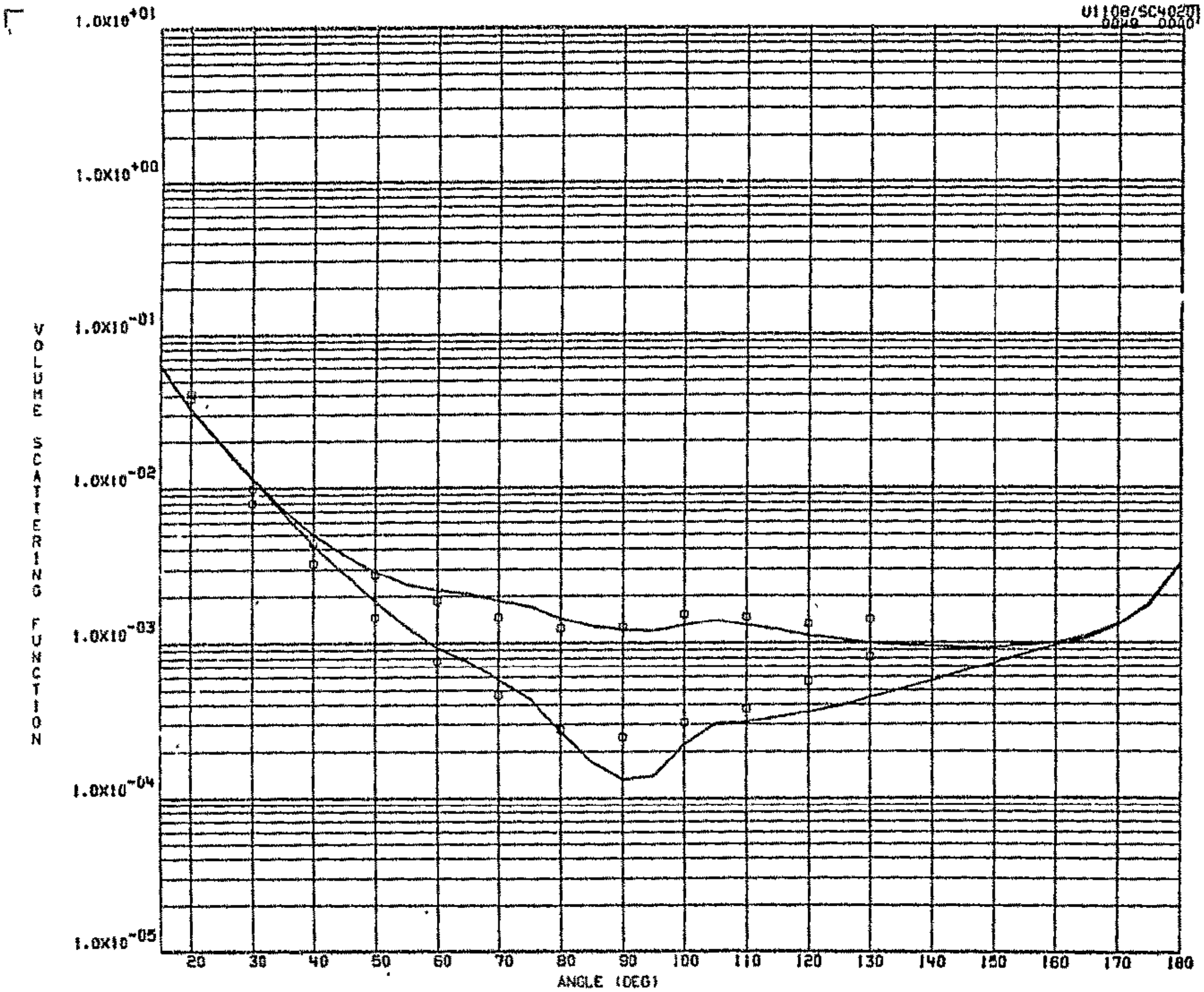


WAVELENGTH 655 NM

CHI SQUARE = 2.40X10^{-02}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	2.218X10^{+03}	2.669X10^{+01}	5.363X10^{-03}	2.467X10^{+00}	3.398X10^{-02}
MODE DIAM			1.22	0.23	4.36
ALPHA			6.00	6.00	6.00
GAMMA	5.63	3.81	0.30	0.39	0.81

SARGASSO SEA

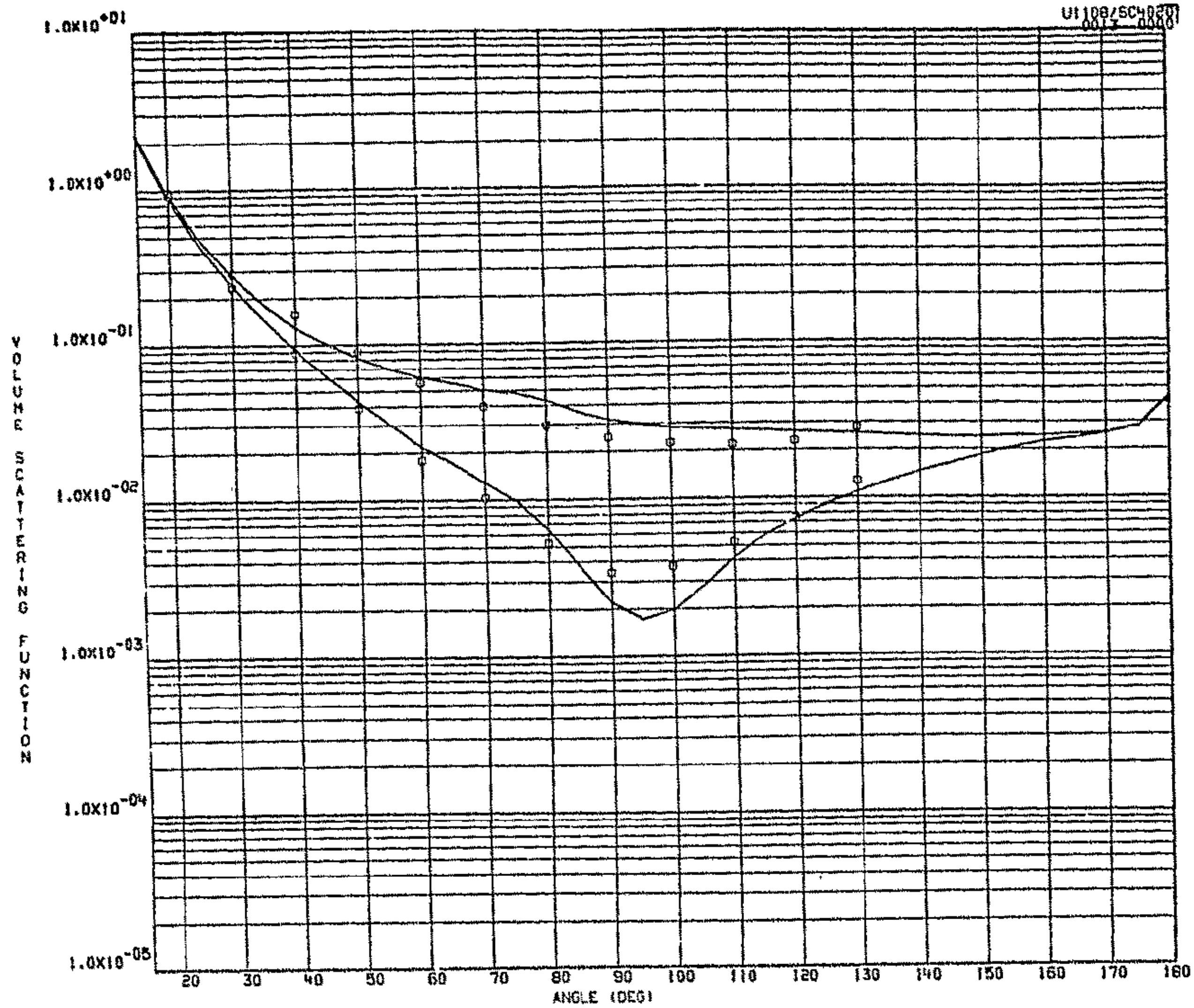


WAVELENGTH 436 NM

CHI SQUARE = 7.58×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	DIATOMS
POPULATION	$1.547 \times 10^{+03}$	$1.645 \times 10^{+04}$	7.662×10^{-03}	6.339×10^{-03}
MODE DIAM			0.25	20.00
ALPHA			6.00	6.00
GAMMA	3.23	7.00	0.17	0.80

STATION 9 SURFACE

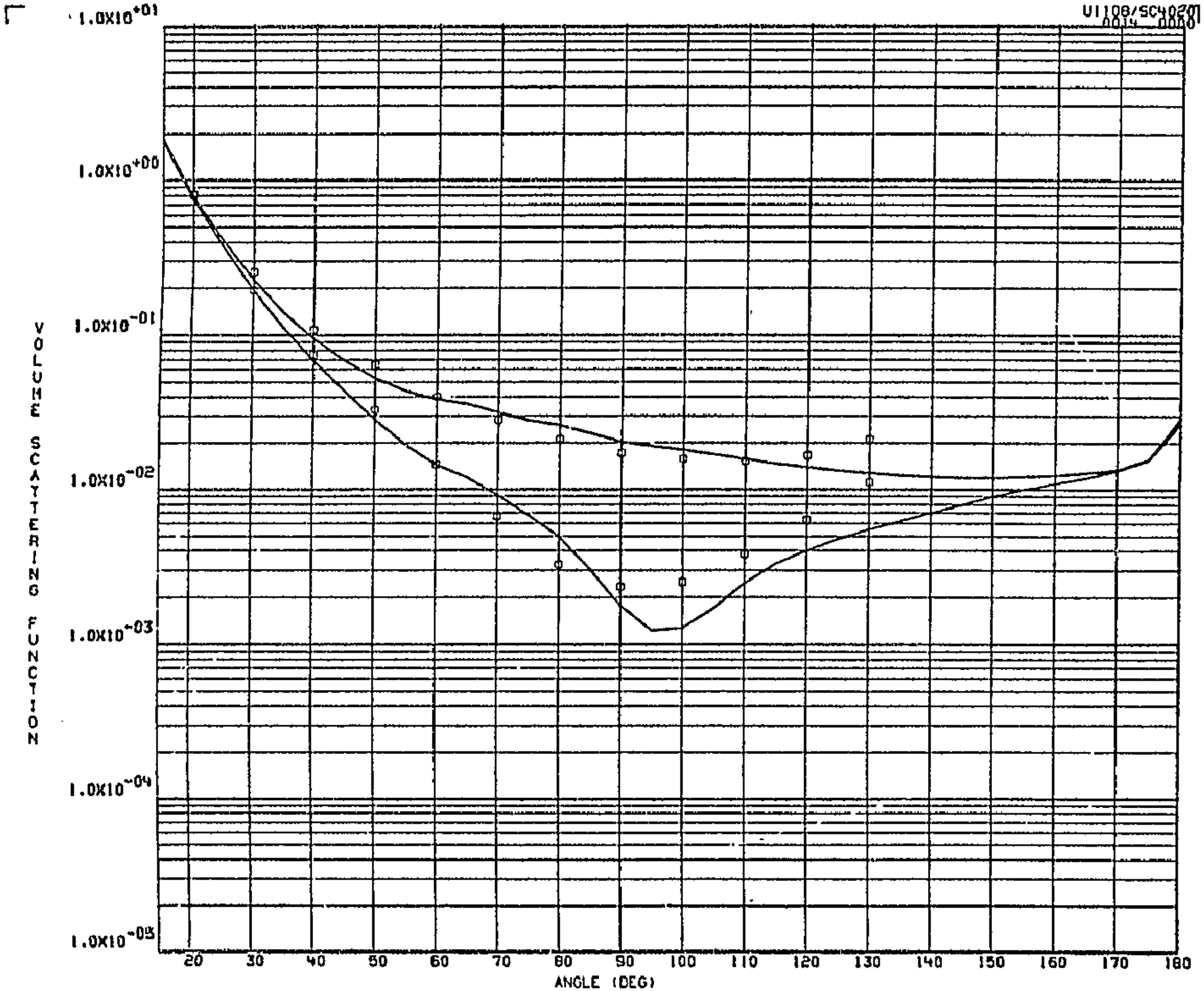


WAVELENGTH 436 NM

CHI SQUARE = $1.17 \times 10^{+00}$

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$6.395 \times 10^{+05}$	$1.103 \times 10^{+05}$	$2.345 \times 10^{+03}$	9.736×10^{-01}	1.594×10^{-01}
MODE DIAM			0.19	1.50	12.42
ALPHA			6.00	6.00	6.00
GAMMA	6.00	4.20	0.29	0.22	0.50

STATION 11 SURFACE

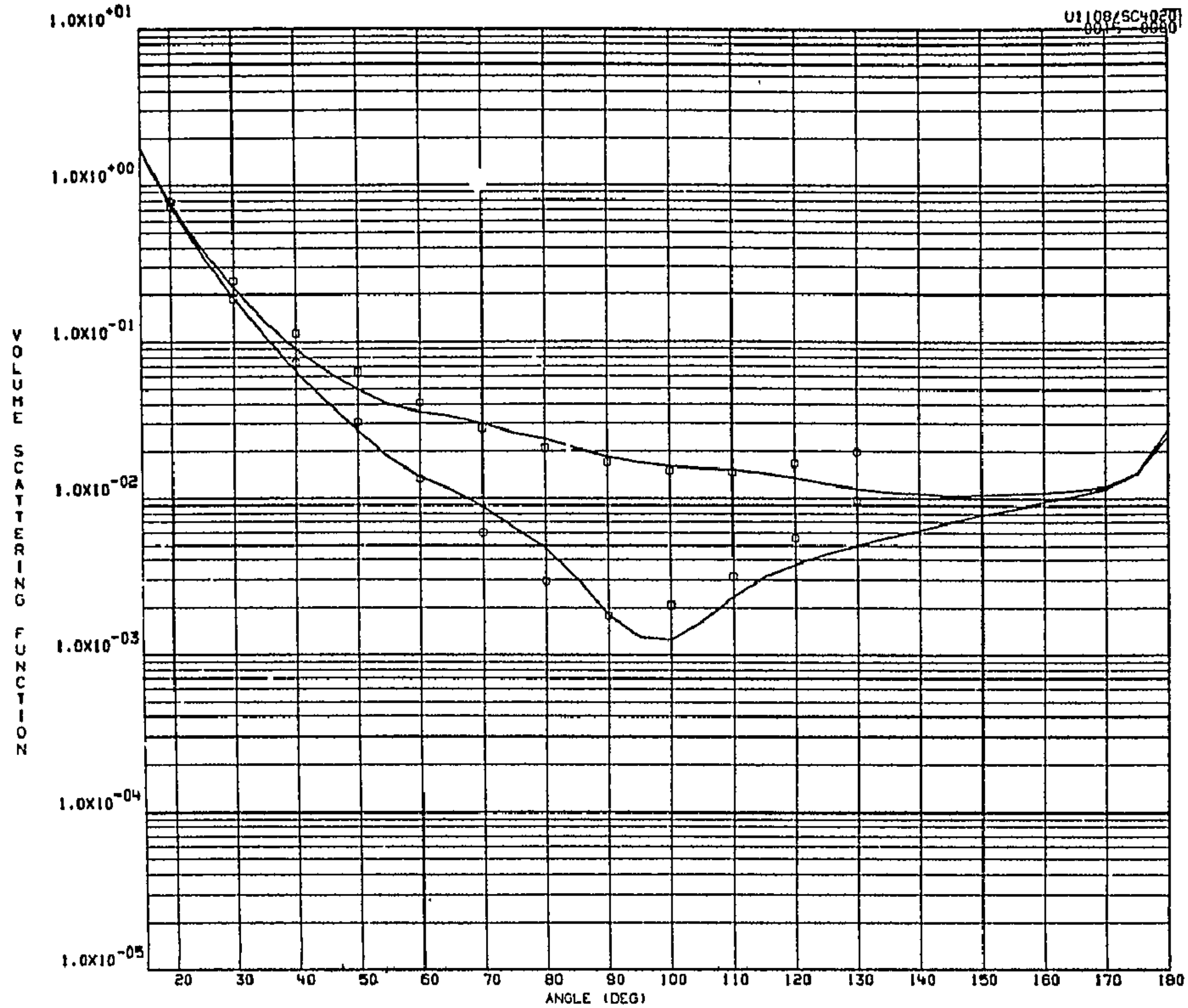


WAVELENGTH 546 NM

CHI SQUARE = $1.17 \times 10^{+00}$

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$6.395 \times 10^{+05}$	$1.103 \times 10^{+05}$	$2.345 \times 10^{+03}$	9.736×10^{-01}	1.594×10^{-01}
MODE DIAM			0.19	1.50	12.42
ALPHA			6.00	6.00	6.00
GAMMA	6.00	4.20	0.29	0.22	0.50

STATION 11 SURFACE

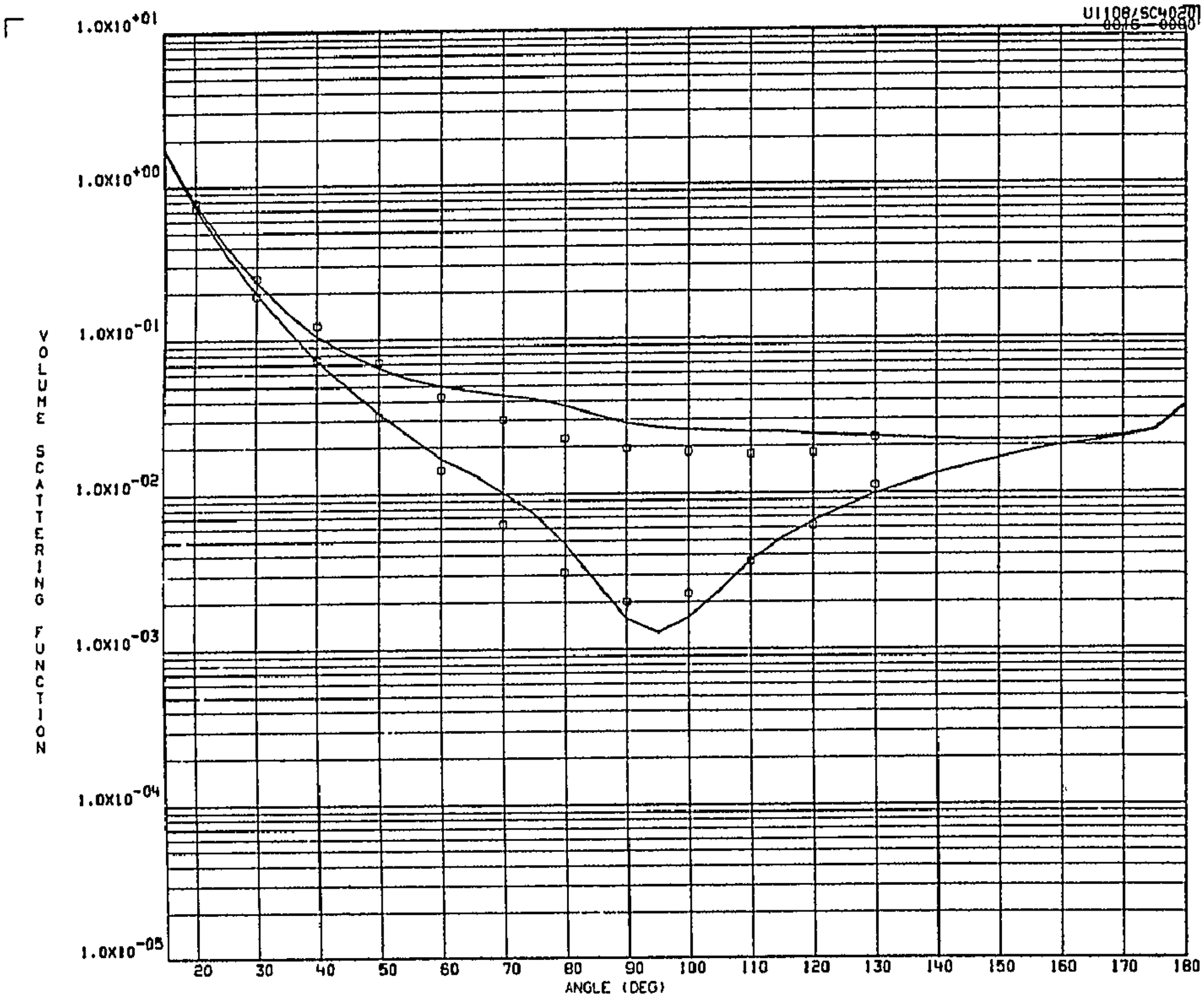


WAVELENGTH 578 NM

CHI SQUARE = 1.17X10^{+00}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	6.395X10^{+05}	1.103X10^{+05}	2.345X10^{+03}	9.736X10^{-01}	1.594X10^{-01}
MODE DIAM			0.19	1.50	12.42
ALPHA			6.00	6.00	6.00
GAMMA	6.00	4.20	0.29	0.22	0.50

STATION 11 SURFACE

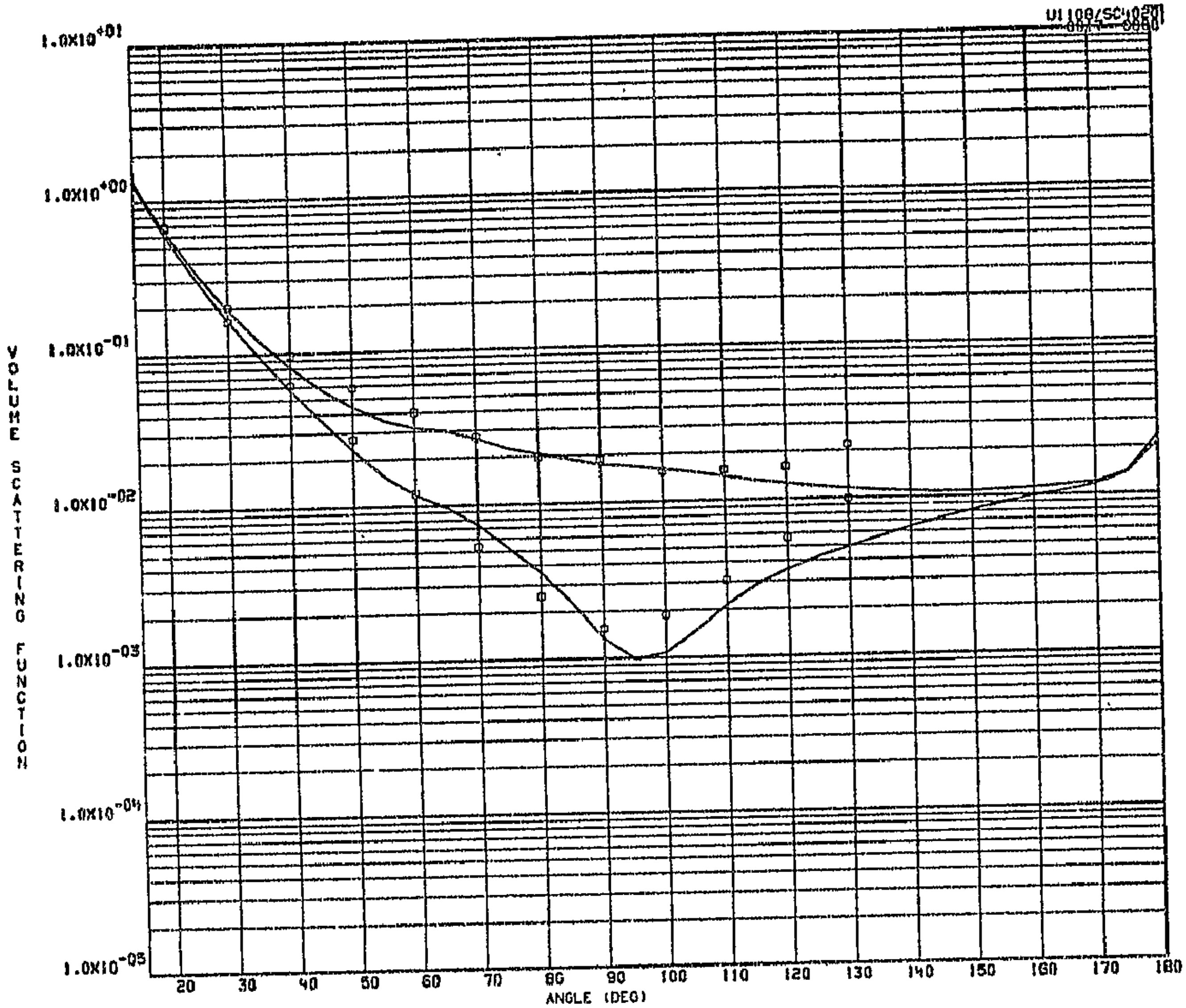


WAVELENGTH 436 NM

CHI SQUARE = $1.25 \times 10^{+00}$

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$6.597 \times 10^{+05}$	$6.159 \times 10^{+04}$	$3.000 \times 10^{+03}$	4.502×10^{-01}	2.329×10^{-01}
MODE DIAM			0.20	1.60	9.52
ALPHA			6.00	6.00	6.00
GAMMA	6.00	4.20	0.35	0.22	0.50

STATION 41 DEPTH 3 METERS

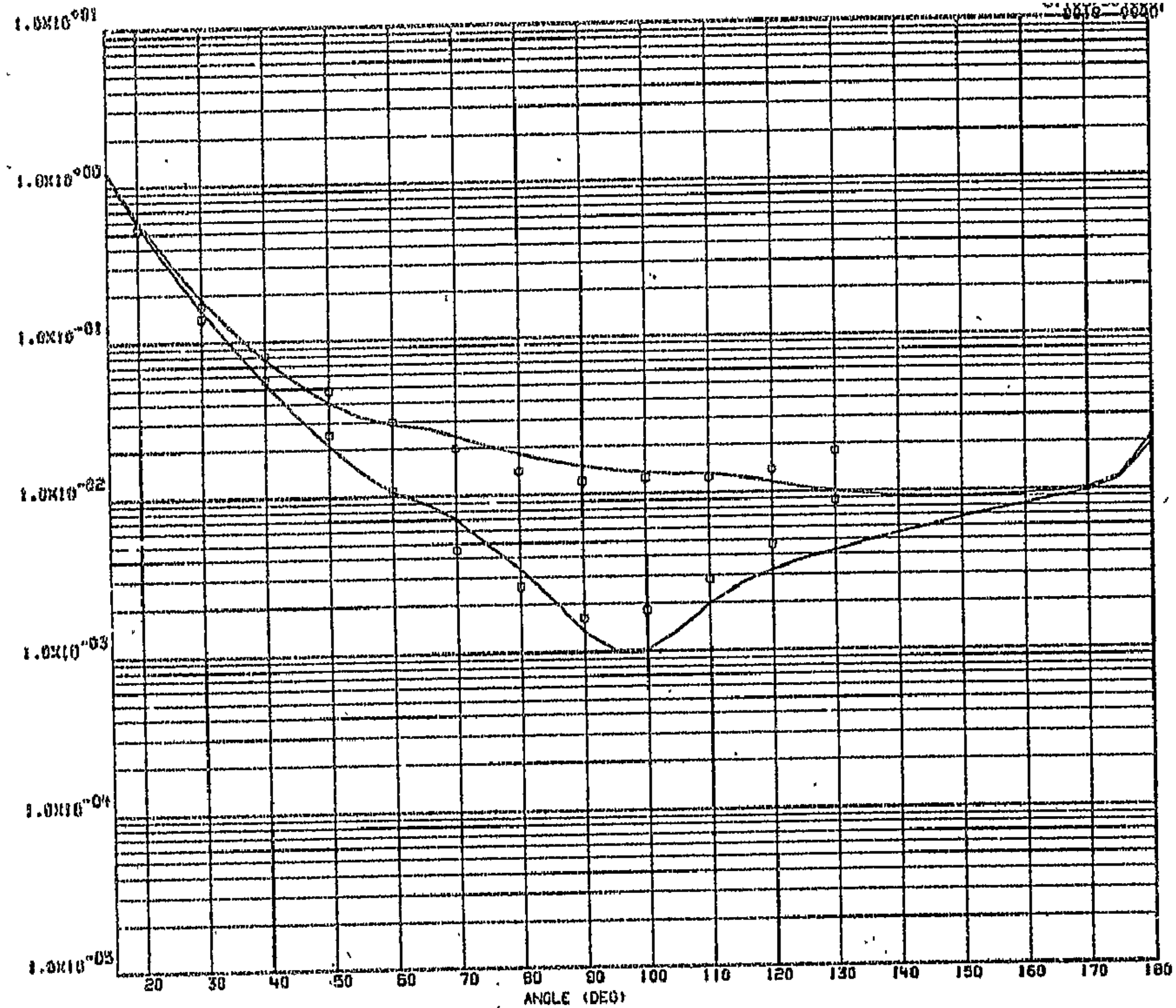


WAVELENGTH 546 NM

CHI SQUARE = 1.25X10^{+00}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	6.597X10^{+05}	6.159X10^{+04}	3.000X10^{+03}	4.502X10^{-01}	2.329X10^{-01}
MODE DIAM			0.20	1.50	9.52
ALPHA			6.00	6.00	6.00
GAMMA	6.00	4.20	0.35	0.22	0.50

STATION 11 DEPTH 3 METERS

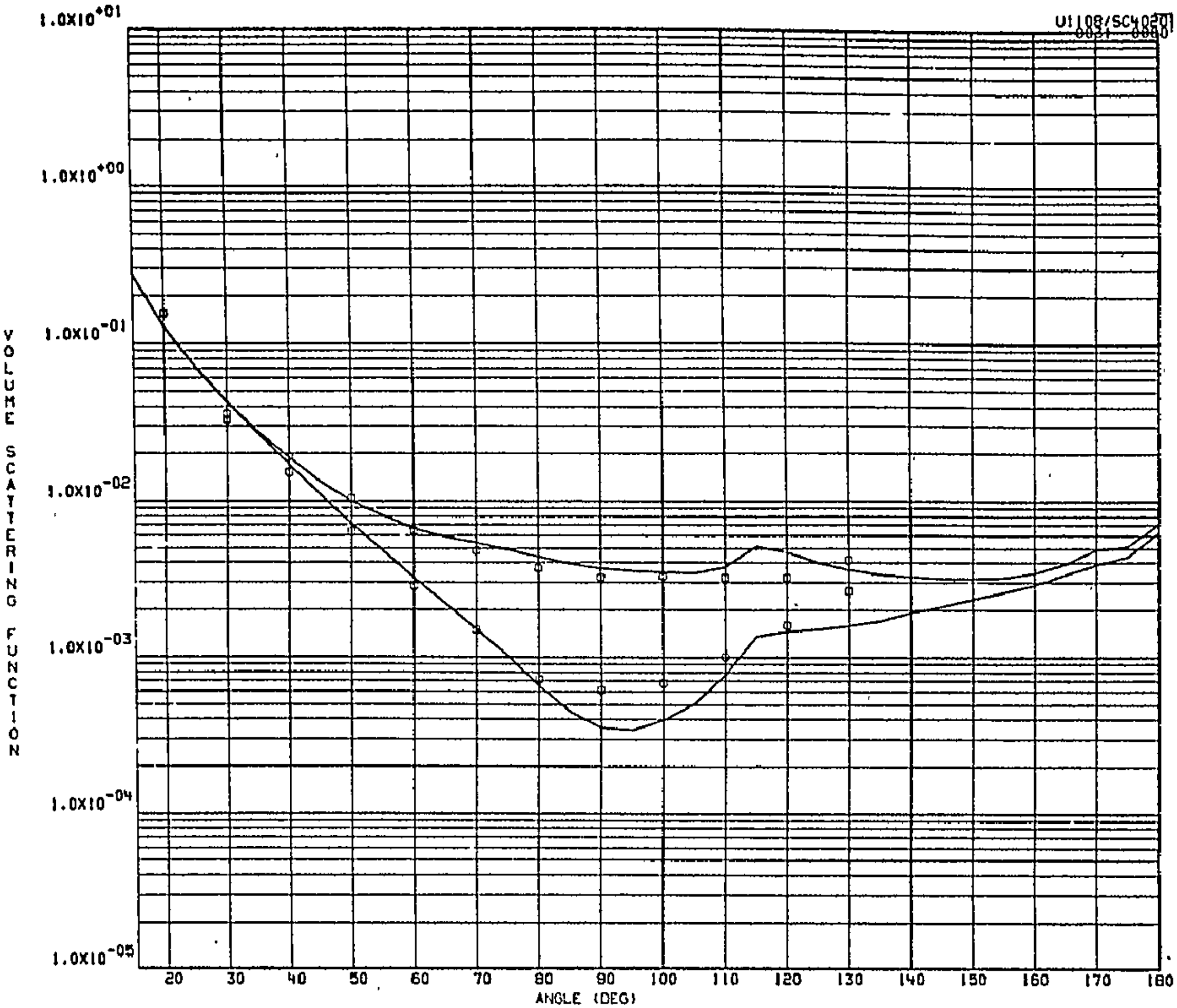


WAVELENGTH 570 NM

CHI SQUARE = $1.25 \times 10^{+00}$

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$6.597 \times 10^{+05}$	$6.159 \times 10^{+04}$	$3.000 \times 10^{+03}$	4.502×10^{-01}	2.329×10^{-01}
MODE DIAM			0.20	1.50	9.52
ALPHA			6.00	6.00	6.00
GAMMA	6.00	4.20	0.35	0.22	0.50

STATION 11 DEPTH 3 METERS

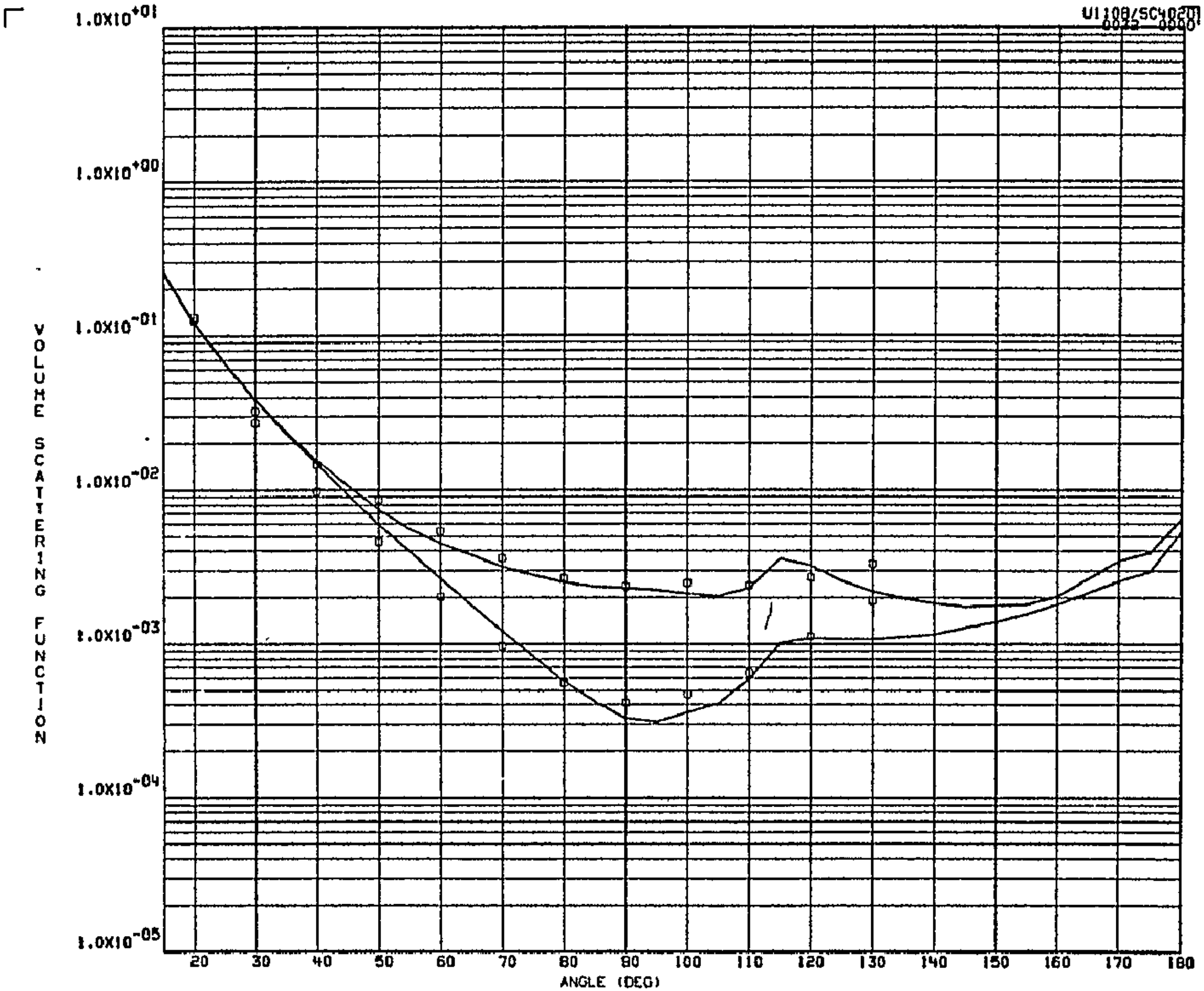


WAVELENGTH 436 NM

CHI SQUARE = 7.78×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$9.413\times10^{+04}$	$6.953\times10^{+02}$	$6.466\times10^{+01}$	5.045×10^{-04}	3.230×10^{-03}
MODE DIAM			0.29	1.50	15.00
ALPHA			6.00	6.00	6.00
GAMMA	6.00	2.85	0.29	0.40	0.70

STATION 12 SURFACE



WAVELENGTH 546 NM

CHI SQUARE = 7.78×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$9.413 \times 10^{+04}$	$6.953 \times 10^{+02}$	$6.466 \times 10^{+01}$	5.045×10^{-04}	3.230×10^{-03}
MODE DIAM			0.29	1.50	15.00
ALPHA			6.00	6.00	6.00
GAMMA	6.00	2.85	0.29	0.40	0.70

STATION 12 SURFACE

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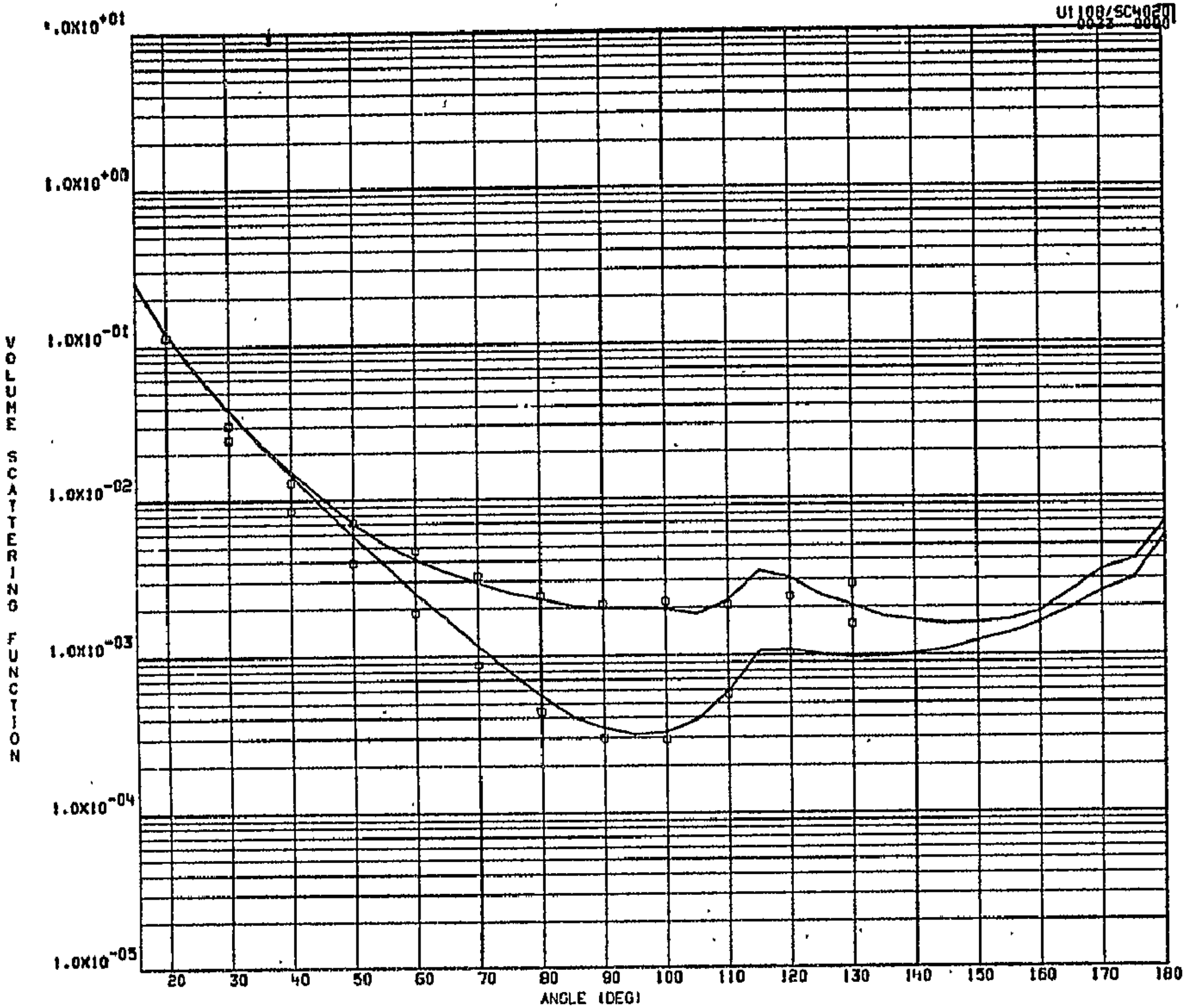
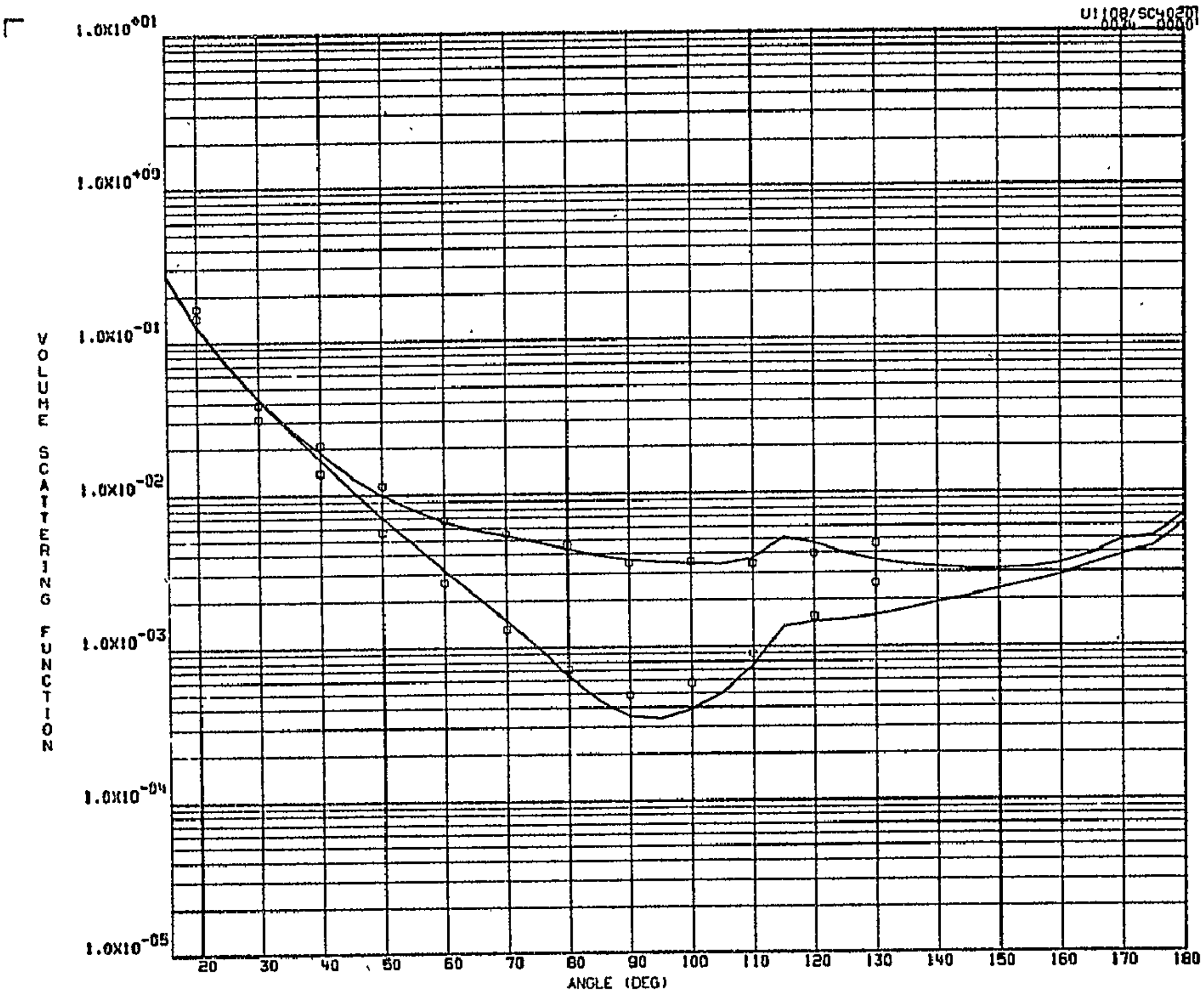


WAVELENGTH 578 NM

CHI SQUARE = 7.78×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$9.413 \times 10^{+04}$	$6.953 \times 10^{+02}$	$6.466 \times 10^{+01}$	5.045×10^{-04}	3.230×10^{-03}
MODE DIAM			0.29	1.50	15.00
ALPHA			6.00	6.00	6.00
GAMMA	6.00	2.85	0.29	0.40	0.70

STATION 12 SURFACE

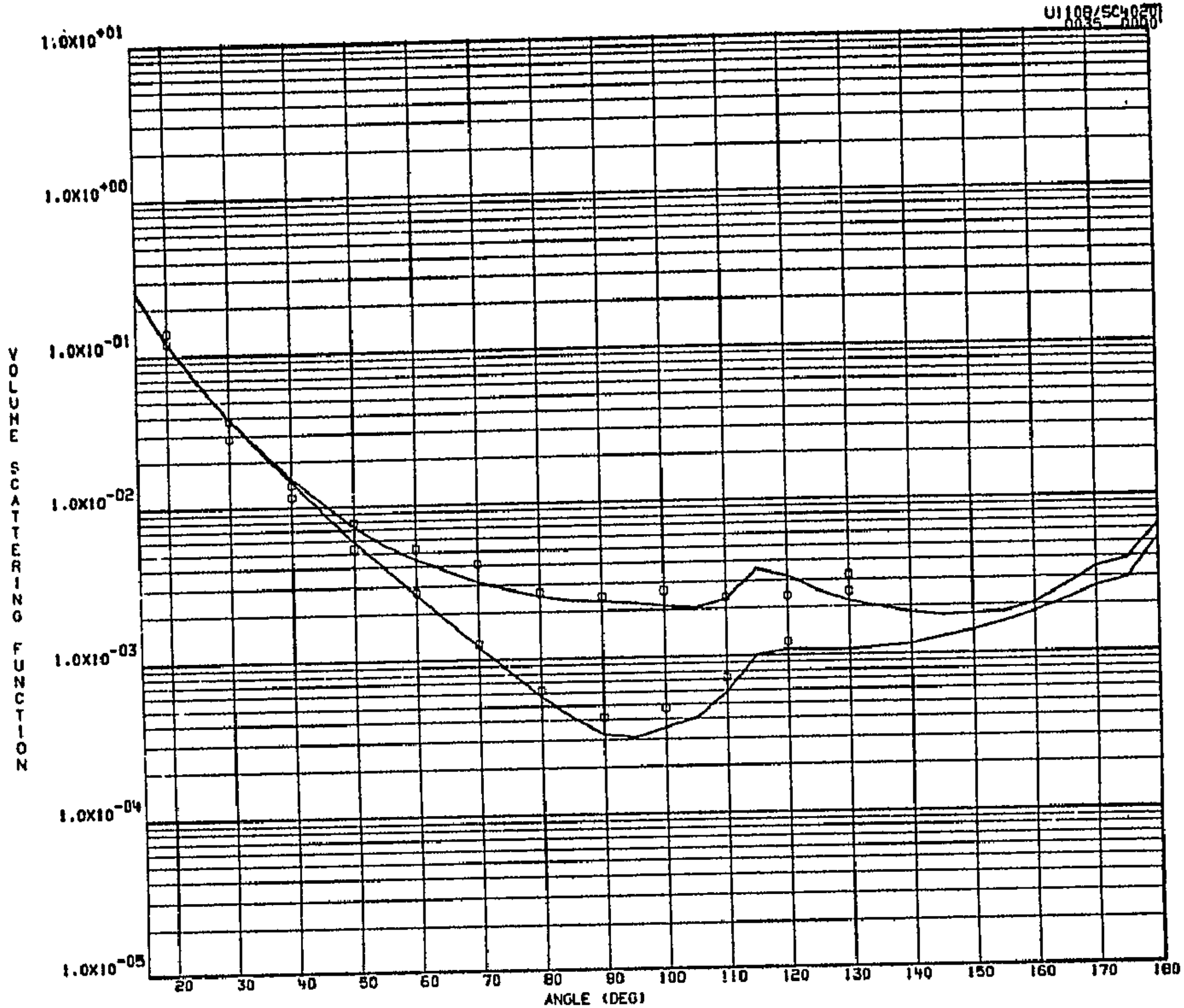


WAVELENGTH 436 NM

CHI SQUARE = 6.79×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$9.413 \times 10^{+04}$	$6.953 \times 10^{+02}$	$6.466 \times 10^{+01}$	5.045×10^{-04}	3.230×10^{-03}
MODE DIAM			0.29	1.50	15.00
ALPHA			6.00	6.00	6.00
GAMMA	6.00	2.85	0.29	0.40	0.70

STATION 12 DEPTH 1 METER

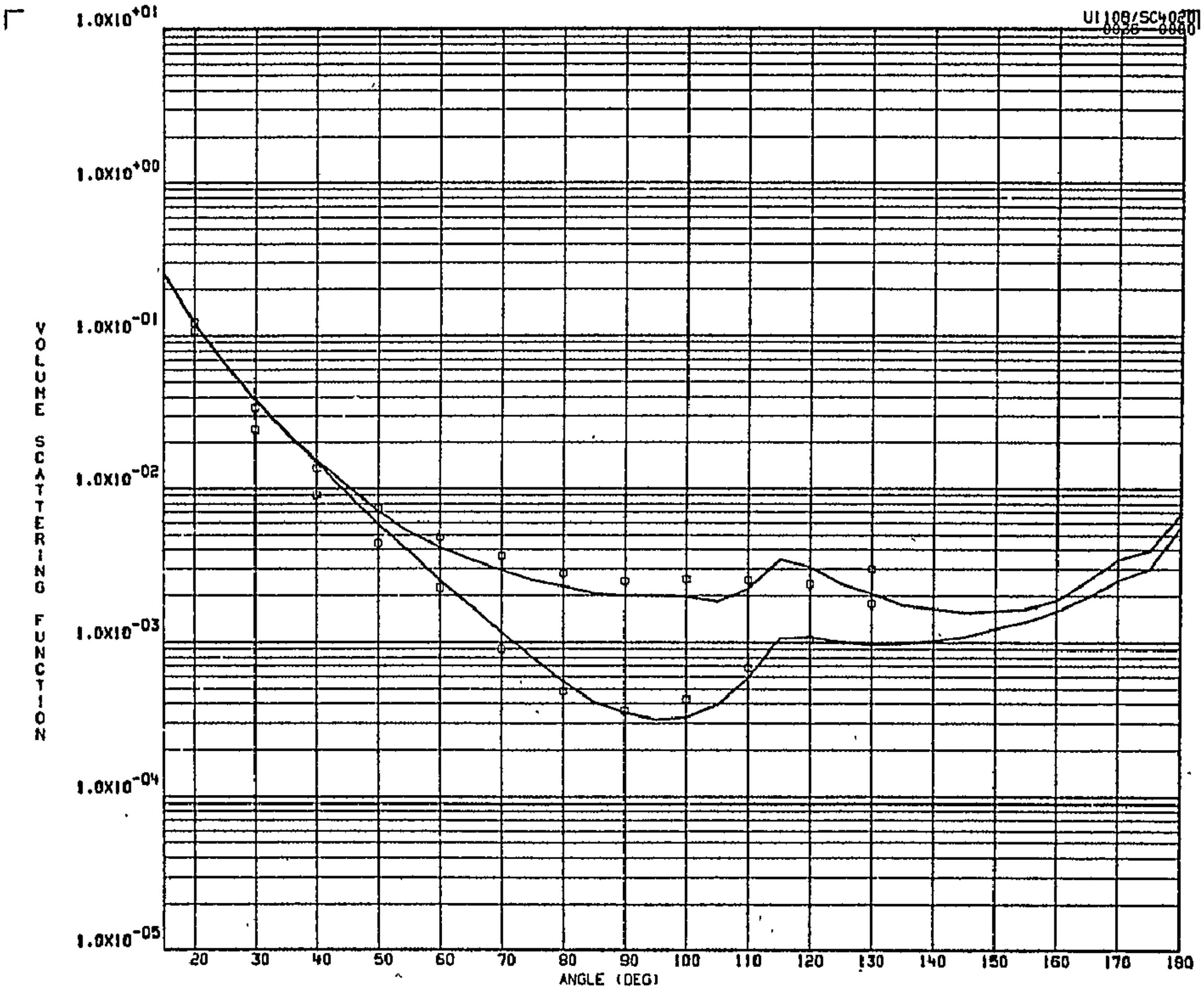


WAVELENGTH 546 NM

CHI SQUARE = 6.79×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$9.413 \times 10^{+04}$	$6.953 \times 10^{+02}$	$6.466 \times 10^{+01}$	5.045×10^{-04}	3.230×10^{-03}
MODE DIAM			0.29	1.50	15.00
ALPHA			6.00	6.00	6.00
GAMMA	6.00	2.85	0.29	0.40	0.70

STATION 12 DEPTH 1 METER

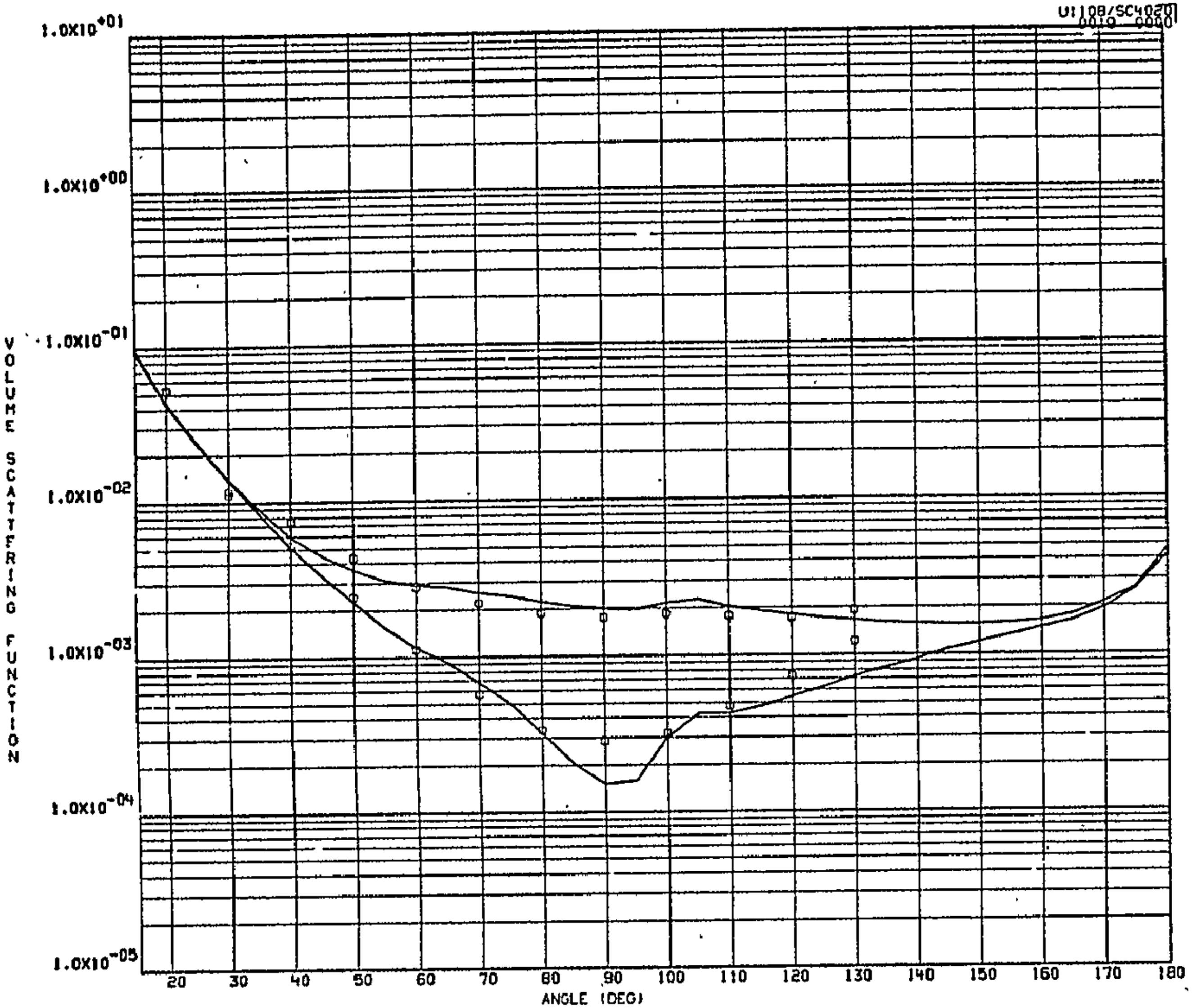


WAVELENGTH 578 NM

CHI SQUARE = 6.79×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$9.413\times10^{+04}$	$6.953\times10^{+02}$	$6.466\times10^{+01}$	5.045×10^{-04}	3.230×10^{-03}
MODE DIAM			0.29	1.50	15.00
ALPHA			6.00	6.00	6.00
GAMMA	6.00	2.85	0.29	0.40	0.70

STATION 12 DEPTH 1 METER

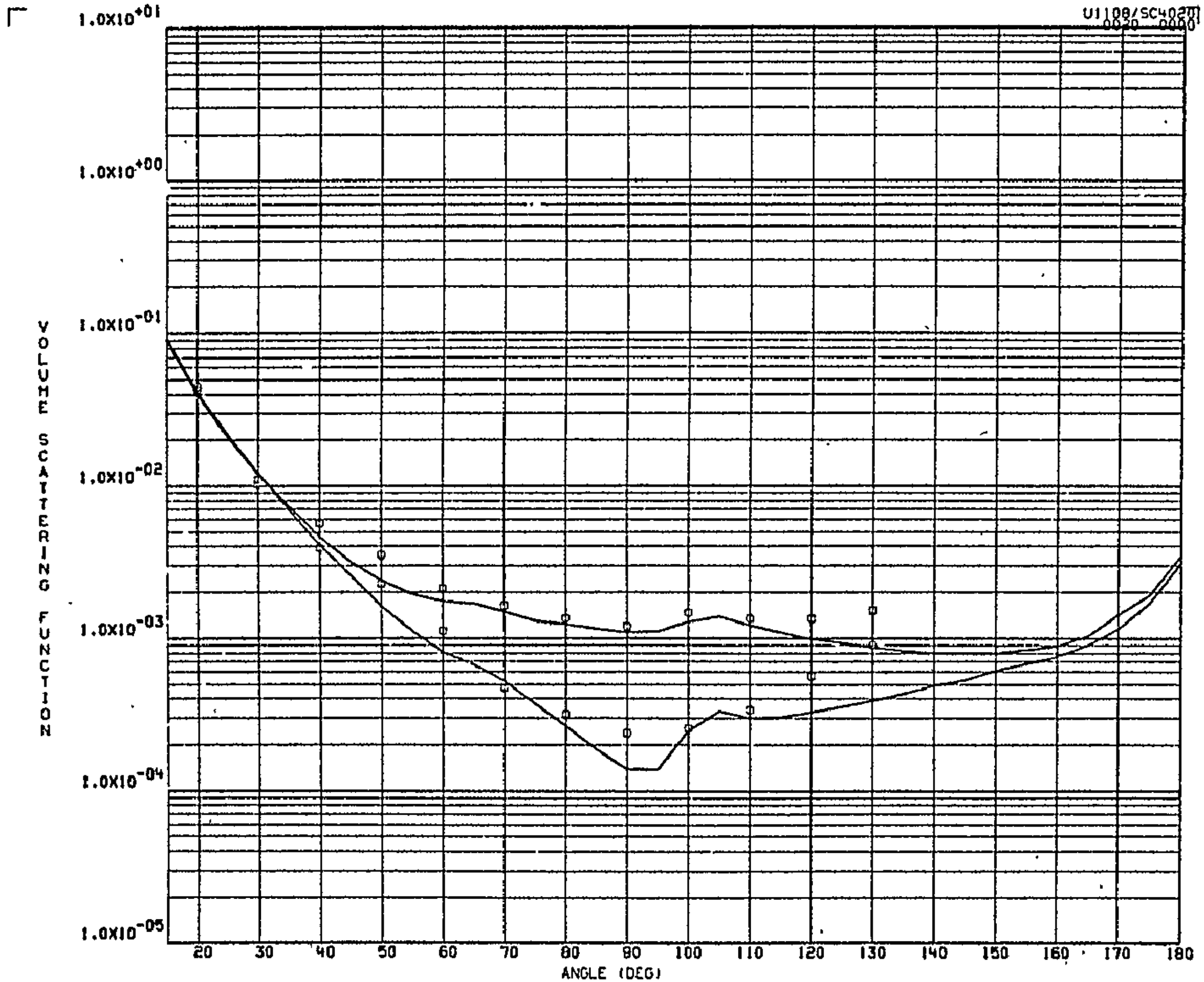


WAVELENGTH 436 NM

CHI SQUARE = 5.71×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$5.077 \times 10^{+02}$	$3.063 \times 10^{+04}$	1.314×10^{-01}	8.399×10^{-01}	8.832×10^{-03}
MODE DIAM			0.47	1.51	15.00
ALPHA			6.00	6.00	6.00
GAMMA	2.99	7.00	0.37	0.80	0.80

STATION 13 SURFACE

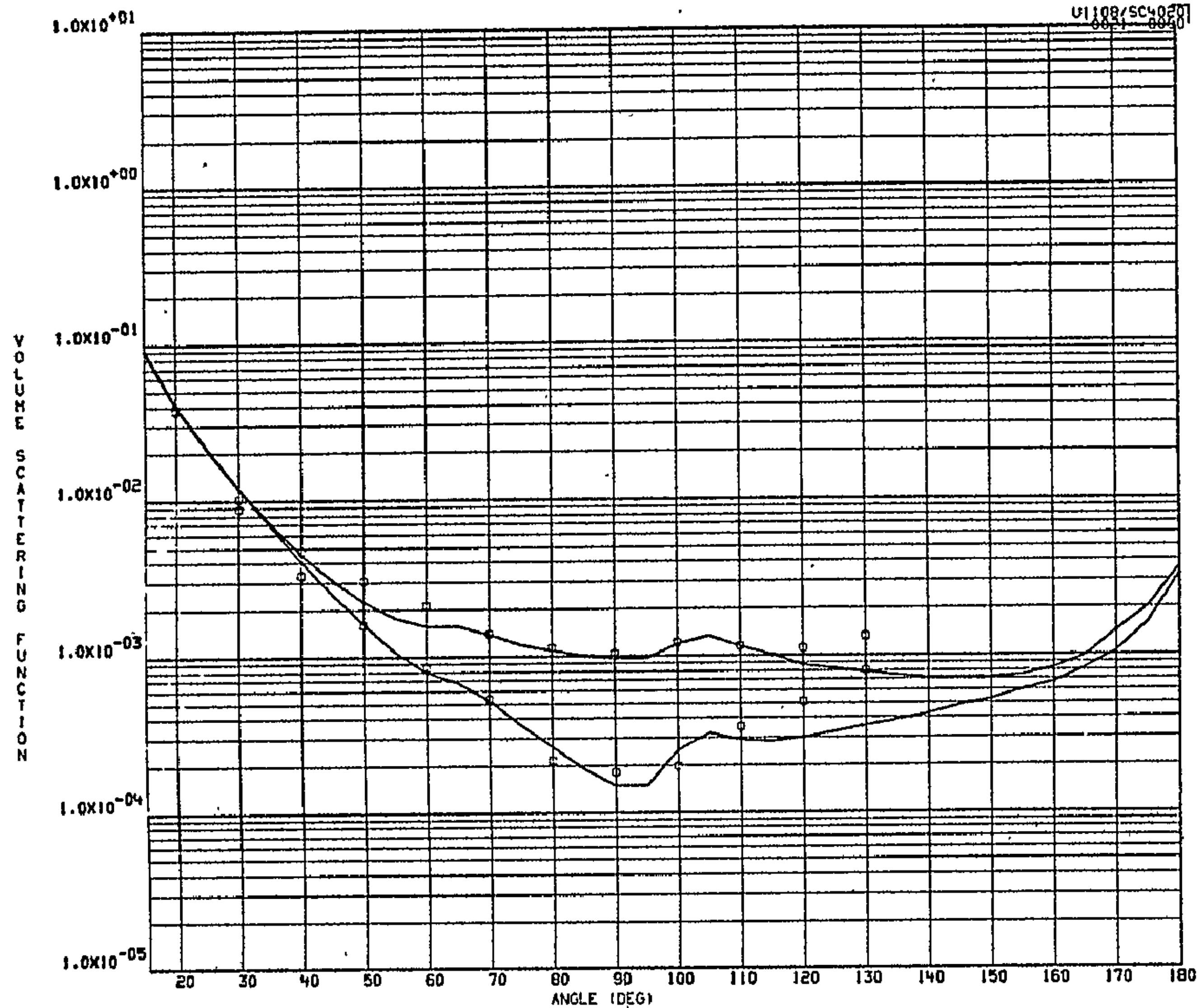


WAVELENGTH 546 NM

CHI SQUARE = 5.71X10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	5.077X10^{+02}	3.063X10^{+04}	1.314X10^{-01}	8.399X10^{-01}	8.832X10^{-03}
MODE DIAM			0.47	1.51	15.00
ALPHA			6.00	6.00	6.00
GAMMA	2.99	7.00	0.37	0.80	0.80

STATION 13 SURFACE

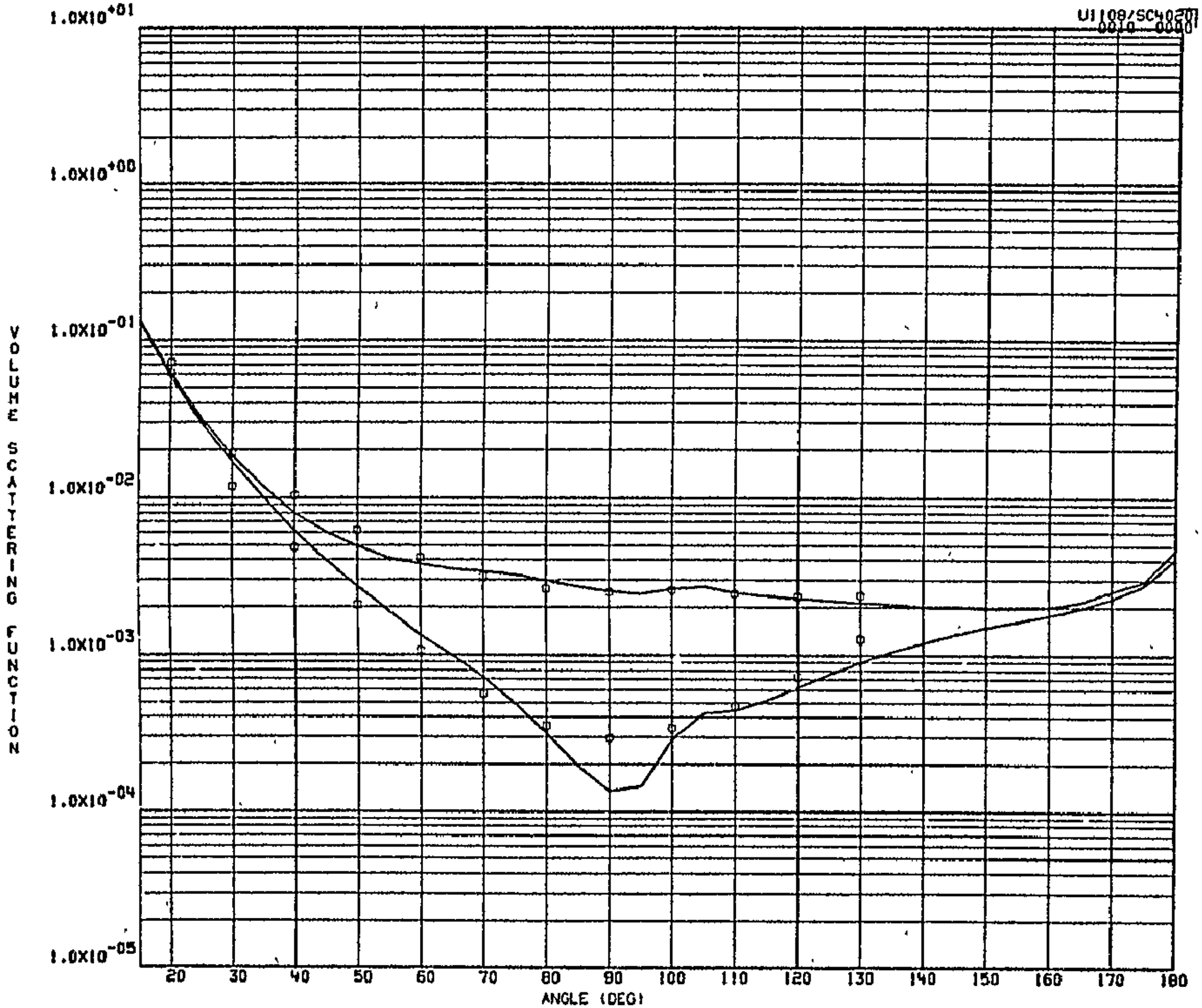


WAVELENGTH 578 NM

CHI SQUARE = 5.71×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$5.077 \times 10^{+02}$	$3.063 \times 10^{+04}$	1.314×10^{-01}	8.399×10^{-01}	8.832×10^{-03}
MODE DIAM			0.47	1.51	15.00
ALPHA			6.00	6.00	6.00
GAMMA	2.99	7.00	0.37	0.80	0.80

STATION 13 SURFACE

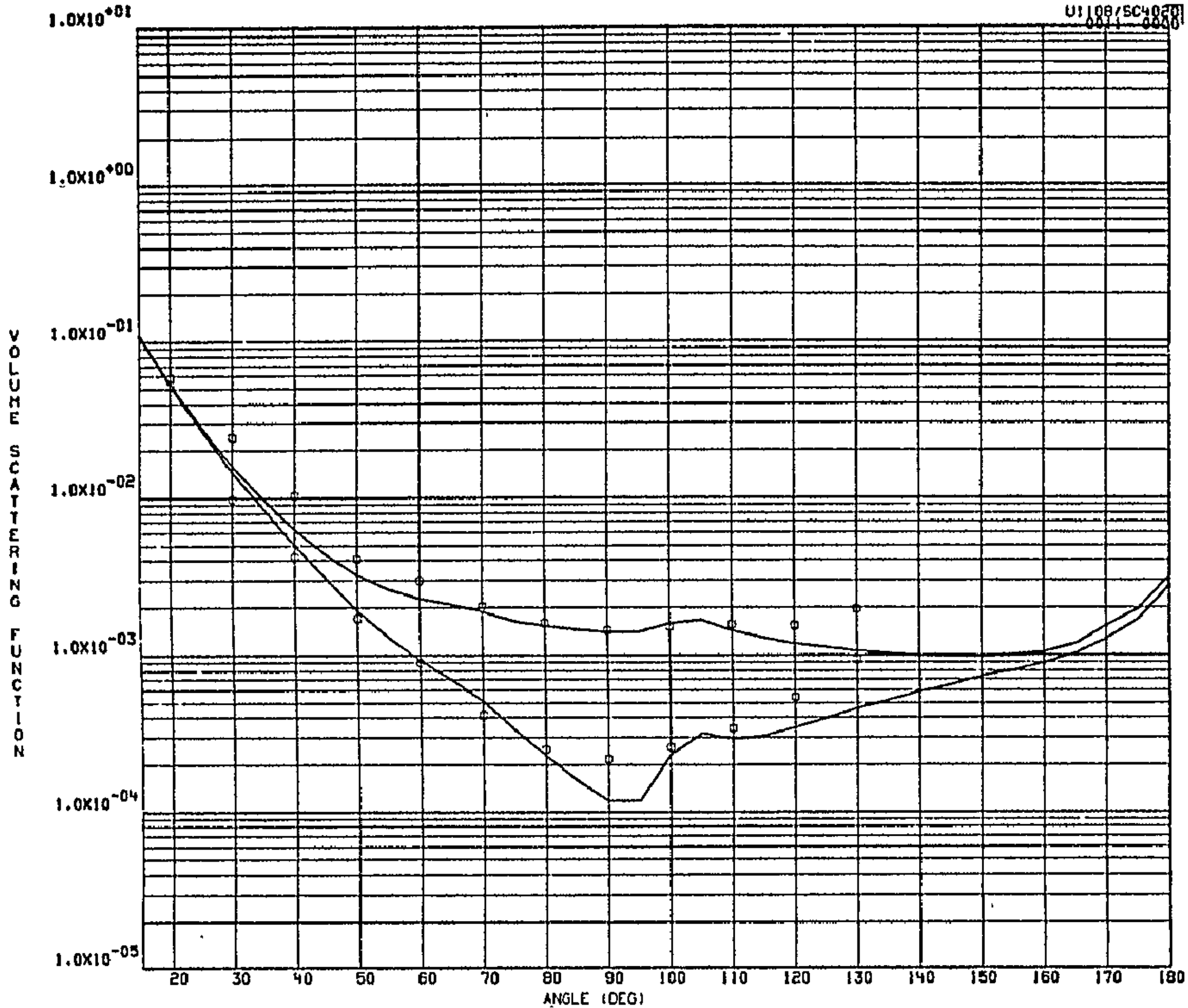


WAVELENGTH 436 NM

CHI SQUARE = 7.21X10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	2.053X10^{+02}	4.032X10^{+04}	1.701X10^{+02}	1.221X10^{-01}	1.543X10^{-02}
MODE DIAM			0.20	1.50	9.25
ALPHA			6.00	6.00	6.00
GAMMA	2.85	6.00	0.38	0.40	0.70

STATION 43 SURFACE

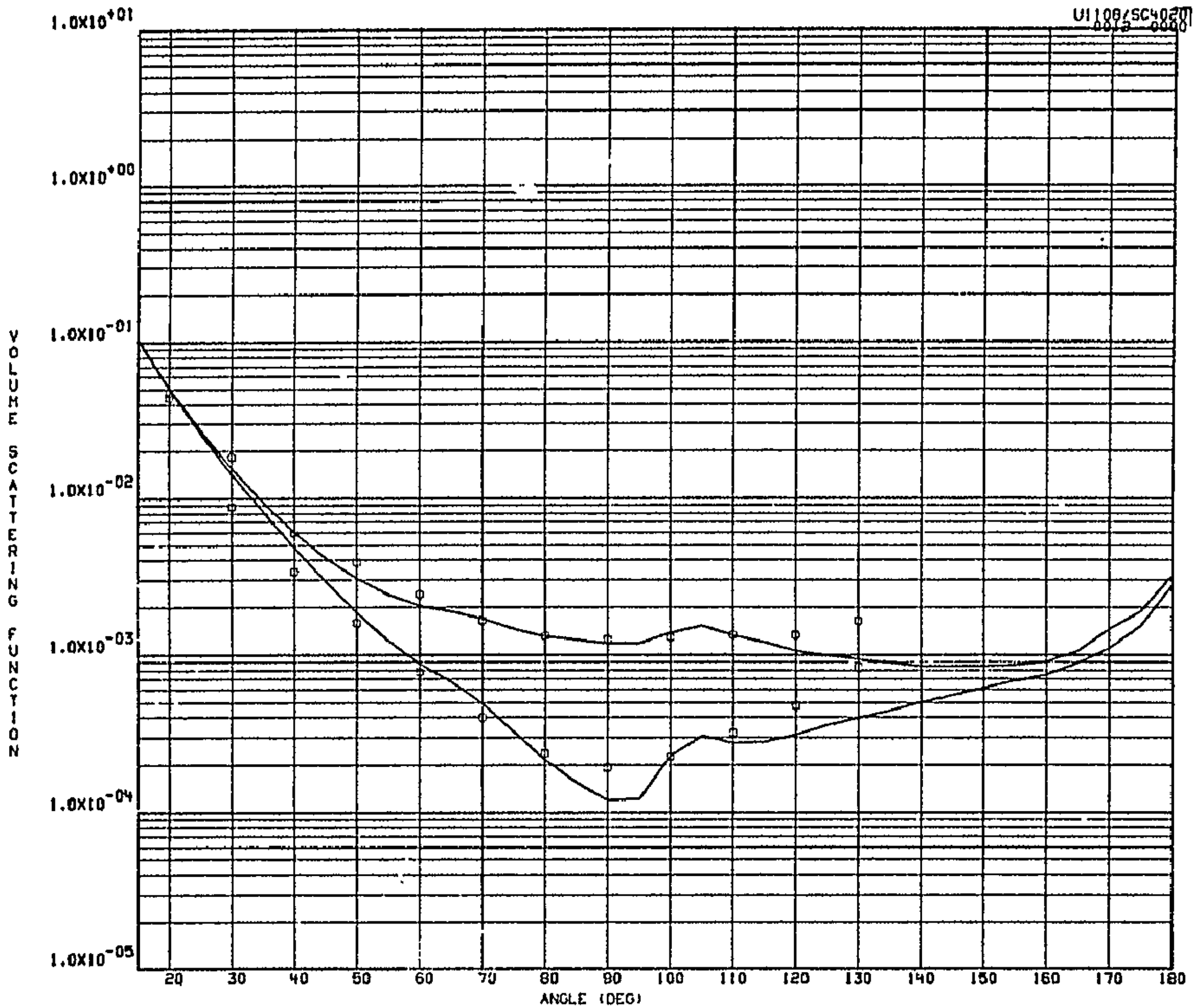


WAVELENGTH 546 NM

CHI SQUARE = 7.21X10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	2.053X10^{+02}	4.032X10^{+04}	1.701X10^{+02}	1.221X10^{-01}	1.543X10^{-02}
MODE DIAM			0.20	1.50	9.25
ALPHA			6.00	6.00	6.00
GAMMA	2.85	6.00	0.38	0.40	0.70

STATION 43 SURFACE

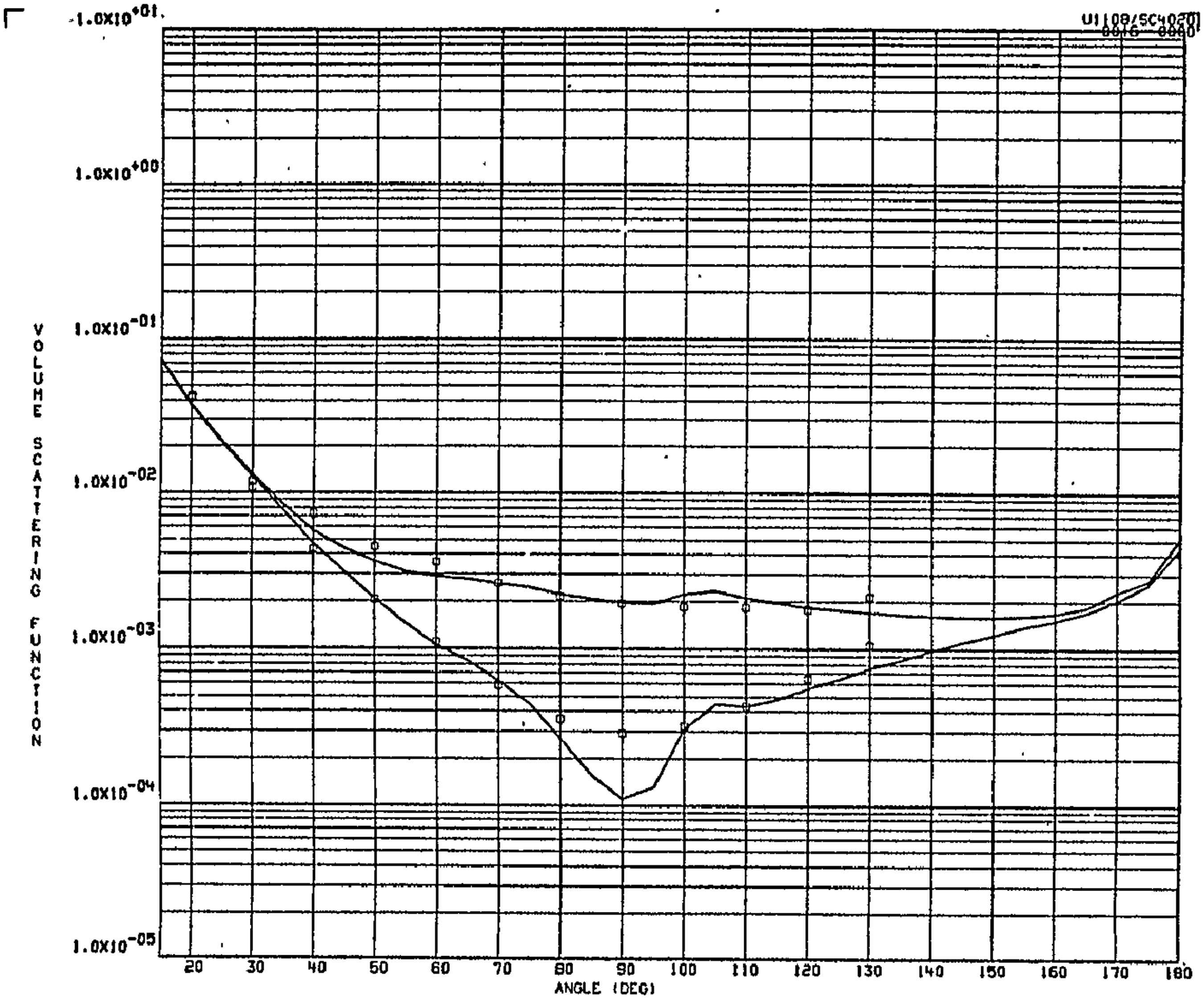


WAVELENGTH 578 NM

CHI SQUARE = 7.21X10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	2.053X10^{+02}	4.032X10^{+04}	1.701X10^{+02}	1.221X10^{-01}	1.543X10^{-02}
MODE DIAM			0.20	1.50	9.25
ALPHA			6.00	6.00	6.00
GAMMA	2.85	6.00	0.38	0.40	0.70

STATION 43 SURFACE



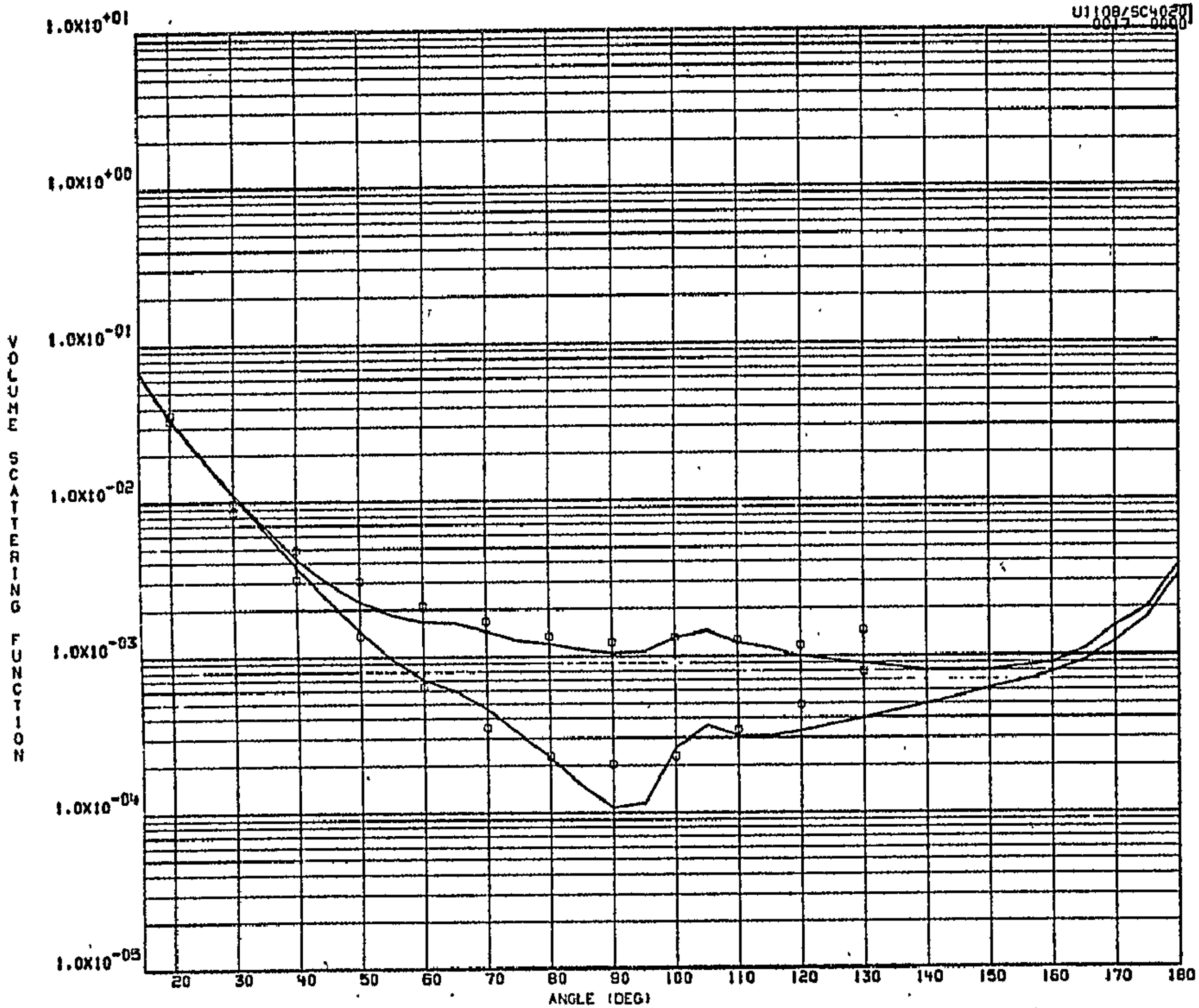
WAVELENGTH 436 NM

CHI SQUARE = 5.06X10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	DIATOMS
POPULATION	1.492X10^{+02}	3.179X10^{+04}	4.358X10^{+01}	9.257X10^{-03}
MODE DIAM			0.20	14.60
ALPHA			6.00	6.00
GAMMA	2.77	6.00	0.38	0.70

STATION 43 DEPTH 2 METERS

ORIGINAL PAGE IS OF POOR QUALITY

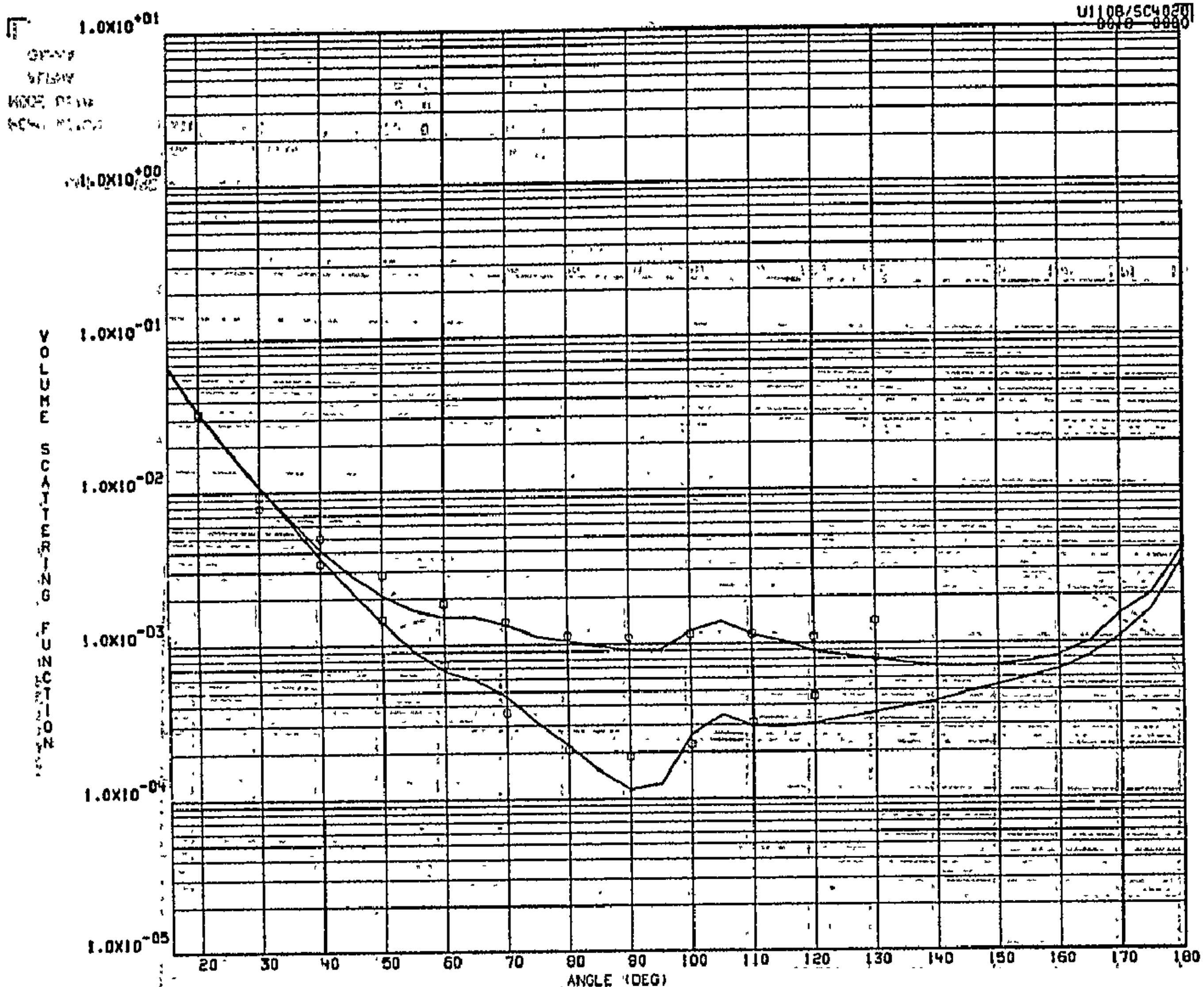


WAVELENGTH 546 NM

CHI SQUARE = 5.06X10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	DIATOMS
POPULATION	1.492X10^{+02}	3.179X10^{+04}	4.358X10^{+01}	9.257X10^{-03}
MODE DIAM			0.20	14.60
ALPHA			6.00	6.00
GAMMA	2.77	6.00	0.38	0.70

STATION 43 DEPTH 2 METERS

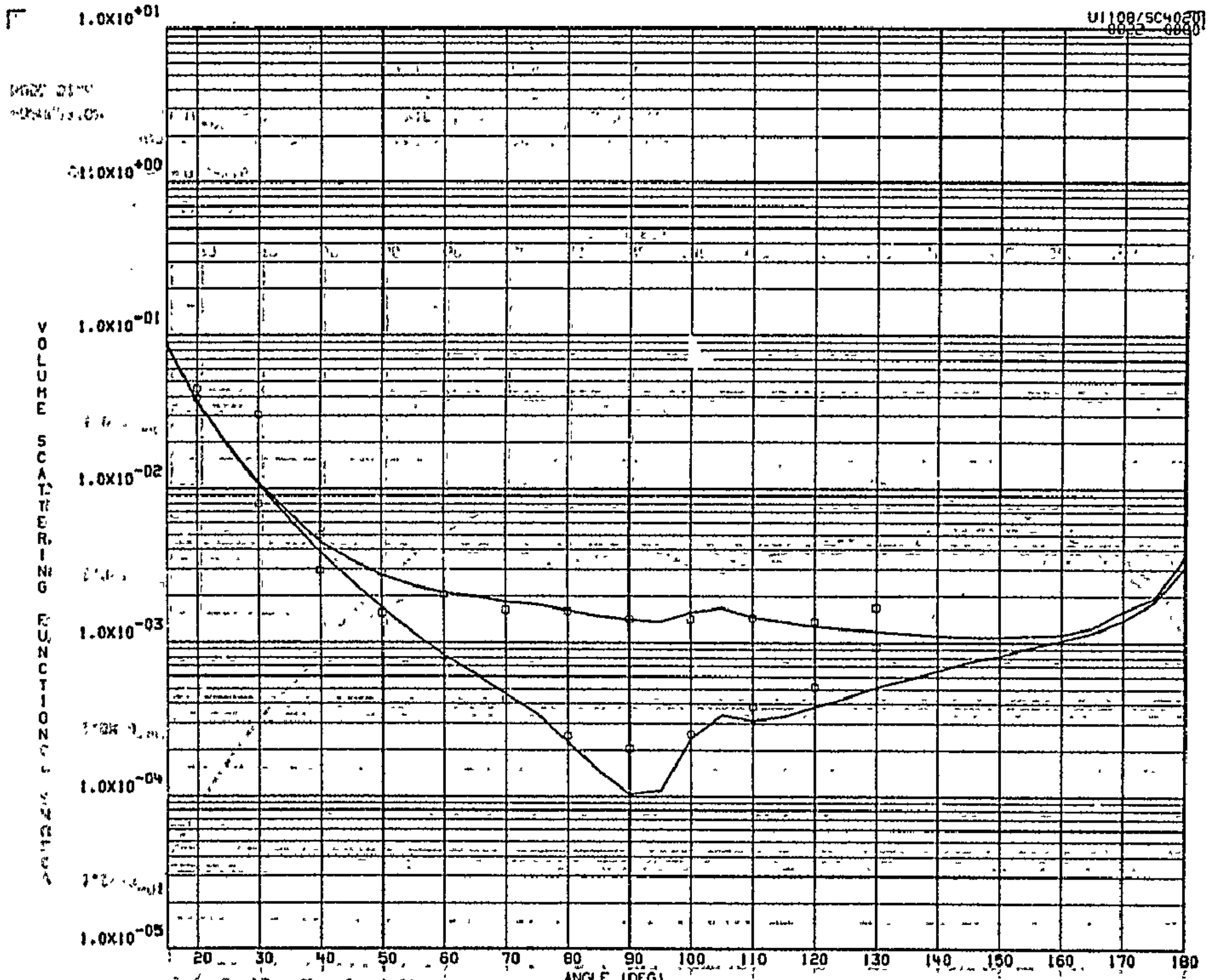


WAVELENGTH = 578 NM

CHI SQUARE = 5.06×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	DIATOMS
POPULATION	$1.492\times10^{+02}$	$3.179\times10^{+04}$	$4.359\times10^{+01}$	9.257×10^{-03}
MODE DIAM			0.20	14.60
ALPHA			6.00	6.00
GAMMA	2.77	6.00	0.38	0.70

STATION 43 DEPTH 2 METERS

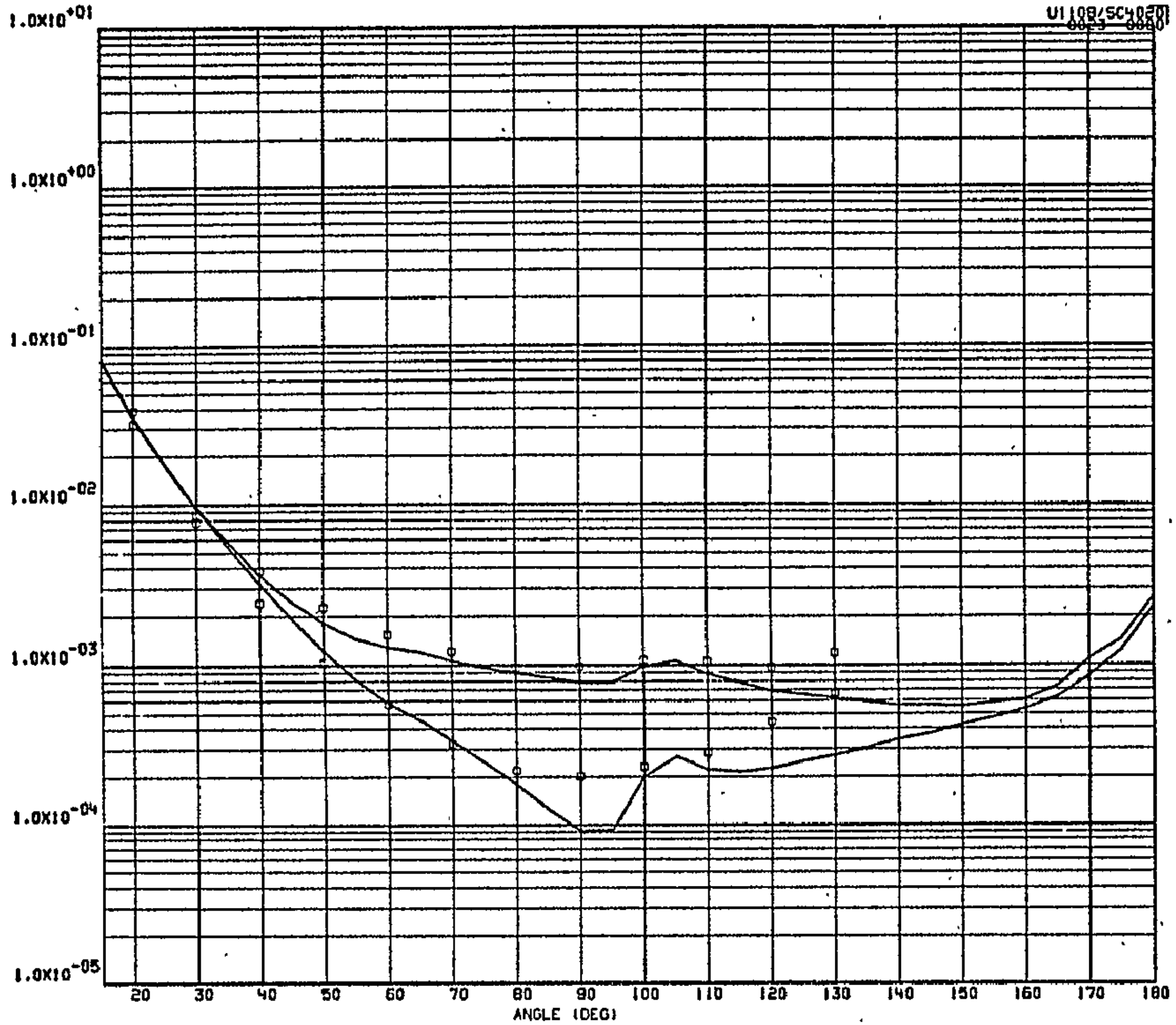


WAVELENGTH 436 NM

CHI SQUARE 8.32×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$1.069\times10^{+02}$	$2.126\times10^{+04}$	$2.398\times10^{+01}$	2.069×10^{-01}	3.554×10^{-03}
MODE DIAM			0.20	1.50	16.43
ALPHA			6.00	6.00	6.00
GAMMA	2.76	6.00	0.25	0.40	0.70

STATION 43 DEPTH 7 METERS

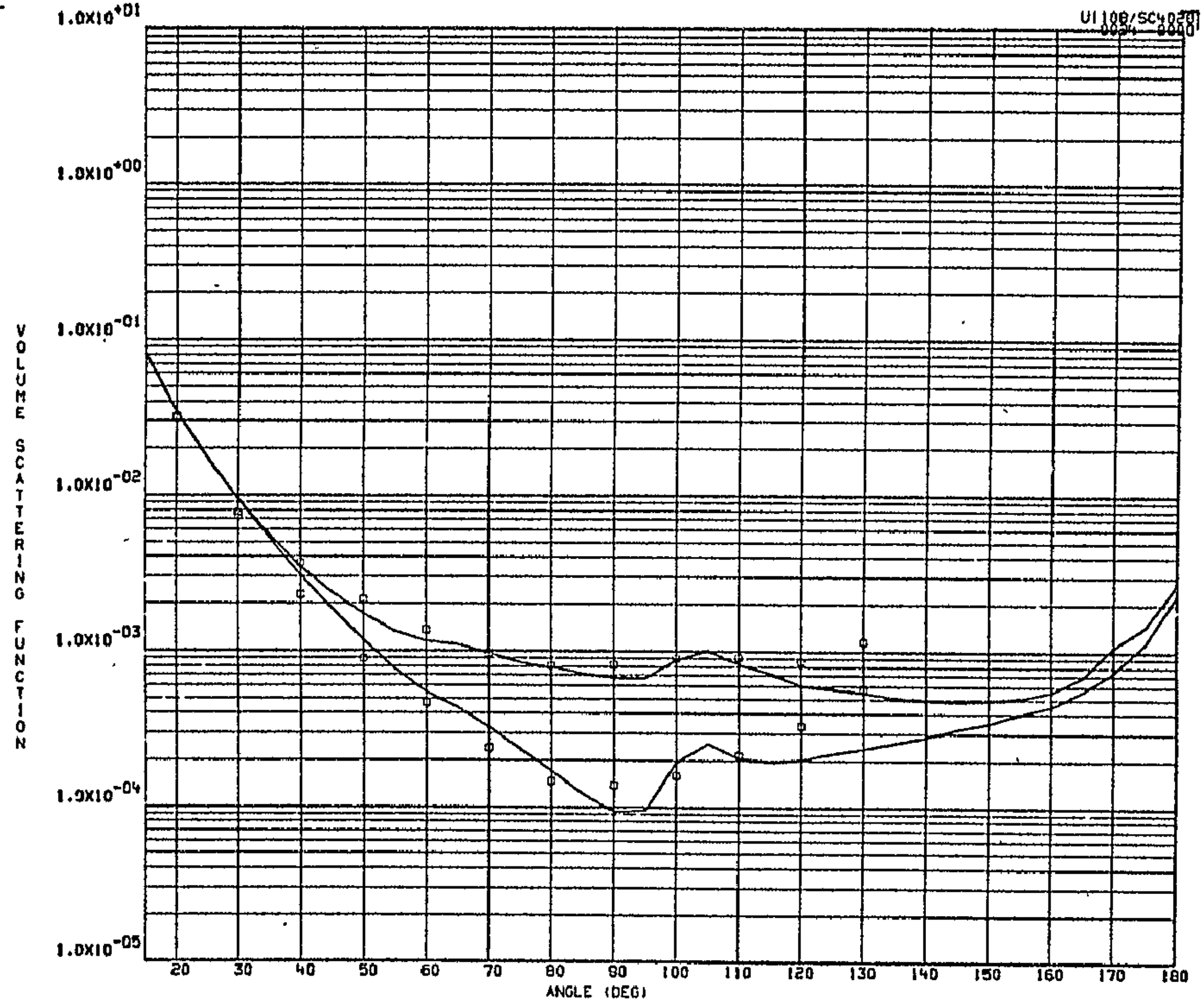


WAVELENGTH 546 NM

CHI SQUARE = 8.32×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$1.069\times10^{+02}$	$2.126\times10^{+04}$	$2.348\times10^{+01}$	2.069×10^{-01}	3.554×10^{-03}
MODE DIAM			0.20	1.50	16.43
ALPHA			6.00	6.00	6.00
GAMMA	2.76	6.00	0.25	0.40	0.70

STATION 43 DEPTH 7 METERS

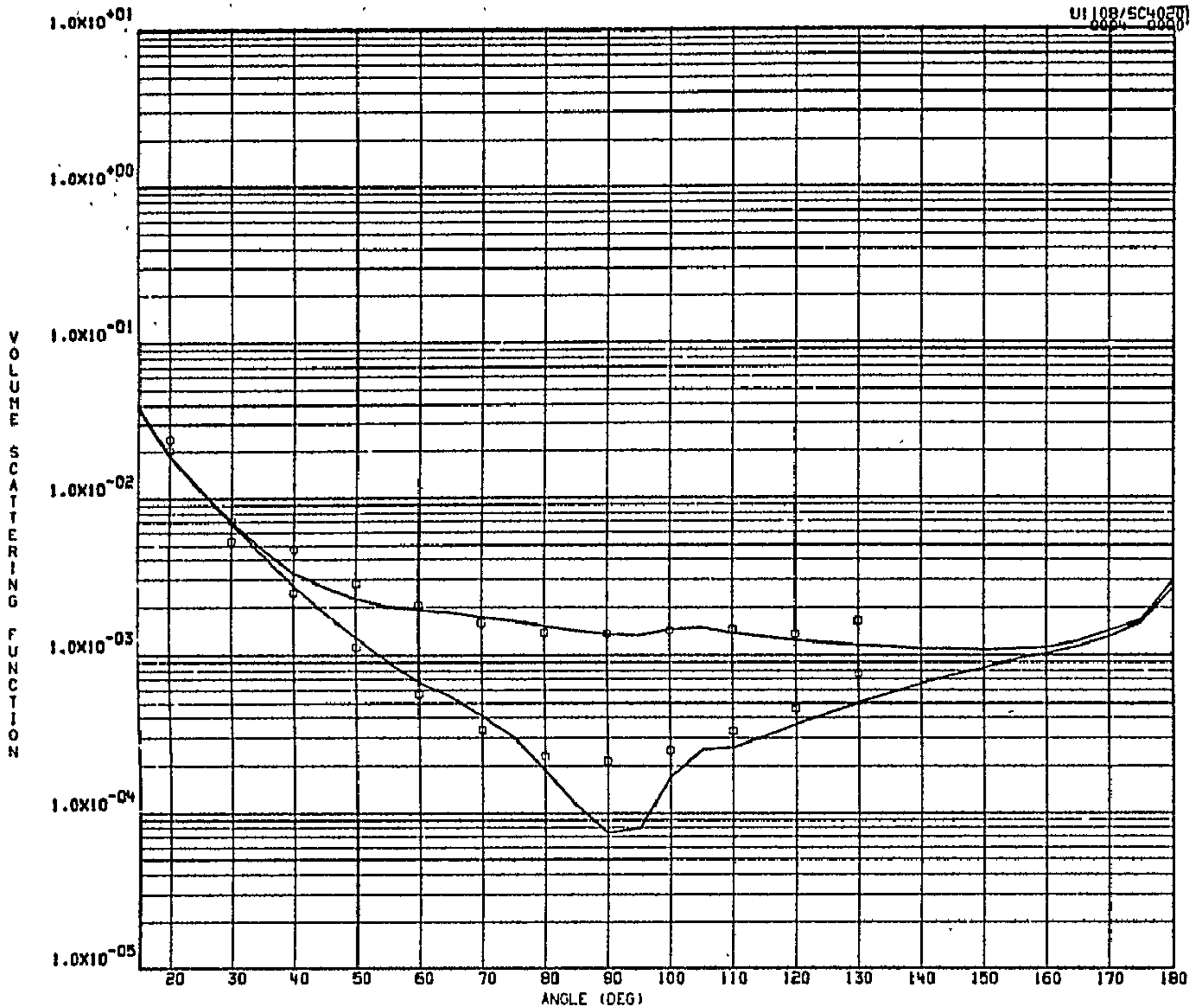


WAVELENGTH 578 NM

CHI SQUARE = 8.32×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$1.069 \times 10^{+02}$	$2.126 \times 10^{+04}$	$2.348 \times 10^{+01}$	2.069×10^{-01}	3.554×10^{-03}
MODE DIAM			0.20	1.50	16.43
ALPHA			6.00	6.00	6.00
GAMMA	2.76	6.00	0.25	0.40	0.70

STATION 43 DEPTH 7 METERS

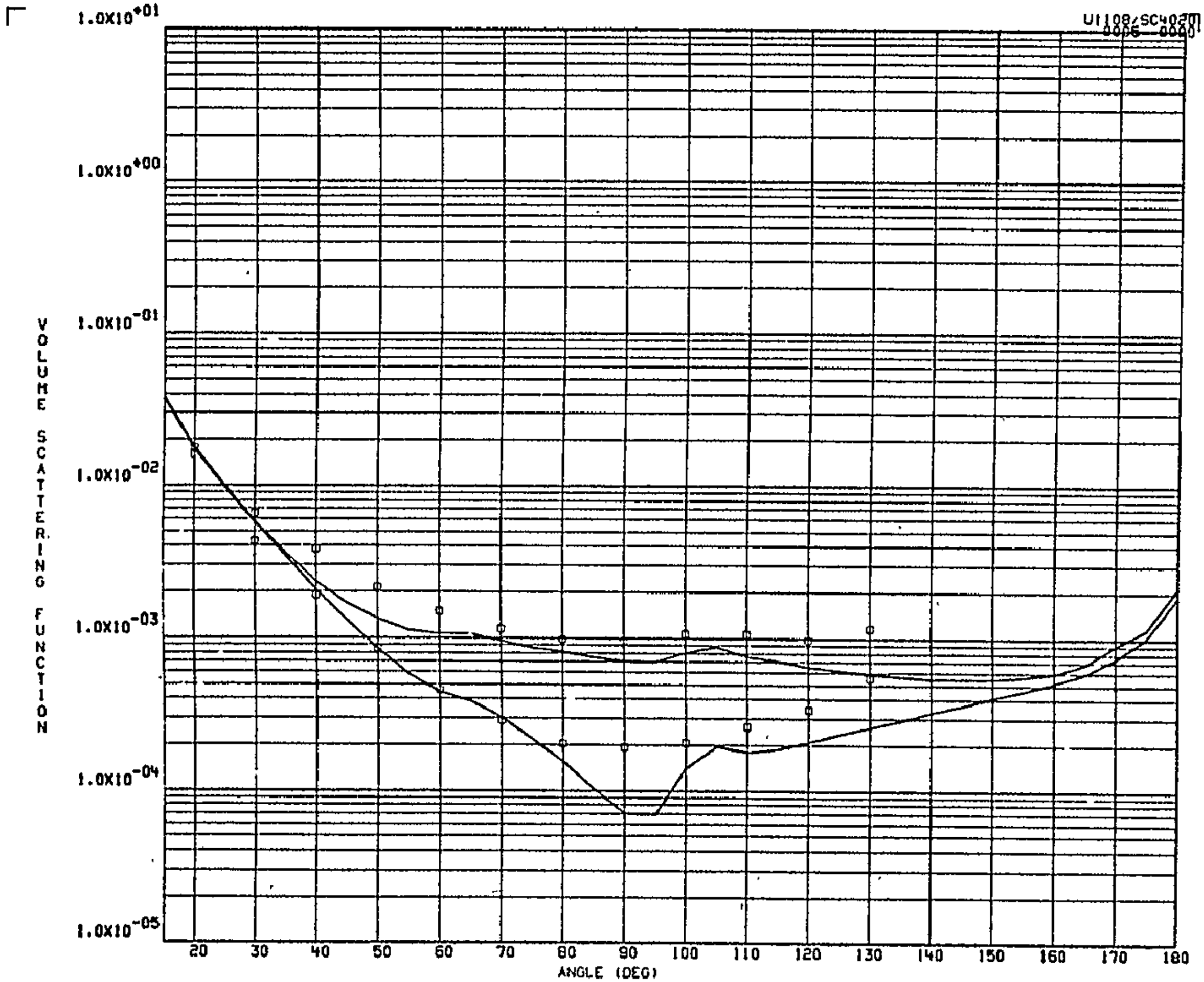


WAVELENGTH 436 NM

CHI SQUARE = 6.57×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$7.144 \times 10^{+01}$	$2.220 \times 10^{+04}$	3.356×10^{-01}	9.633×10^{-02}	5.776×10^{-03}
MODE DIAM			0.20	1.50	15.07
ALPHA			6.00	6.00	6.00
GAMMA	2.76	6.00	0.25	0.40	0.70

STATION 44 SURFACE

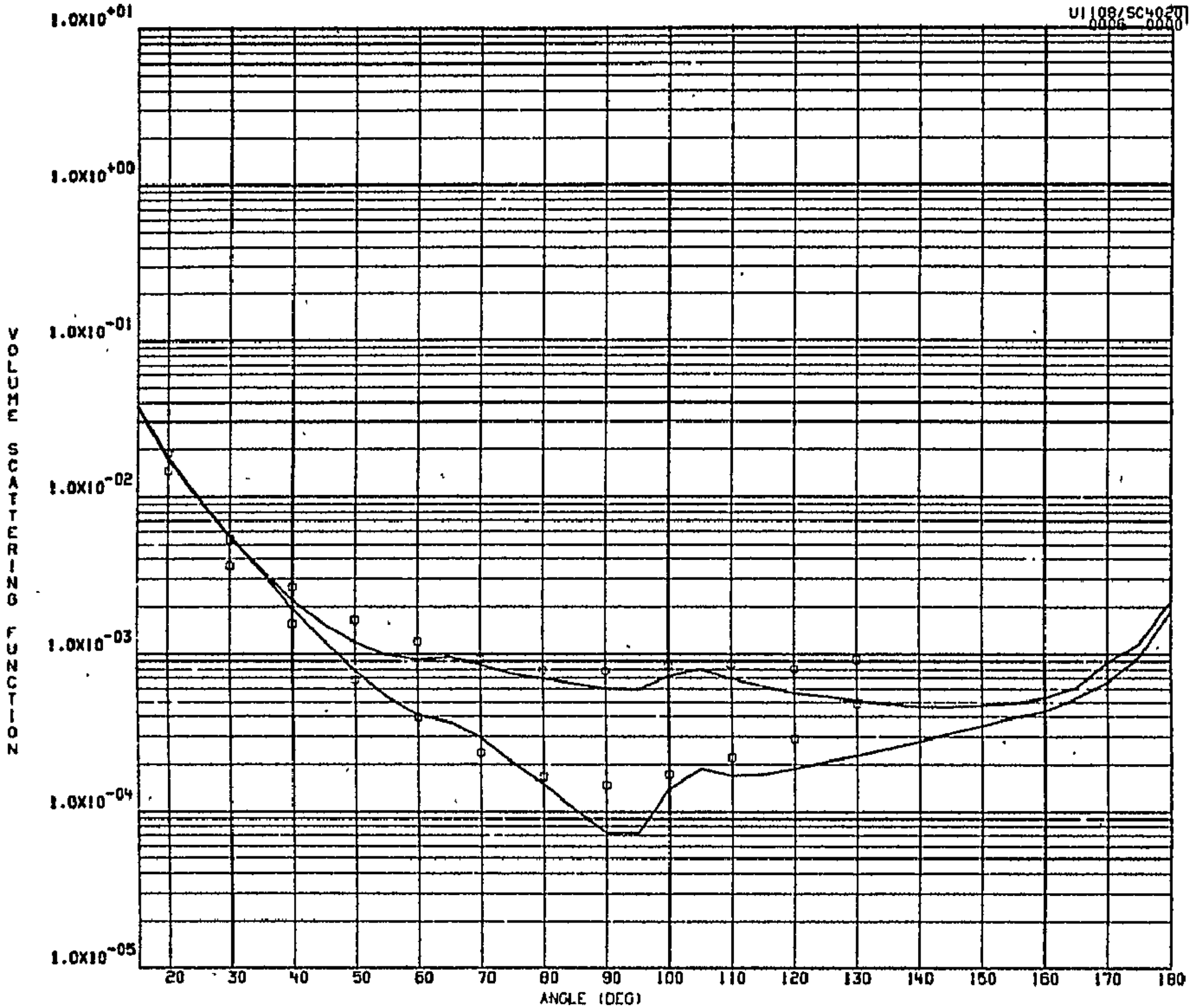


WAVELENGTH 546 NM

CHI SQUARE = 6.57×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$7.144 \times 10^{+01}$	$2.220 \times 10^{+04}$	3.356×10^{-01}	9.633×10^{-02}	5.776×10^{-03}
MODE DIAM			0.20	1.50	15.07
ALPHA			6.00	6.00	6.00
GAMMA	2.76	6.00	0.25	0.40	0.70

STATION 44 SURFACE

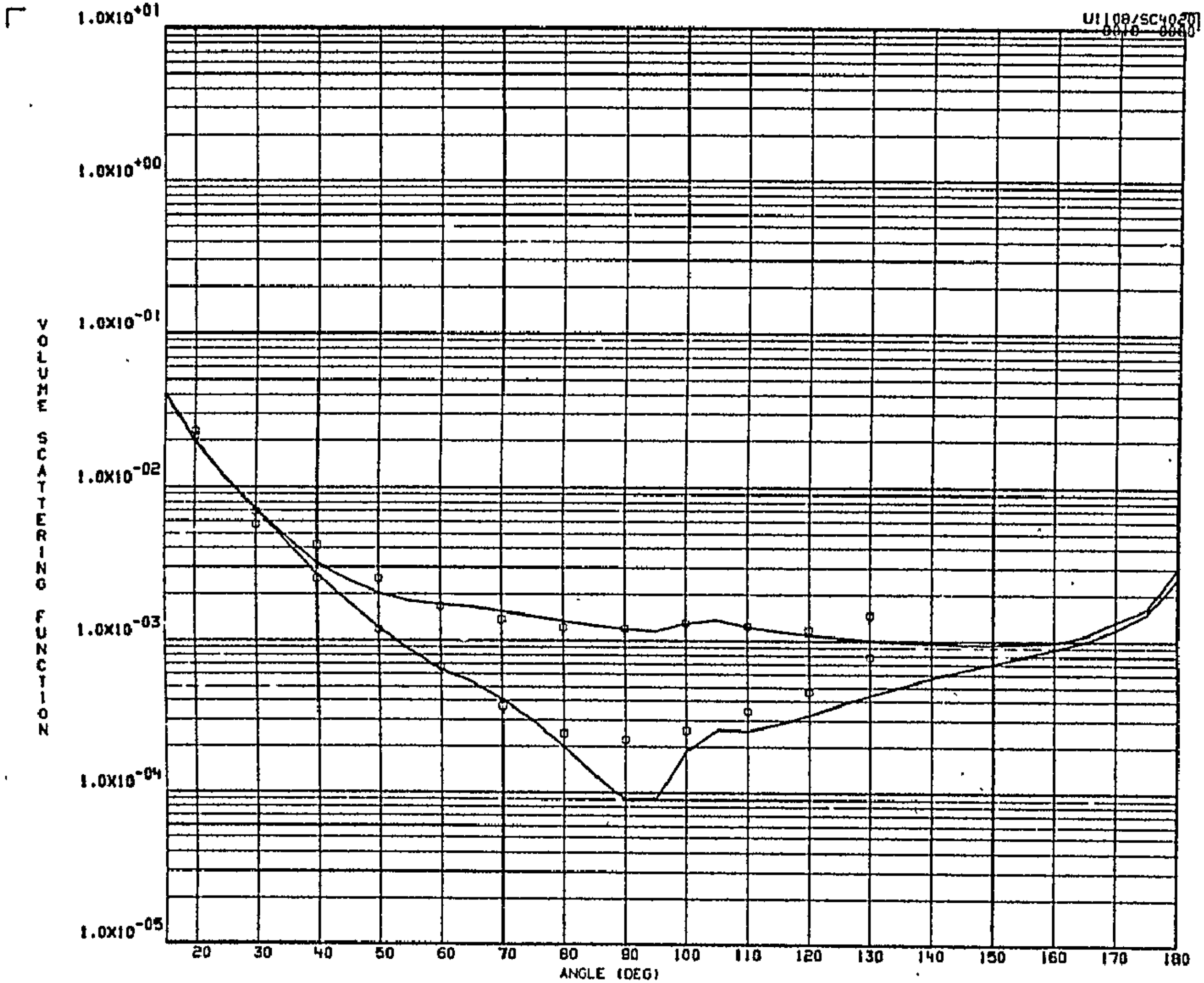


WAVELENGTH 578 NM

CHI SQUARE = 6.57×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$7.144 \times 10^{+01}$	$2.220 \times 10^{+04}$	3.356×10^{-01}	9.633×10^{-02}	5.776×10^{-03}
MODE DIAM			0.20	1.50	15.07
ALPHA			6.00	6.00	6.00
GAMMA	2.76	6.00	0.25	0.40	0.70

STATION 44 SURFACE

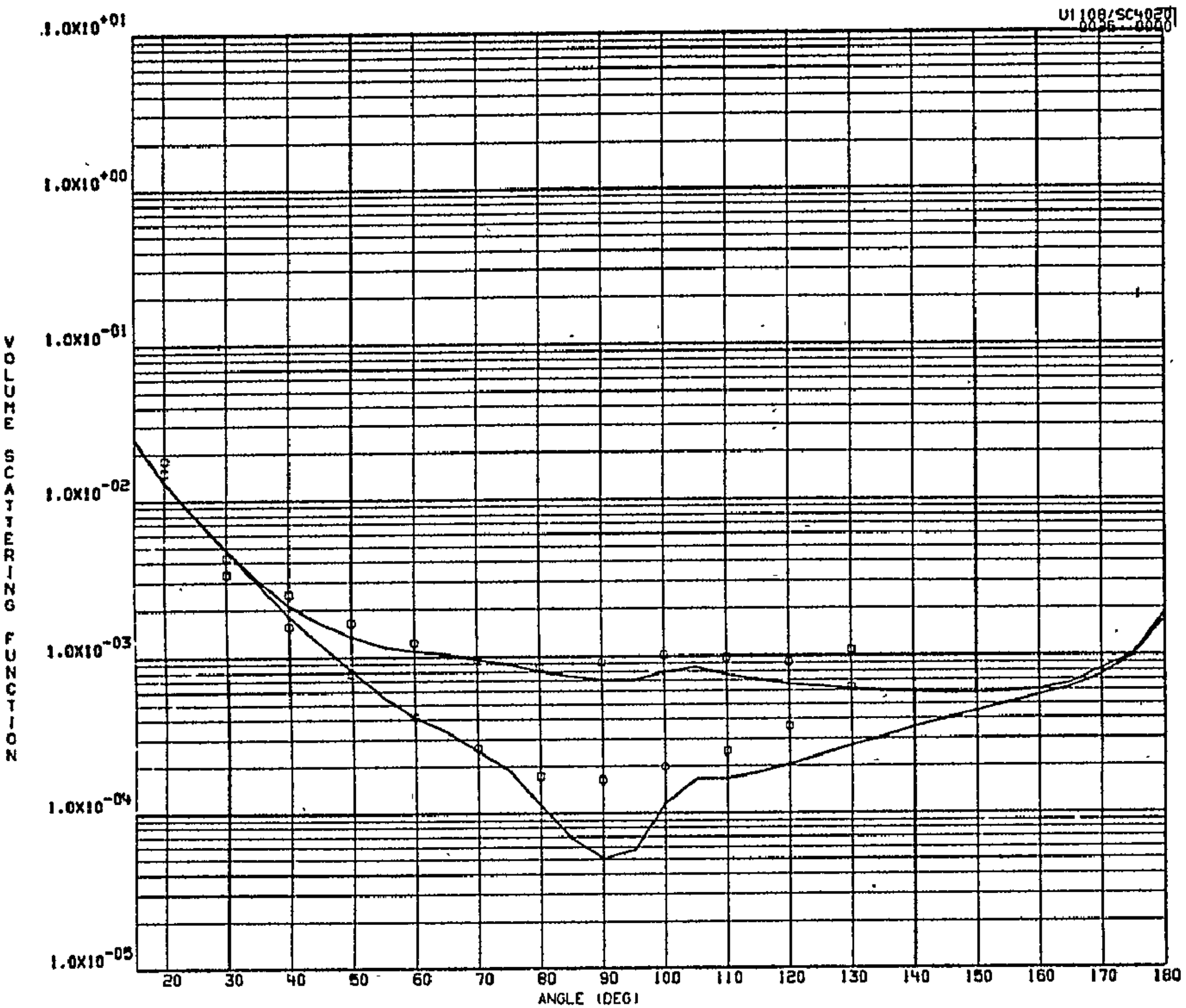


WAVELENGTH 436 NM

CHI SQUARE = 6.45X10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	6.011X10^{+01}	1.852X10^{+04}	2.834X10^{-01}	9.595X10^{-02}	1.286X10^{-02}
MODE DIAM			0.20	1.50	10.43
ALPHA			6.00	6.00	6.00
GAMMA	2.72	6.00	0.25	0.40	0.70

STATION 44 DEPTH 5 METERS

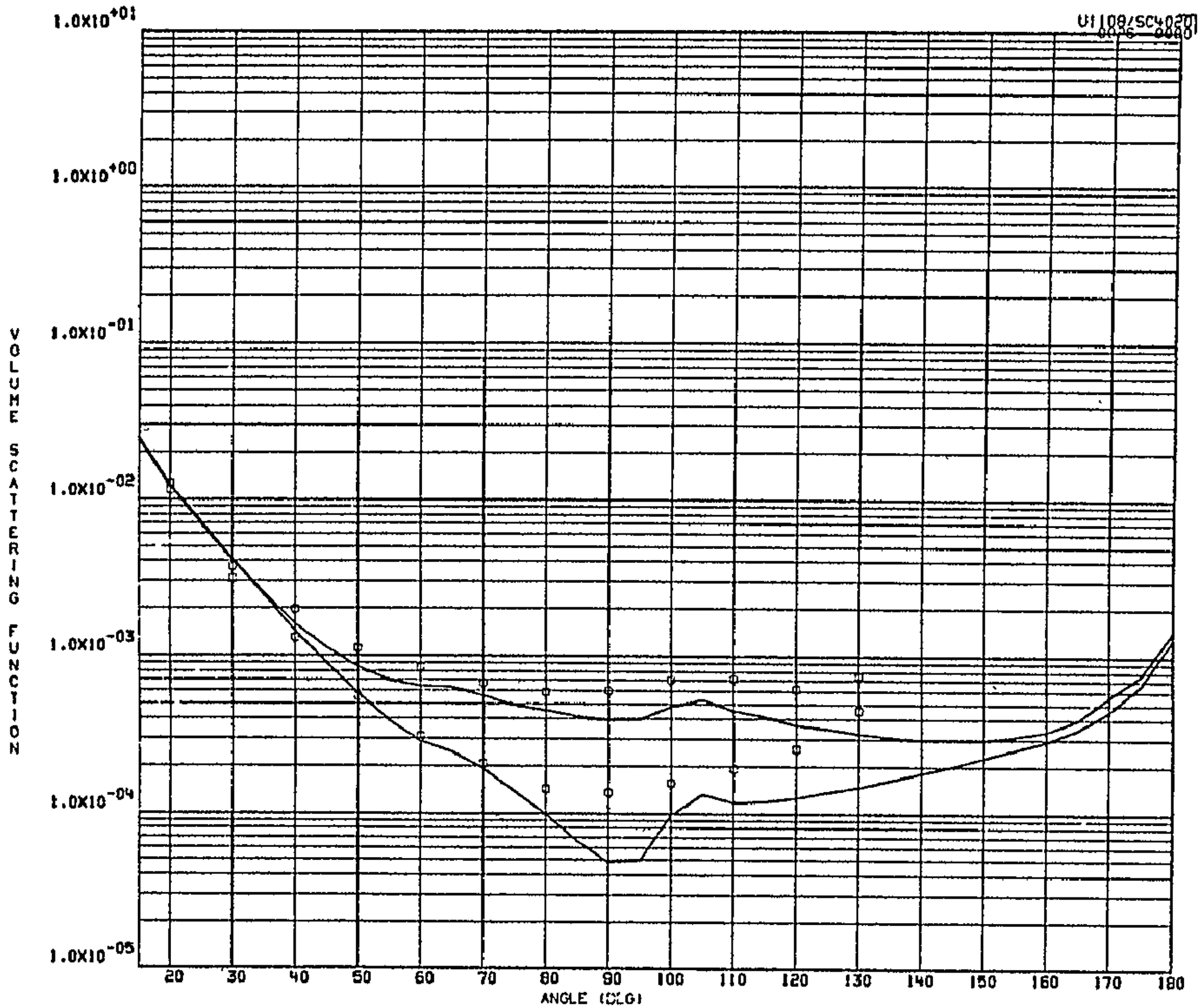


WAVELENGTH 436 NM

CHI SQUARE = 6.65×10^{-01}

	INORGN 1	INORGN 2	PL FRG 2	DIATOMS
POPULATION	$1.466 \times 10^{+02}$	$1.123 \times 10^{+04}$	1.145×10^{-02}	3.457×10^{-03}
MODE DIAM			1.50	16.22
ALPHA			6.00	6.00
GAMMA	2.93	6.00	0.50	0.70

STATION 44 DEPTH 21 METERS

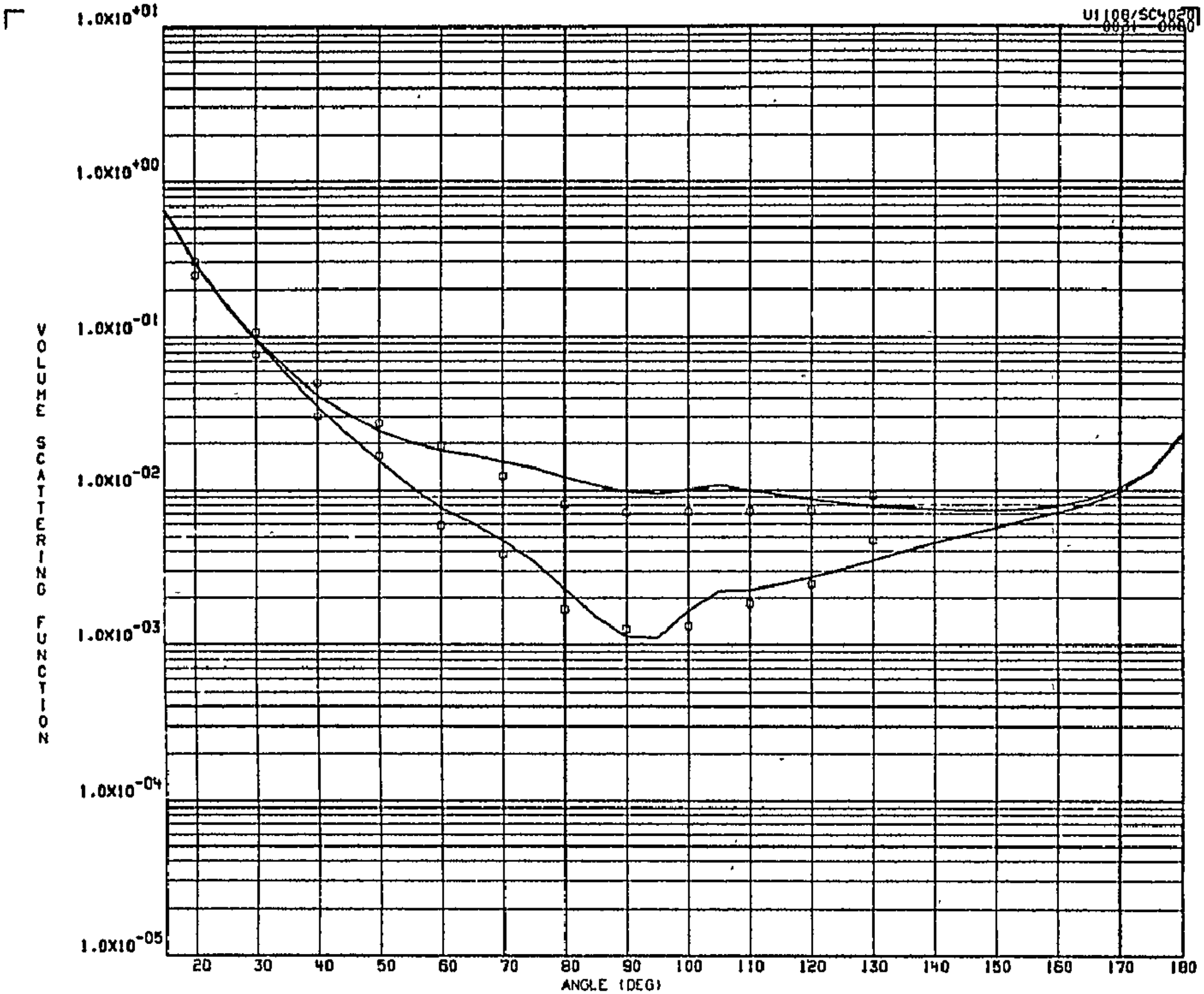


WAVELENGTH 546 NM

CHI SQUARE = 6.65×10^{-01}

	INORGN 1	INORGN 2	PL FRG 2	DIATOMS
POPULATION	$1.466 \times 10^{+02}$	$1.123 \times 10^{+04}$	1.145×10^{-02}	3.457×10^{-03}
MODE DIAM			1.50	16.22
ALPHA			6.00	6.00
GAMMA	2.93	6.00	0.50	0.70

STATION 44 DEPTH 21 METERS

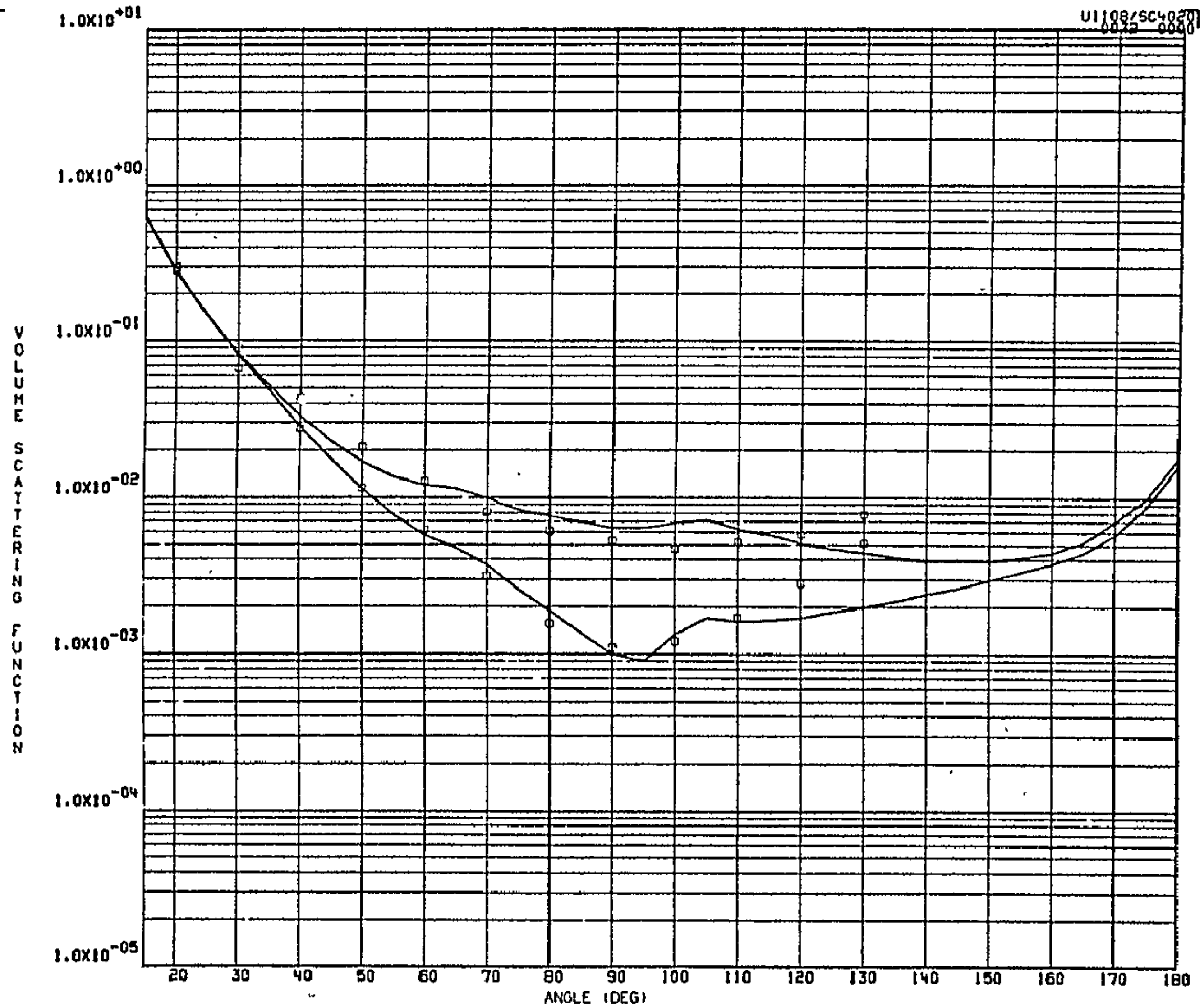


WAVELENGTH 436 NM

CHI SQUARE = $1.09 \times 10^{+00}$

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$1.004 \times 10^{+04}$	$1.298 \times 10^{+05}$	$3.802 \times 10^{+01}$	$1.101 \times 10^{+00}$	9.268×10^{-02}
MODE DIAM			0.50	1.50	12.50
ALPHA			6.00	6.00	6.00
GAMMA	3.23	6.00	0.36	0.50	0.70

STATION 54 SURFACE

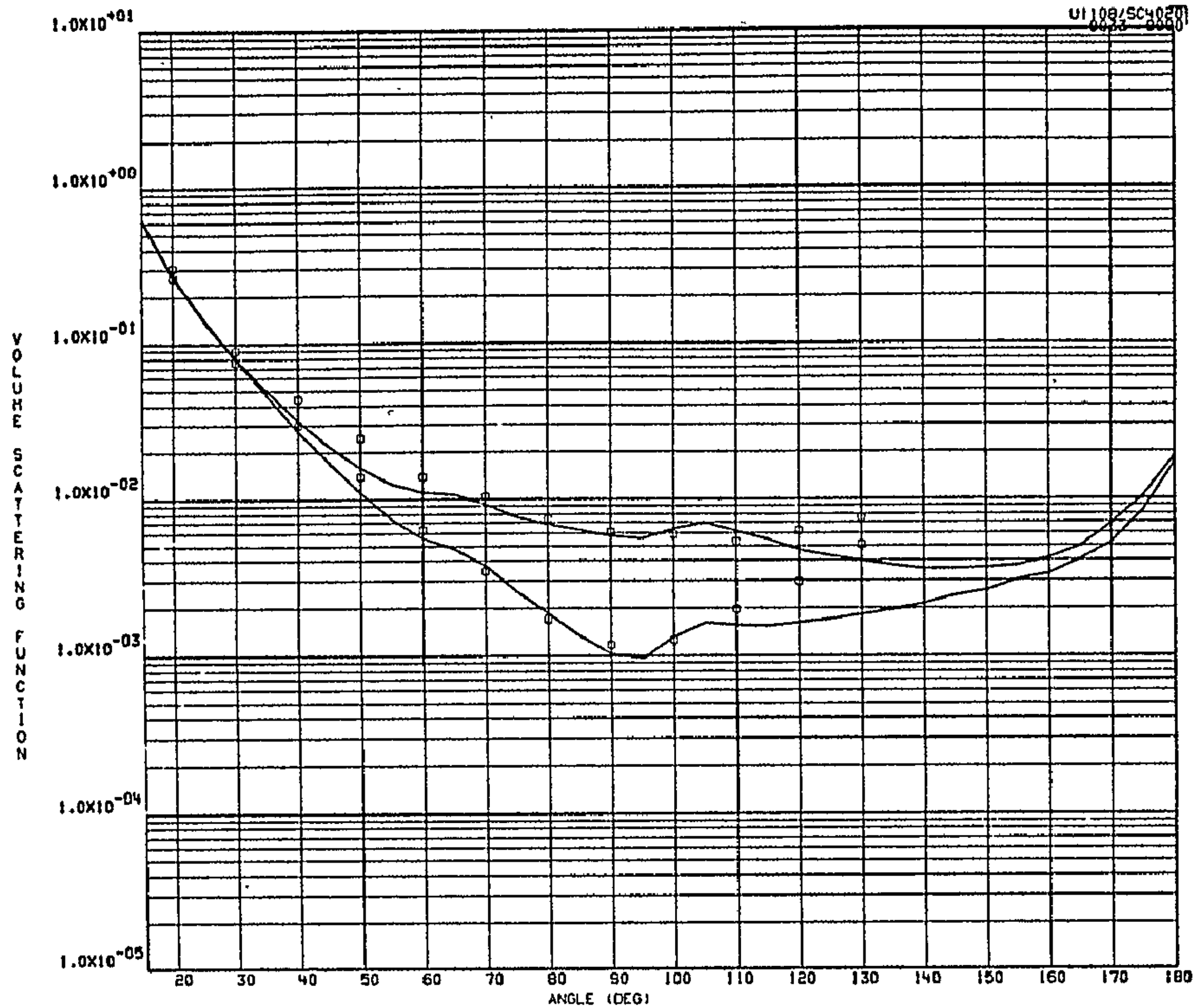


WAVELENGTH 546 NM

CHI SQUARE = $1.09 \times 10^{+00}$

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$1.004 \times 10^{+04}$	$1.298 \times 10^{+05}$	$3.802 \times 10^{+01}$	$1.101 \times 10^{+00}$	8.268×10^{-02}
MODE DIAM			0.50	1.50	12.50
ALPHA			6.00	6.00	6.00
GAMMA	3.23	6.00	0.36	0.50	0.70

STATION 54 SURFACE

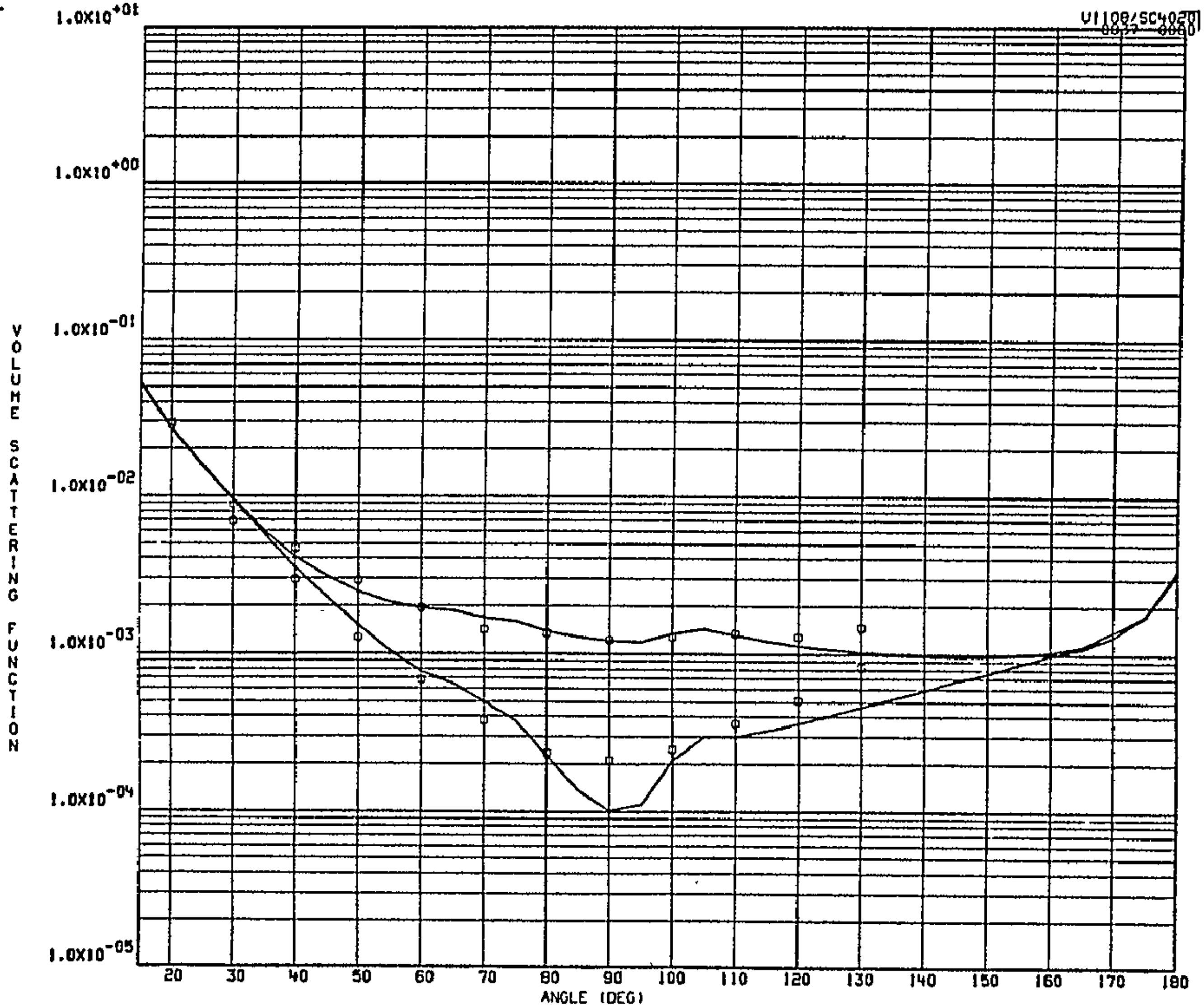


WAVELENGTH 578 NM

CHI SQUARE = $1.09\times10^{+00}$

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$1.004\times10^{+04}$	$1.298\times10^{+05}$	$3.802\times10^{+01}$	$1.101\times10^{+00}$	8.268×10^{-02}
MODE DIAM			0.50	1.50	12.50
ALPHA			6.00	6.00	6.00
GAMMA	3.23	6.00	0.36	0.50	0.70

STATION 54 SURFACE

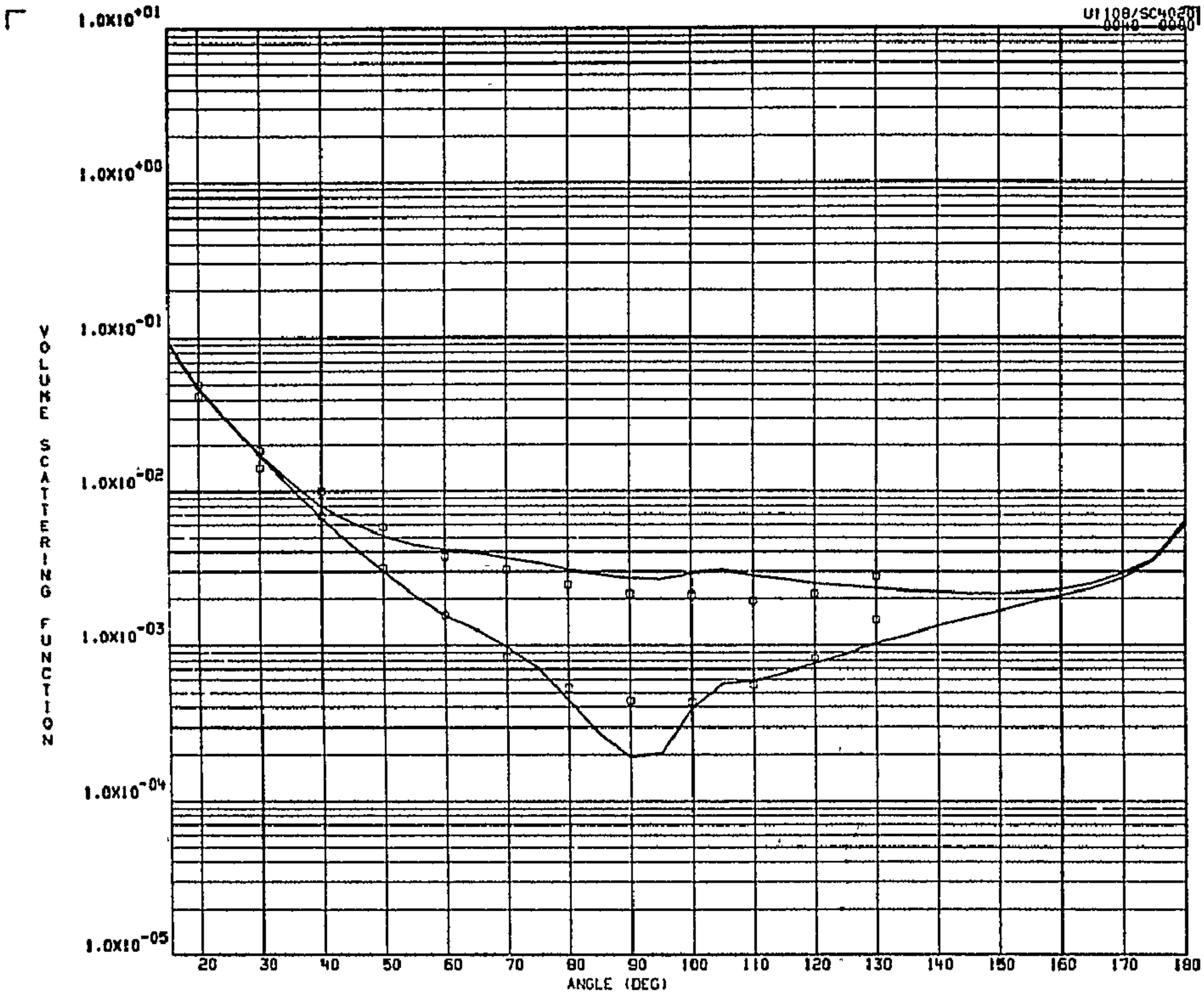


WAVELENGTH 436 NM

CHI SQUARE = 6.29×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$4.000 \times 10^{+02}$	$1.815 \times 10^{+04}$	$6.242 \times 10^{+00}$	1.096×10^{-02}	6.569×10^{-03}
MODE DIAM			0.25	1.50	18.00
ALPHA			6.00	6.00	6.00
GAMMA	3.00	6.00	0.36	0.50	0.70

STATION 54 DEPTH 15 METERS

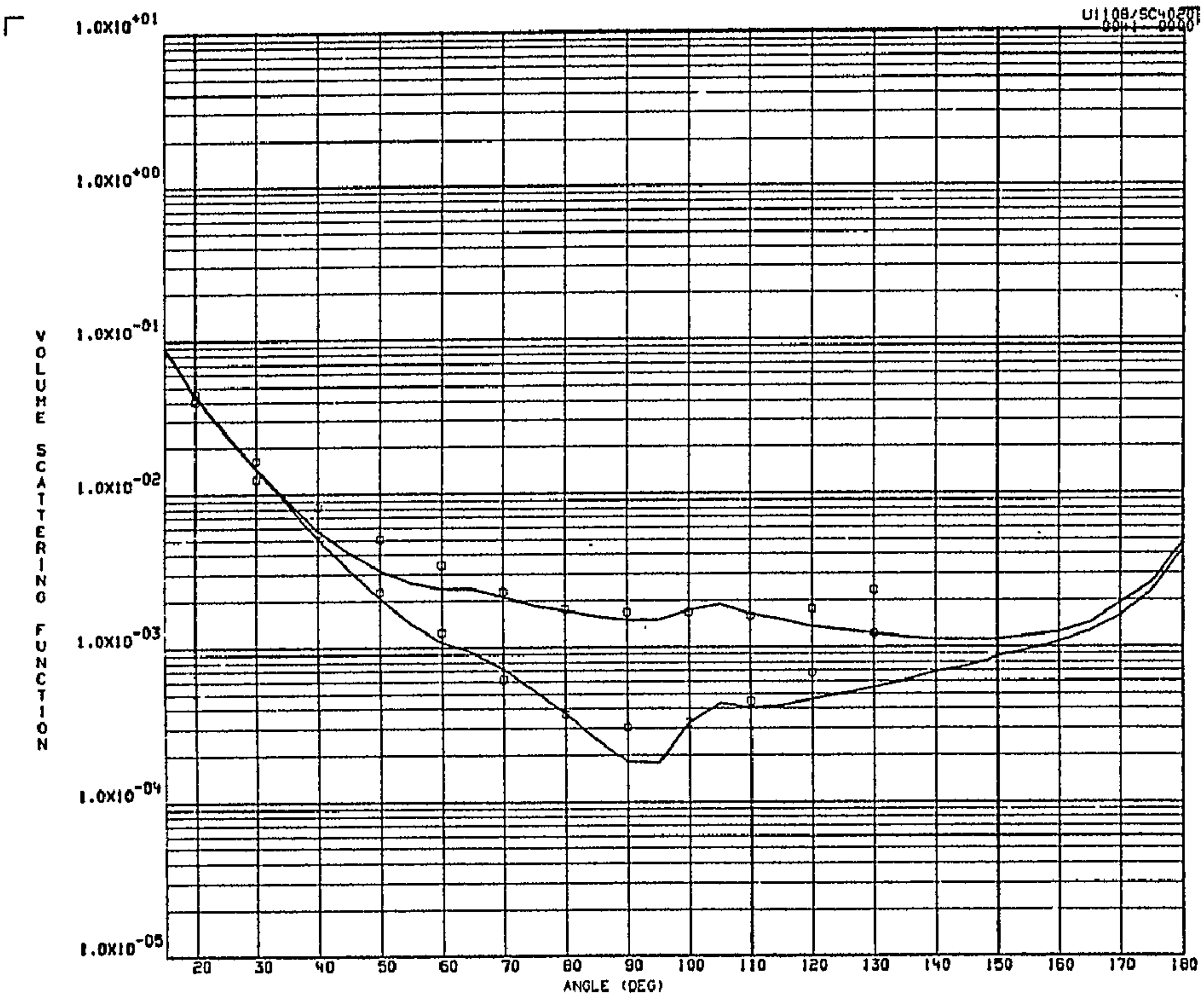


WAVELENGTH 436 NM

CHI SQUARE = 7.77×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$6.279 \times 10^{+02}$	$4.295 \times 10^{+04}$	4.567×10^{-01}	1.485×10^{-01}	1.429×10^{-02}
MODE DIAM			0.25	1.50	14.86
ALPHA			6.00	6.00	6.00
GAMMA	2.98	6.00	0.36	0.50	0.70

STATION 54 DEPTH 25 METERS

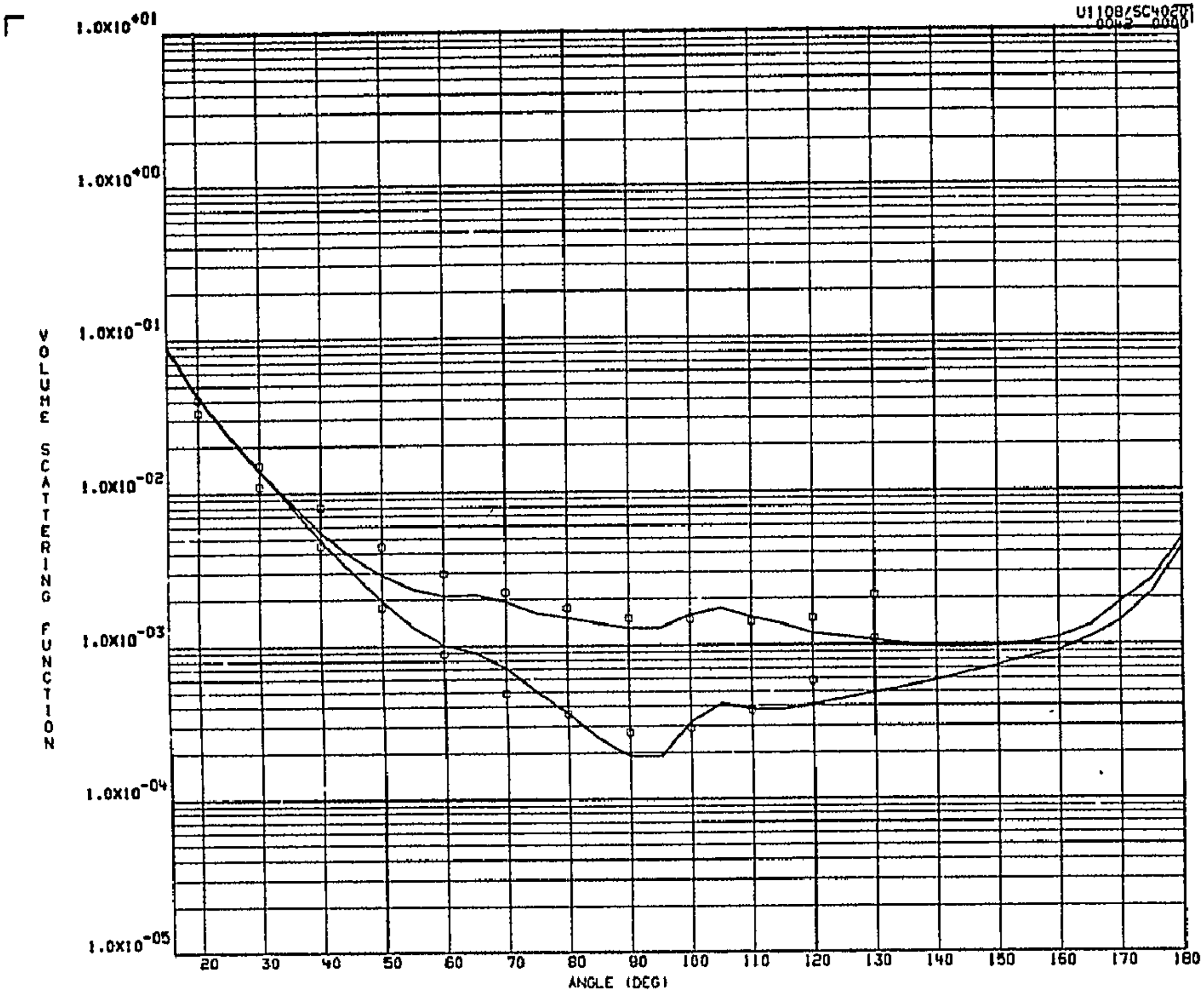


WAVELENGTH 546 NM

CHI SQUARE = 7.77×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$6.279 \times 10^{+02}$	$4.295 \times 10^{+04}$	4.567×10^{-01}	1.485×10^{-01}	1.429×10^{-02}
MODE DIAM			0.25	1.50	14.86
ALPHA			6.00	6.00	6.00
GAMMA	2.98	6.00	0.36	0.50	0.70

STATION 54 DEPTH 25 METERS

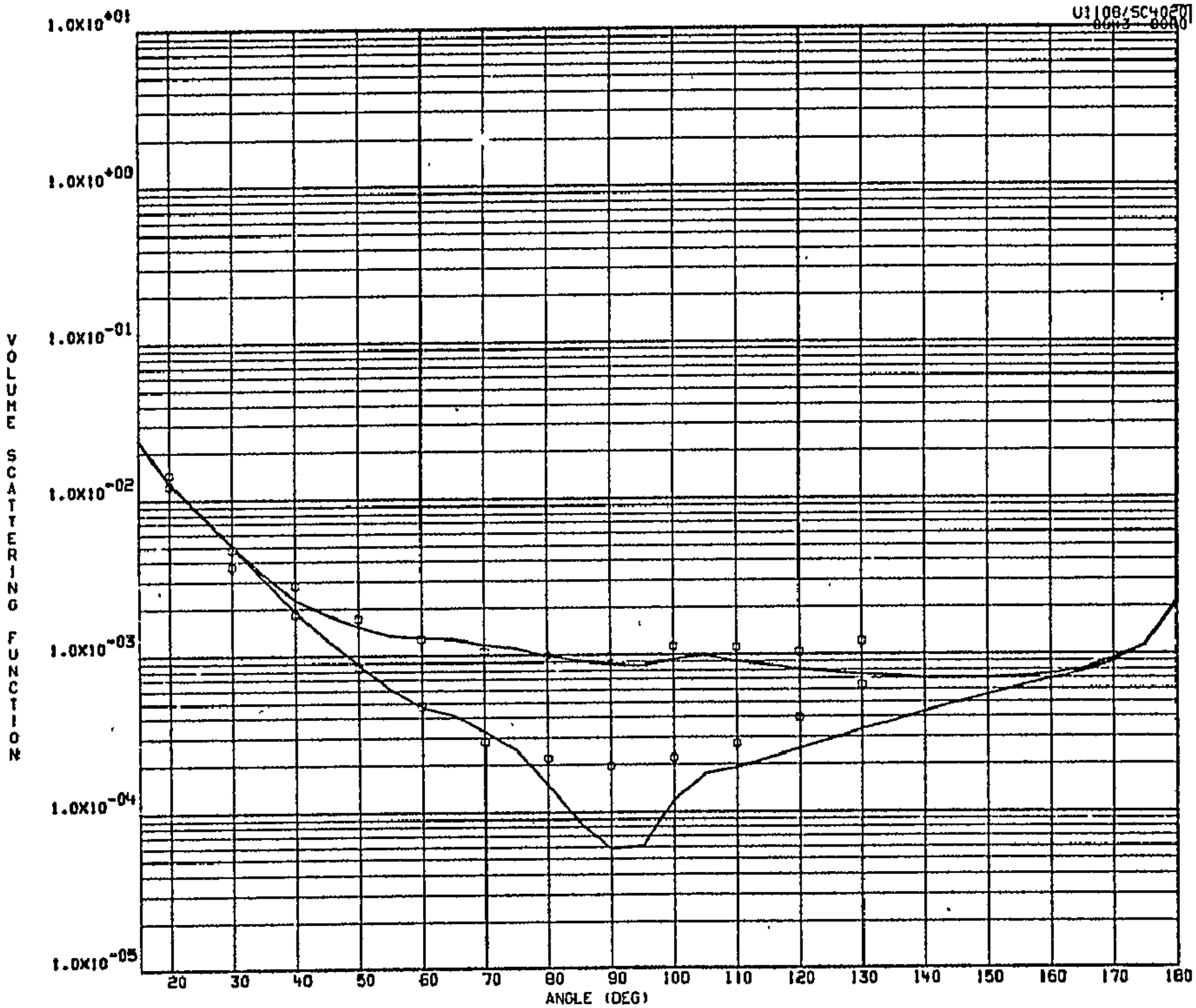


WAVELENGTH 578 NM

CHI SQUARE = 7.77X10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	6.279X10^{+02}	4.295X10^{+04}	4.567X10^{-01}	1.485X10^{-01}	1.429X10^{-02}
MODE DIAM			0.25	1.50	14.86
ALPHA			6.00	6.00	6.00
GAMMA	2.98	6.00	0.36	0.50	0.70

STATION 54 DEPTH 25 METERS

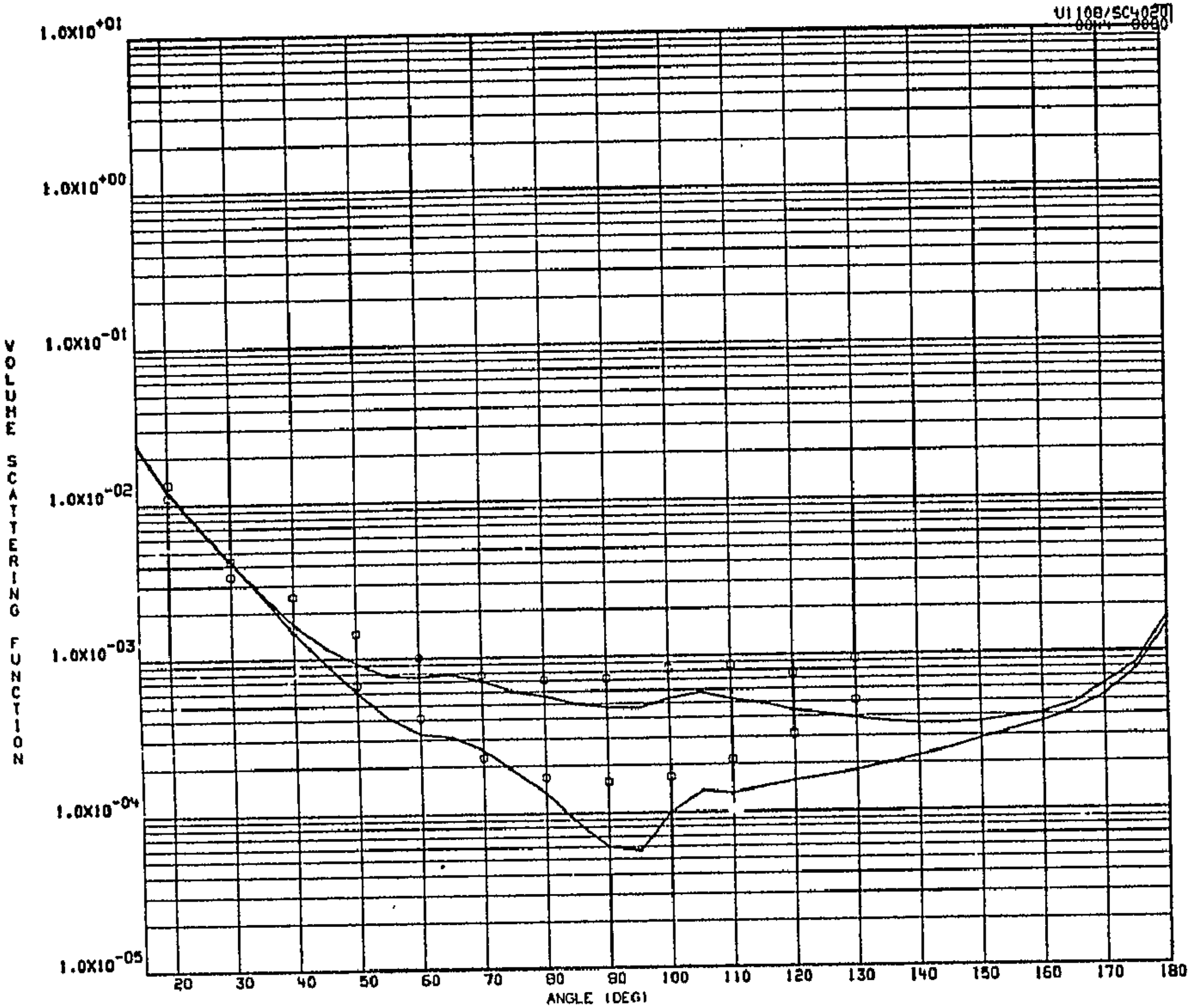


WAVELENGTH 436 NM

CHI SQUARE = 7.48×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$1.277 \times 10^{+02}$	$1.379 \times 10^{+04}$	1.517×10^{-01}	1.568×10^{-03}	6.181×10^{-03}
MODE DIAM			0.25	1.50	15.73
ALPHA			6.00	6.00	6 00
GAMMA	2.92	6.00	0.36	0.50	0.70

STATION 54 DEPTH 40 METERS

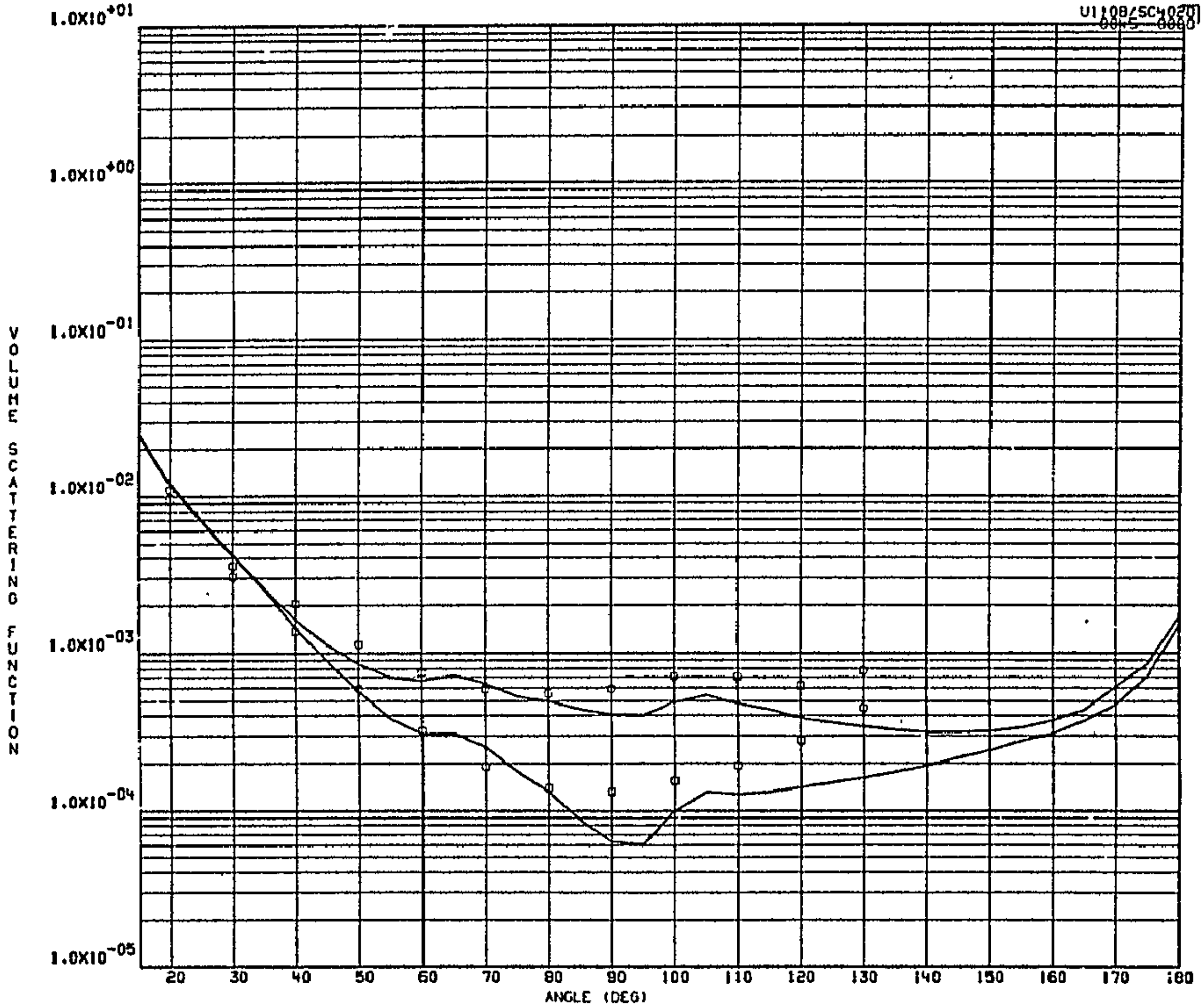


WAVELENGTH 546 NM

CHI SQUARE = 7.48×10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$1.277\times10^{+02}$	$1.379\times10^{+04}$	1.517×10^{-01}	1.568×10^{-03}	6.181×10^{-03}
MODE DIAM			0.25	1.50	15.73
ALPHA			6.00	6.00	6.00
GAMMA	2.92	6.00	0.36	0.50	0.70

STATION 54 DEPTH 40 METERS

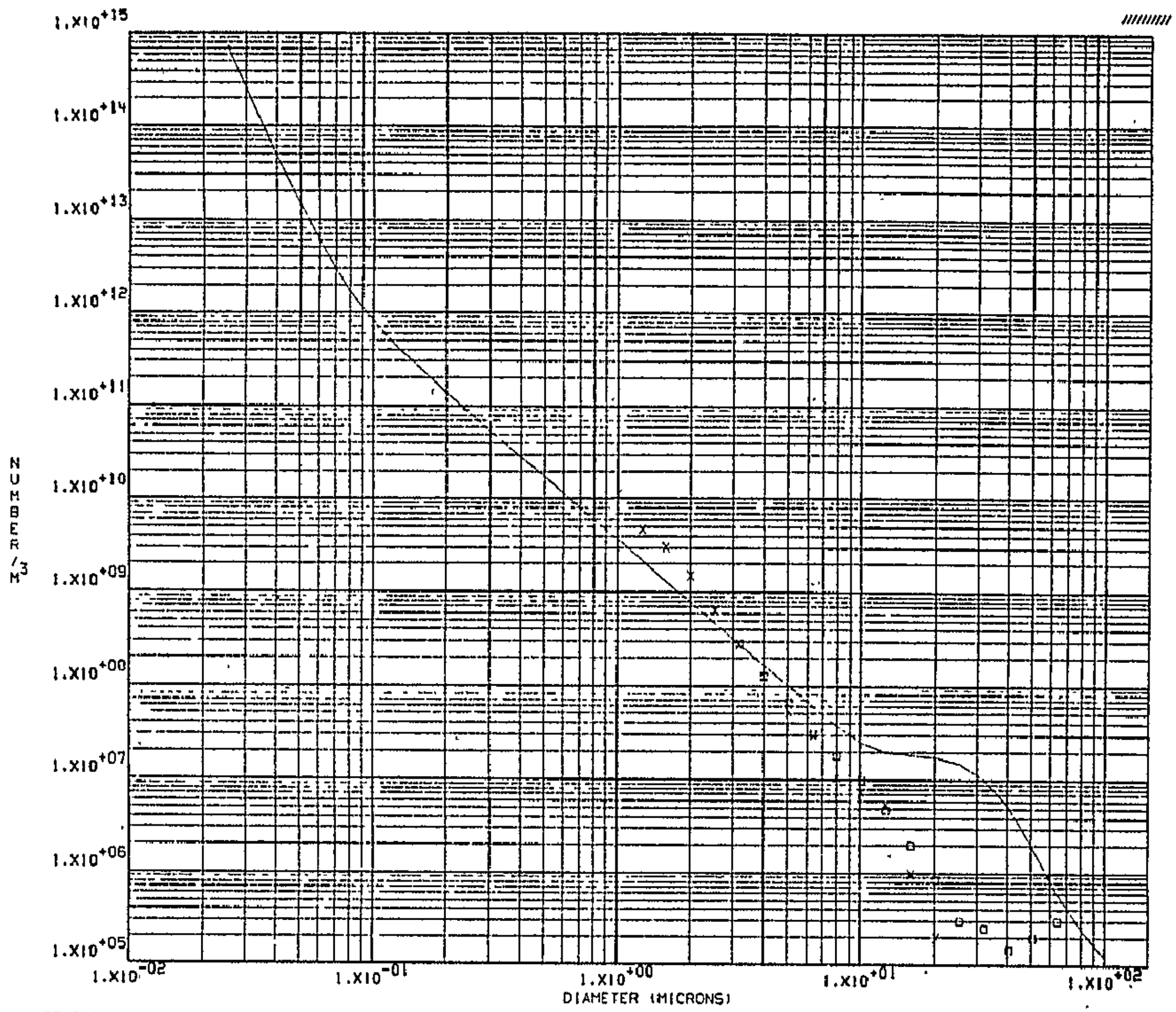


WAVELENGTH 578 NM

CHI SQUARE = 7.48X10^{-01}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	1.277X10^{+02}	1.379X10^{+04}	1.517X10^{-01}	1.568X10^{-03}	6.181X10^{-03}
MODE DIAM			0.25	1.50	15.73
ALPHA			6.00	6.00	6.00
GAMMA	2.92	6.00	0.36	0.50	0.70

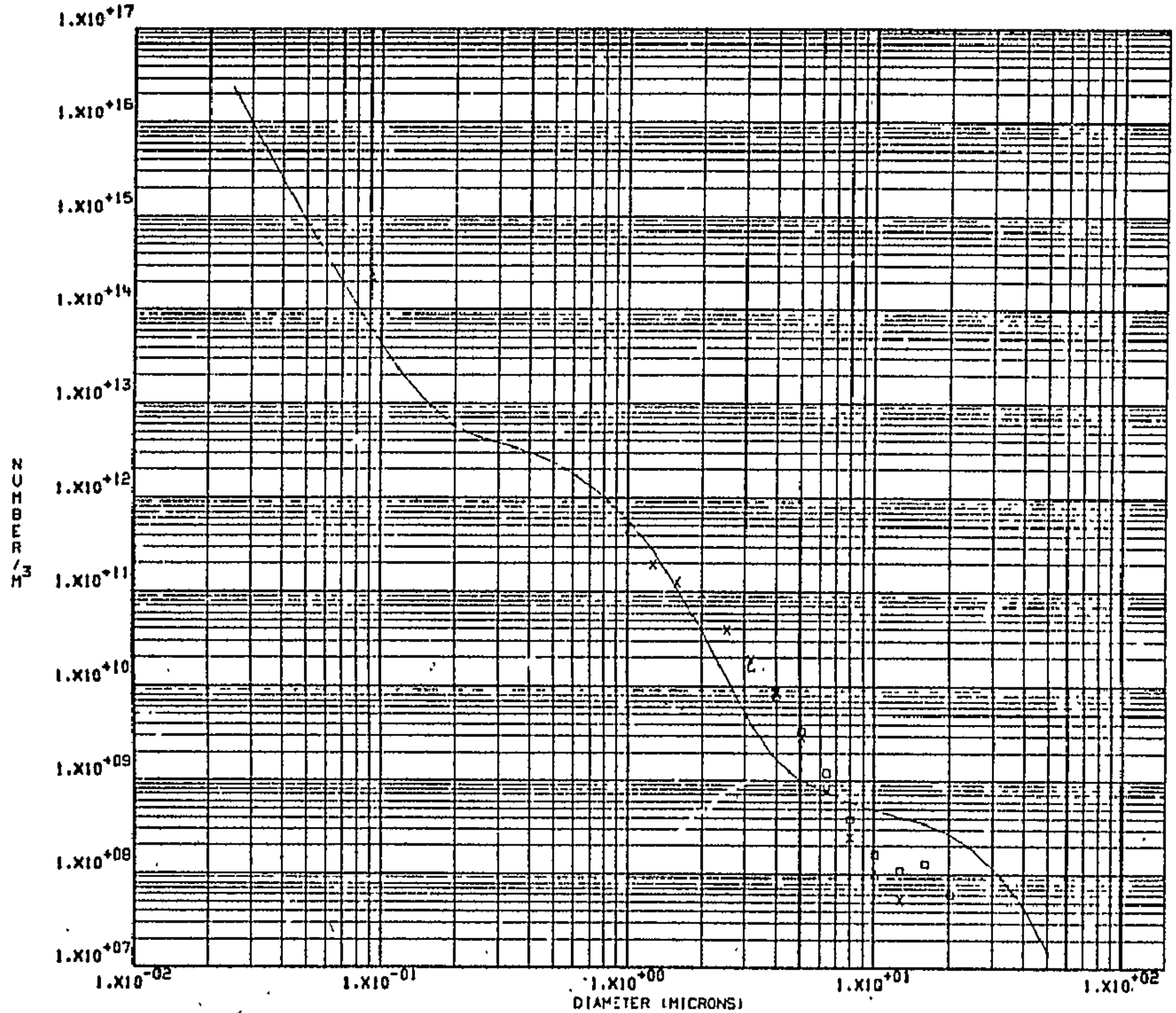
STATION 54 DEPTH 40 METERS



STATION 9 SURFACE

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
¤	138-3	07/22/77	9	SURFACE	1607	10	200	2 00	1.000
X	138-3	07/22/77	9	SURFACE	1607	10	50	.50	1.000

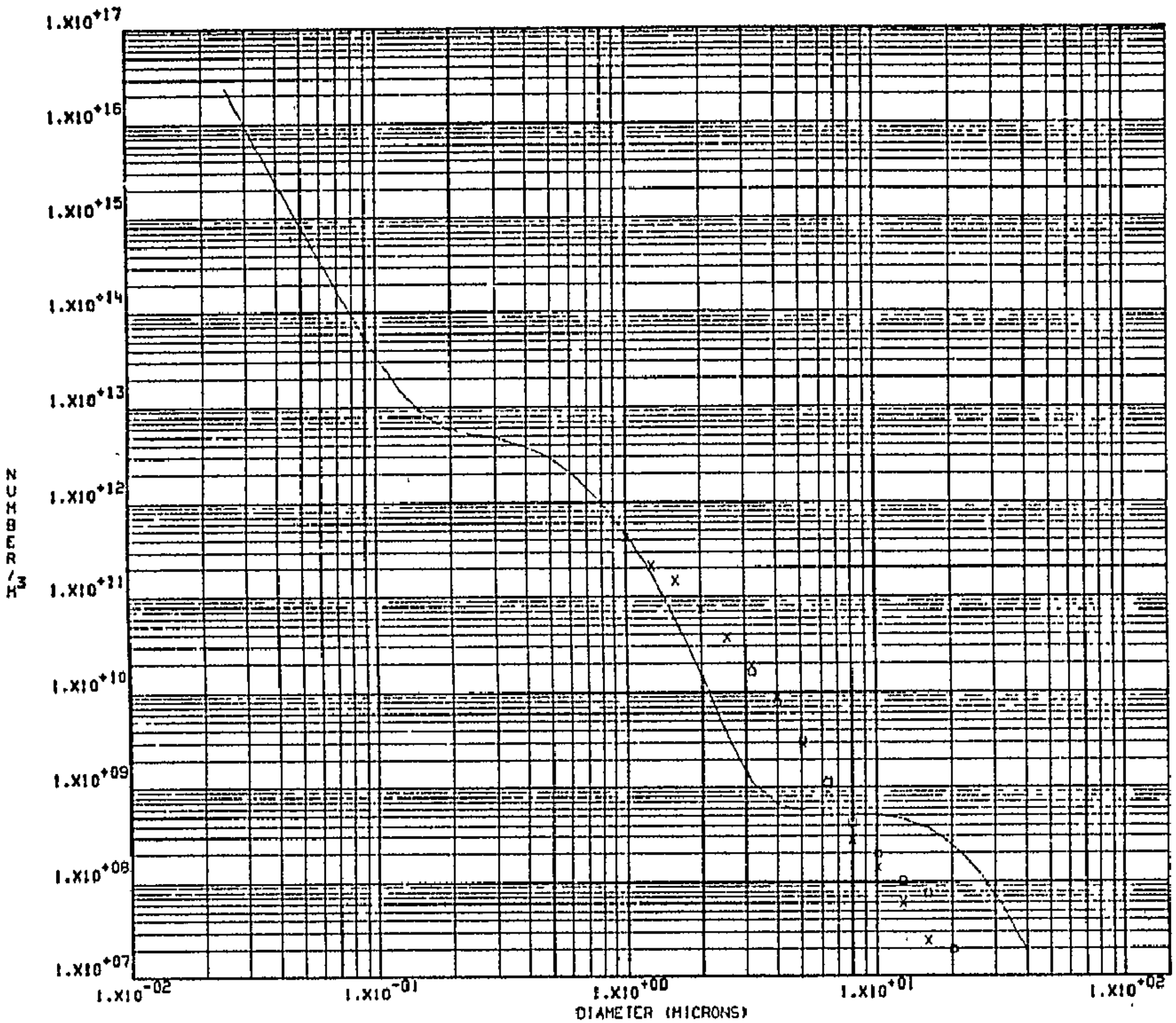
	INORGN 1	INORGN 2	PL FRG 1	DIATOMS
POPULATION	$1.547X10^{+13}$	$1.645X10^{+14}$	$7.662X10^{+07}$	$6.338X10^{+07}$
MODE DIAM	0 00	0.00	0 25	20.00
ALPHA	0.00	0.00	6 00	6.00
GAMMA	3.23	7.00	0.17	0.80



STATION 11 SURFACE

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-4	09/18/77	11	SURFACE	1549	10	200	2.00	.200
X	138-4	09/18/77	11	SURFACE	1549	10	50	.50	.200

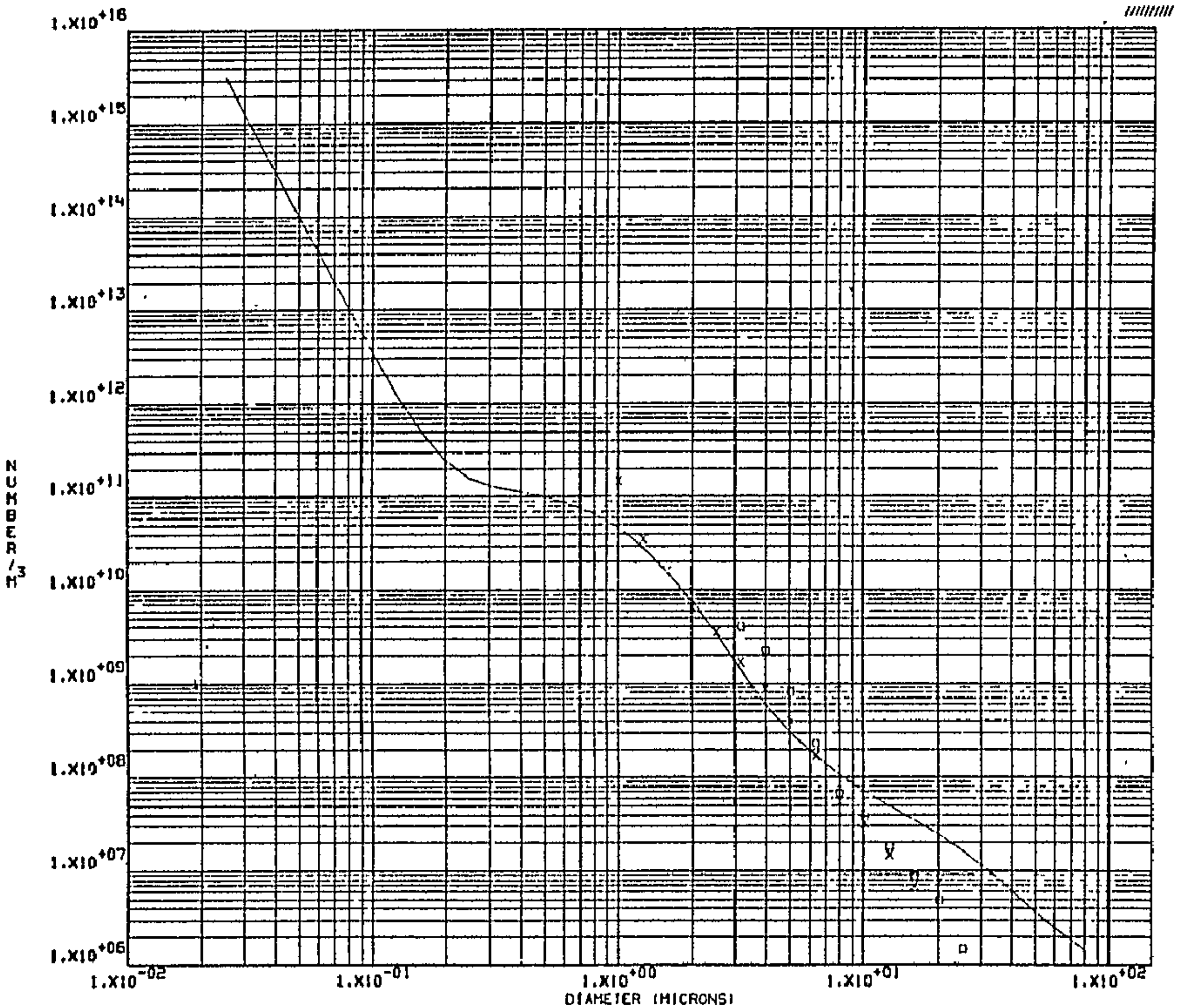
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$6.395 \times 10^{+15}$	$1.103 \times 10^{+15}$	$2.345 \times 10^{+13}$	$9.736 \times 10^{+09}$	$1.594 \times 10^{+09}$
MODE DIAM	0.00	0.00	0.19	1.50	12.42
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	6.00	4.20	0.29	0.22	0.50



STATION 11 DEPTH 3 METERS

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-4	09/18/77	11	9 FT	1620	11	200	2.00	.200
X	138-4	09/18/77	11	9 FT	1620	10	50	.50	.200

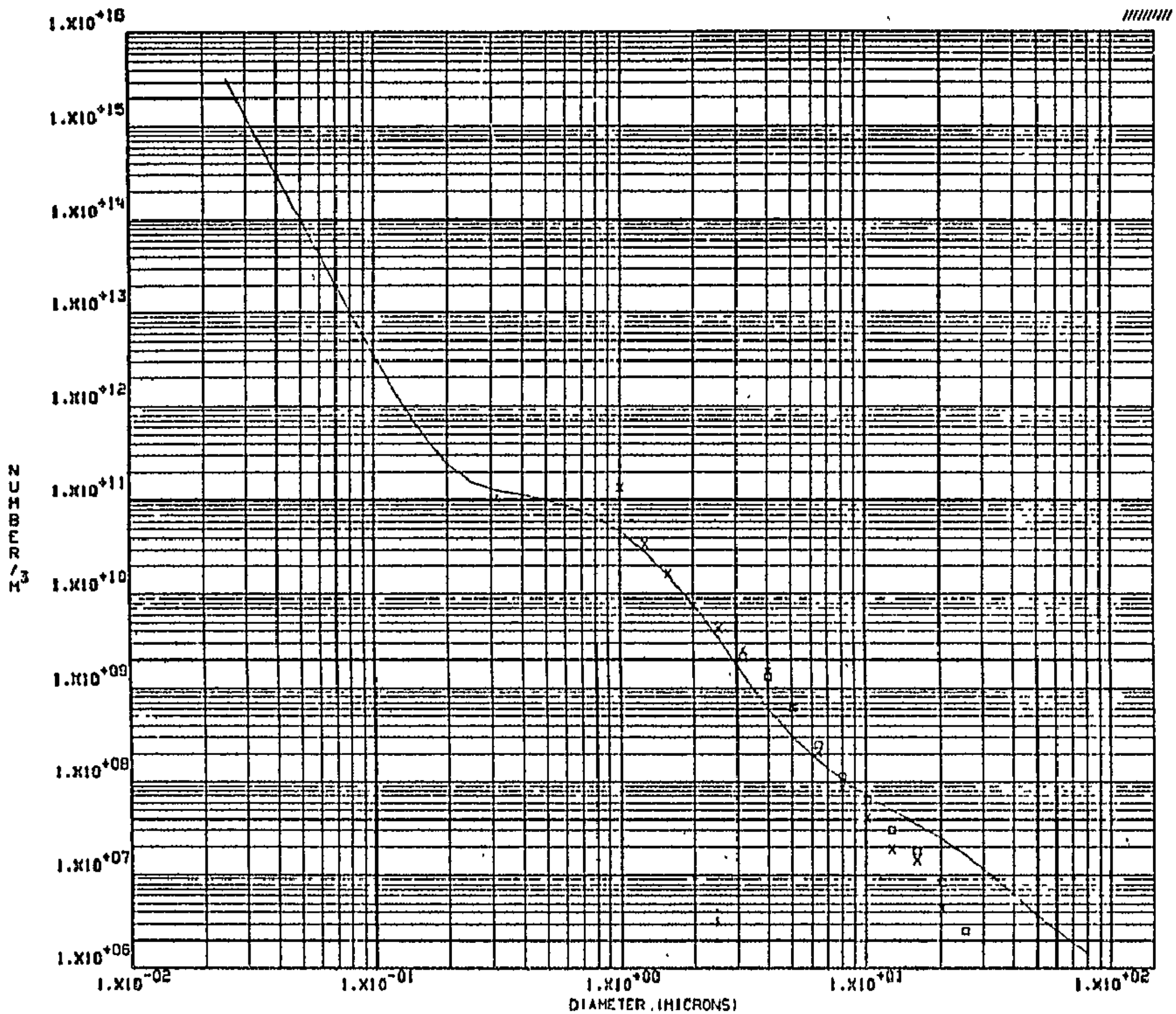
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$6.597\times10^{+15}$	$6.159\times10^{+14}$	$3.000\times10^{+13}$	$4.502\times10^{+09}$	$2.329\times10^{+09}$
MODE DIAM	0.00	0.00	0.20	1.50	9.52
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	6.00	4.20	0.35	0.22	0.50



STATION 12 SURFACE

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-4	09/18/77	12	SURFACE		10	200	2.00	1.000
X	138-4	09/18/77	12	SURFACE		10	50	.50	1.000

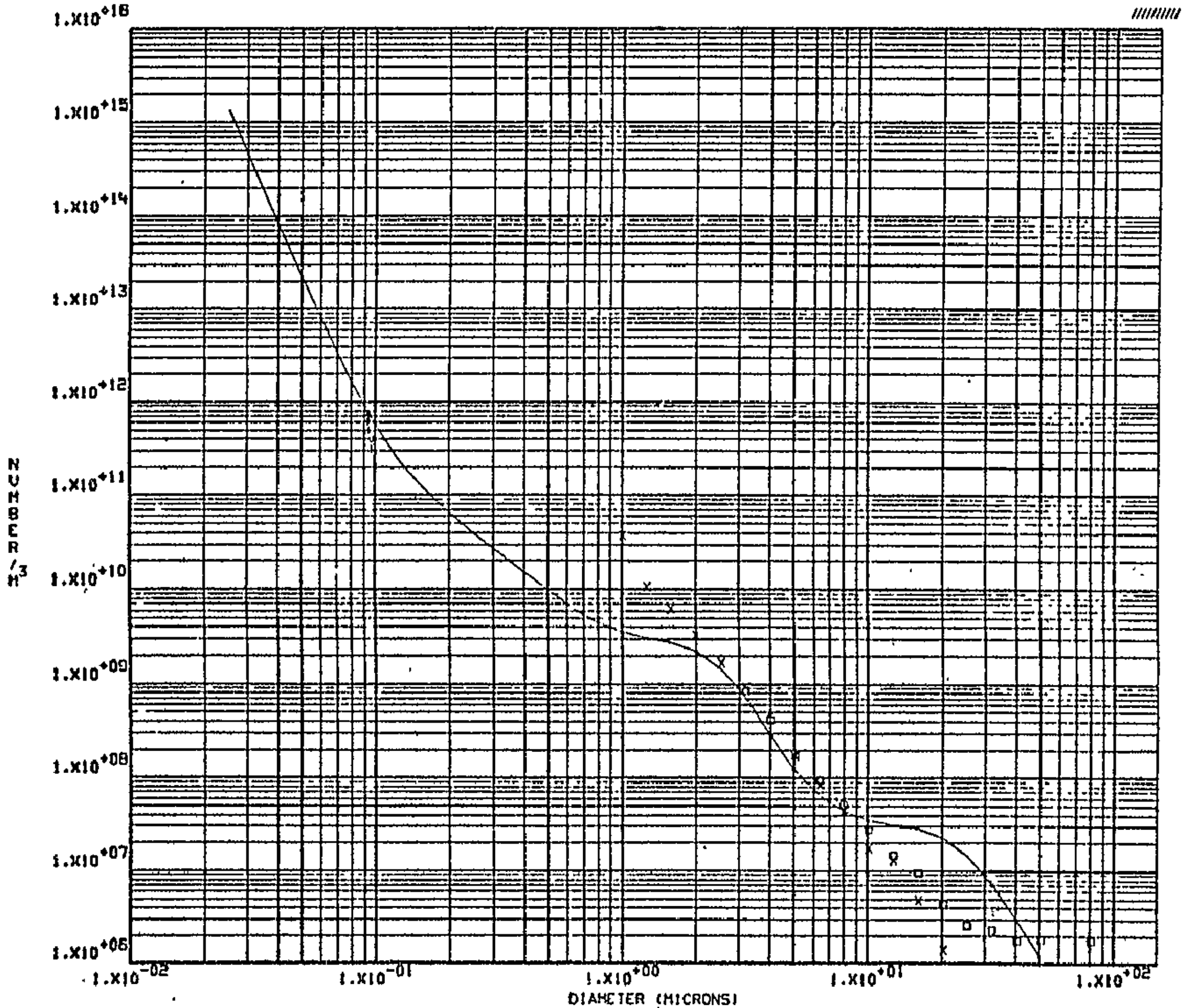
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$9.413\times10^{+14}$	$6.953\times10^{+12}$	$6.466\times10^{+11}$	$5.045\times10^{+06}$	$3.230\times10^{+07}$
MODE DIAM	0.00	0.00	0.29	1.50	15.00
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	6.00	2.85	0.29	0.40	0 70



STATION 12 DEPTH 1 METER

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-4	09/18/77	12	4 FT		10	200	2.00	1.000
X	138-4	09/18/77	12	4 FT		10	50	.50	1.000

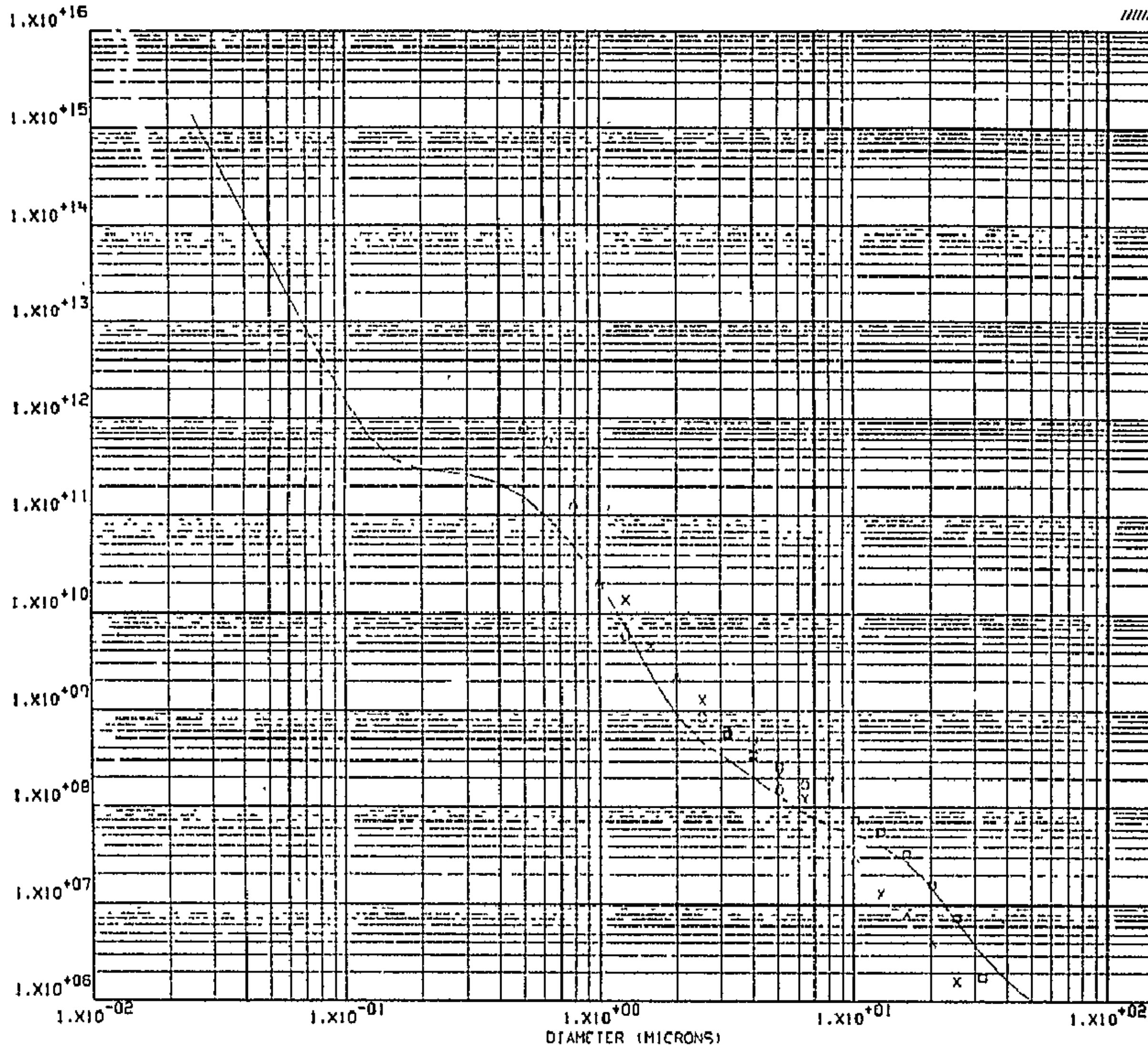
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$9.413 \times 10^{+14}$	$6.953 \times 10^{+12}$	$6.466 \times 10^{+11}$	$5.045 \times 10^{+06}$	$3.230 \times 10^{+07}$
MODE DIAM	0.00	0.00	0.29	1.50	15.00
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	6.00	2.65	0.29	0.40	0.70



STATION 13 SURFACE

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE. APER	TEST VOL	CONC
□	138-4	09/18/77	13	SURFACE	1920	10	200	2.00	1.000
X	138-4	09/18/77	13	SURFACE	1920	10	50	.50	1.000

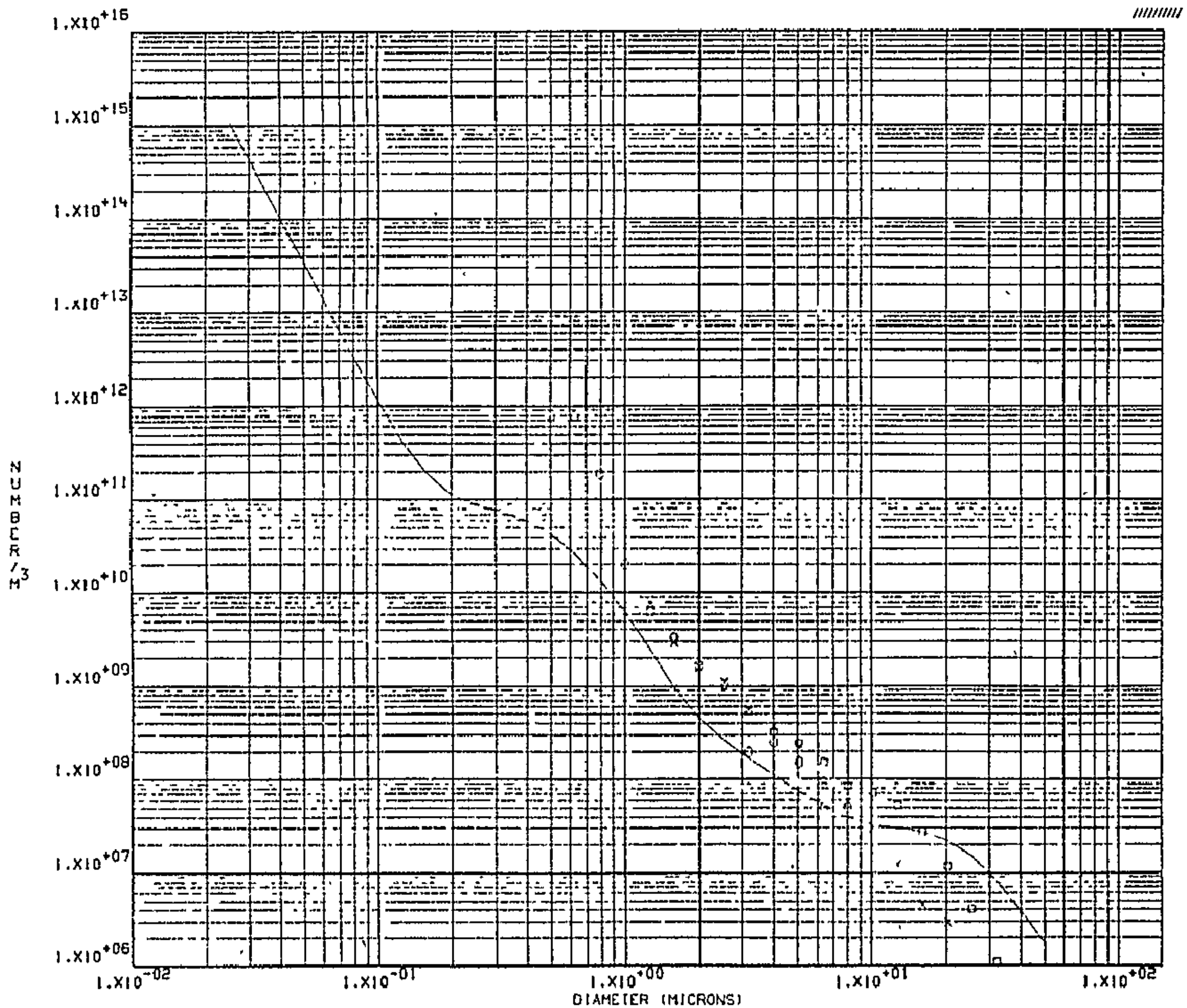
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$5.077 \times 10^{+12}$	$3.063 \times 10^{+14}$	$1.314 \times 10^{+09}$	$8.399 \times 10^{+09}$	$8.832 \times 10^{+07}$
MODE DIAM.	0.00	0.00	0.47	1.51	15.00
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	2.99	7.00	0.37	0.80	0.80



STATION 43 SURFACE

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-8	14 AUG 78	43	SURFACE	2042	10	200	2.00	1.000
X	138-9	14 AUG 78	43	SURFACE	2042	10	70	.50	1.000
O	138-8	14 AUG 78	43	SURFACE	2042	10	15	.02	.100

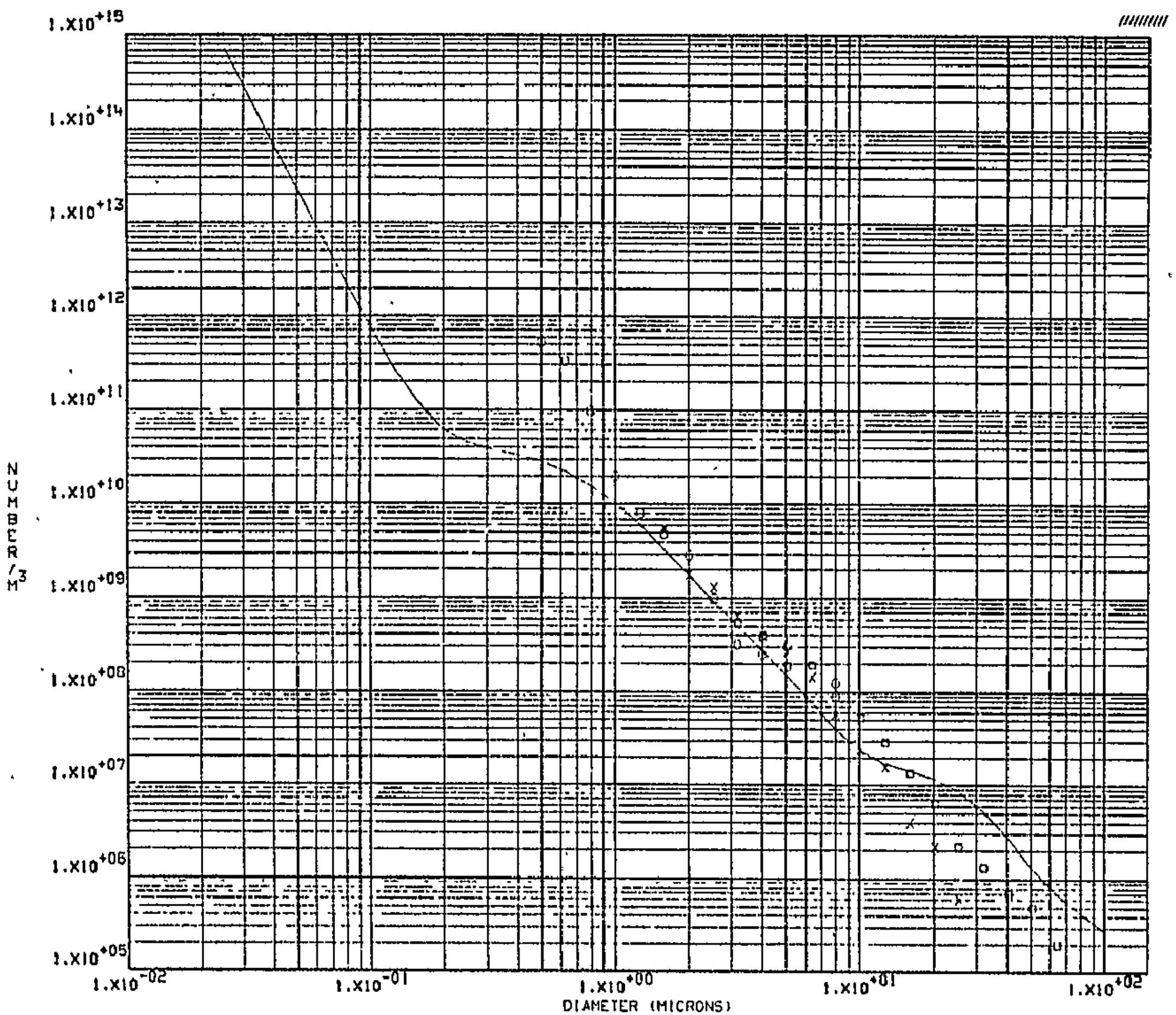
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$2.053\times10^{+12}$	$4.032\times10^{+14}$	$1.701\times10^{+12}$	$1.221\times10^{+09}$	$1.543\times10^{+08}$
MODE DIAM	0.00	0.00	0.20	1.50	9.25
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	2.85	6.00	0.38	0.40	0.70



STATION 43 DEPTH 2 METERS

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-8	14 AUG 78	43	5 FT	2120	10	200	2.00	1.000
X	138-8	14 AUG 78	43	6 FT	2120	10	70	.50	1.000
O	138-8	14 AUG 78	43	5 FT	2120	10	15	.02	.100

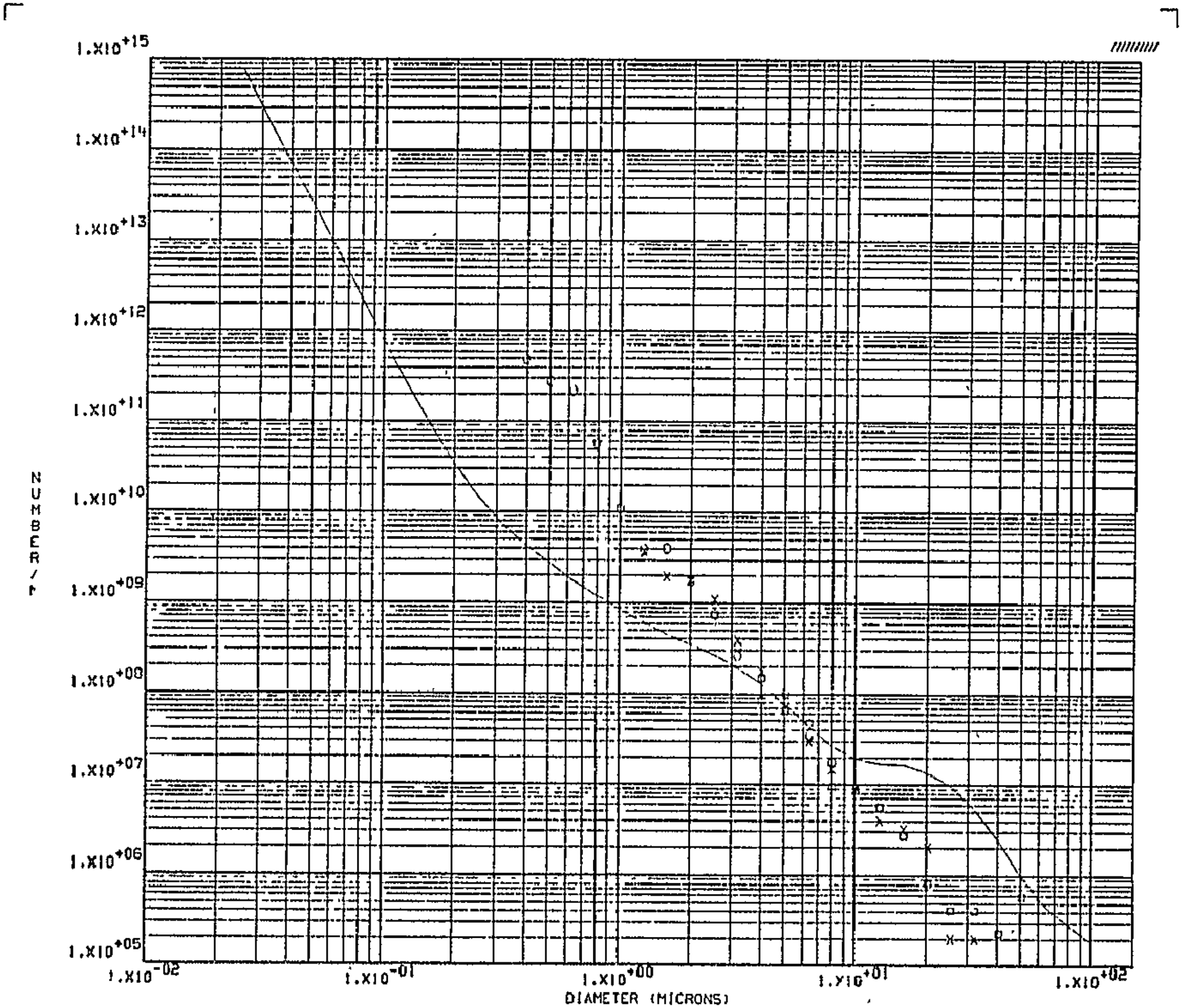
	INORGN 1	INORGN 2	PL FRG 1	DIATOMS
POPULATION	$1.492X10^{+12}$	$3.179X10^{+14}$	$4.358X10^{+11}$	$9.257X10^{+07}$
MODE DIAM	0.00	0.00	0.20	14.60
ALPHA	0.00	0.00	6.00	6.00
GAMMA	2.77	6.00	0.38	0.70



STATION 43 DEPTH 7 METERS

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-8	14 AUG 78	43	30 FT	2126	10	200	2.00	1.000
X	138-8	14 AUG 78	43	30 FT	2126	10	70	.50	1.000
O	138-8	14 AUG 78	43	30 FT	2126	10	15	.02	.100

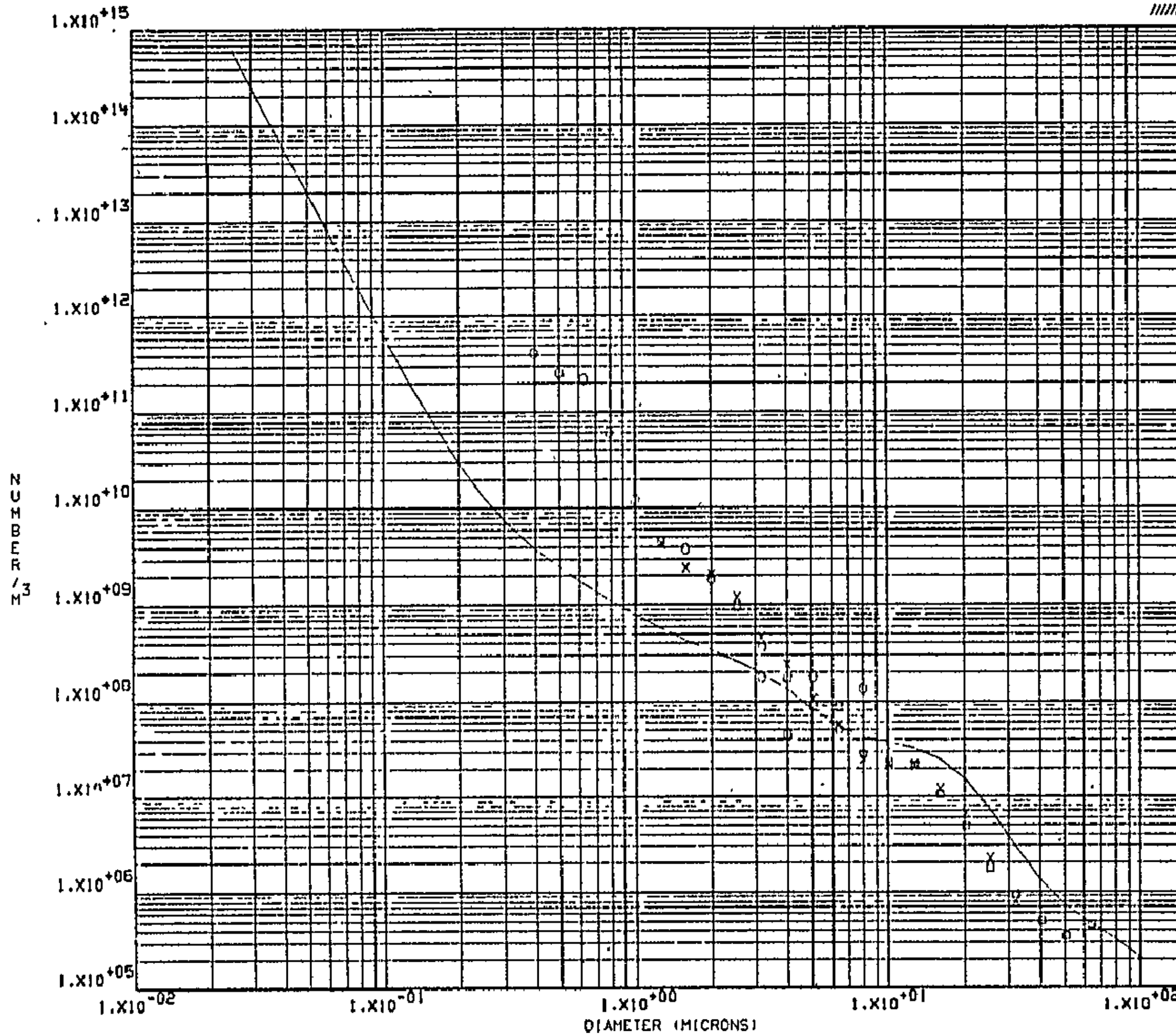
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	1.069X10+12	2.126X10+14	2.348X10+11	2.069X10+09	3.544X10+07
MODE DIAM	0.00	0.00	0.20	1.50	16.43
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	2.76	6.00	0.25	0.40	0.70



STATION 44 SURFACE

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-8	15 AUG 78	44	SURFACE	1430	11	200	2.00	1.000
X	138-8	15 AUG 78	44	SURFACE	1430	10	70	.50	1.000
O	138-8	15 AUG 78	44	SURFACE	1430	10	15	.01	1.000

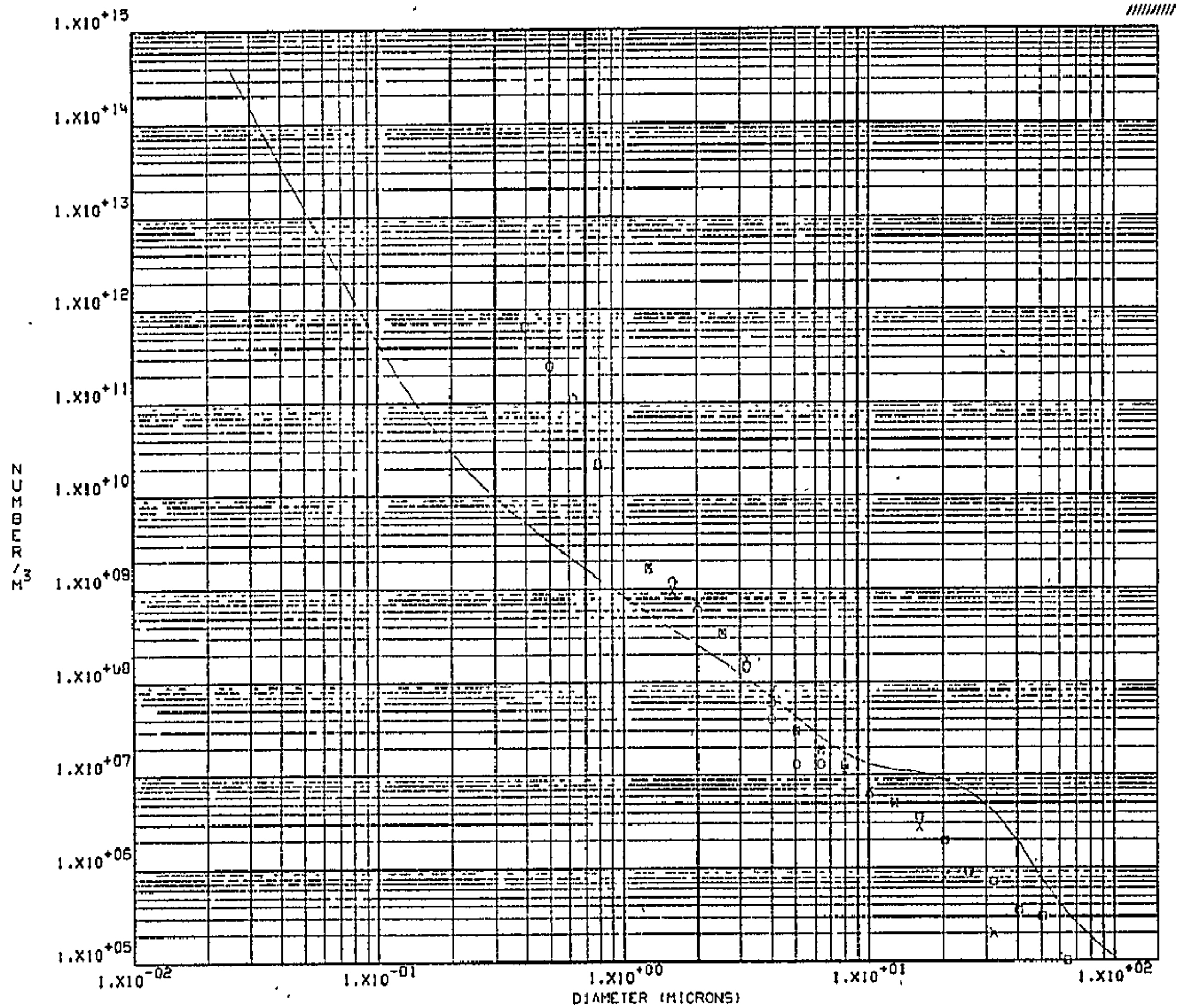
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$7.144\times10^{+11}$	$2.220\times10^{+14}$	$3.356\times10^{+09}$	$9.633\times10^{+08}$	$5.776\times10^{+07}$
MODE DIAM	0.00	0.00	0.20	1.50	15.07
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMM	2.76	6.00	0.25	0.40	0.70



STATION 44 DEPTH 5 METERS

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-8	15 AUG 78	44	18 FT	1455	10	200	2.00	1.000
X	138-8	15 AUG 78	44	18 FT	1455	10	70	.50	1 000
O	138-8	15 AUG 78	44	18 FT	1455	10	15	.01	.200

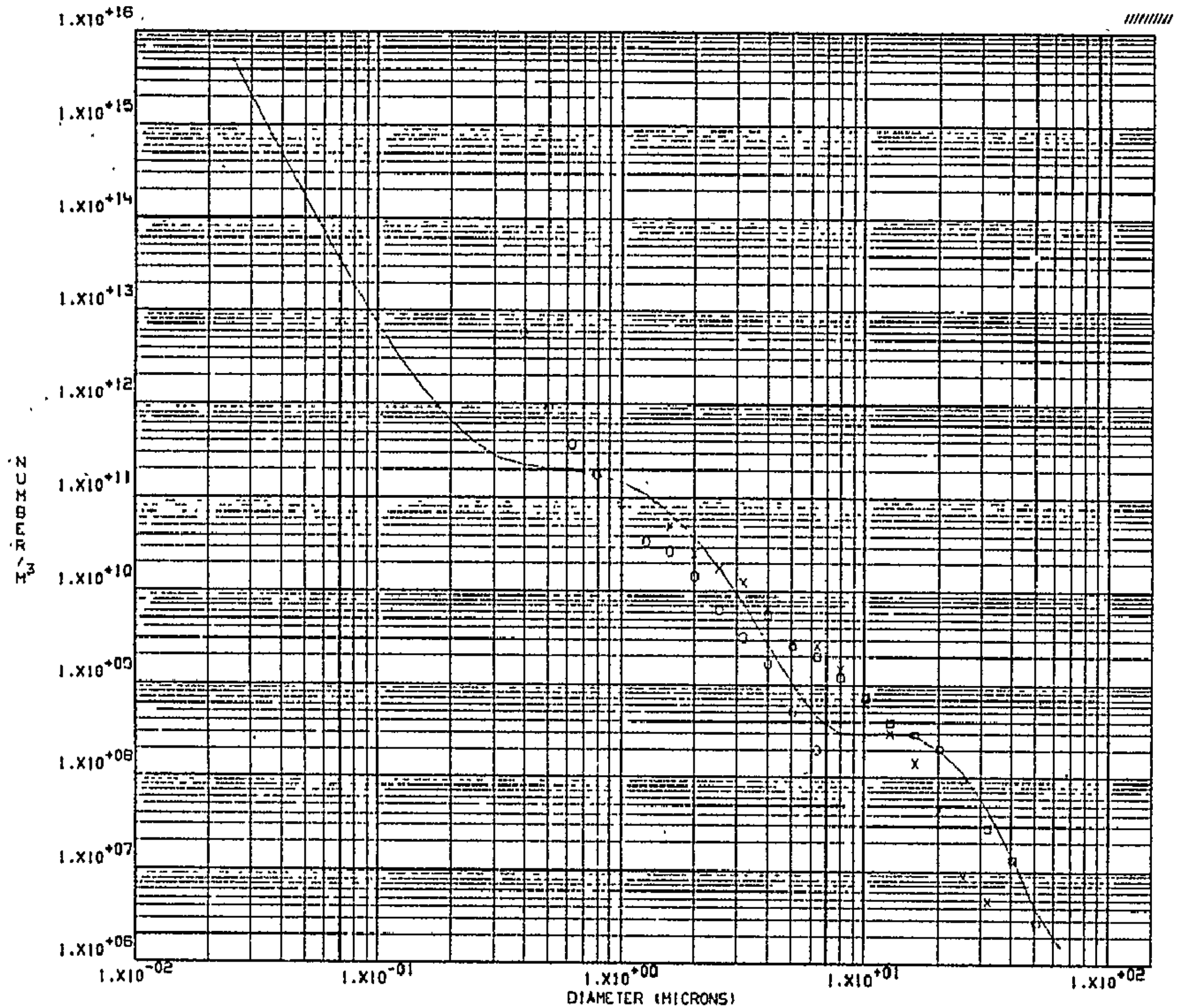
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$6.011\times10^{+11}$	$1.852\times10^{+14}$	$2.834\times10^{+09}$	$9.595\times10^{+08}$	$1.286\times10^{+08}$
MODE DIAM	0.00	0.00	0.20	1.52	10.43
ALPHA	0.00	0.00	6.00	6.00	6 00
GAMMA	2.72	6.00	0 25	0.40	0.70



STATION 44 DEPTH 21 METERS

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-8	15 AUG 78	44	66 FT	1540	10	200	2.00	1.000
X	138-8	15 AUG 78	44	66 FT	1540	10	70	.50	1.000
O	138-8	15 AUG 78	44	66 FT	1540	10	15	.01	1.000

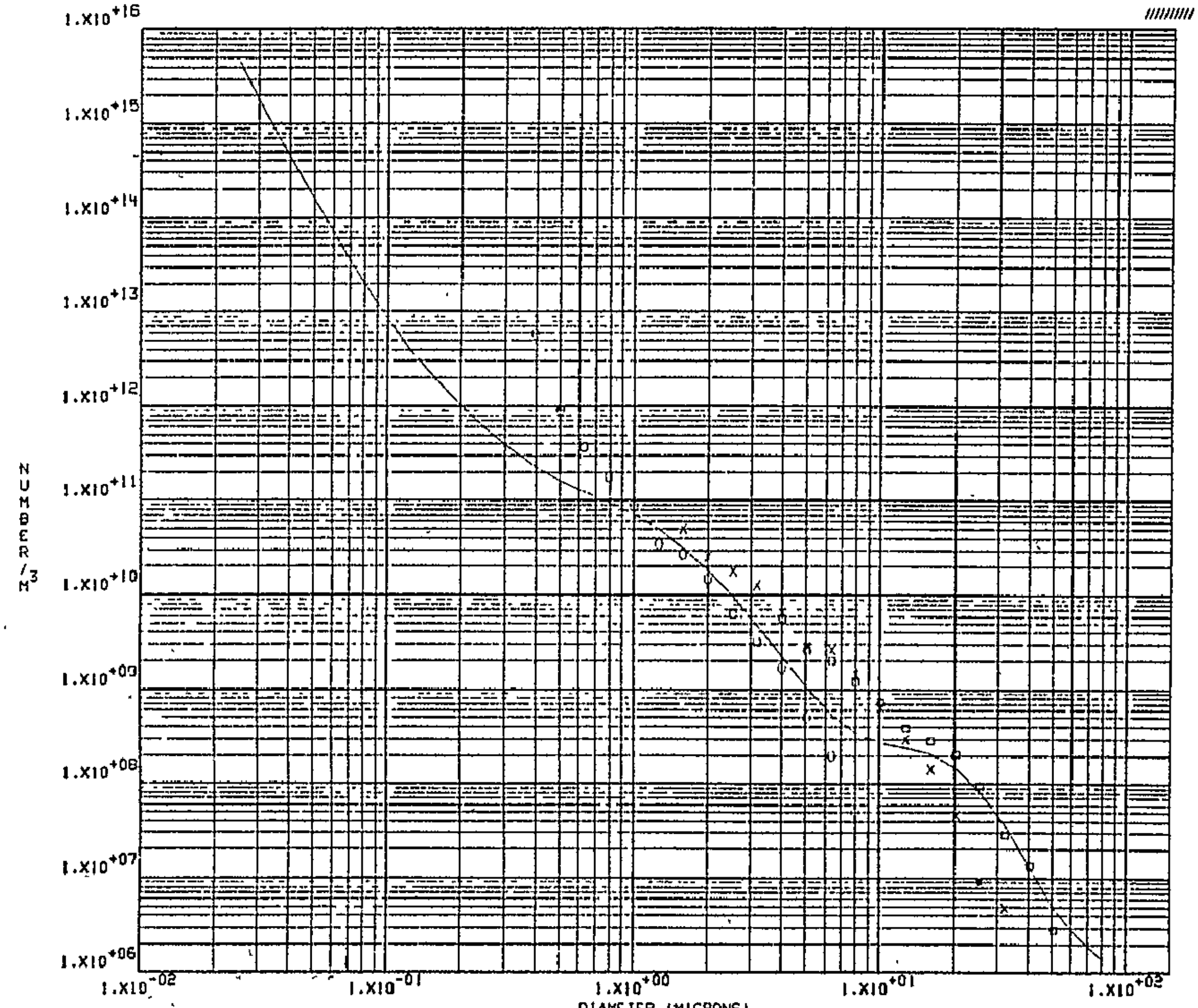
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$1.466X10^{+12}$	$1.123X10^{+14}$	$1.145X10^{+08}$	$1.145X10^{+08}$	$3.457X10^{+07}$
MODE DIAM	0.00	0.00	1.50	1.50	16.22
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	2.93	5 00	0 50	0.50	0.70



STATION 54 SURFACE

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-9	12 NOV 78	54	SURFACE	1715	10	200	2.00	.250
X	138-9	12 NOV 78	54	SURFACE	1715	10	70	.50	.250
O	138 9	12 NOV 78	54	SURFACE	1715	10	15	.02	.100

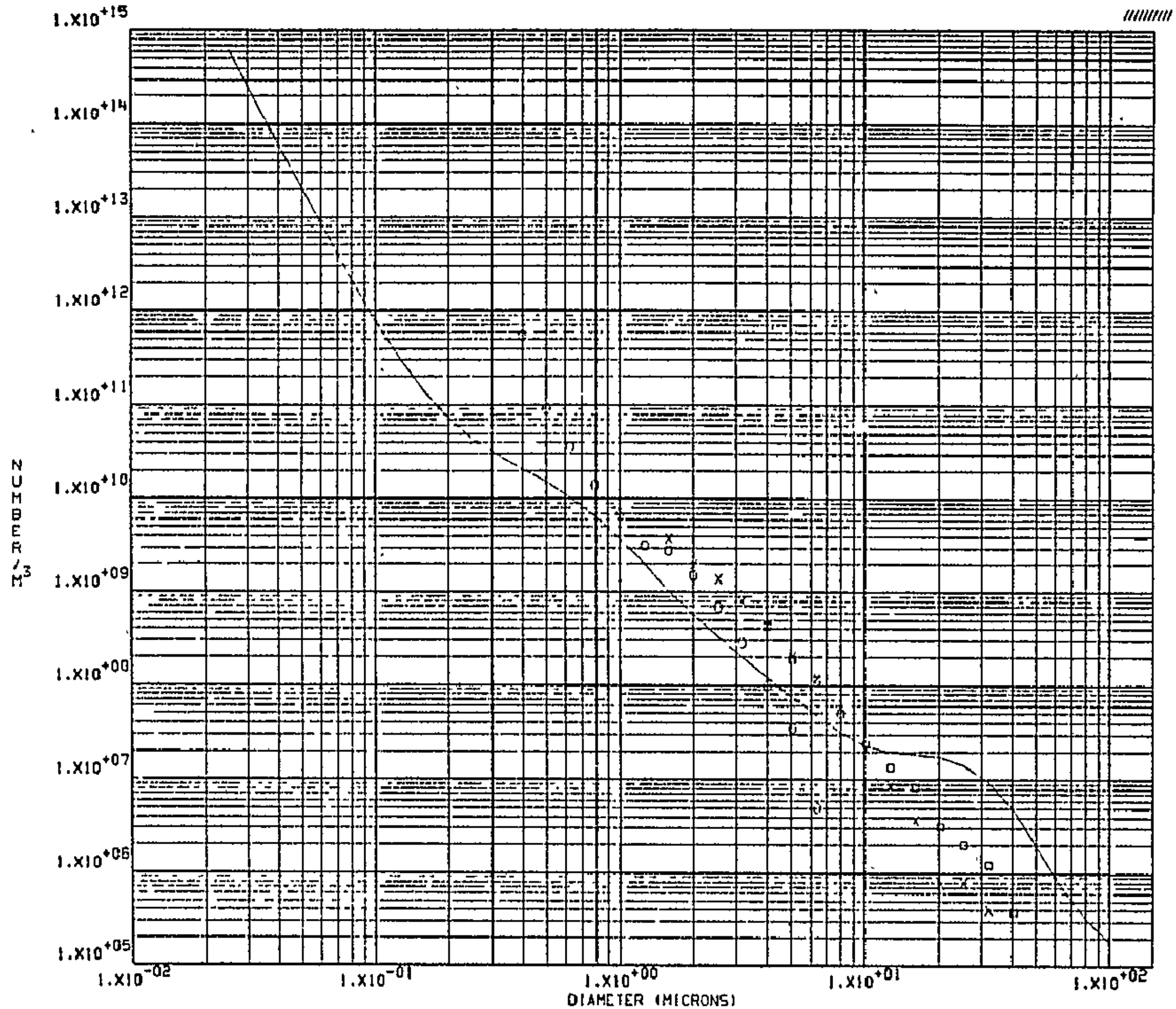
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$5.319 \times 10^{+13}$	$1.495 \times 10^{+15}$	$1.102 \times 10^{+12}$	$1.101 \times 10^{+10}$	$1.302 \times 10^{+09}$
MODE DIAM	0.00	0.00	0.50	1.50	12.49
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	3.21	6.00	0.36	0.50	0.70



STATION 54 SURFACE

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-9	12 NOV 78	54	SURFACE	1715	10	200	2.00	.250
X	138-9	12 NOV 78	54	SURFACE	1715	10	70	.50	.250
O	138-9	12 NOV 78	54	SURFACE	1715	10	15	.02	.100

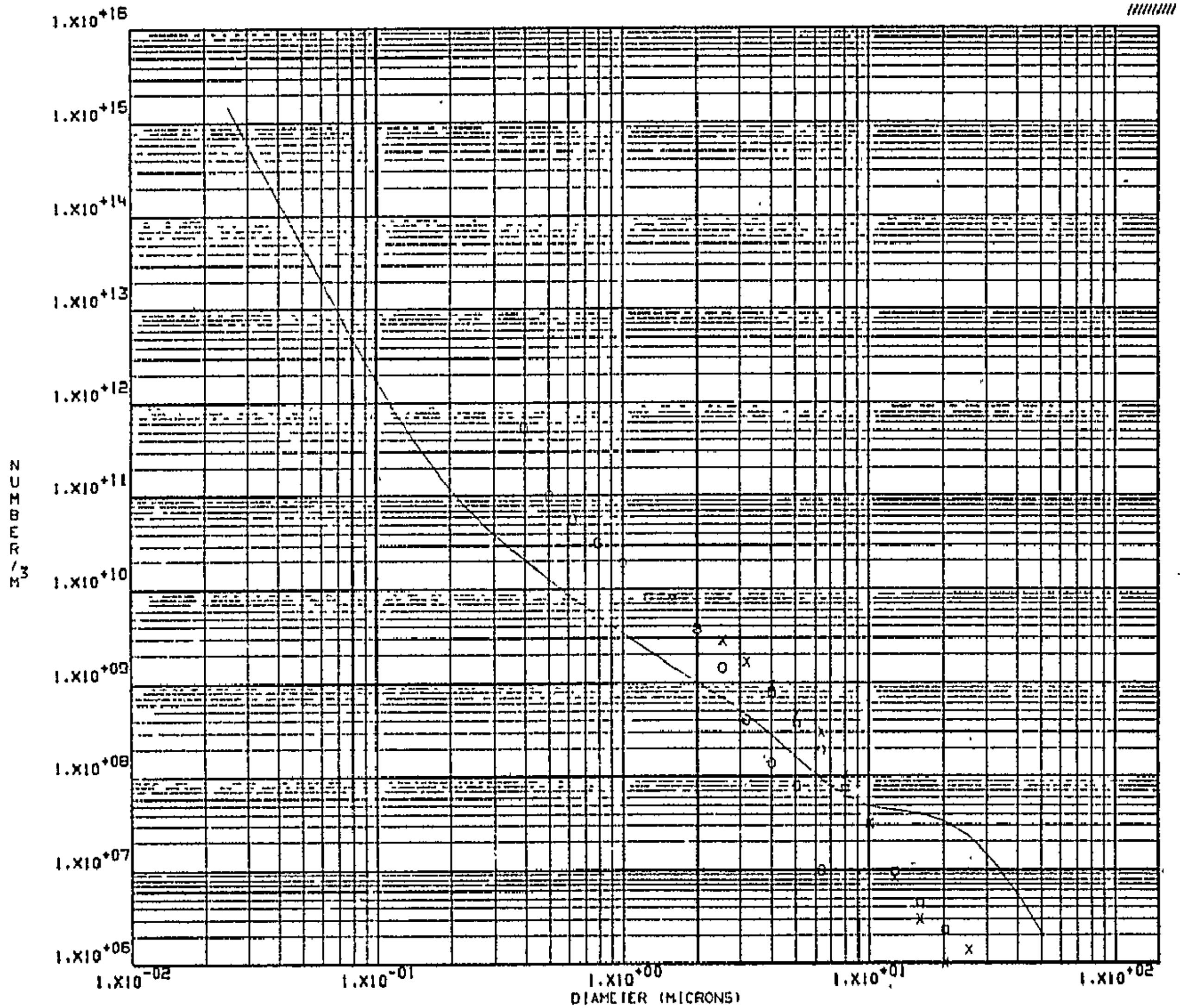
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$1.004 \times 10^{+14}$	$1.298 \times 10^{+15}$	$3.802 \times 10^{+11}$	$1.101 \times 10^{+10}$	$8.268 \times 10^{+08}$
MODE DIAM	0.00	0.00	0.50	1.50	12.50
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	3.23	6.00	0.36	0.50	0.70



STATION 54 DEPTH 15 METERS

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-9	12 NOV 78	54	49	1715	10	200	4 00	1.000
X	138-9	12 NOV 78	54	49	1715	10	70	.50	1.000
O	138 9	12 NOV 78	54	49	1715	10	15	02	1.000

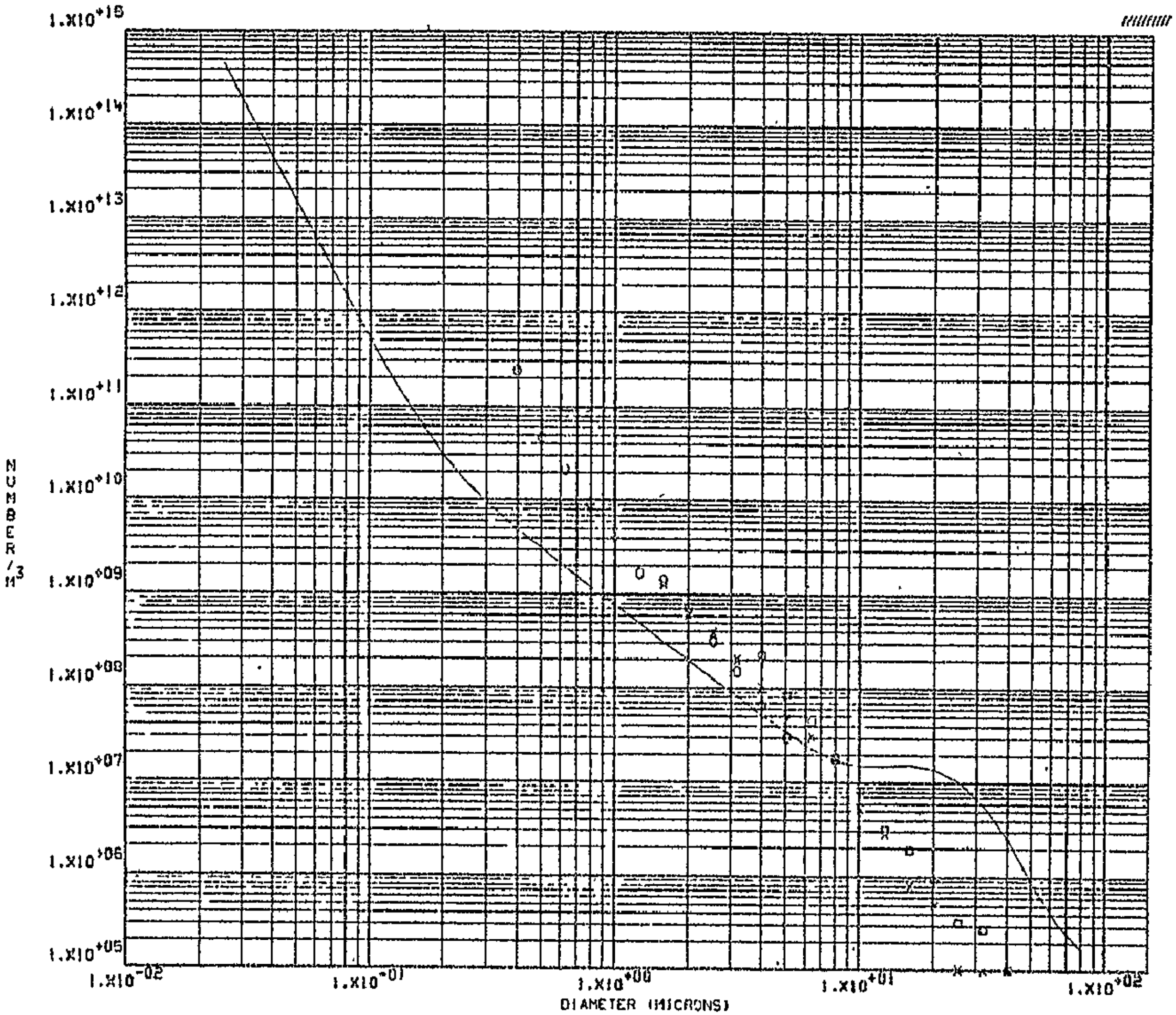
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$4.000X10^{+12}$	$1.815X10^{+14}$	$6.242X10^{+10}$	$1.096X10^{+08}$	$6.569X10^{+07}$
MODE DIAM	0 00	0.00	0.25	1.50	18 00
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	3.00	6 00	0.36	0.50	0.70



STATION 54 DEPTH 25 METERS

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-9	13 NOV 78	54	82	1715	10	200	4.00	1.000
X	138-9	13 NOV 78	54	82	1715	10	70	.50	1.000
O	138-9	13 NOV 78	54	82	1715	10	15	.02	1.000

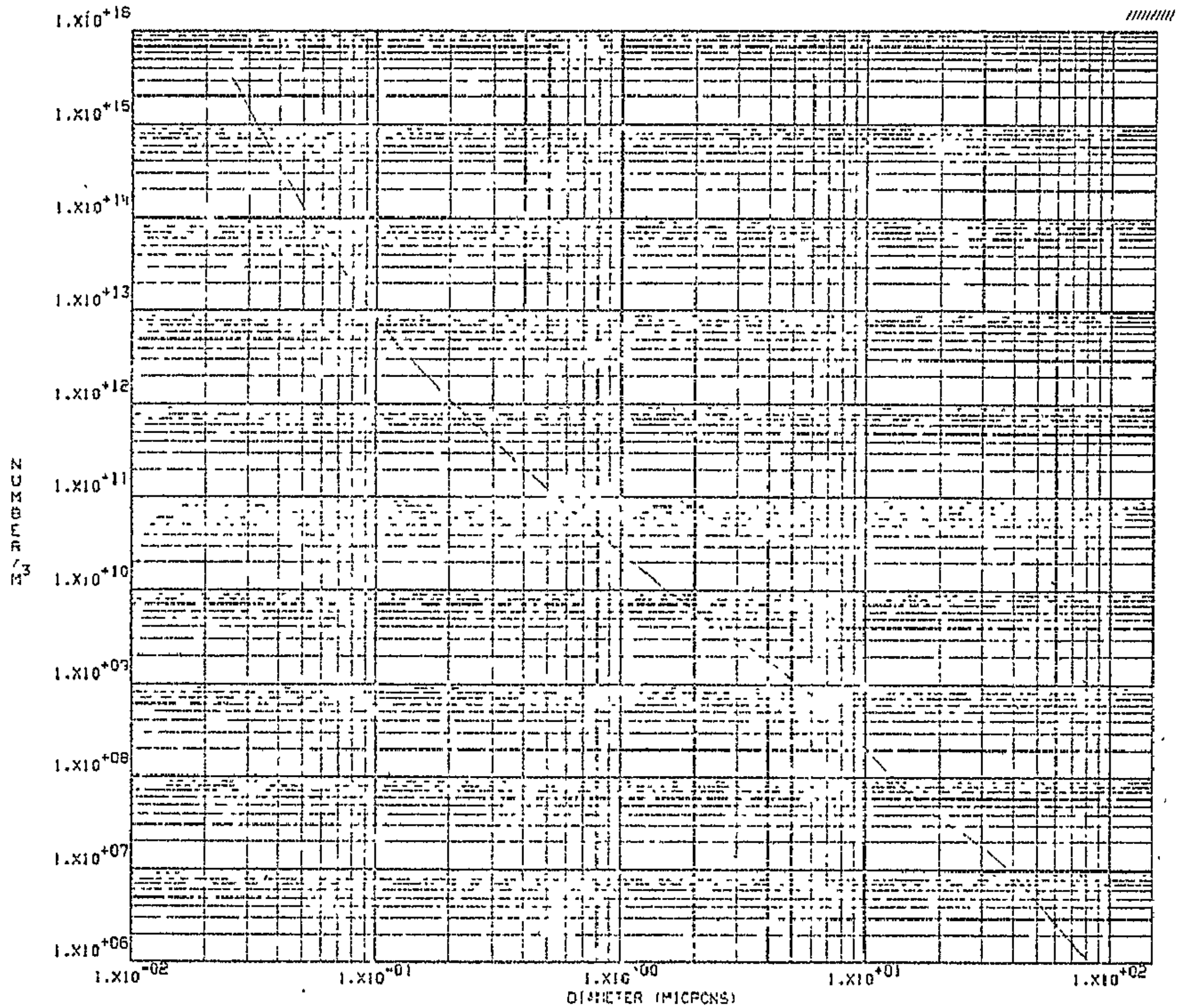
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	6.279X10+12	4.295X10+14	4.567X10+09	1.485X10+09	1.429X10+08
MODE DIAM	0.00	0.00	0.25	1.50	14.86
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	2.98	6.00	0.36	0.50	0.70



STATION 54 DEPTH 40 METERS

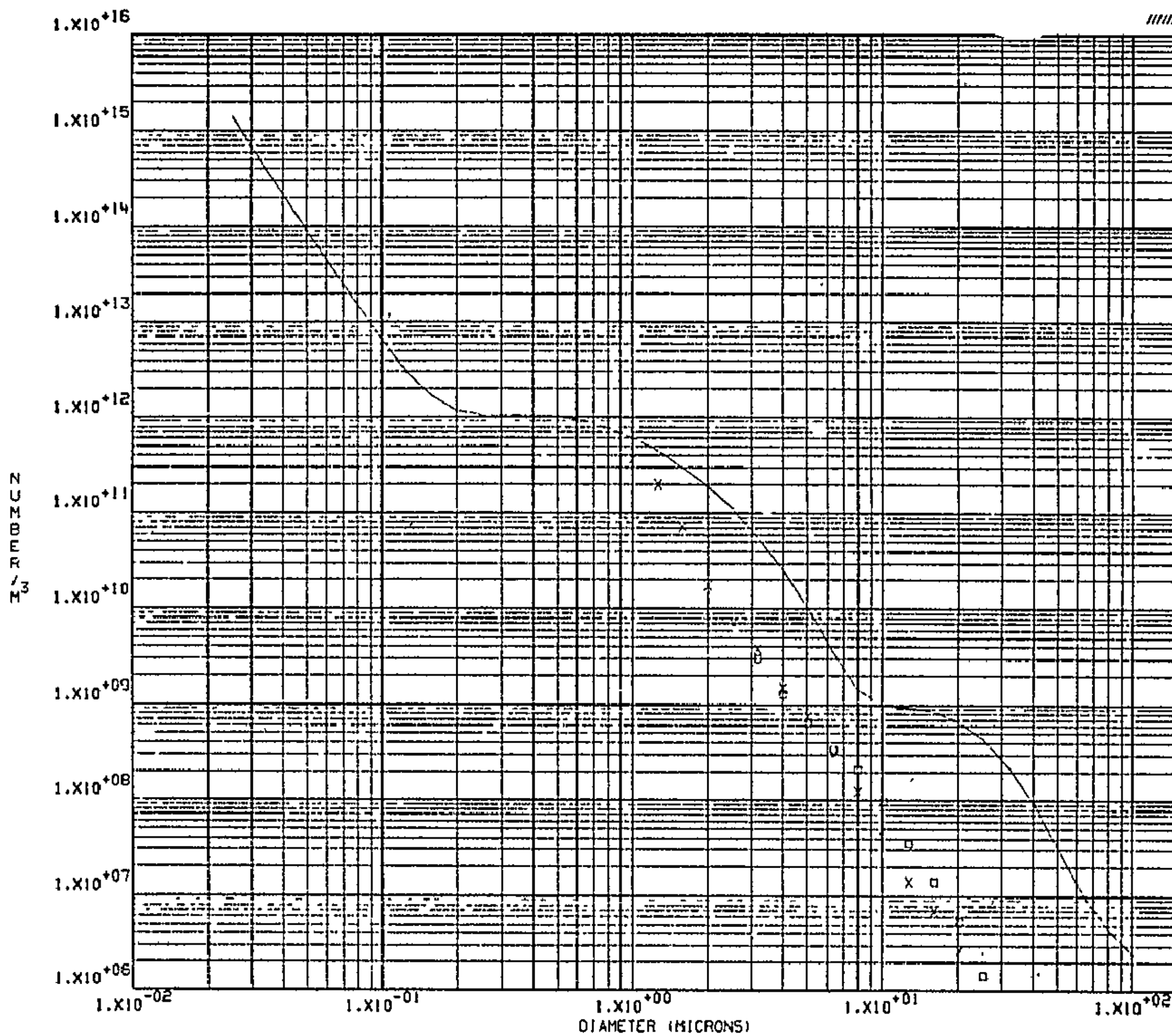
	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-9	13 NOV 78	54	131	1715	10	200	4.00	1.000
X	138-9	13 NOV 78	54	131	1715	10	70	1.00	1.000
O	138-9	13 NOV 78	54	131	1715	10	15	.02	1.000

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$1.277\times10^{+12}$	$1.379\times10^{+14}$	$1.517\times10^{+09}$	$1.568\times10^{+07}$	$6.181\times10^{+07}$
MODE DIAM	0.00	0.00	0.25	1.50	15.73
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	2.92	6.00	0.36	0.50	0.70



STATION 59 SURFACE

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	D.ATOMS
POPULATION	$1.299\times10^{+14}$	$9.829\times10^{+14}$	$3.605\times10^{+10}$	$8.496\times10^{+09}$	$4.913\times10^{+07}$
MODE DIAM	0.00	0.00	0.10	1.50	20.00
ALPHA	0.40	0.00	6.00	6.00	6.00
GAMMA	3.30	6.00	0.50	0.20	0.70



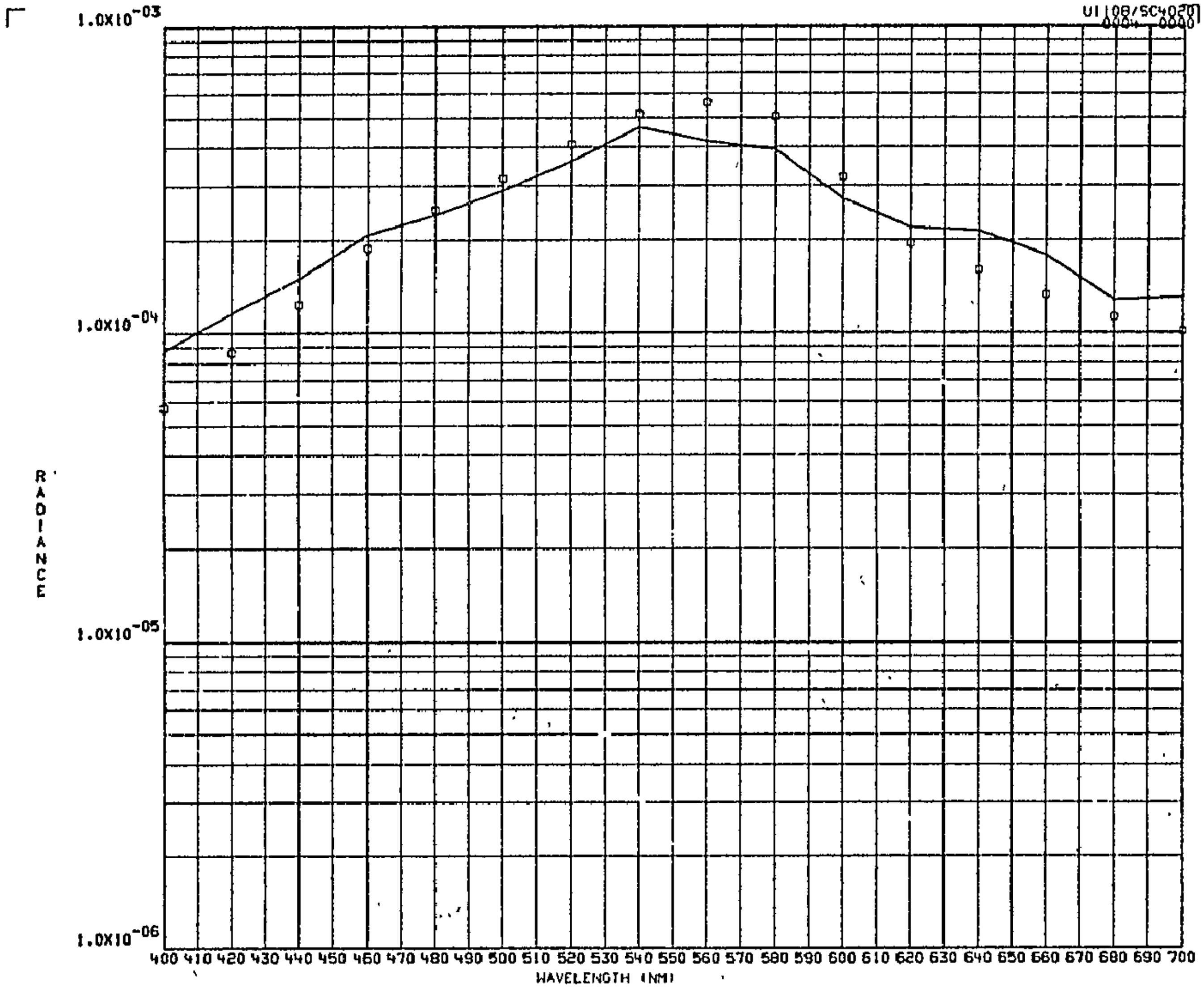
STATION 8 (FROM UPWELLING SPECTRUM)

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-3	07/21/77	8	SURFACE	1418	10	200	2.00	1.000
X	138-3	07/21/77	8	SURFACE	1418	9	50	.50	.500

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$5.876 \times 10^{+14}$	$8.644 \times 10^{+12}$	$8.877 \times 10^{+12}$	$2.372 \times 10^{+11}$	$4.843 \times 10^{+09}$
MODE DIAM	0.00	0.00	0.23	1.37	11.16
ALPHA	0.00	0 00	6.00	6.00	6.00
GAMMA	4.94	2.75	0.21	0.50	0.50

APPENDIX C

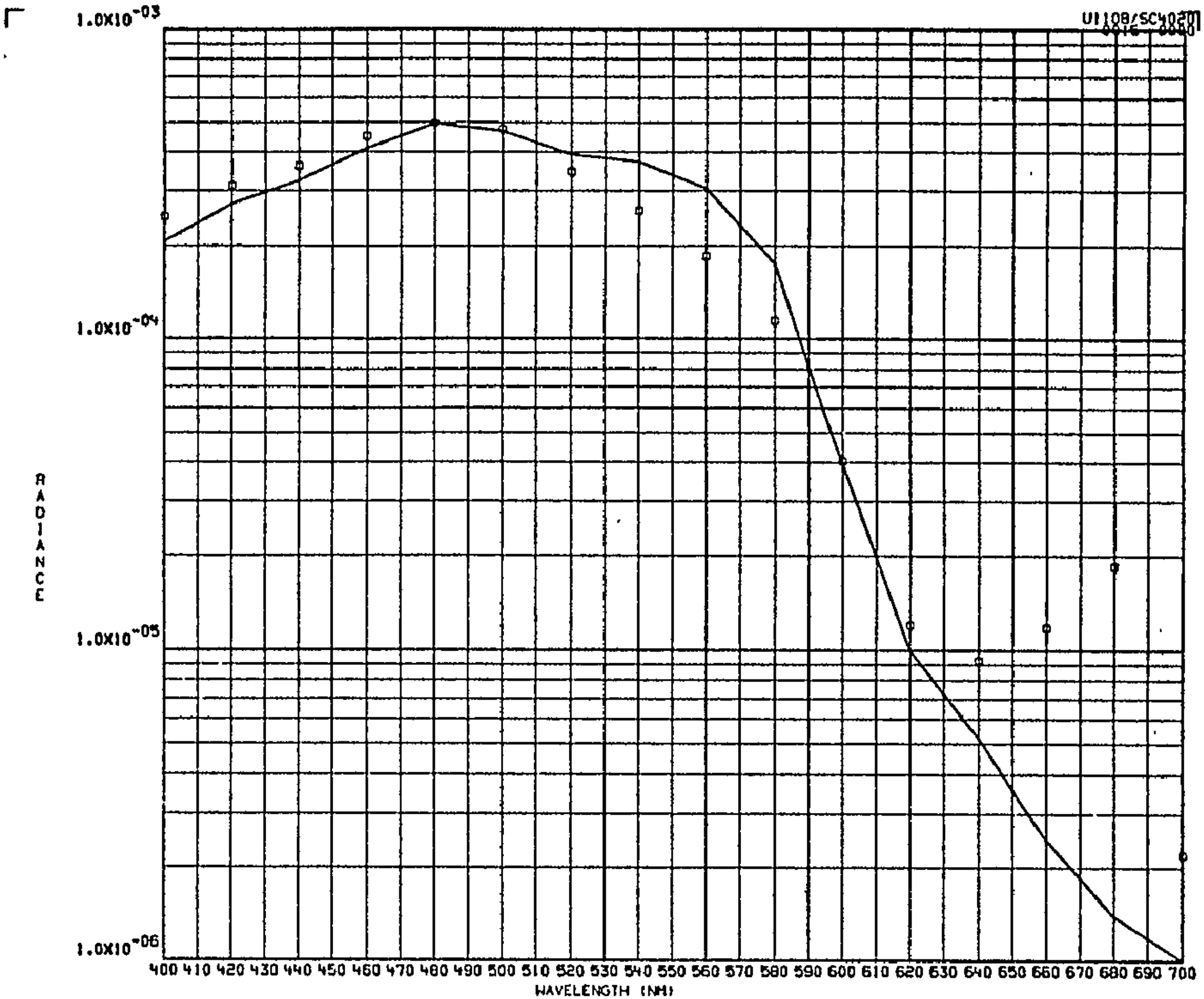
UPWELLING LIGHT SPECTRA



CHI SQUARE = 1.60×10^{-04} DEPTHS(M) IRRAD 0.00, RAD TOP 0.00, RAD BOT 4.57

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$6.988\times10^{+04}$	$1.034\times10^{+03}$	$1.060\times10^{+03}$	$3.621\times10^{+01}$	5.636×10^{-01}	$3.259\times10^{+00}$
MODE DIAM			0.23	1.37	11.16	
ALPHA			6.00	6.00	6.00	
GAMMA	4.94	2.75	0.21	0.50	0.50	

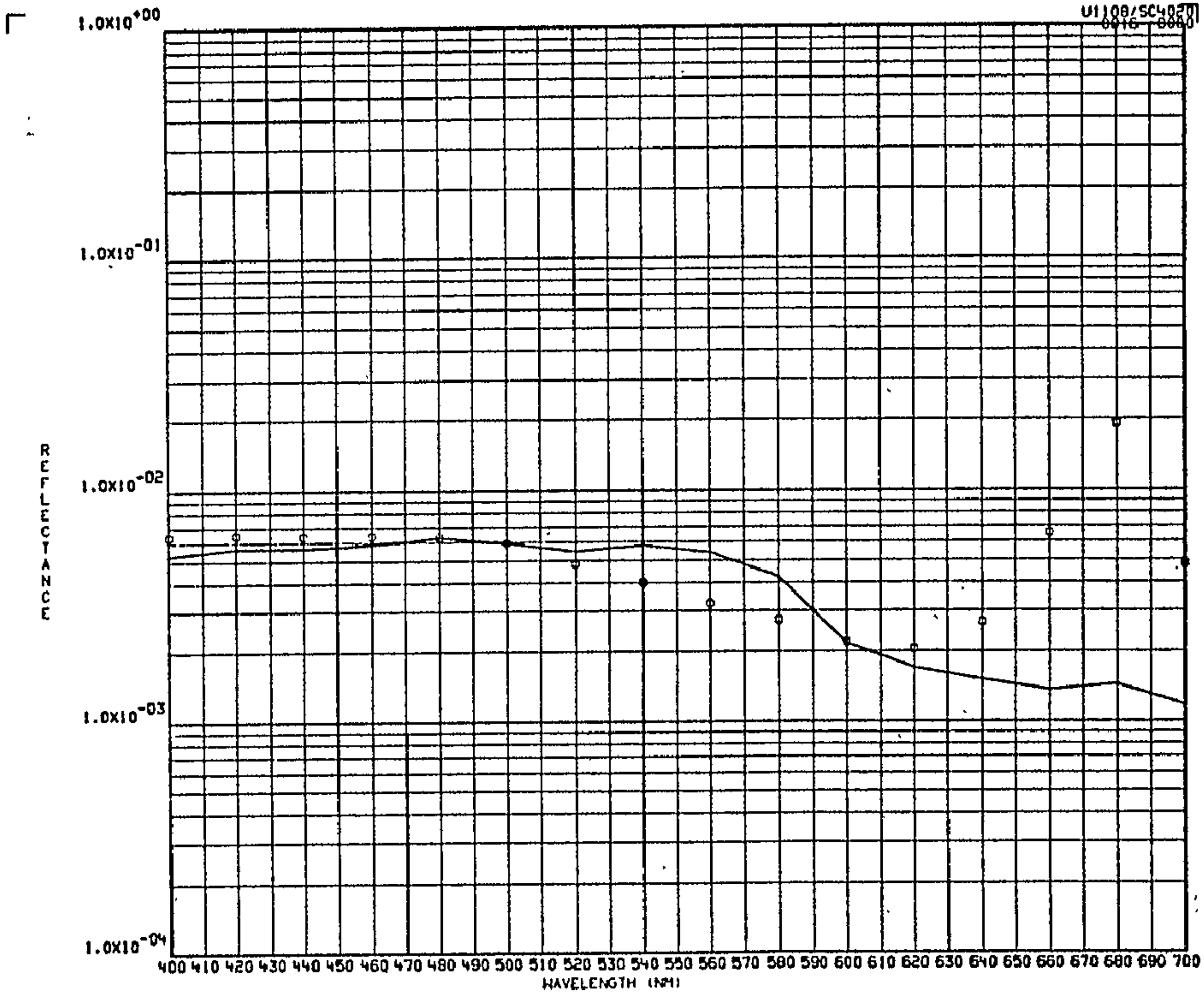
RUN TITLE- STATION 8



CHI SQUARE,= 3 85X10^{-04} DEPTHS(M) IRRAD 7.62, RAD TOP 7.62, INFINITELY DEEP SEA ASSUMED

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	5.771X10^{+03}	1.079X10^{+04}	5.628X10^{-01}	2.464X10^{+02}	6.627X10^{-02}	3.227X10^{-01}
MODE DIAM			1.00	0.50	15.00	
ALPHA			6.00	6.00	6.00	
GAMMA	3.23	7.00	0.40	0.40	0.70	

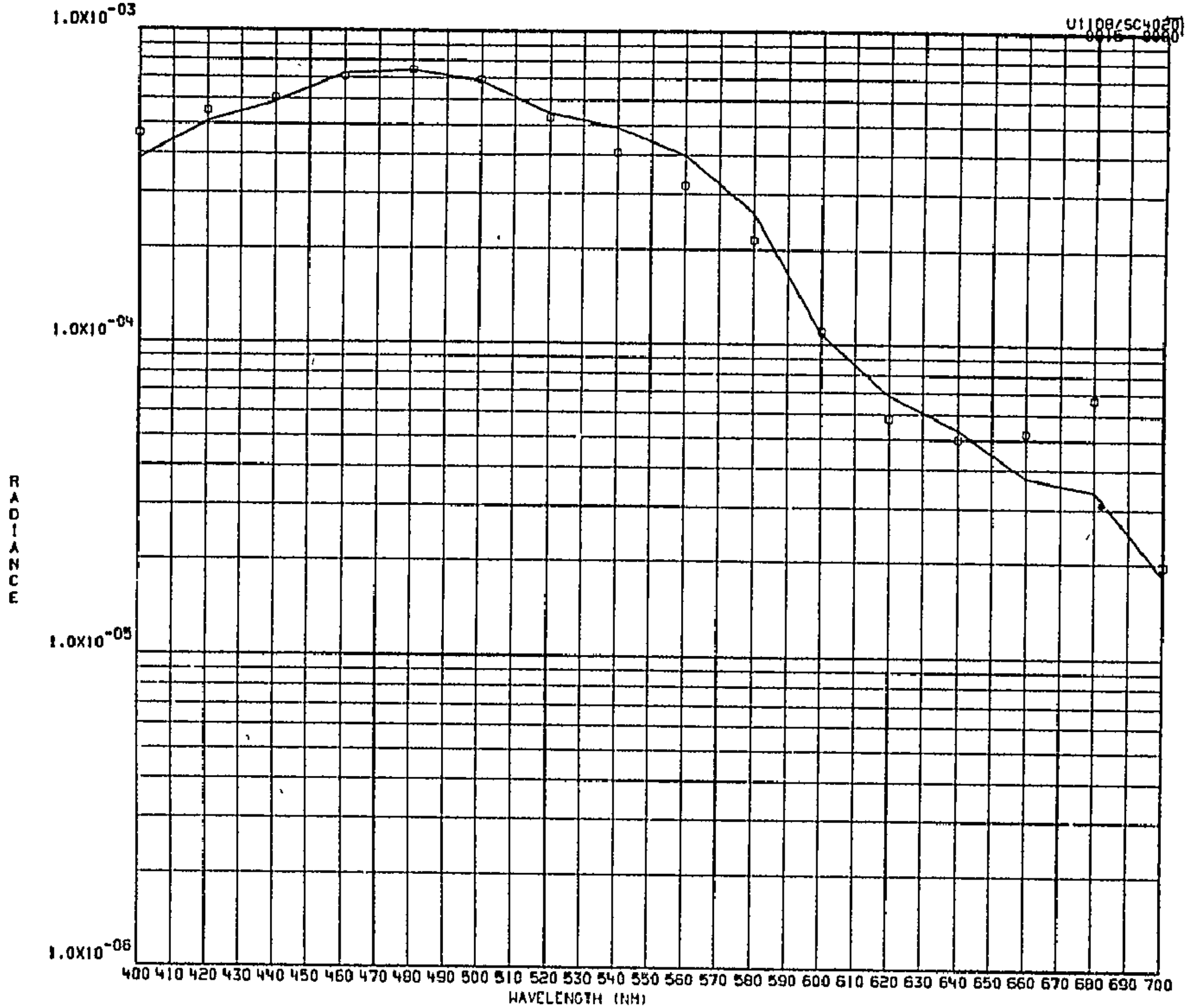
RUN TITLE- STATION 9



CHI SQUARE = 3.85X10^{-04} DEPTHS(M) IRRAD 7.62, RAD TOP 7.62, INFINITELY DEEP SEA ASSUMED

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	5.771X10^{+03}	1.079X10^{+04}	5.628X10^{-01}	2.464X10^{+02}	6.627X10^{-02}	3.227X10^{-01}
MODE DIAM			1.00	0.50	15.00	
ALPHA			6.00	6.00	6.00	
GAMMA	3.23	7.00	0.40	0.40	0.70	

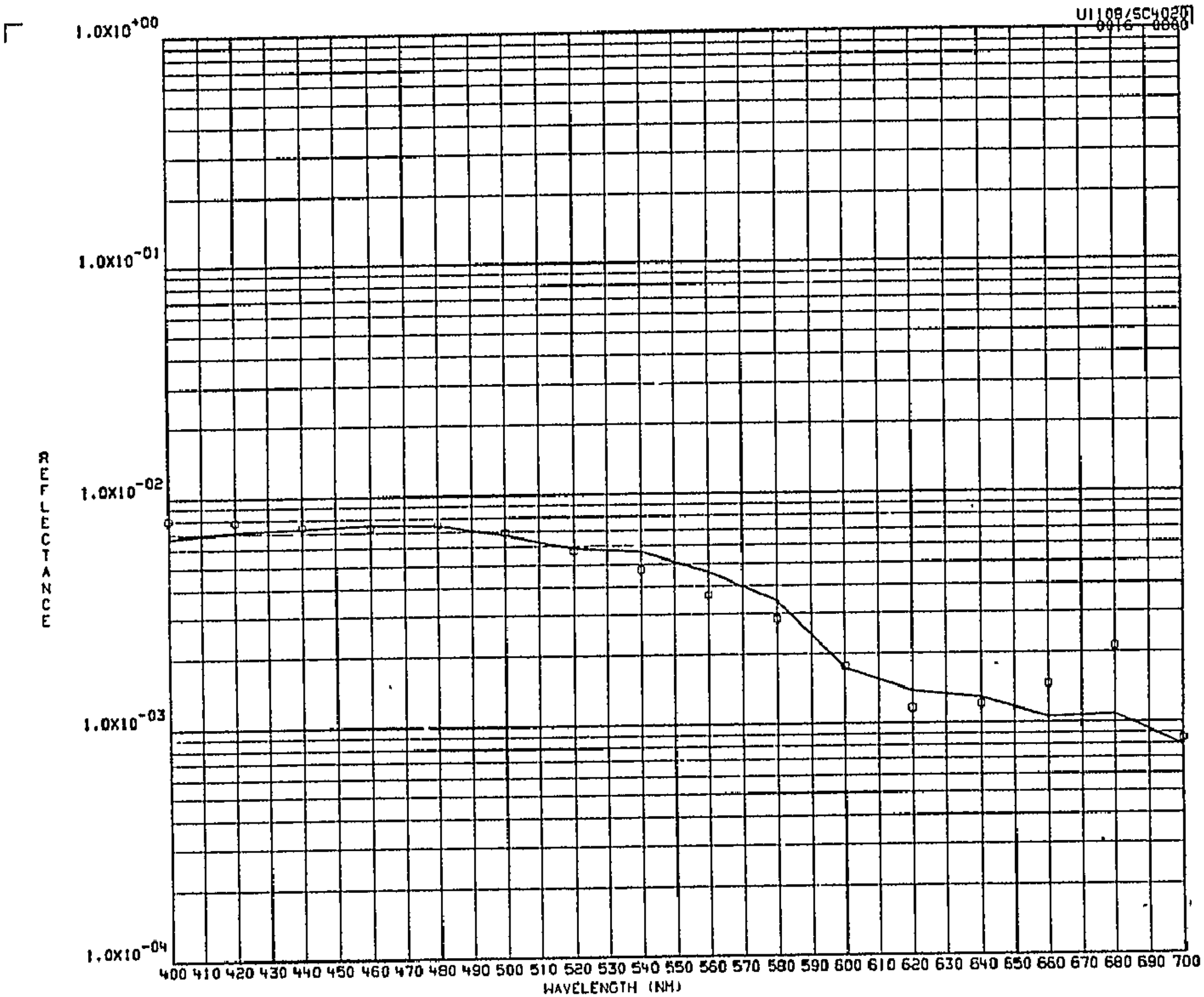
RUN TITLE- , STATION 9



CHI SQUARE = 9.77×10^{-05} INFITELY DEEP SEA (FROM SURFACE)

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$3.443 \times 10^{+04}$	$3.913 \times 10^{+02}$	$3.679 \times 10^{+02}$	$1.676 \times 10^{+01}$	2.517×10^{-02}	2.774×10^{-01}
MODE DIAM			0.23	1.37	11.16	0.00
ALPHA			6.00	6.00	6.00	0.00
GAMMA	4.94	3.00	0.21	0 50	0.50	0.00

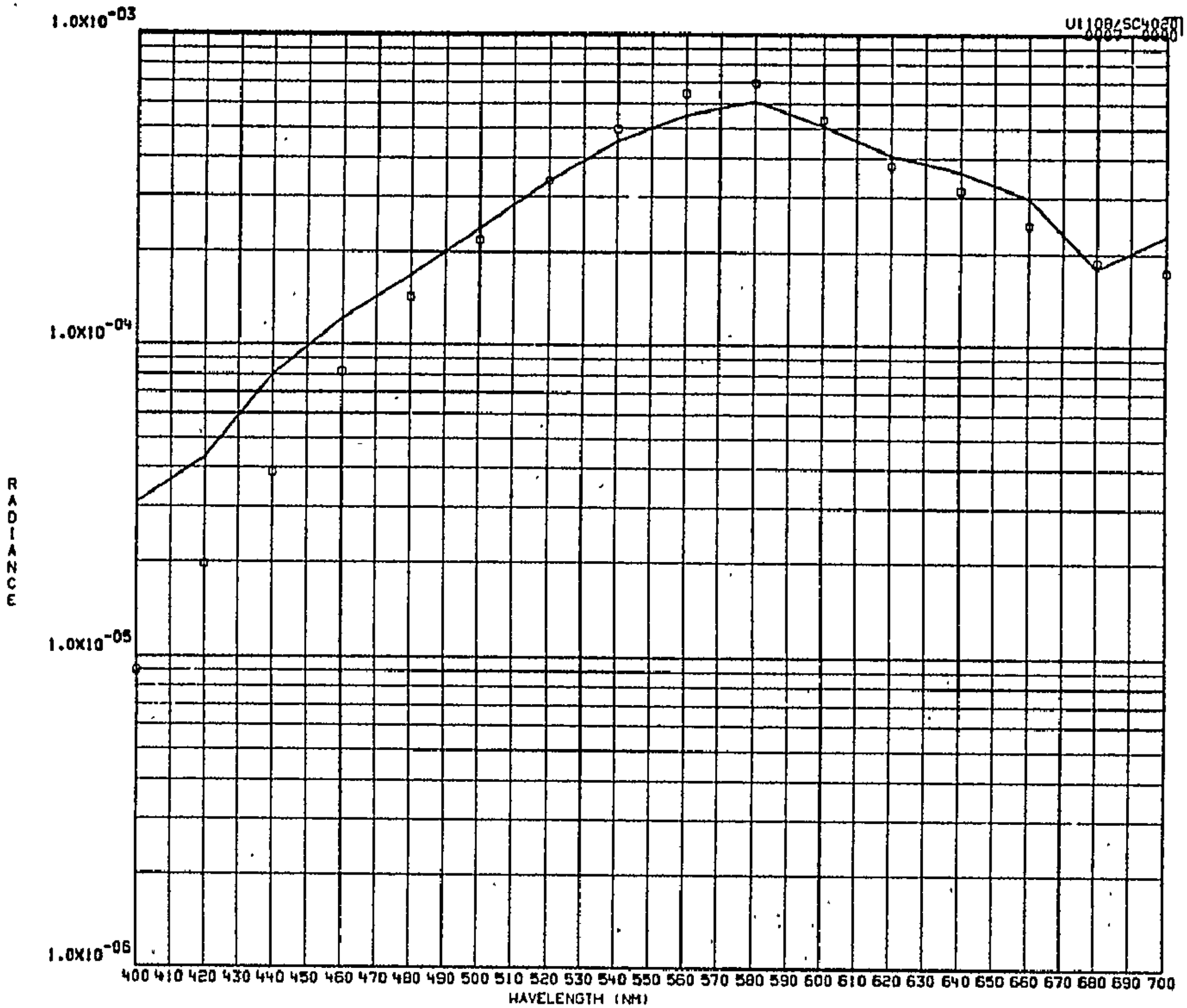
RUN TITLE- STATION 9



CHI SQUARE = 9.77×10^{-05}

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$3.443 \times 10^{+04}$	$3.913 \times 10^{+02}$	$3.679 \times 10^{+02}$	$1.676 \times 10^{+01}$	2.517×10^{-02}	2.774×10^{-01}
MODE DIAM			0.23	1.37	1	0.00
ALPHA			6.00	6.00		0.00
GAMMA	4.94	3.00	0.21	0.50		0.00

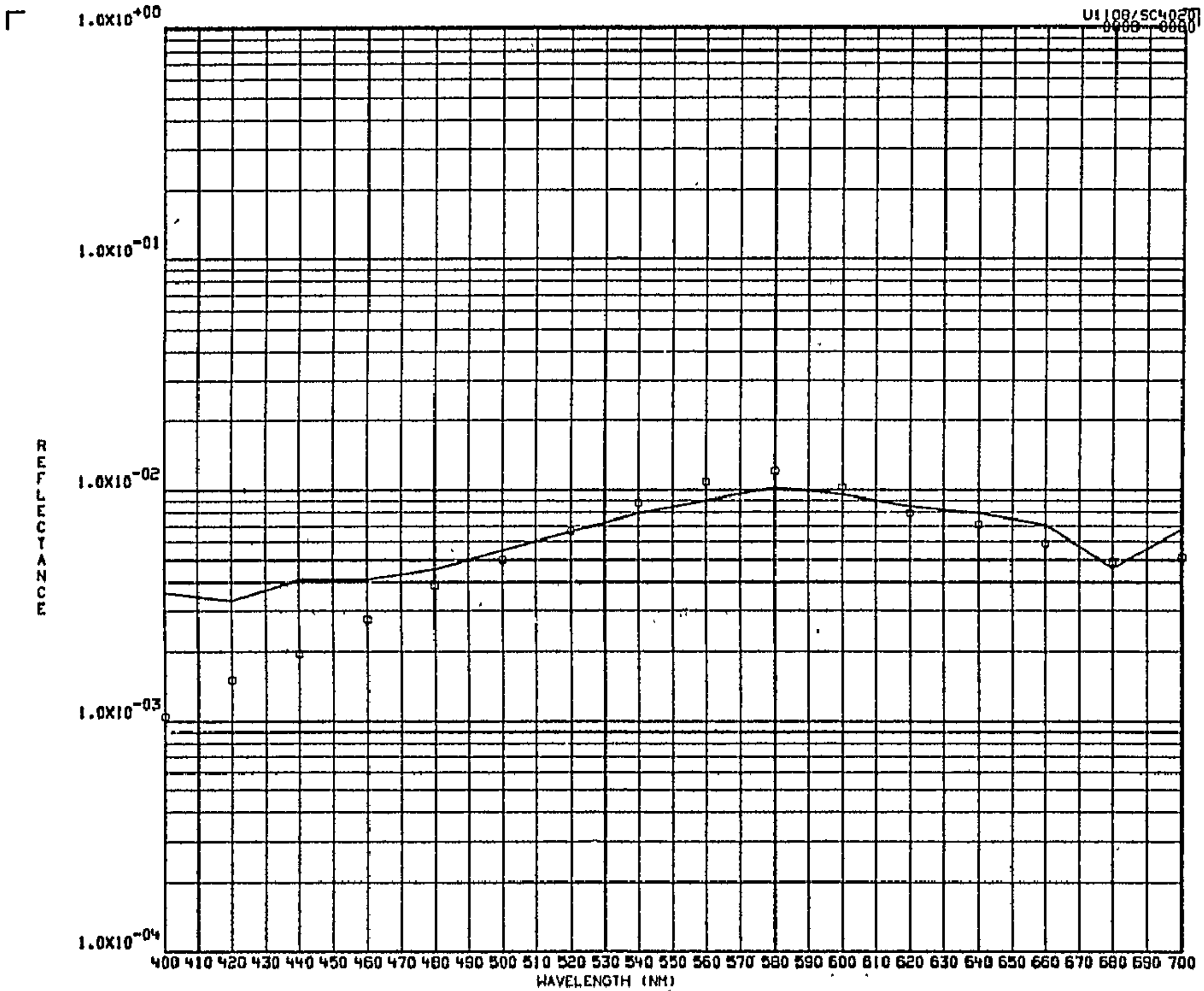
RUN TITLE- STATION 9



CHI SQUARE = 1.32×10^{-04} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 3.65

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$2.416 \times 10^{+03}$	$3.047 \times 10^{+02}$	$2.510 \times 10^{+03}$	4.719×10^{-01}	$1.458 \times 10^{+00}$	$3.385 \times 10^{+00}$
MODE DIAM			0.19	1.50	20.00	
ALPHA			6.00	6.00	6.00	
GAMMA	2.61	6.00	0.29	0.30	0.70	

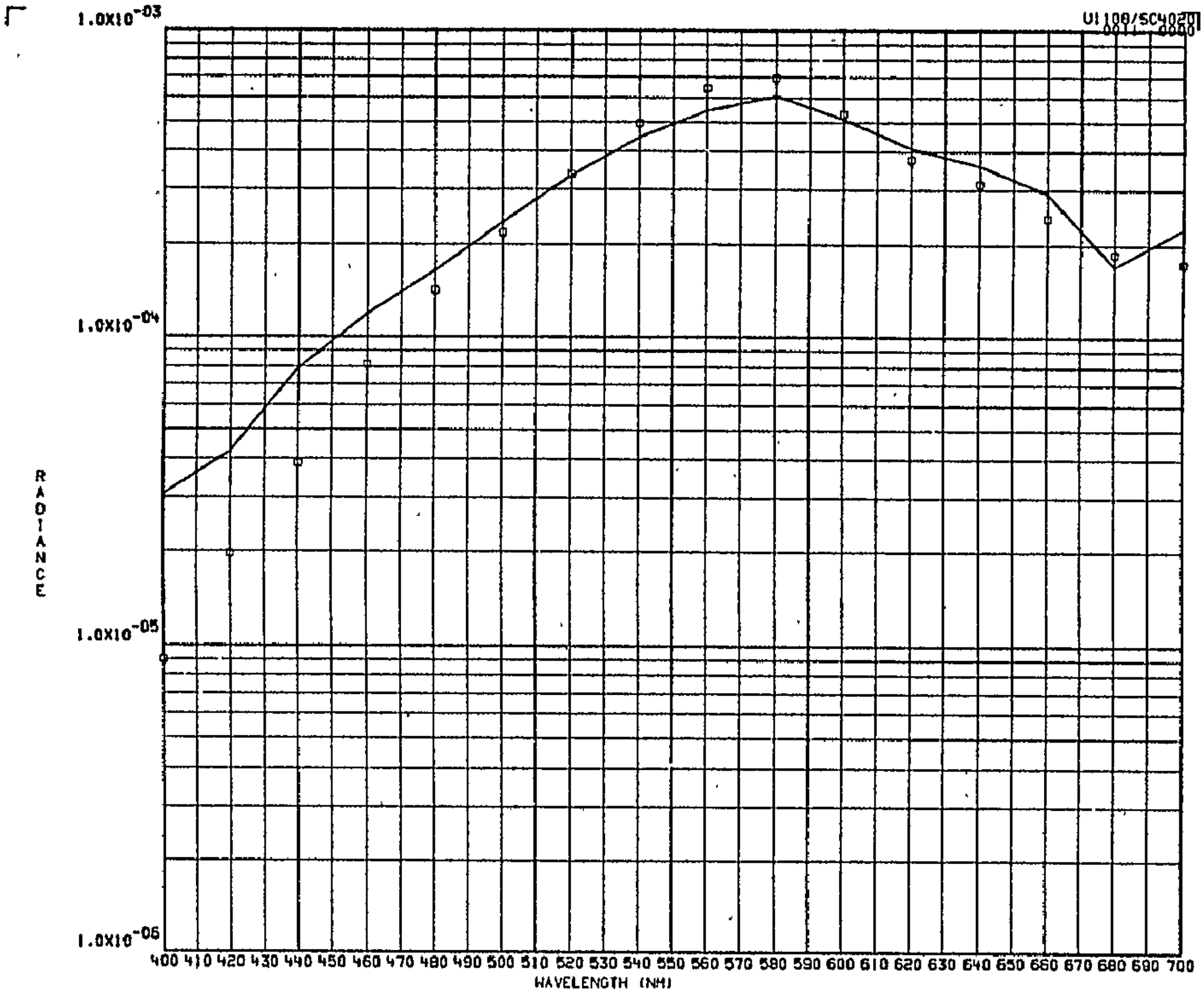
RUN TITLE- STATION 11



CHI SQUARE = 1.32X10^{-04} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 3.65

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	2.416X10^{+03}	3.047X10^{+02}	2.510X10^{+03}	4.719X10^{-01}	1.458X10^{+00}	3.385X10^{+00}
MODE DIAM			0.19	1.50	20.00	
ALPHA			6.00	6.00	6.00	
GAMMA	2.61	6.00	0.29	0.30	0.70	

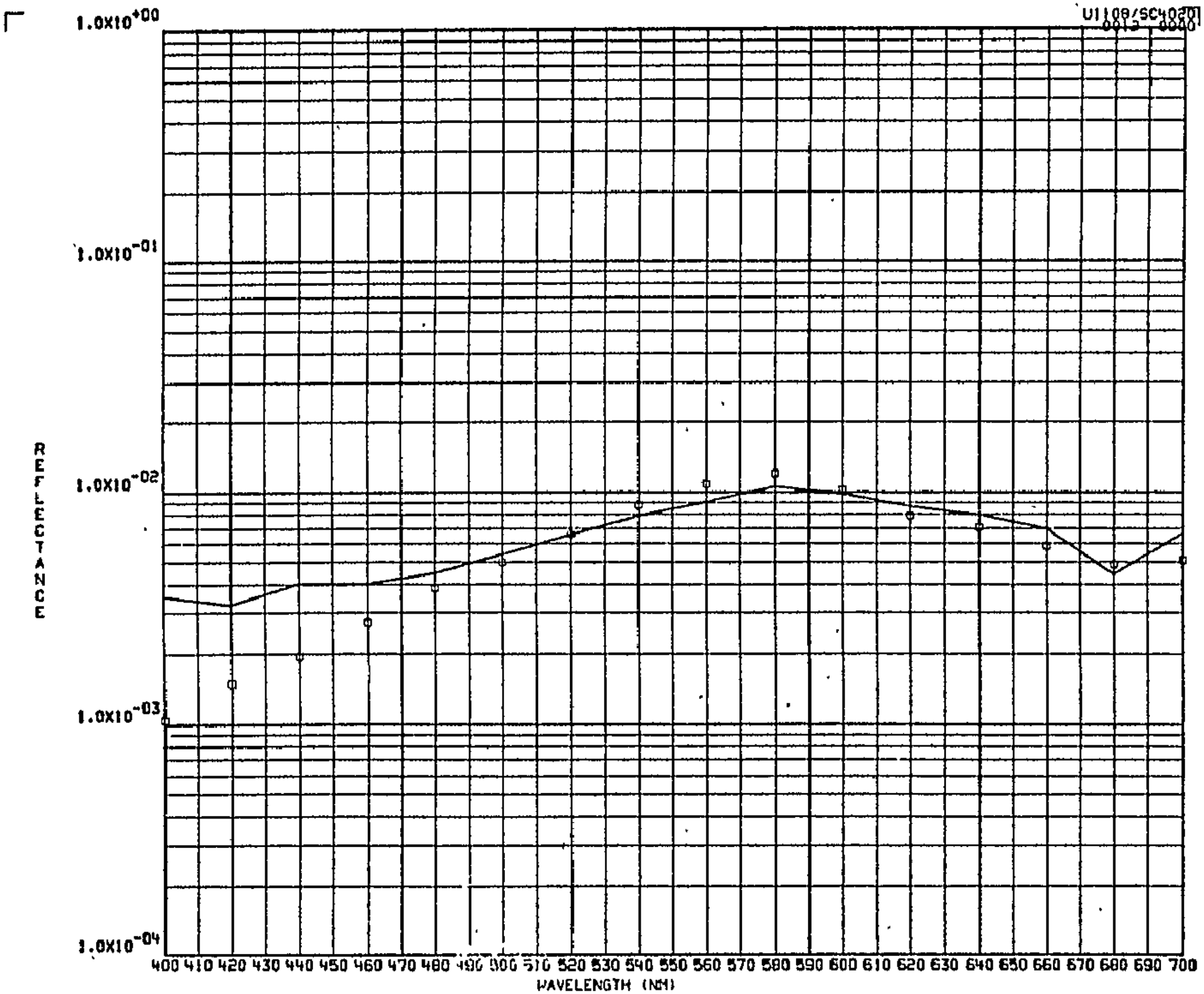
RUN TITLE- STATION 11



CHI SQUARE = 1.31X10^{-04} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, INFINITELY DEEP SEA ASSUMED

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	2.470X10^{+03}	2.632X10^{+02}	7.200X10^{+01}	4.610X10^{-01}	1.565X10^{+00}	3.476X10^{+00}
MODE DIAM			0.19	1.50	20.00	
ALPHA			6.00	6.00	6.00	
GAMMA	2.61	6.00	0.29	0.30	0.70	

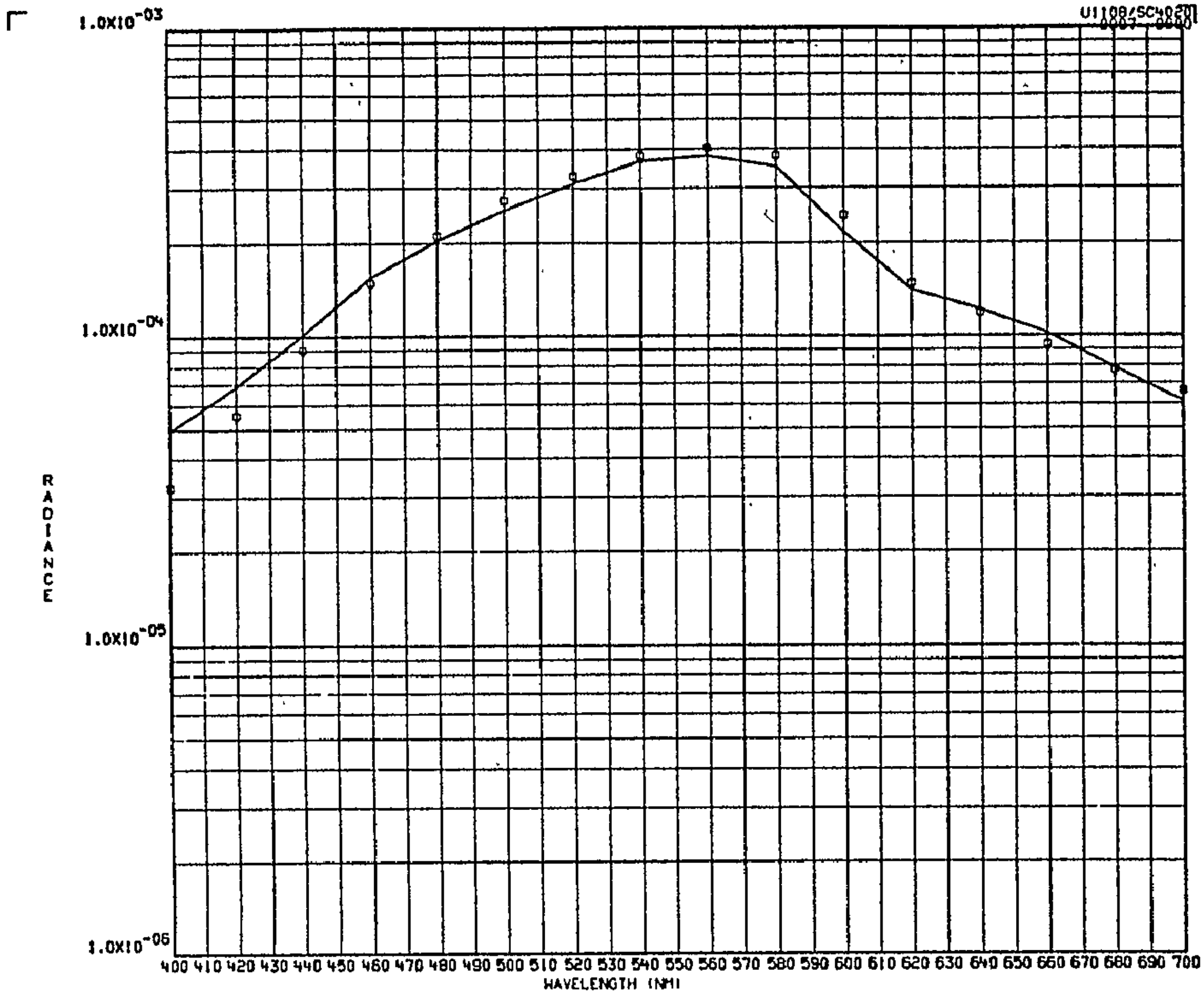
RUN TITLE- STATION 11



CHI SQUARE = 1.31×10^{-04} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, INFINITELY DEEP SEA ASSUMED

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$2.470 \times 10^{+03}$	$2.632 \times 10^{+02}$	$7.200 \times 10^{+01}$	4.610×10^{-01}	$1.565 \times 10^{+00}$	$3.476 \times 10^{+00}$
MODE DIAM			0.19	1.50	20.00	
ALPHA			6.00	6.00	6.00	
GAMMA	2.61	6.00	0.29	0.30	0.70	

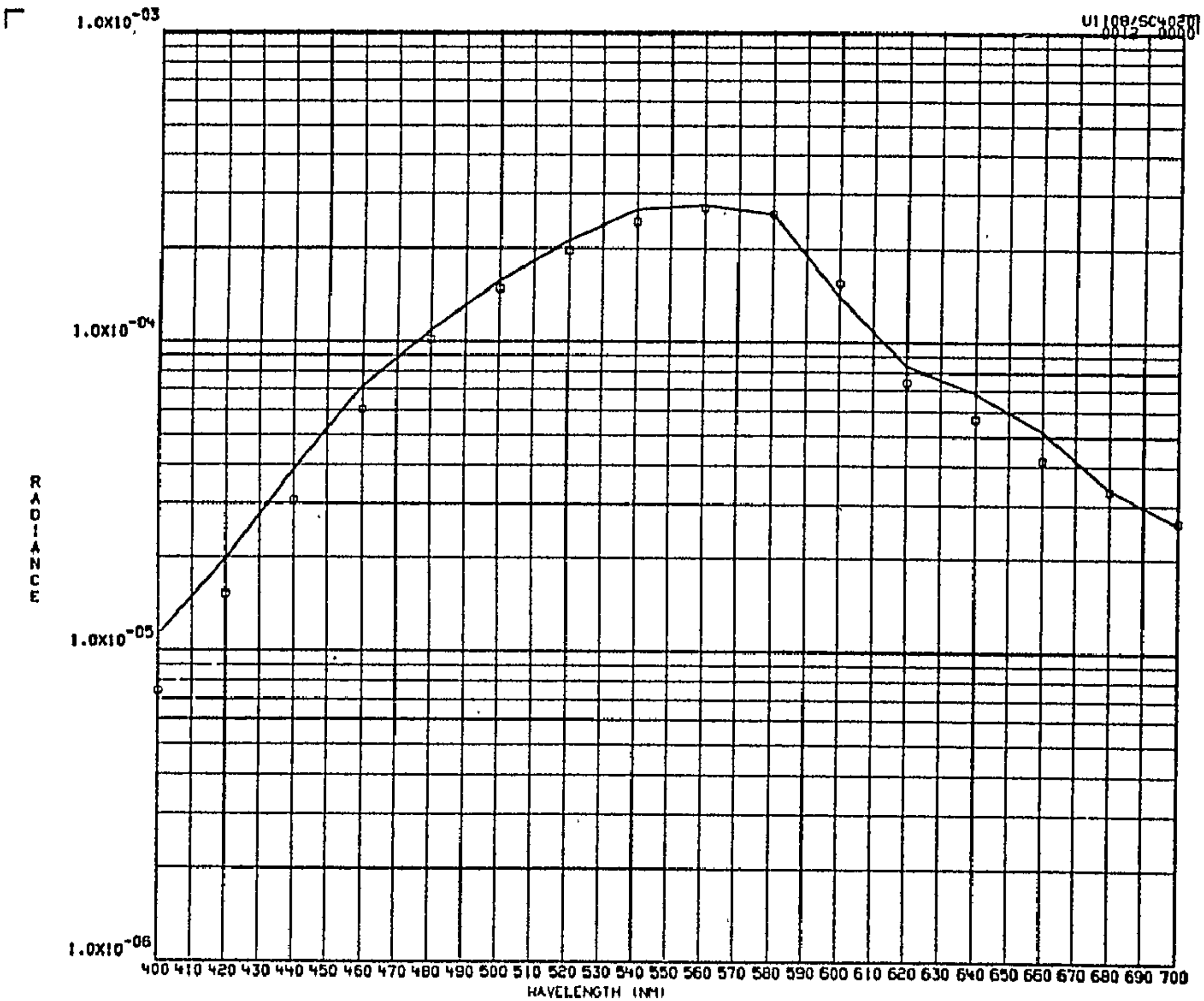
RUN TITLE- STATION 11



CHI SQUARE = $2.18X10^{-05}$ DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 2.13

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$3.368X10^{+02}$	$5.349X10^{+02}$	$8.654X10^{+02}$	$3.468X10^{+00}$	$1.933X10^{-01}$	$1.064X10^{+00}$
MODE DIAM			0.29	1.51	15.00	
ALPHA			6.00	6.00	6.00	
GAMMA	6.00	2.85	0.29	0.40	0.70	

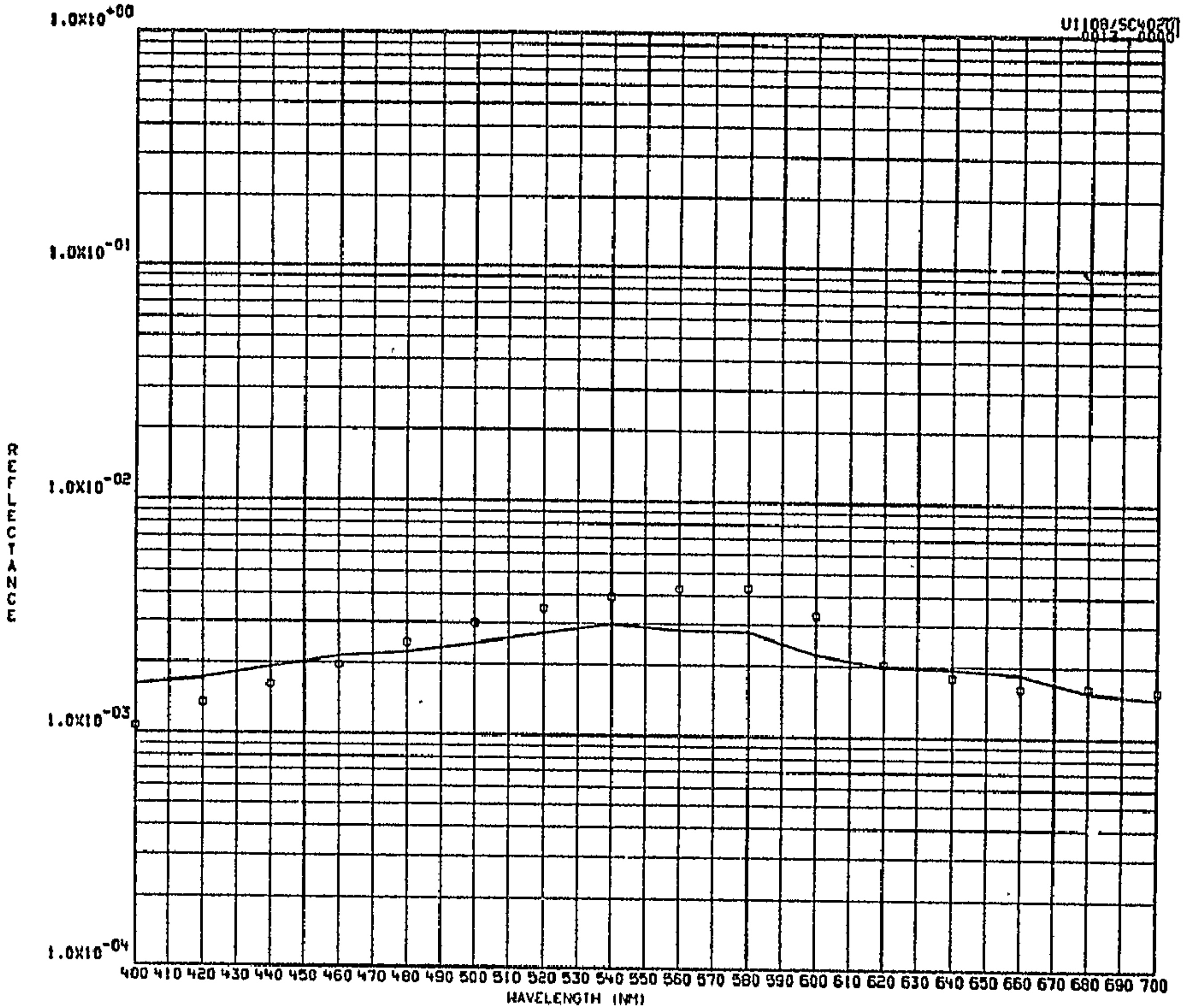
RUN TITLE- STATION 12



CHI SQUARE = 1.71×10^{-05} DEPTHS(M) IRRAD 2.13, RAD TOP 2.13, RAD BOT 4.26

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$3.413\times10^{+01}$	$9.596\times10^{+02}$	$6.723\times10^{+02}$	$1.644\times10^{+00}$	2.379×10^{-01}	$2.033\times10^{+00}$
MODE DIAM			0.29	1.51	15.00	
ALPHA			6.00	6.00	6.00	
GAMMA	6.00	2.85	0.29	0.40	0.70	

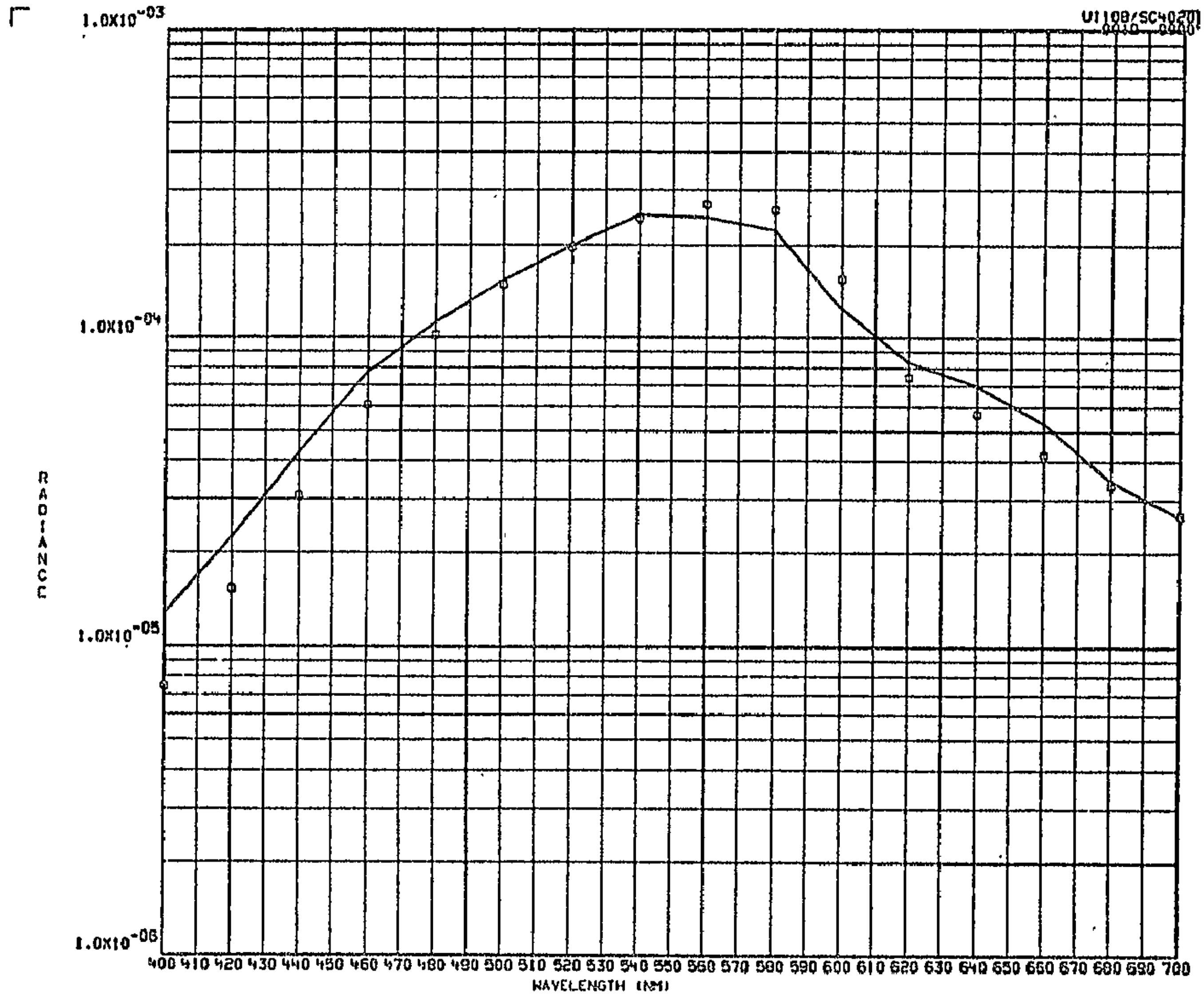
RUN TITLE- STATION 12



CHI SQUARE = 1.71X10^{-05} DEPTHS(M) IRRAD 2.13, RAD TOP 2.13, RAD BOT 4.26

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	3.413X10^{+01}	9.596X10^{+02}	6.723X10^{+02}	1.644X10^{+00}	2.379X10^{-01}	2.033X10^{+00}
MODE DIAM			0.29	1.51	15.00	
ALPHA			6.00	6.00	6.00	
GAMMA	6.00	2.85	0.29	0.40	0.70	

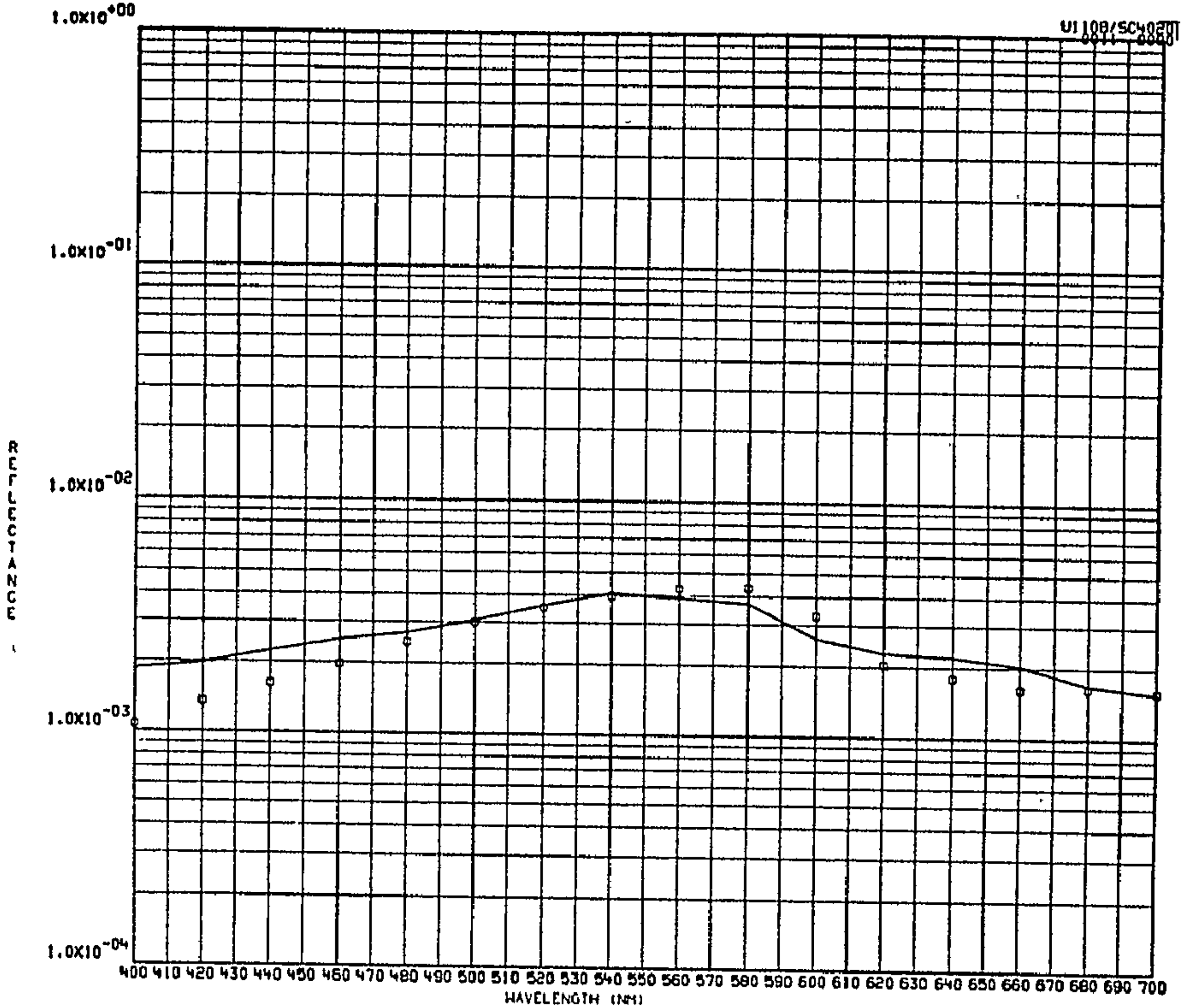
RUN TITLE- STATION 12



CHI SQUARE = 3.52×10^{-05} DEPTHS(M) IRRAD 2.13, RAD TOP 2.13, INFINITELY DEEP SEA ASSUMED

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$1.835 \times 10^{+03}$	$9.764 \times 10^{+02}$	$7.101 \times 10^{+02}$	$2.119 \times 10^{+00}$	2.388×10^{-01}	$1.794 \times 10^{+00}$
MODE DIAM			0.29	1.51	15.00	
ALPHA			6.00	6.00	6.00	
GAMMA	6.00	2.85	0.29	0.40	0.70	

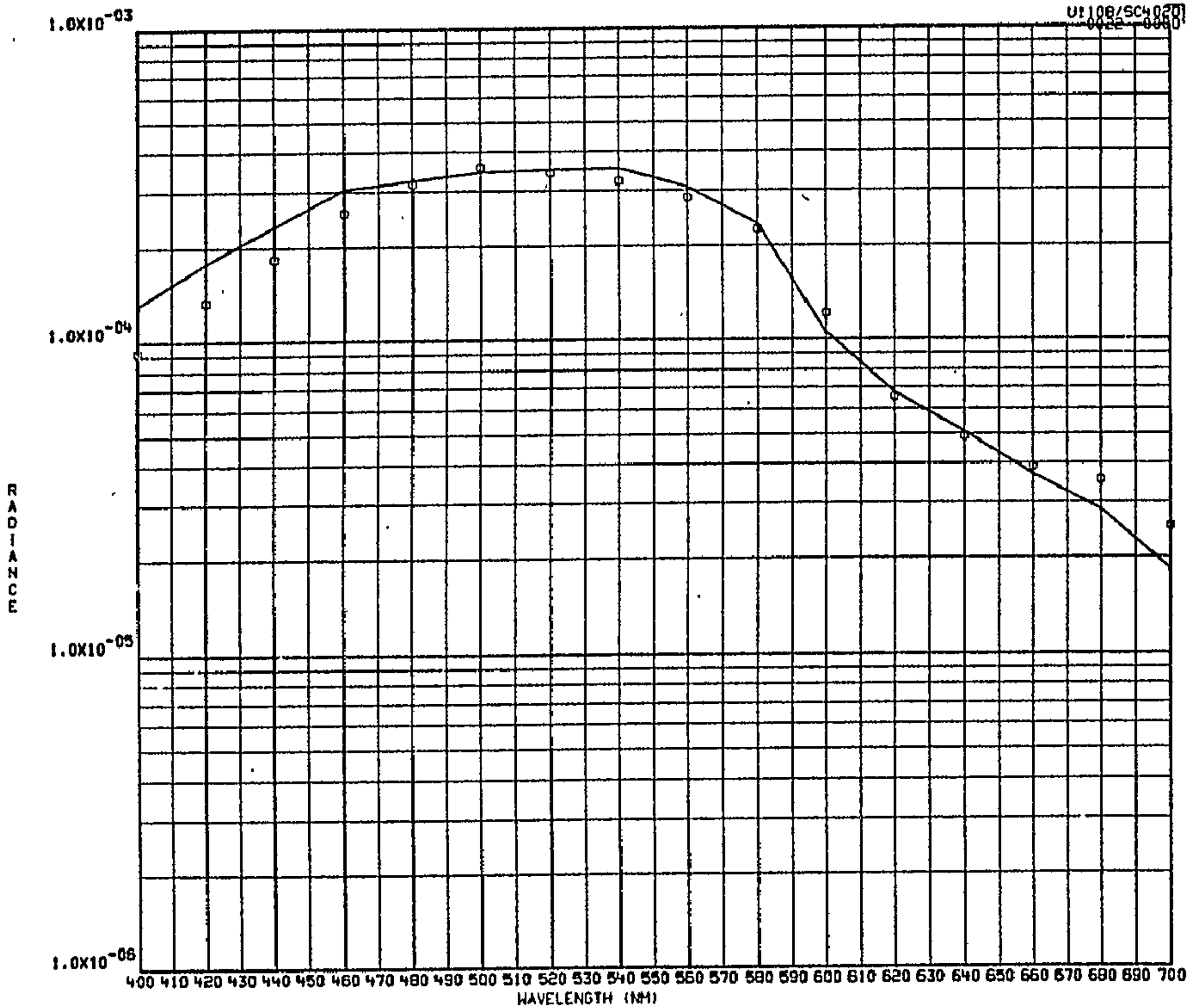
RUN TITLE- STATION 12



CHI SQUARE = 3.52X10^{-05} DEPTHS(M) IRRAD 2.13, RAD TOP 2.13, INFINITELY DEEP SEA ASSUMED

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	1.835X10^{+03}	9.764X10^{+02}	7.101X10^{+02}	2.119X10^{+00}	2.388X10^{-01}	1.794X10^{+00}
MODE DIAM			0.29	1.51	15.00	
ALPHA	)		6.00	6.00	6.00	
GAMMA	6.00	2.85	0.29	0.40	0.70	

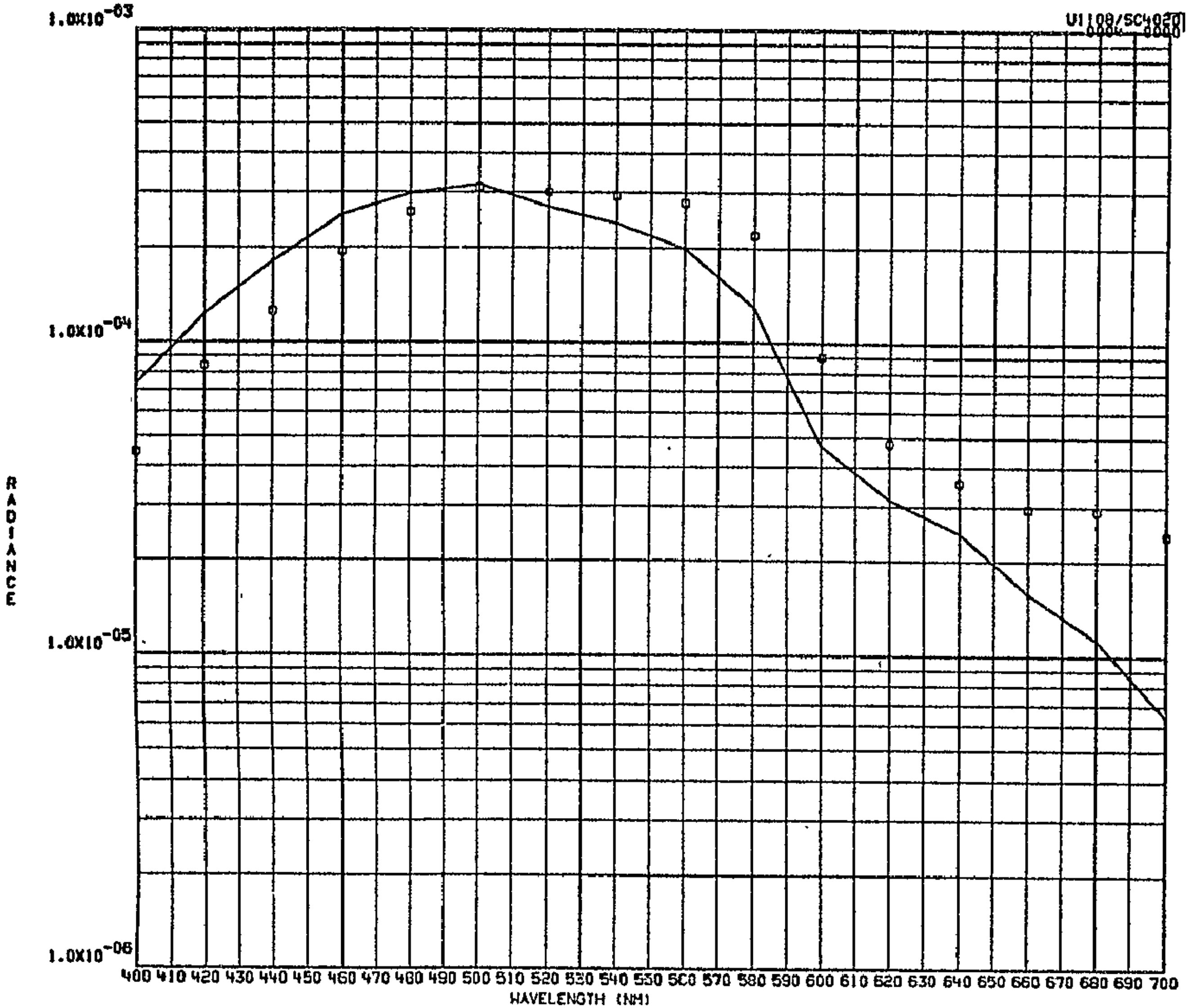
RUN TITLE- STATION 12



CHI SQUARE = 1.19X10^{-05} INFINITELY DEEP SEA (FROM 1METER)

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	3.945X10^{+02}	3.063X10^{+04}	3.614X10^{+02}	8.399X10^{-01}	9.267X10^{-02}	7.777X10^{-01}
MODE DIAM			0.47	1.51	15.00	0.00
ALPHA			6.00	6.00	6.00	0.00
GAMMA	2.99	7.00	0.37	0.60	0.80	0.00

RUN TITLE- STATION 13

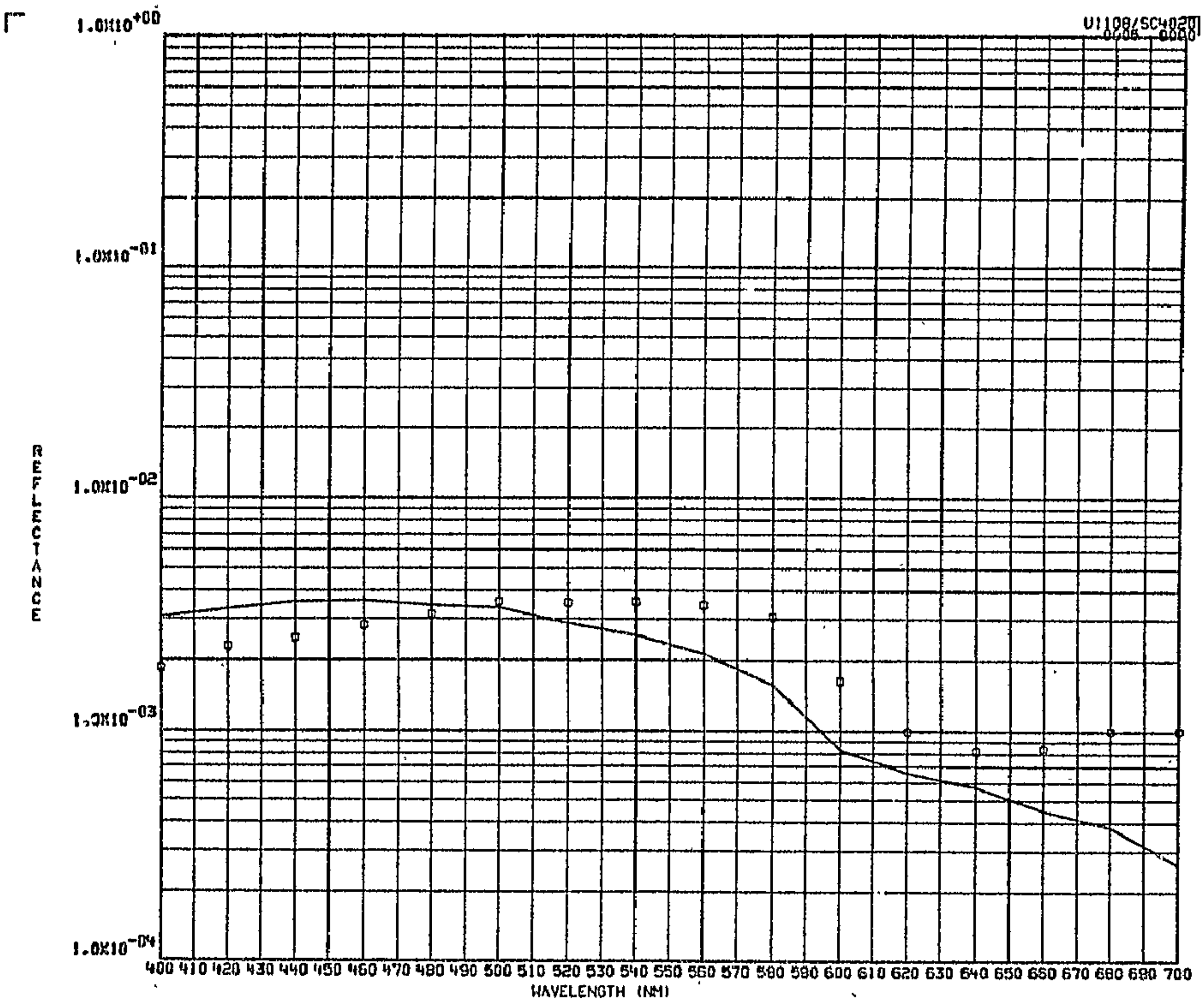


CHI SQUARE = 3.10×10^{-04} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 10.97

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$2.058 \times 10^{+02}$	$4.032 \times 10^{+04}$	$1.706 \times 10^{+02}$	1.220×10^{-01}	1.543×10^{-02}	7.567×10^{-01}
MODE DIAM			0.20	1.50	9.25	
ALPHA			6.00	6.00	6.00	
GAMMA	2.85	6.00	0.38	0.40	0.70	

RUN TITLE- STATION 43 ... FLORIDA COASTAL WATERS

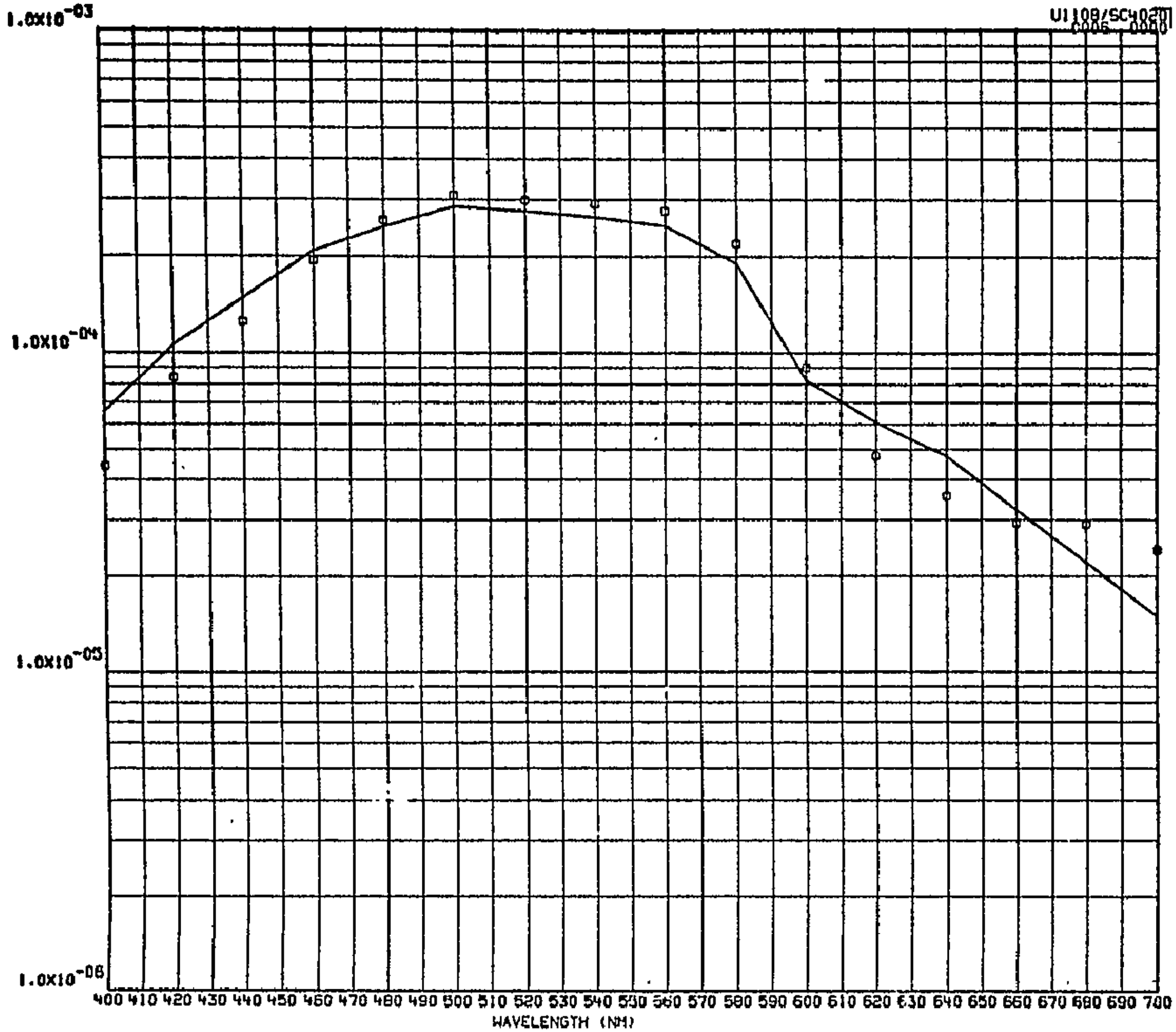
Constituents as determined by Volume Scattering Function Analysis



CHI SQUARE = 3.10X10^{-04} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 10.97

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	2.058X10^{+02}	4.032X10^{+04}	1.706X10^{+02}	1.220X10^{-01}	1.543X10^{-02}	7.567X10^{-01}
MODE DIAM			0.20	1.50	9.25	
ALPHA			6.00	6.00	6.00	
GAMMA	2.65	6.00	0.38	0.40	0.70	

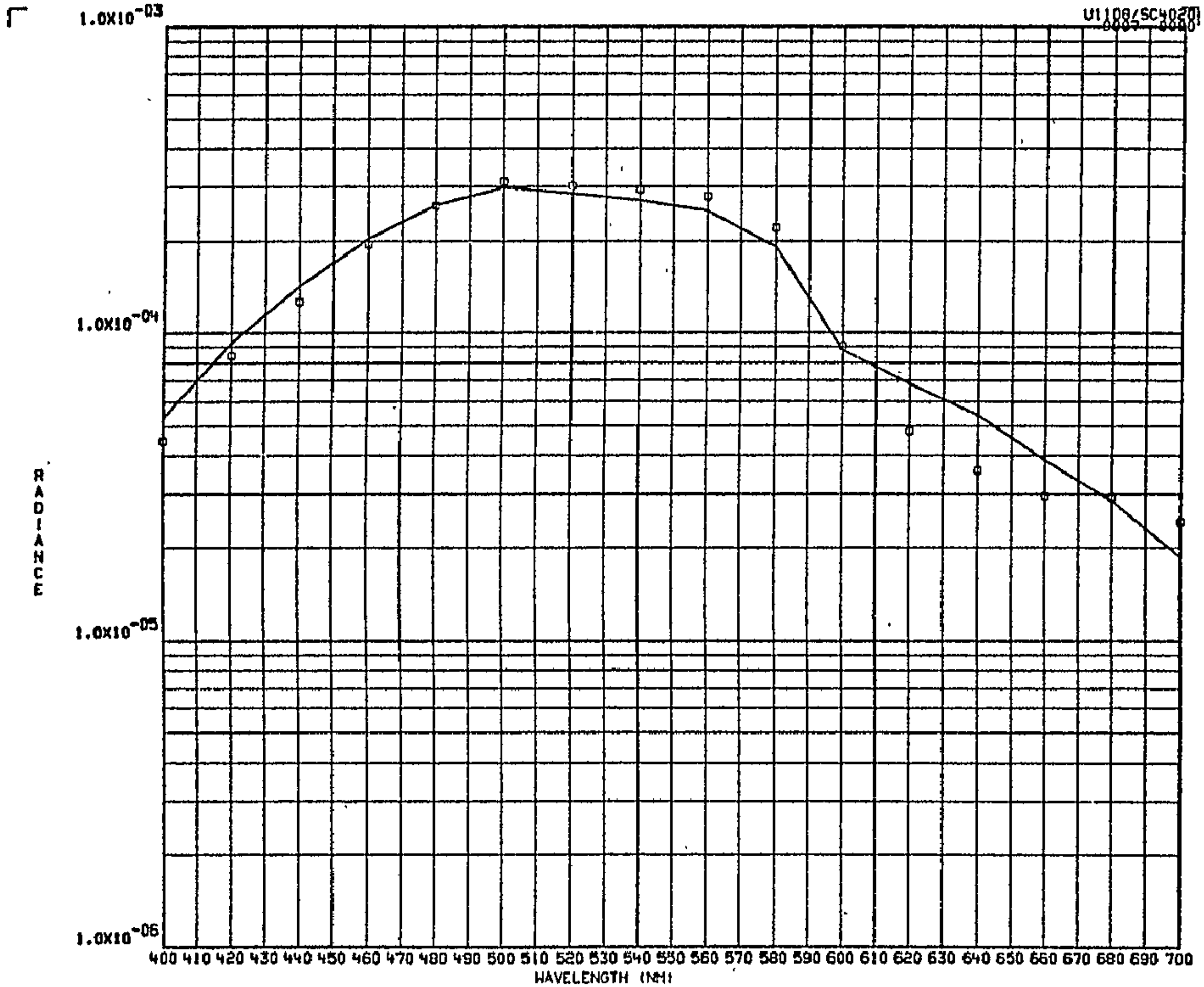
RUN TITLE- STATION 43 ... FLORIDA COASTAL WATERS



CHI SQUARE = 4.50×10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 10.97

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$1.042 \times 10^{+03}$	$3.583 \times 10^{+04}$	$2.888 \times 10^{+02}$	$4.547 \times 10^{+00}$	1.699×10^{-01}	8.663×10^{-01}
MODE DIAM			0.20	1.50	2.25	
ALPHA			6.00	6.00	6.00	
GAMMA	2.85	6.00	0.38	0.40	0.70	

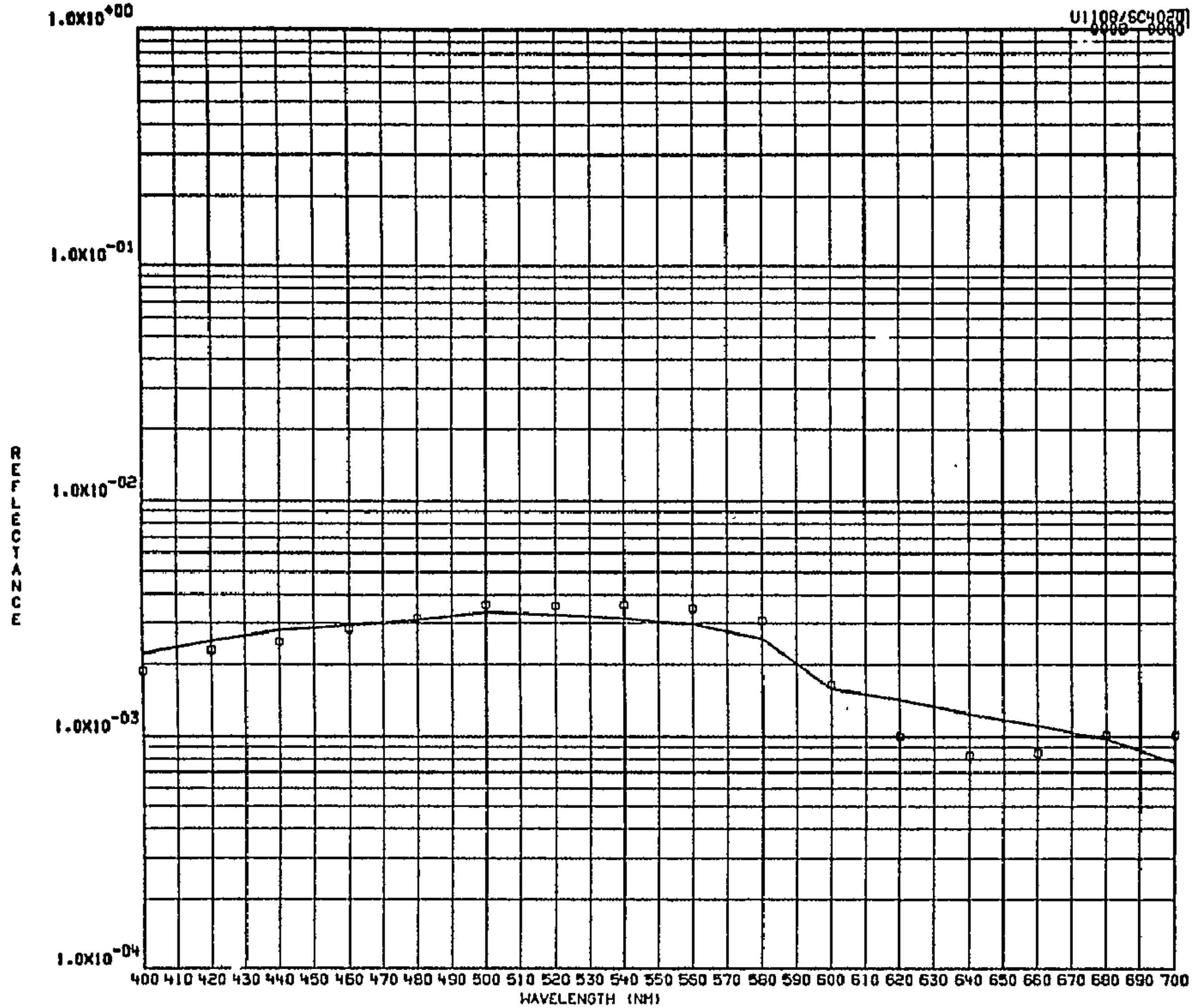
RUN TITLE- STATION 43 ... FLORIDA COASTAL WATERS



CHI SQUARE = 3.07×10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 10.97

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$2.228 \times 10^{+03}$	$3.583 \times 10^{+04}$	$2.889 \times 10^{+02}$	$4.547 \times 10^{+00}$	5.888×10^{-02}	$1.461 \times 10^{+00}$
MODE DIAM			0.20	1.50	9.25	
ALPHA			6.00	6.00	6.00	
GAMMA	2.85	6.00	0.38	0.40	0.70	

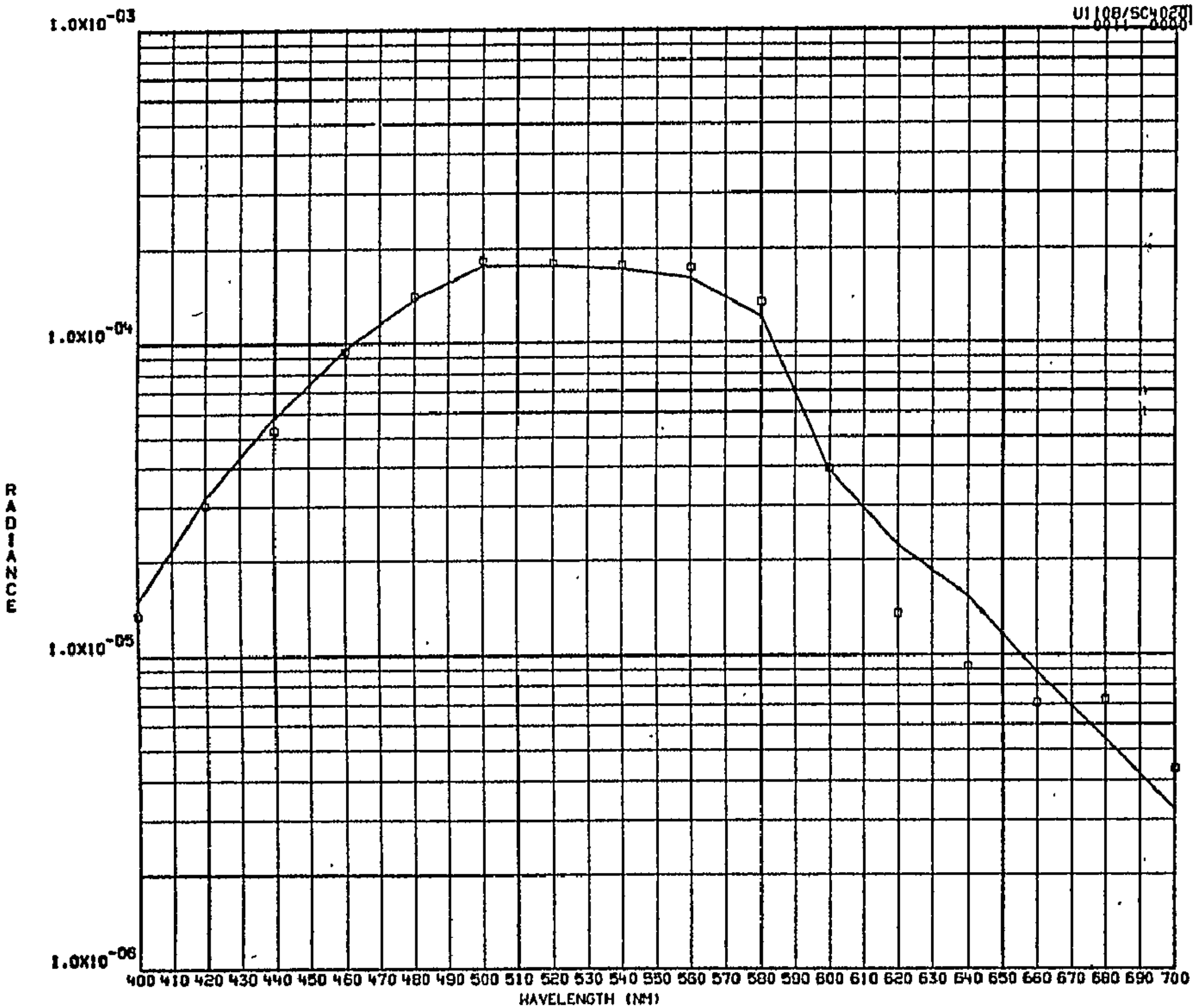
RUN TITLE- STATION 43 ... FLORIDA COASTAL WATERS



CHI SQUARE = 3.07×10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 10.97

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$2.228 \times 10^{+03}$	$3.583 \times 10^{+04}$	$2.889 \times 10^{+02}$	$4.547 \times 10^{+00}$	5.888×10^{-02}	$1.461 \times 10^{+00}$
MODE DIAM			0.20	1.50	9.25	
ALPHA			6.00	6.00	6.00	
GAMMA	2.85	6.00	0.38	0.40	0.70	

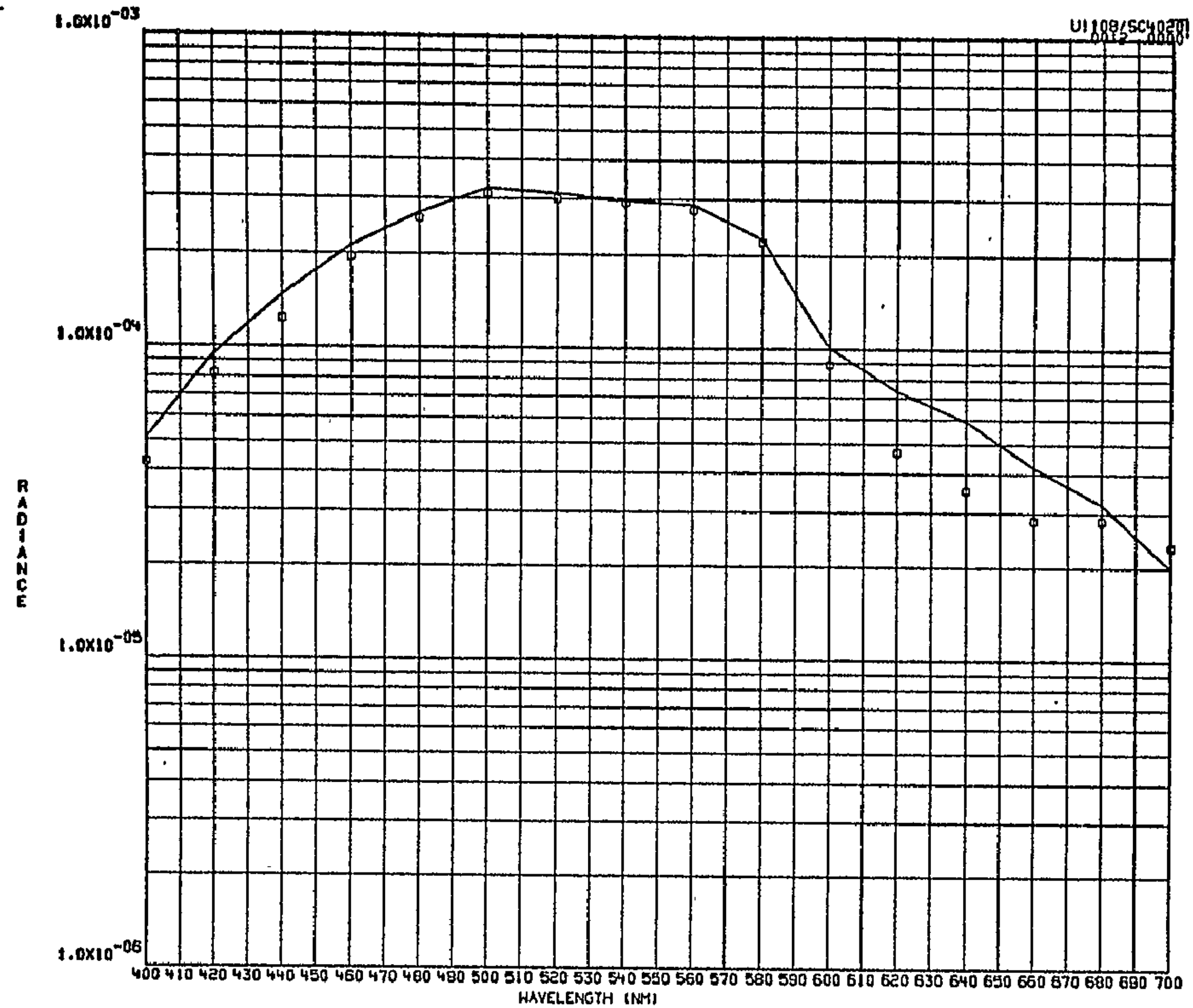
RUN TITLE- STATION 43 ... FLORIDA COASTAL WATERS



CHI SQUARE = 1.14X10^{-05} DEPTHS(M) IRRAD 3.65, RAD TOP 3.65, RAD BOT 10.97

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	3.097X10^{+03}	3.729X10^{+04}	3.716X10^{+02}	5.834X10^{+00}	6.938X10^{-03}	1.724X10^{+00}
MODE DIAM			0.20	1.50	9.25	
ALPHA			6.00	6.00	6.00	
GAMMA	2.85	6.00	0.38	0.40	0.70	

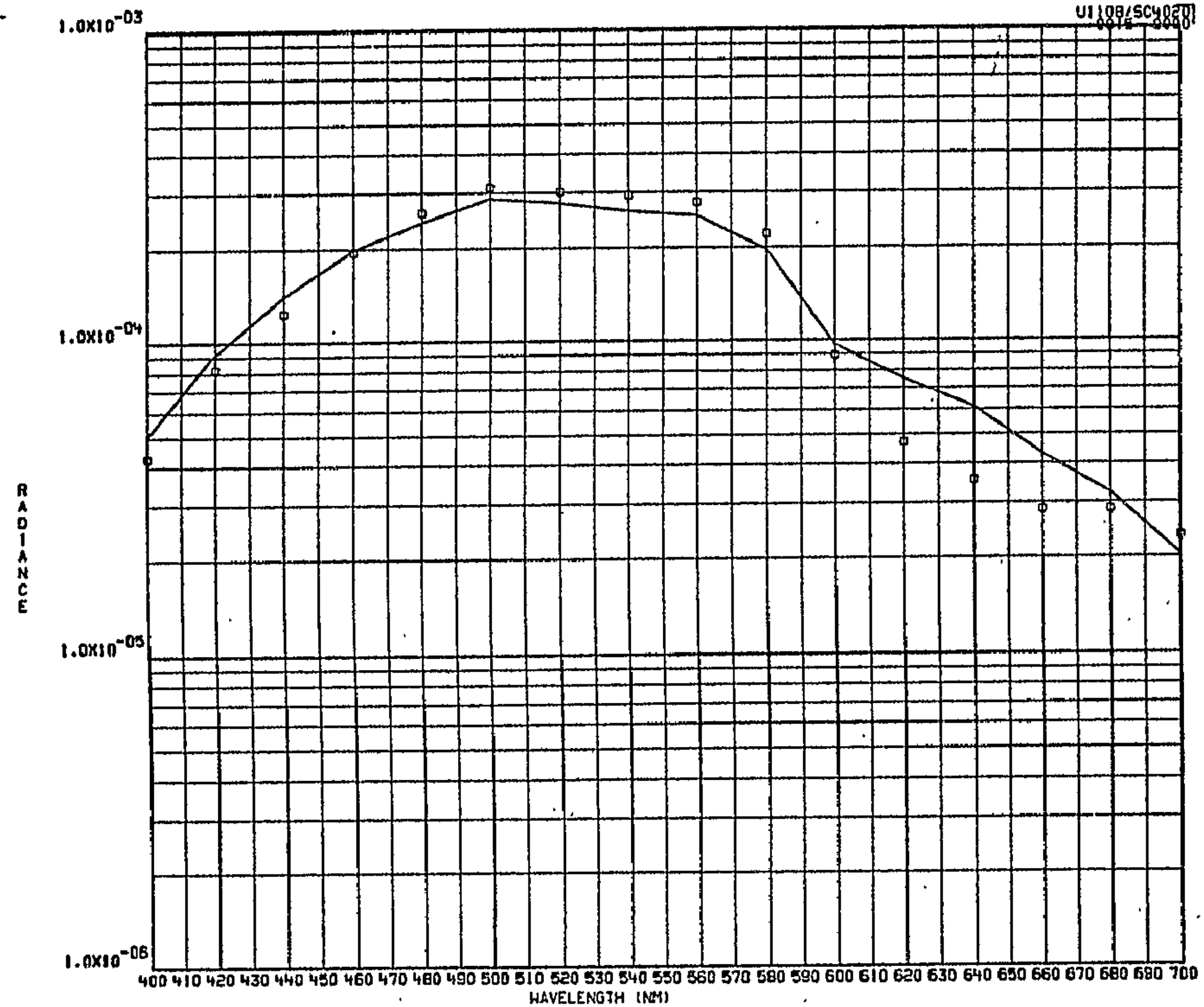
RUN TITLE- STATION 43 ... FLORIDA COASTAL WATERS



CHI SQUARE = $3.65X10^{-05}$ DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 3.65

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$3.029X10^{+03}$	$3.616X10^{+04}$	$1.882X10^{+02}$	$5.316X10^{+00}$	$1.980X10^{-03}$	$1.741X10^{+00}$
MODE DIAM			0.20	1.50	9.25	
ALPHA			6.00	6.00	6.00	
GAMMA	2.85	6.00	0.38	0.40	0.70	

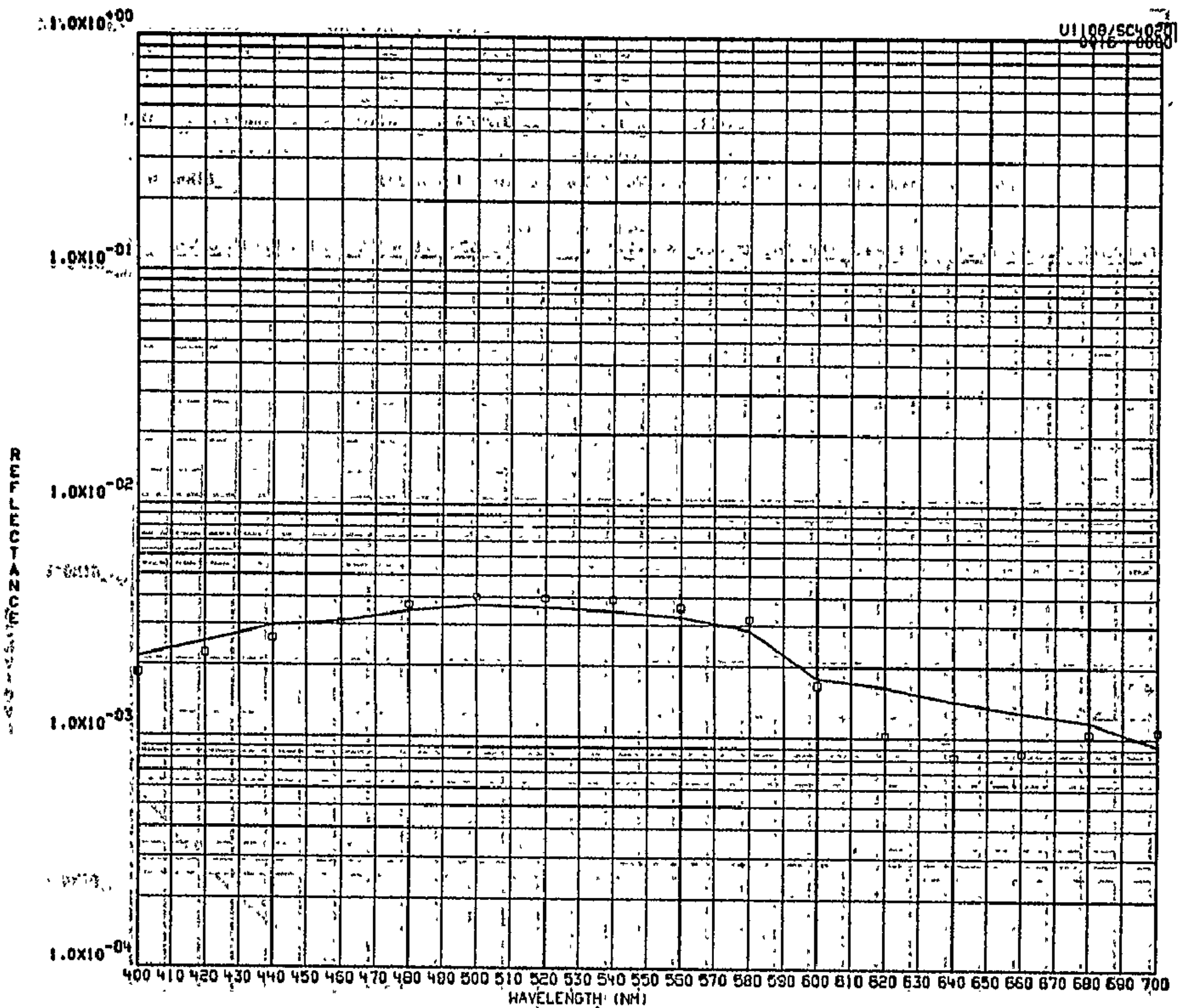
RUN TITLE- STATION 43 ... FLORIDA COASTAL WATERS



CHI SQUARE = 4.64×10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, INFINITELY DEEP SEA ASSUMED

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$3.063\times10^{+03}$	$3.620\times10^{+04}$	$1.963\times10^{+02}$	$5.538\times10^{+00}$	5.971×10^{-03}	$1.715\times10^{+00}$
MODE DIAM			0.20	1.50	20.73	
ALPHA			6.00	6.00	6.00	
GAMMA	2.85	6.00	0.38	0.40	0.70	

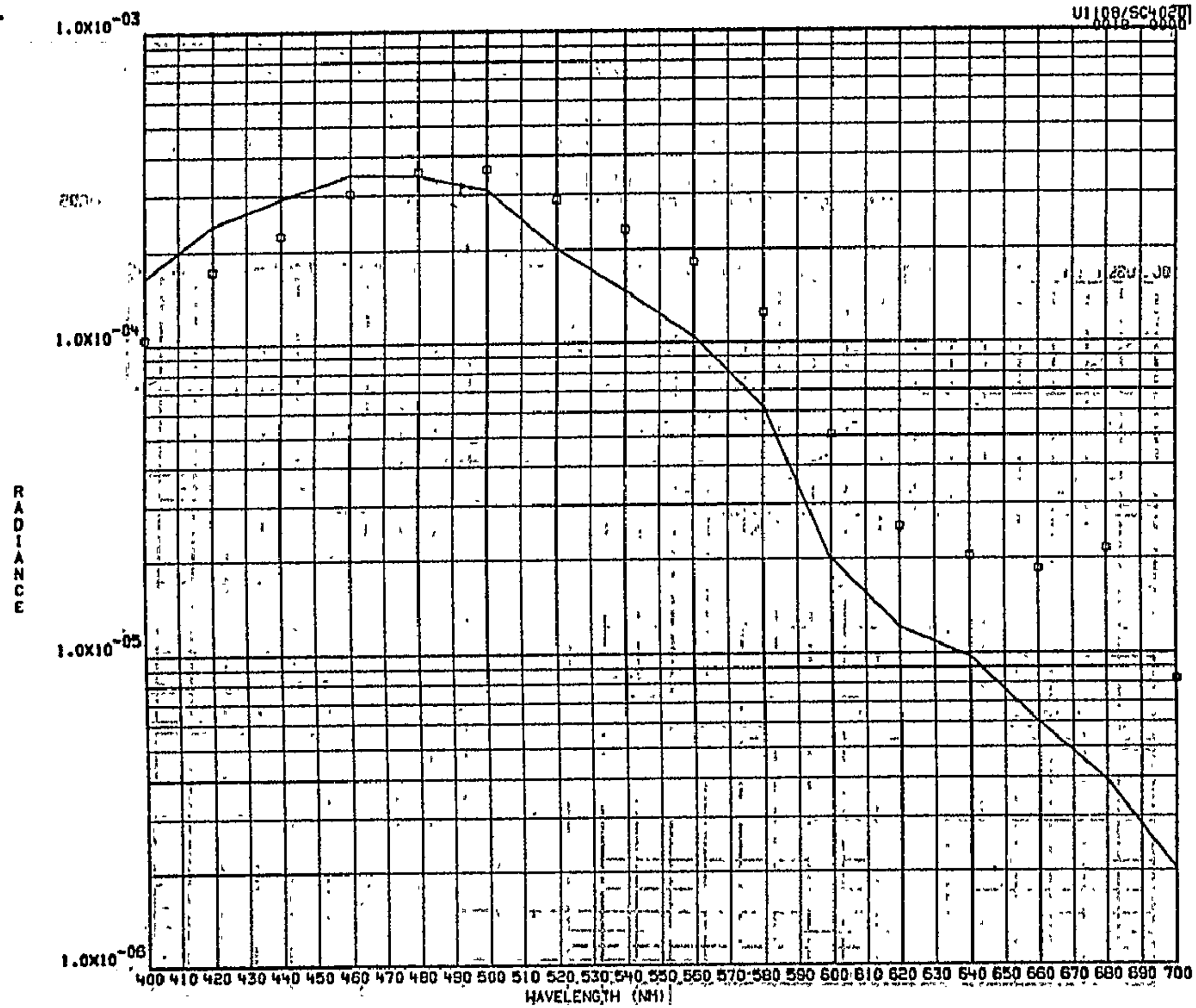
RUN TITLE- STATION 43 ... FLORIDA COASTAL WATERS



CHI SQUARE = $4.64X10^{-05}$ DEPTHS(M) IRRAD 0.91 RAD TOP 0.91 INFINITELY DEEP SEA ASSUMED

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$3.063X10^{+03}$	$3.620X10^{+04}$	$1.963X10^{+02}$	$.538X10^{+00}$	$5.971X10^{-03}$	$1.715X10^{+0}$
MODE DIAM			0.20	1.50	20.73	
ALPHA			6.00	6.00	6.00	
GAMMA	2.85	6.00	0.38	0.40	0.70	

RUN TITLE= STATION 43 ... FLORIDA COASTAL WATERS

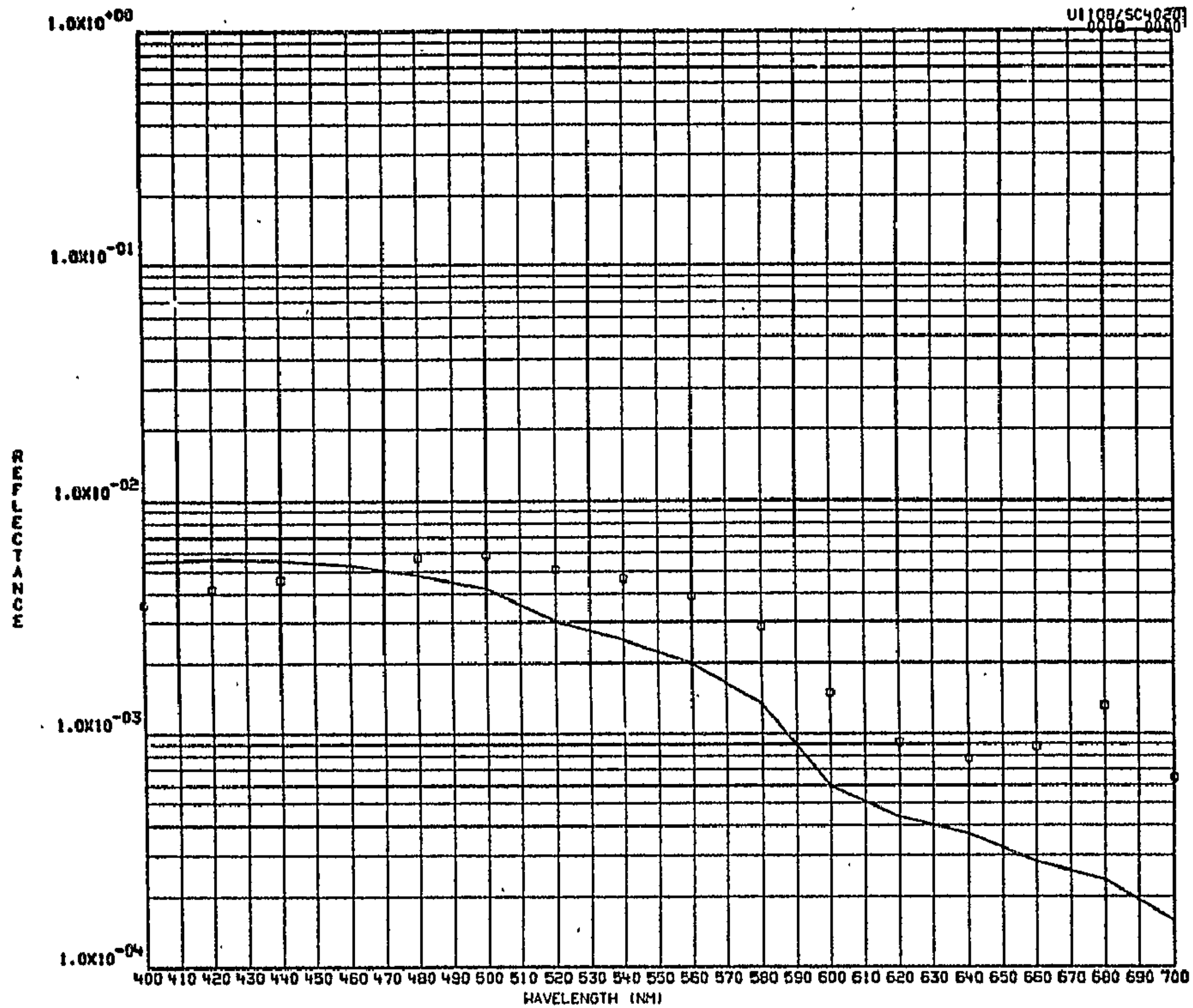


CHI SQUARE- 4.76×10^{-04} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 15.24

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	7.144×10^{01}	$2.222\times10^{+04}$	3.356×10^{-01}	9.633×10^{-02}	5.776×10^{-03}	1.934×10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.78	6.00	0.25	0.40	0.70	

RUN TITLE- STATION 44 . GULF OF MEXICO

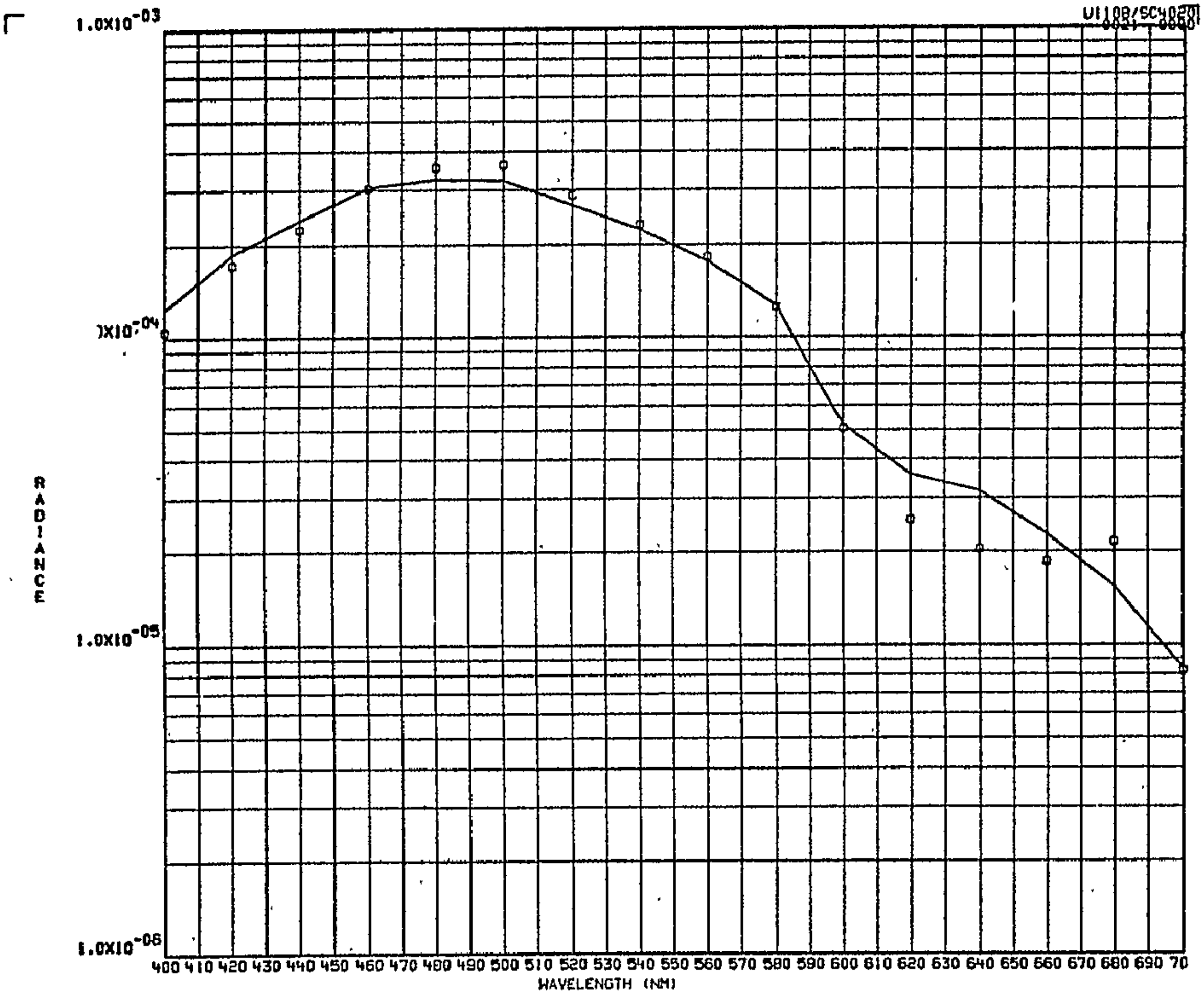
Constituents as determined by Volume Scattering Function Analysis



CHI SQUARE $= 4.76 \times 10^{-04}$ DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 15.24

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$7.144 \times 10^{+01}$	$2.222 \times 10^{+04}$	3.356×10^{-01}	9.633×10^{-02}	5.776×10^{-03}	1.934×10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

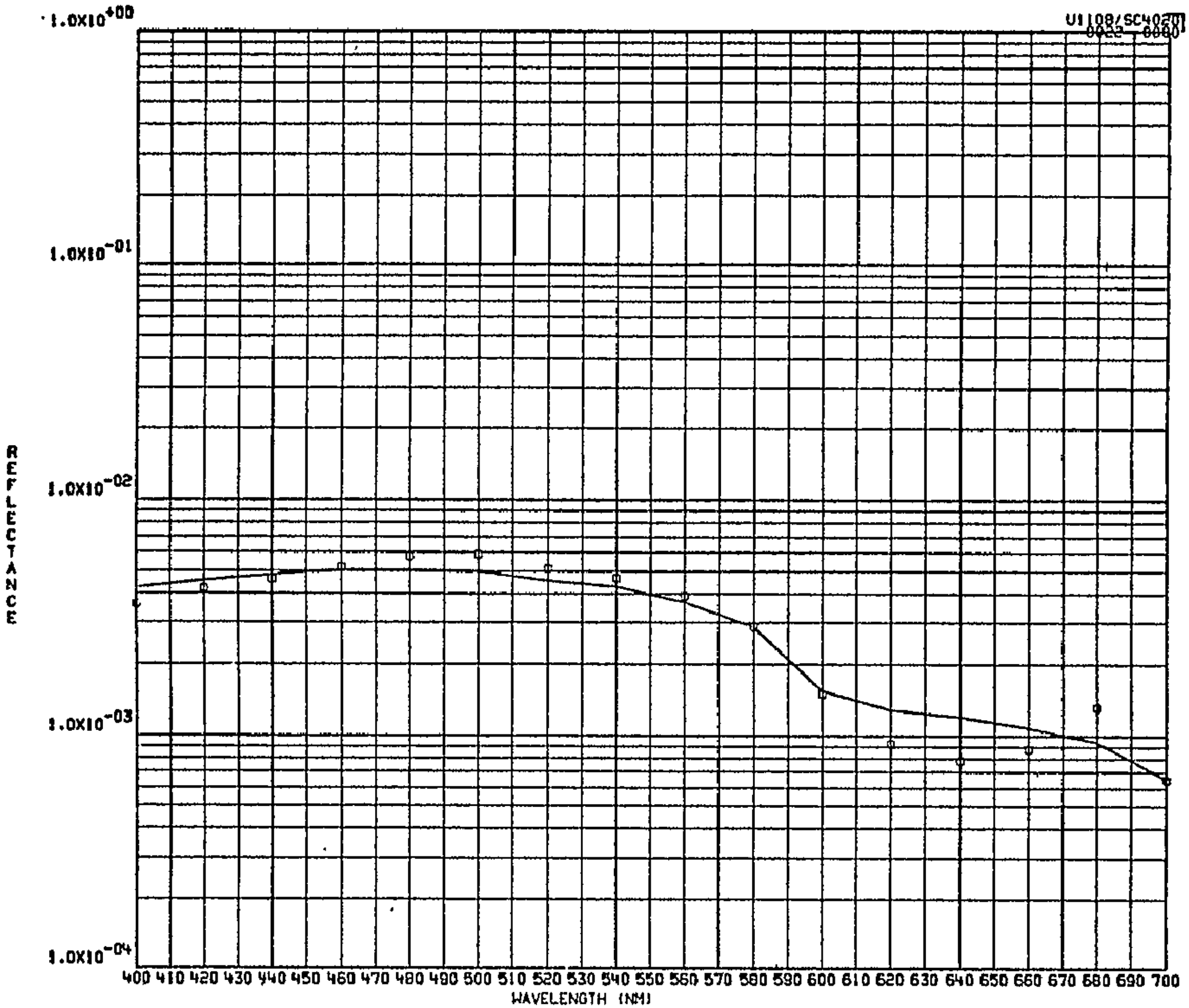
RUN TITLE- STATION 44 ... GULF OF MEXICO



CHI SQUARE = 2.41X10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 15.24

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	4.412X10^{+02}	3.261X10^{+04}	6.070X10^{+02}	5.462X10^{+00}	3.759X10^{-02}	5.632X10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

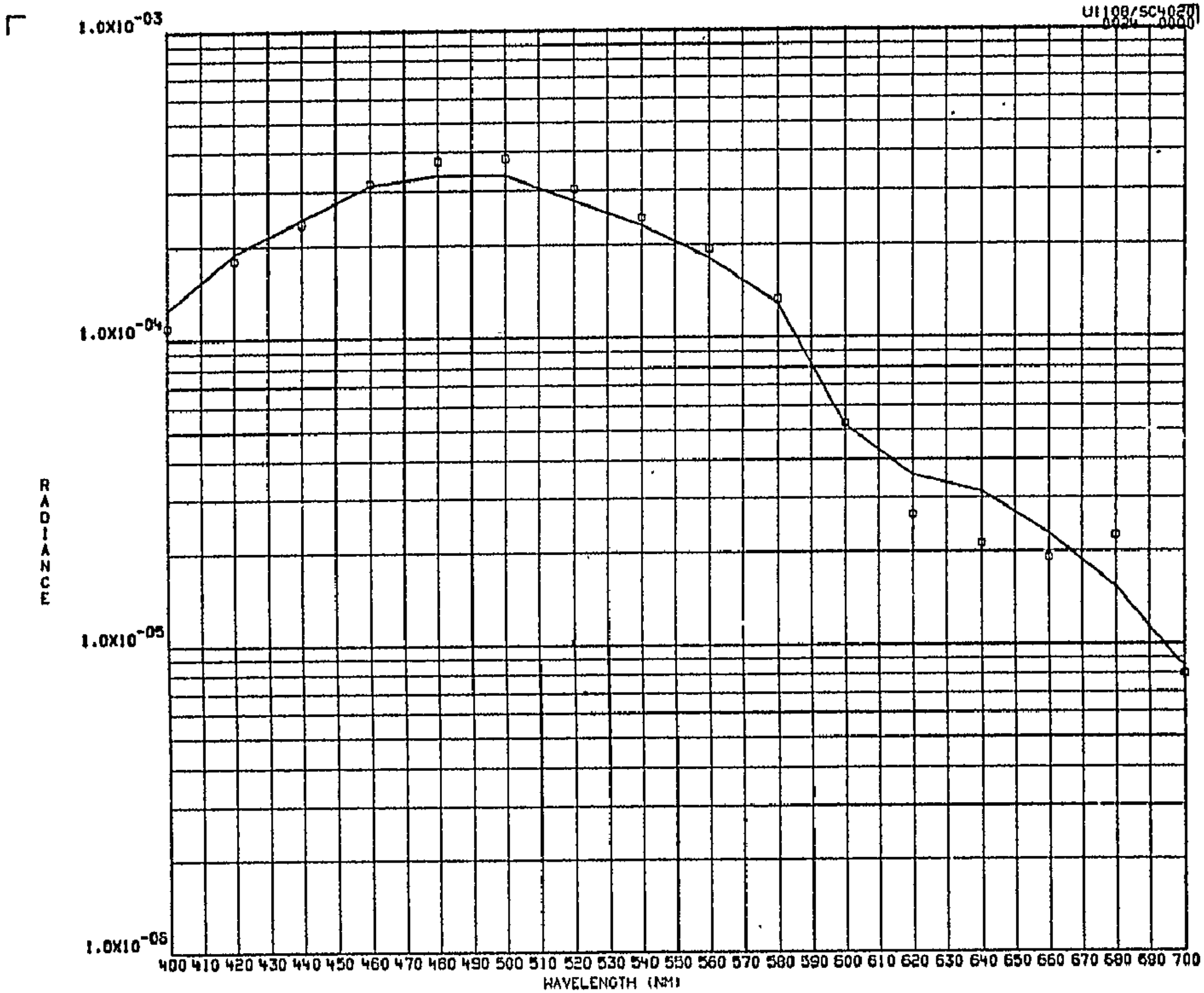
RUN TITLE- STATION 44 ... GULF OF MEXICO



CHI SQUARE = 2.41X10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 15.24

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	4.412X10^{+02}	3.261X10^{+04}	6.070X10^{+02}	5.462X10^{+00}	3.759X10^{-02}	5.632X10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

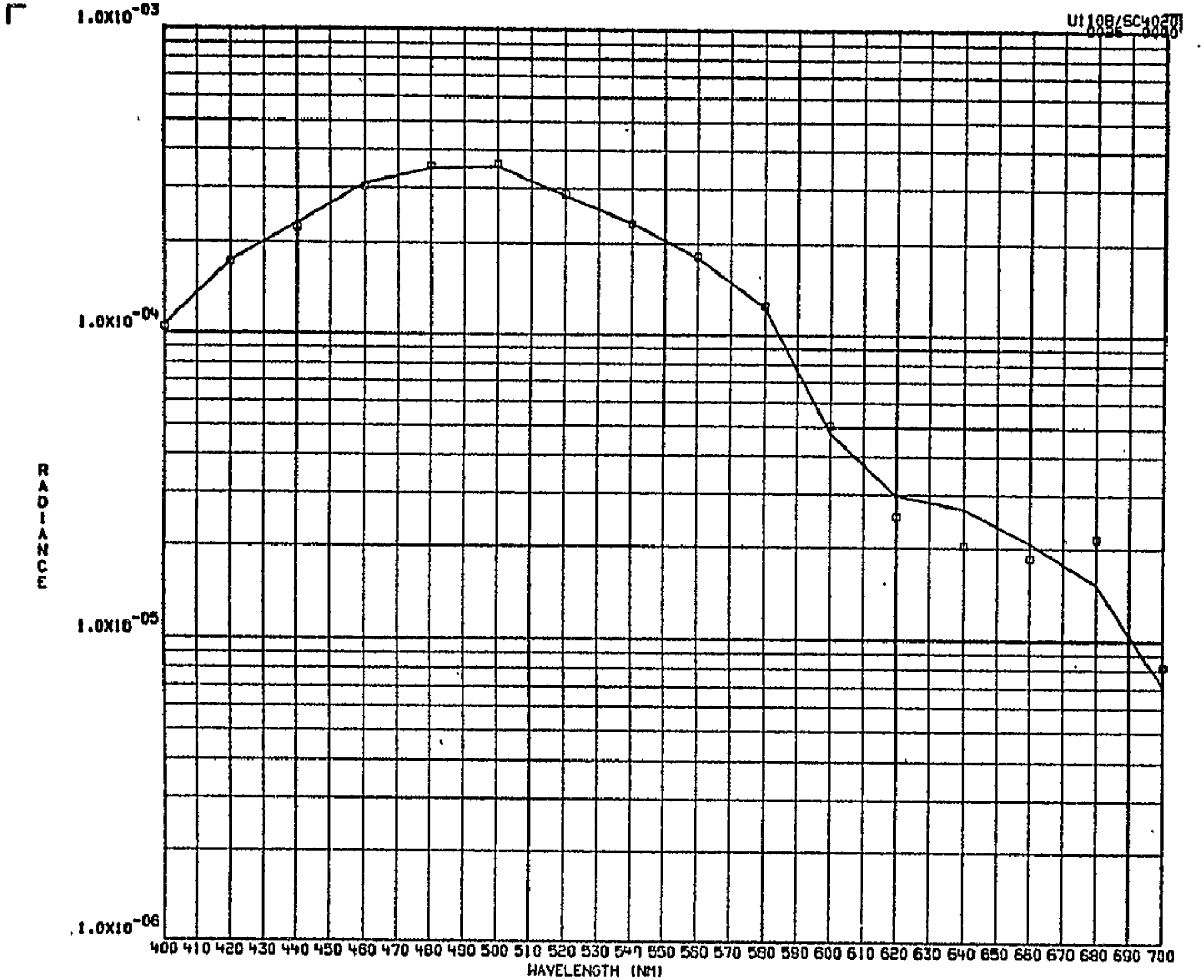
RUN TITLE- STATION 44 ... GULF OF MEXICO



CHI SQUARE = $2.45X10^{-05}$ DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 11.27

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$4.413X10^{+02}$	$3.261X10^{+04}$	$6.072X10^{+02}$	$5.463X10^{+00}$	$3.759X10^{-02}$	$5.633X10^{-01}$
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

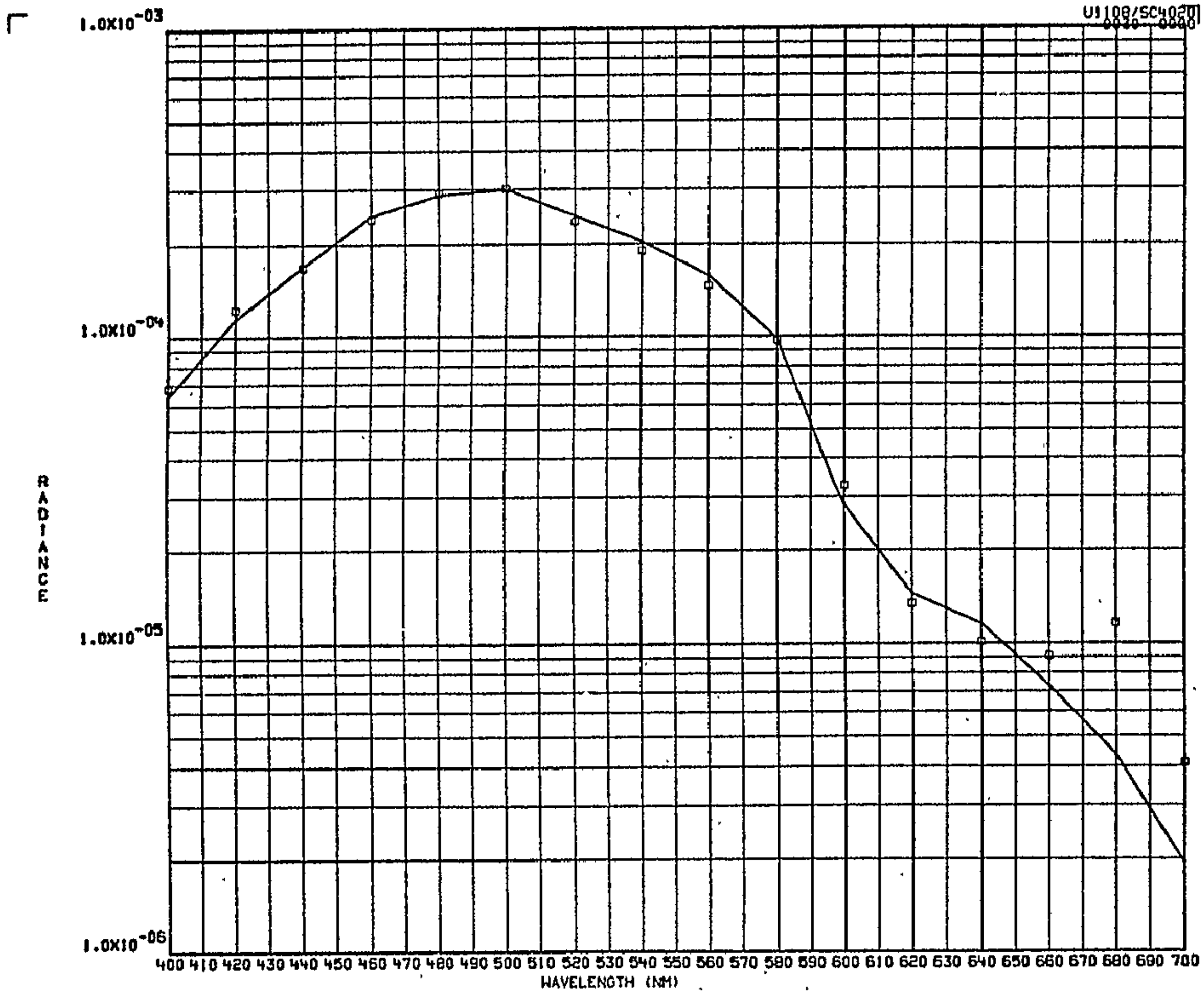
RUN TITLE- STATION 44 ... GULF OF MEXICO



CHI SQUARE = 6.27×10^{-06} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 3.65

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$3.002 \times 10^{+02}$	$3.261 \times 10^{+04}$	$8.047 \times 10^{+02}$	$2.709 \times 10^{+00}$	9.759×10^{-03}	8.190×10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

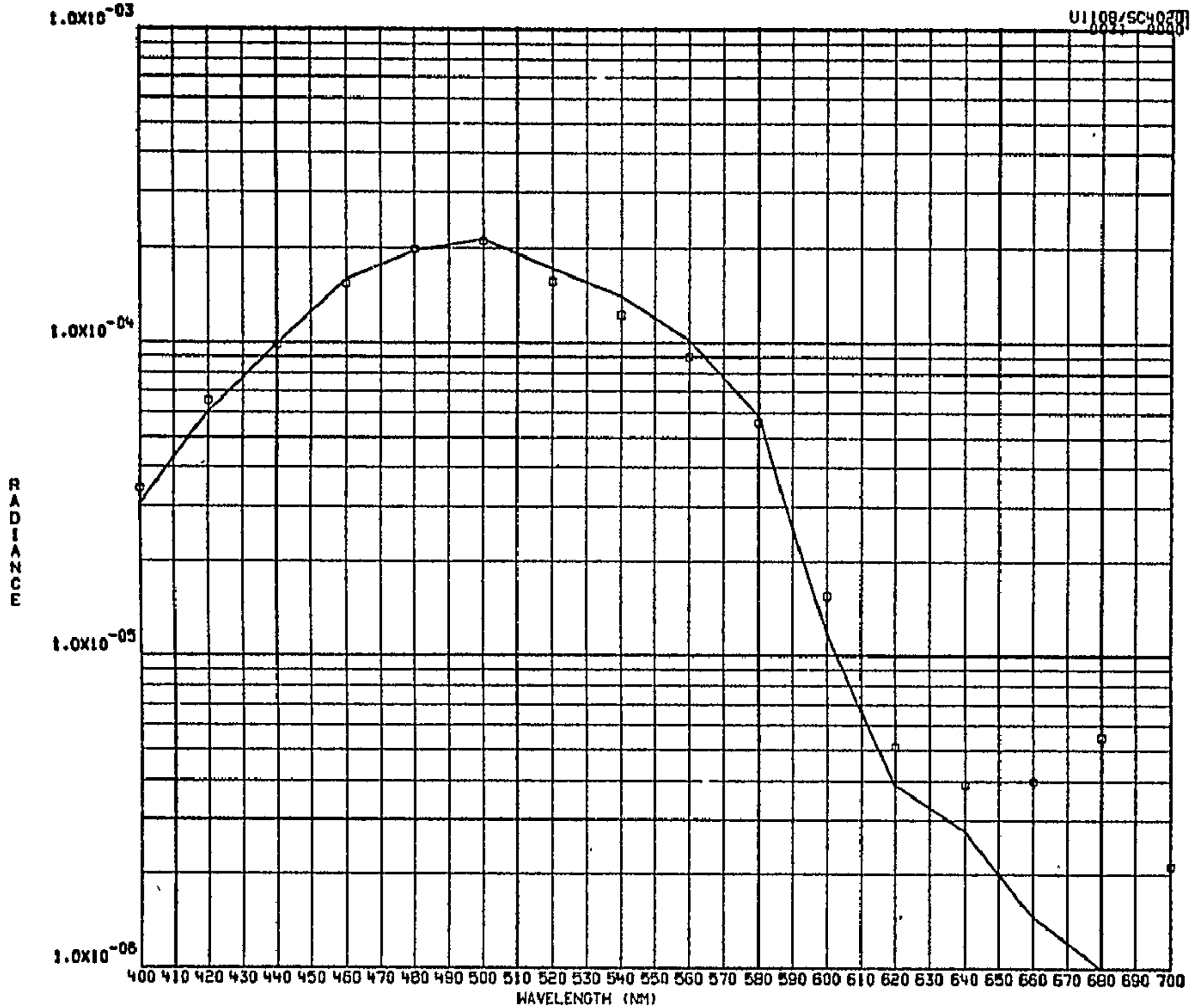
RUN TITLE- STATION 44 ... GULF OF MEXICO



CHI SQUARE = 1.93×10^{-05} DEPTHS(M) IRRAD 3.65, RAD TOP 3.65, RAD BOT 7.62

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$2.933 \times 10^{+02}$	$3.255 \times 10^{+04}$	$8.167 \times 10^{+02}$	$2.547 \times 10^{+00}$	9.405×10^{-03}	8.131×10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

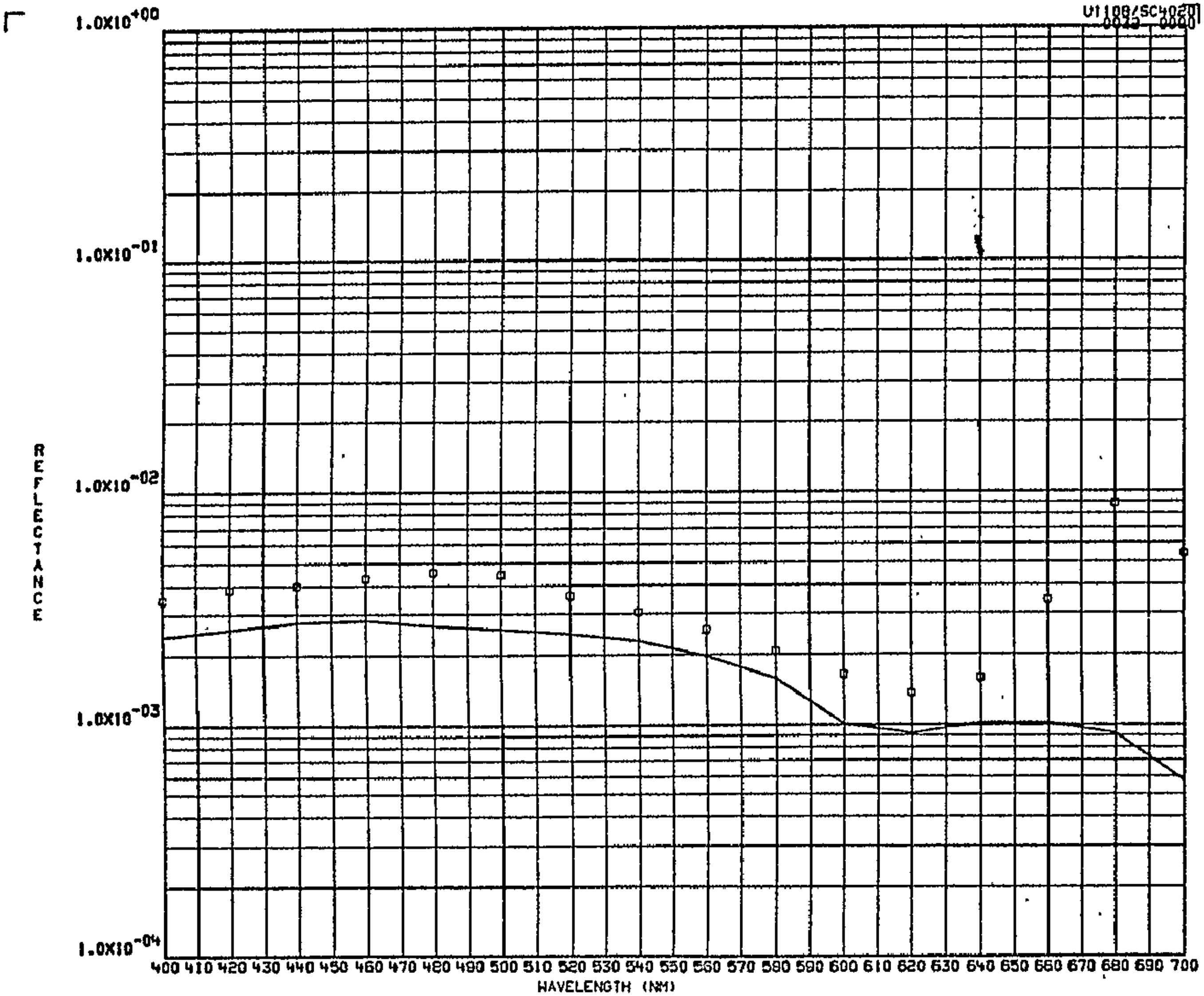
RUN TITLE- STATION 44 ... GULF OF MEXICO



CHI SQUARE = 4.53X10^{-05} DEPTHS(M) IRRAD 7.62, RAD TOP 7.62, RAD BOT 11.27

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	2.644X10^{+02}	2.539X10^{+04}	1.446X10^{+03}	4.400X10^{-02}	1.092X10^{-02}	8.556X10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

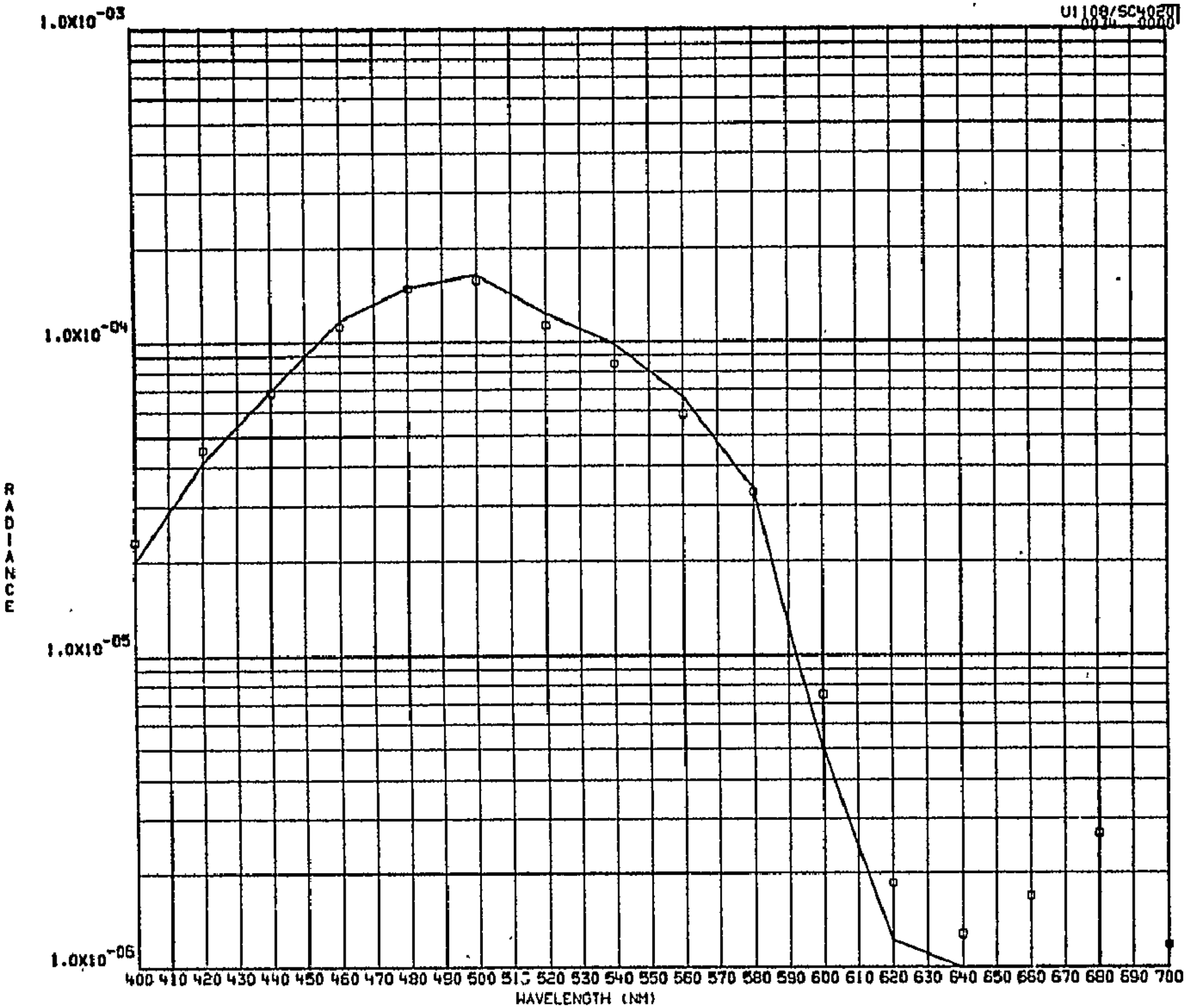
RUN TITLE- STATION 44 ... GULF OF MEXICO



CHI SQUARE = 4.53×10^{-05} DEPTHS(M) IRRAD 7.62, RAD TOP 7.62, RAD BOT 11.27

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$2.644 \times 10^{+02}$	$2.539 \times 10^{+04}$	$1.446 \times 10^{+03}$	4.400×10^{-02}	1.092×10^{-02}	8.556×10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

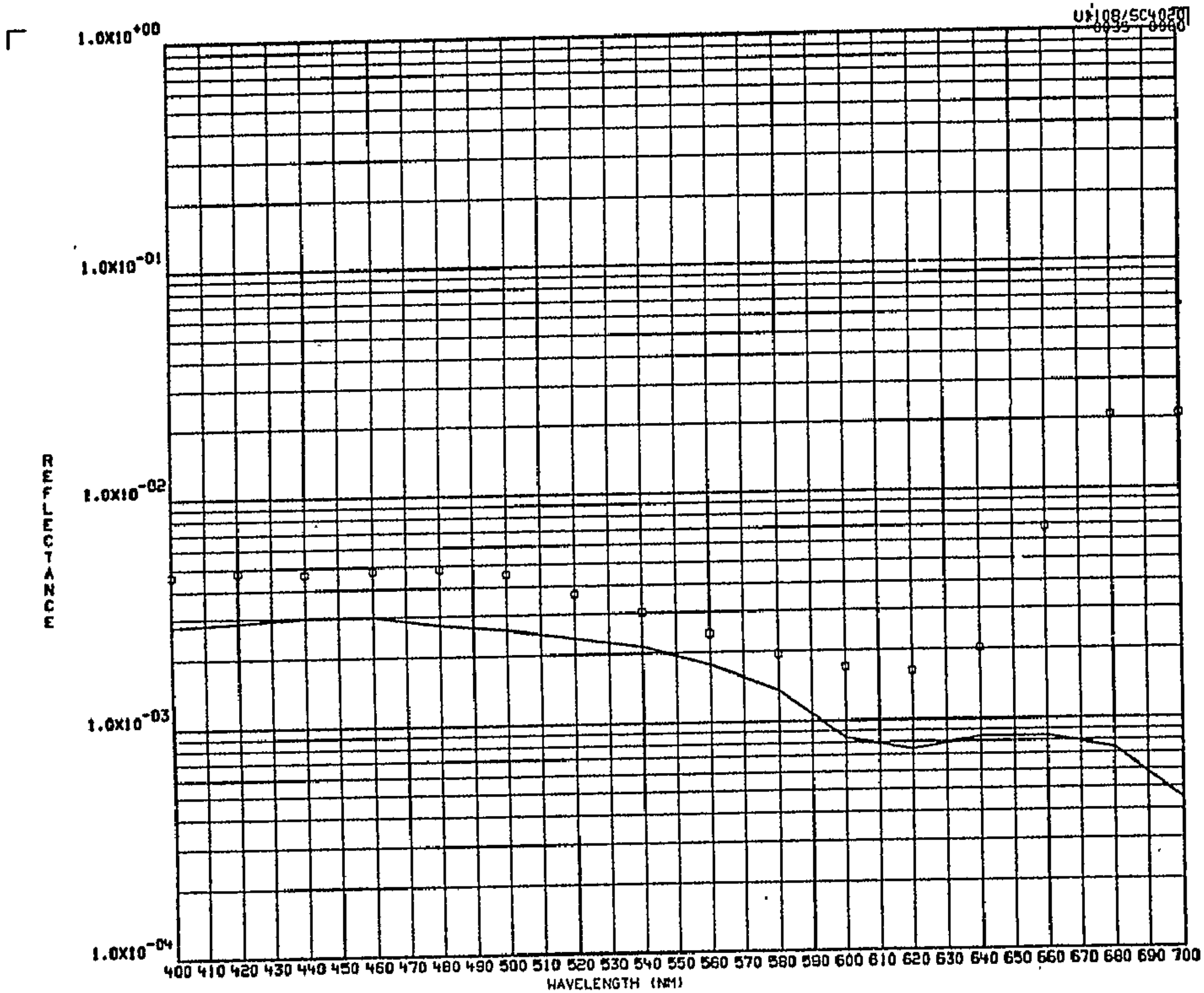
RUN TITLE- STATION 44 ... GULF OF MEXICO



CHI SQUARE = 3.82×10^{-05} DEPTHS(M) IRRAD 11.27, RAD TOP 11.27, RAD BOT 15.24

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$6.922\times10^{+01}$	$2.539\times10^{+04}$	$1.221\times10^{+03}$	4.400×10^{-02}	2.469×10^{-03}	6.342×10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

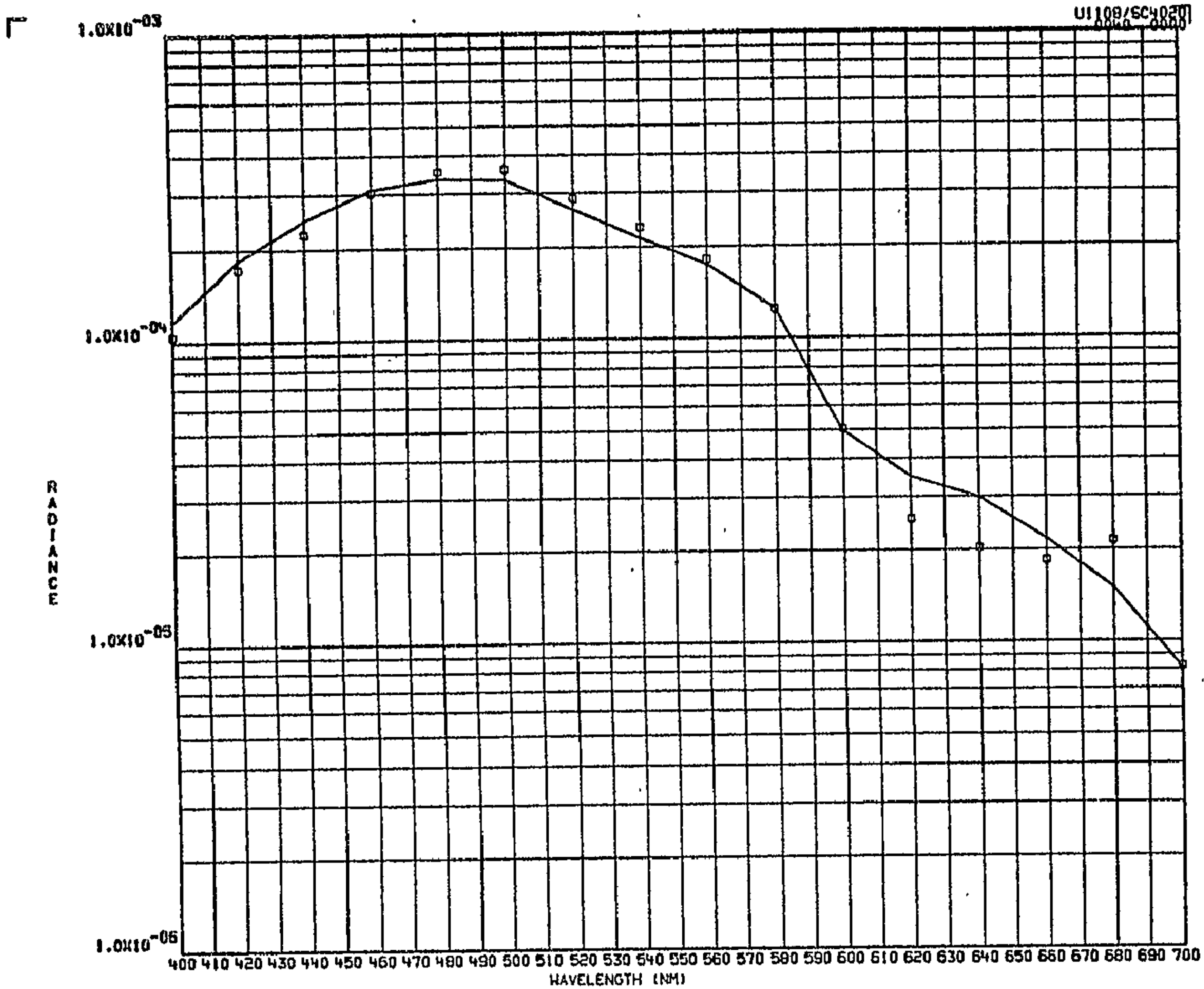
RUN TITLE- STATION 44 ... GULF OF MEXICO



CHI SQUARE = 3.82×10^{-05} DEPTHS(M) IRRAD 11.27, RAD TOP 11.27, RAD BOT 15.24

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$6.922 \times 10^{+01}$	$2.539 \times 10^{+04}$	$1.221 \times 10^{+03}$	4.400×10^{-02}	2.469×10^{-03}	6.342×10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

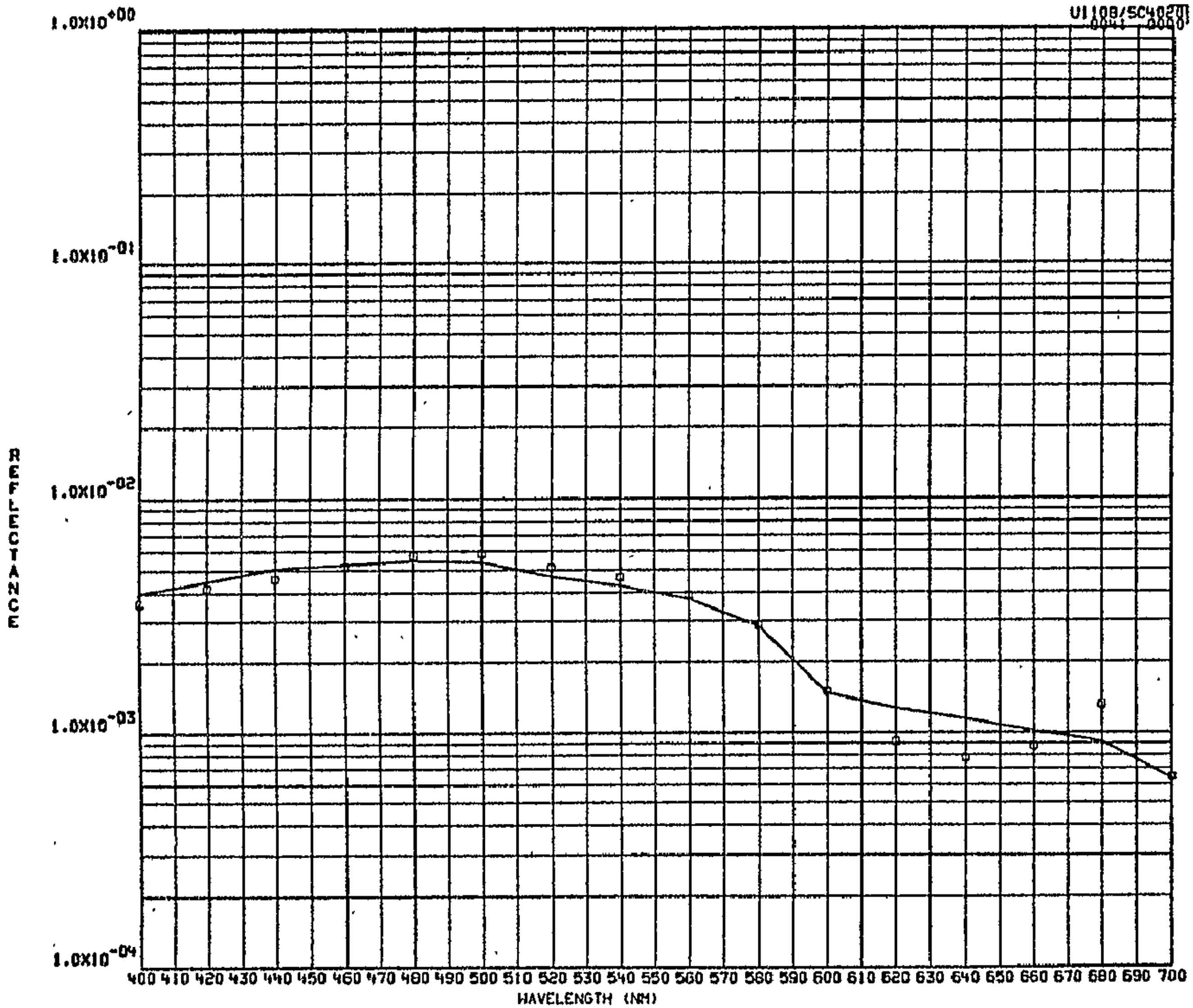
RUN TITLE- STATION 44 ... GULF OF MEXICO



CHI SQUARE = 2.05X10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, INFINITELY DEEP SEA ASSUMED

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	1.039X10^{+03}	3.201X10^{+04}	4.277X10^{+02}	4.400X10^{-02}	5.235X10^{-03}	6.195X10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

RUN TITLE- STATION 44 ... GULF OF MEXICO



CHI SQUARE = 2.05X10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, INFINITELY DEEP SEA ASSUMED

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	1.039X10^{+03}	3.201X10^{+04}	4.277X10^{+02}	4.400X10^{-02}	5.235X10^{-03}	6.195X10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

RUN TITLE- STATION 44 ... GULF OF MEXICO

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APPENDIX D

DIFFUSE ATTENUATION COEFFICIENT

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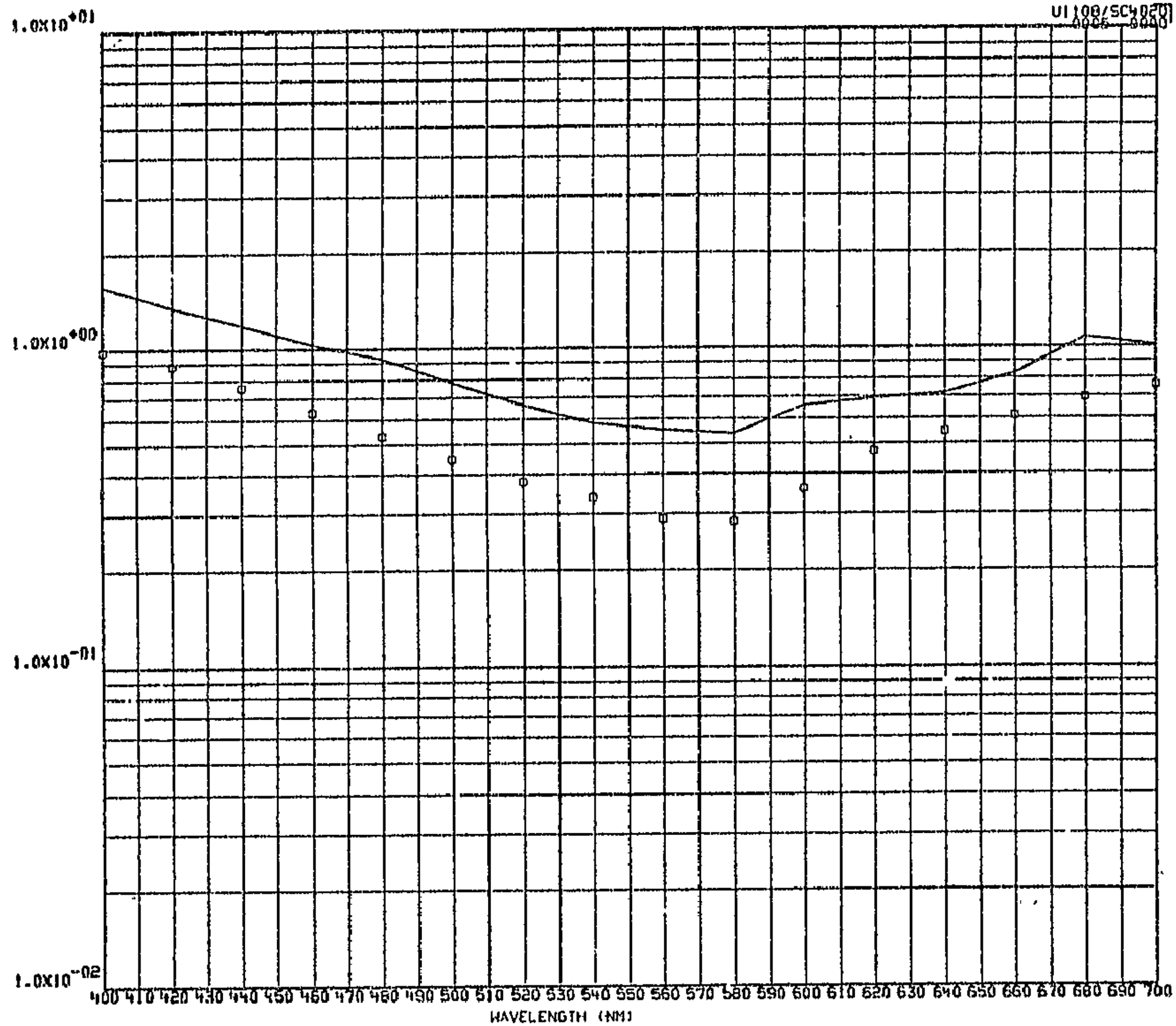
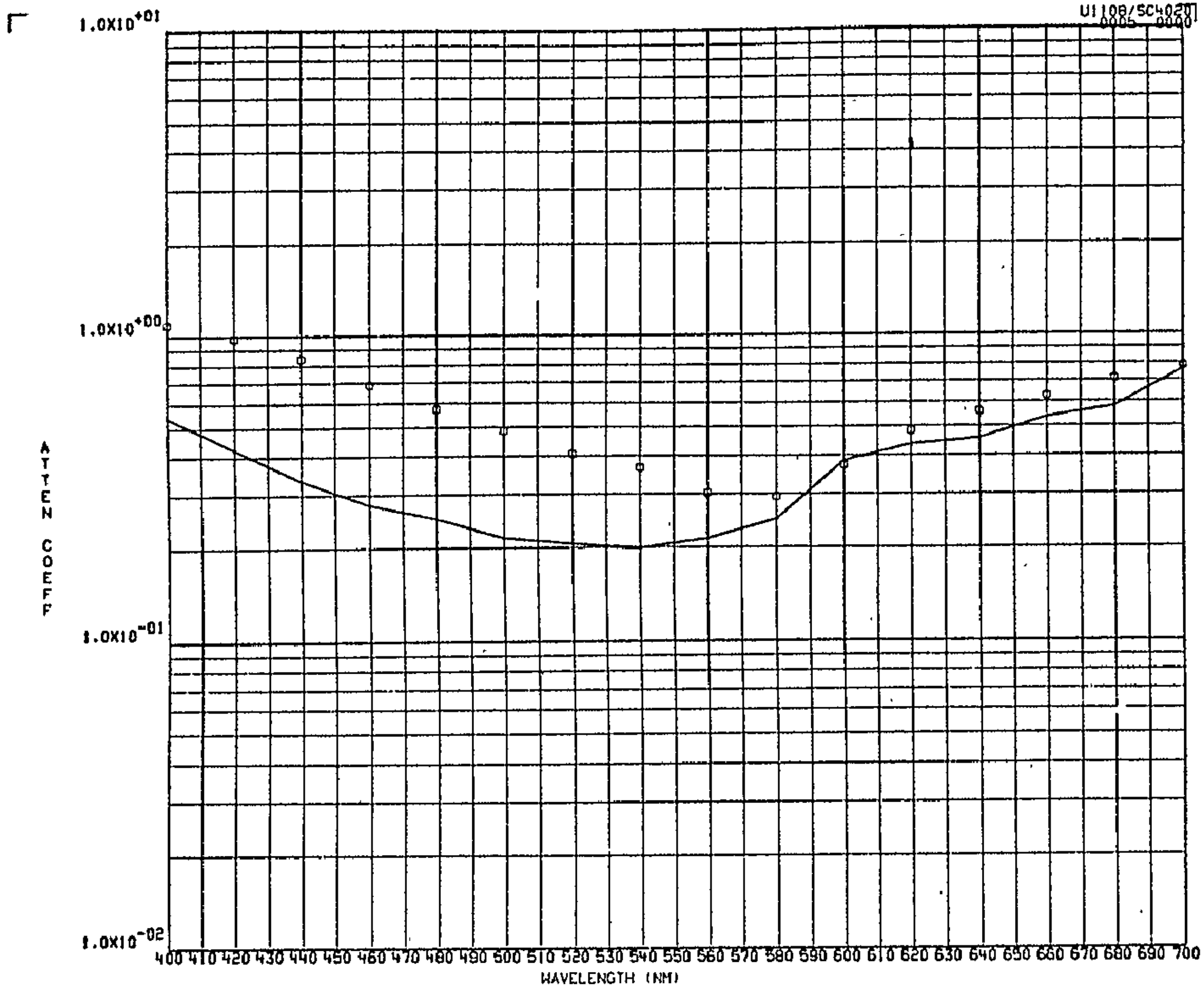


CHI SQUARE = 1.60×10^{-04} DEPTHS(M) IRRAD 0.00, RAD TOP 0.00, RAD BOT 4.57

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$6.988 \times 10^{+04}$	$1.034 \times 10^{+03}$	$1.060 \times 10^{+03}$	$3.621 \times 10^{+01}$	5.636×10^{-01}	$3.259 \times 10^{+00}$
MODE DIAM			0.23	1.37	11.16	
ALPHA			6.00	6.00	6.00	
GAMMA	4.94	2.75	0.21	0.50	0.50	

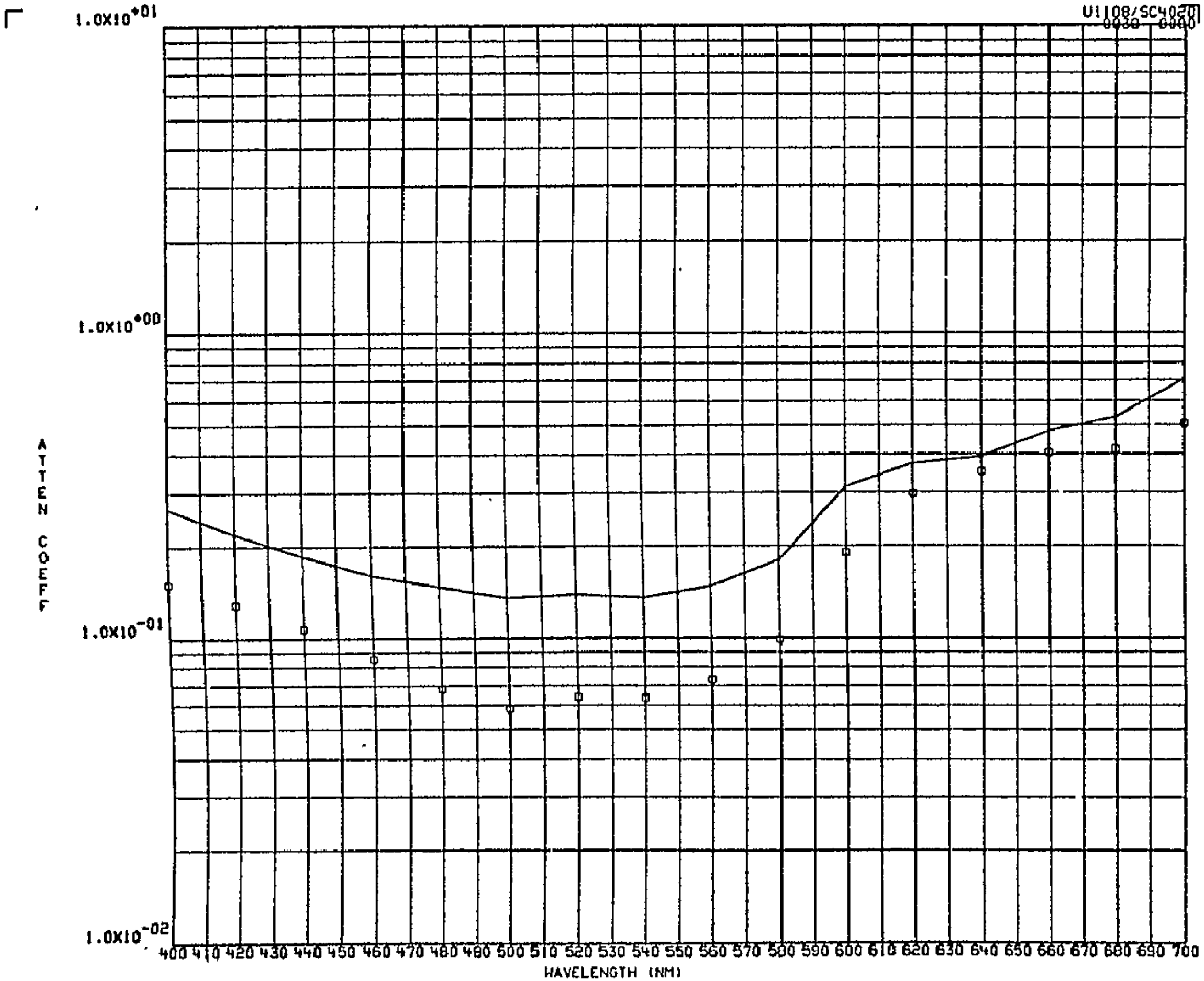
RUN TITLE- STATION 8



CHI SQUARE = $6\ 27 \times 10^{-04}$ DEPTHS(M) IRRAD 0.00, RAD TOP 0.00, RAD BOT 3.04

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$9.436 \times 10^{+04}$	$3.140 \times 10^{+03}$	$2.291 \times 10^{+02}$	1.461×10^{-01}	1.359×10^{-03}	$1.422 \times 10^{+00}$
MODE DIAM			0.23	1.37	23 00	
ALPHA			6.00	6.00	6.00	
GAMMA	5.00	3.09	0.21	12.23	0.70	

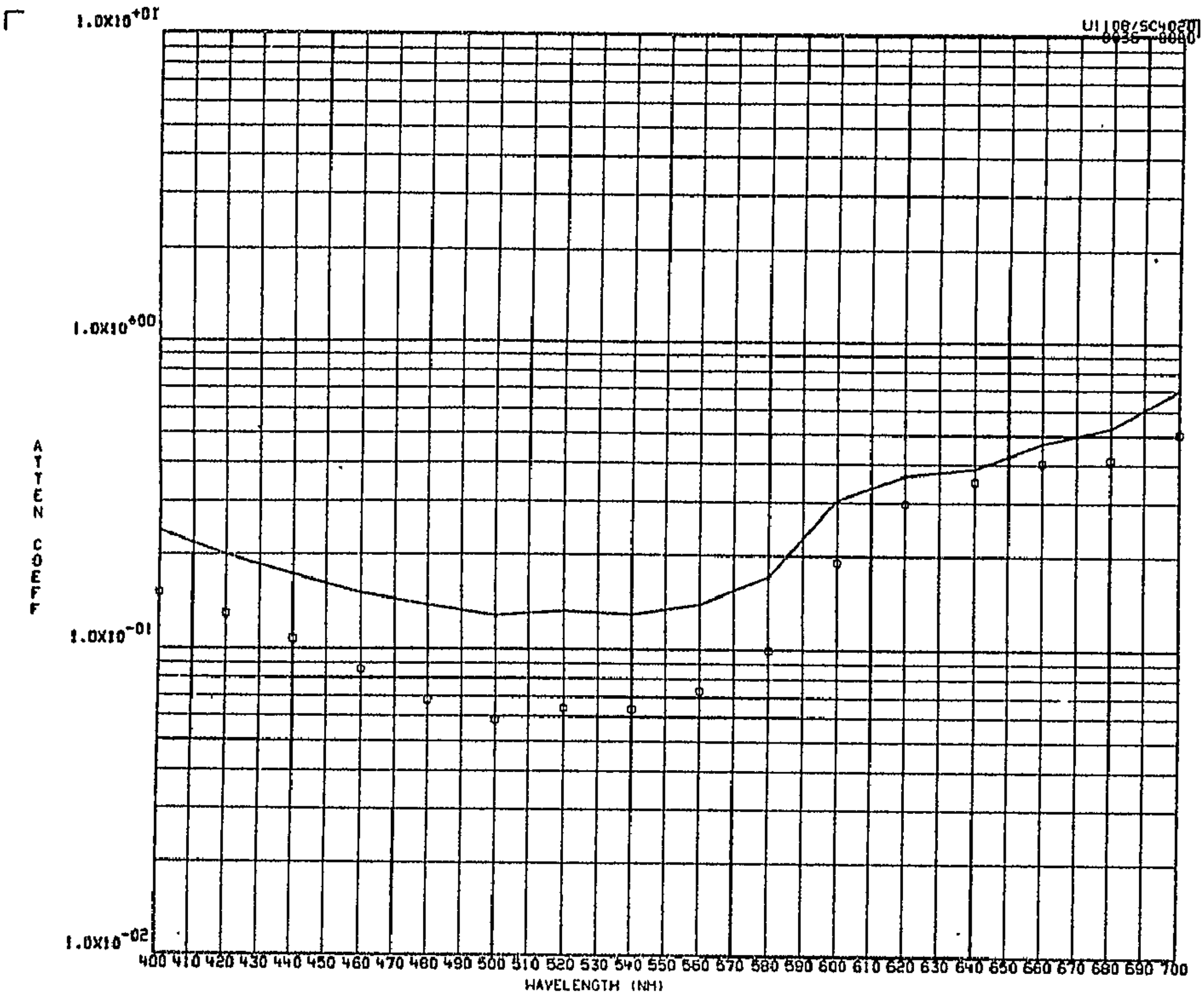
RUN TITLE- STATION B SURFACE



CHI SQUARE = 2.41×10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 15.24

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$4.417 \times 10^{+02}$	$3.261 \times 10^{+04}$	$6.075 \times 10^{+02}$	$5.462 \times 10^{+00}$	3.759×10^{-02}	5.632×10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

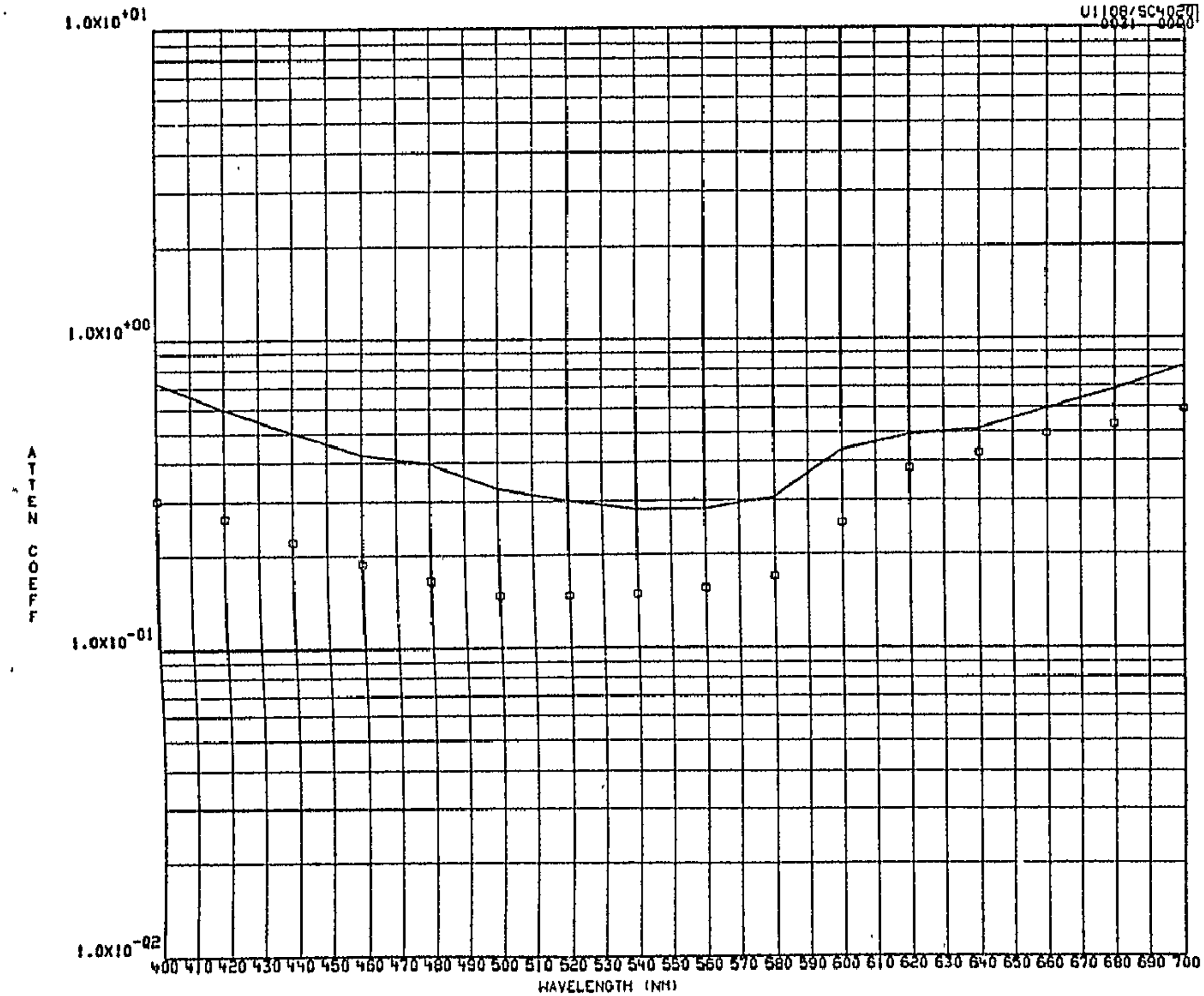
RUN TITLE- STATION 44



CHI SQUARE = 2.68×10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 15.24

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$3.613 \times 10^{+02}$	$3.041 \times 10^{+04}$	$5.656 \times 10^{+02}$	$4.728 \times 10^{+00}$	4.489×10^{-02}	4.754×10^{-01}
MODE DIAM			0.20	1.50	15.07	
ALPHA			6.00	6.00	6.00	
GAMMA	2.76	6.00	0.25	0.40	0.70	

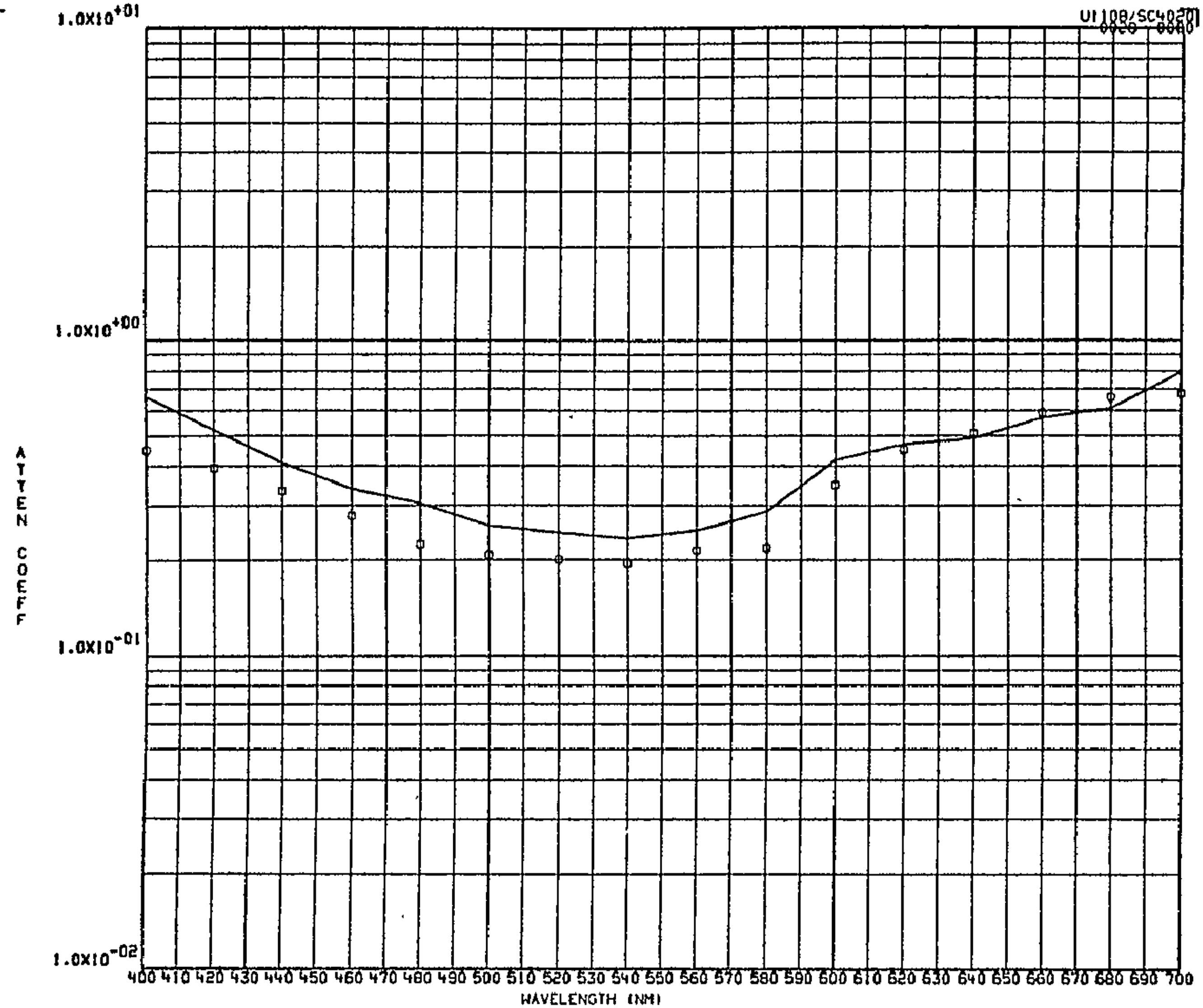
RUN TITLE- STATION 44



CHI SQUARE $= 9.06\times10^{-06}$ DEPTHS(M) IRRAD 7.31, RAD TOP 7.31, RAD BOT 10.97

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$3.634\times10^{+03}$	$2.861\times10^{+04}$	$1.881\times10^{+03}$	$6.135\times10^{+00}$	1.366×10^{-01}	$1.697\times10^{+00}$
MODE DIAM			0.20	1.50	9.25	
ALPHA			6.00	6.00	6.00	
GAMMA	2.85	6.00	0.38	0.40	0.70	

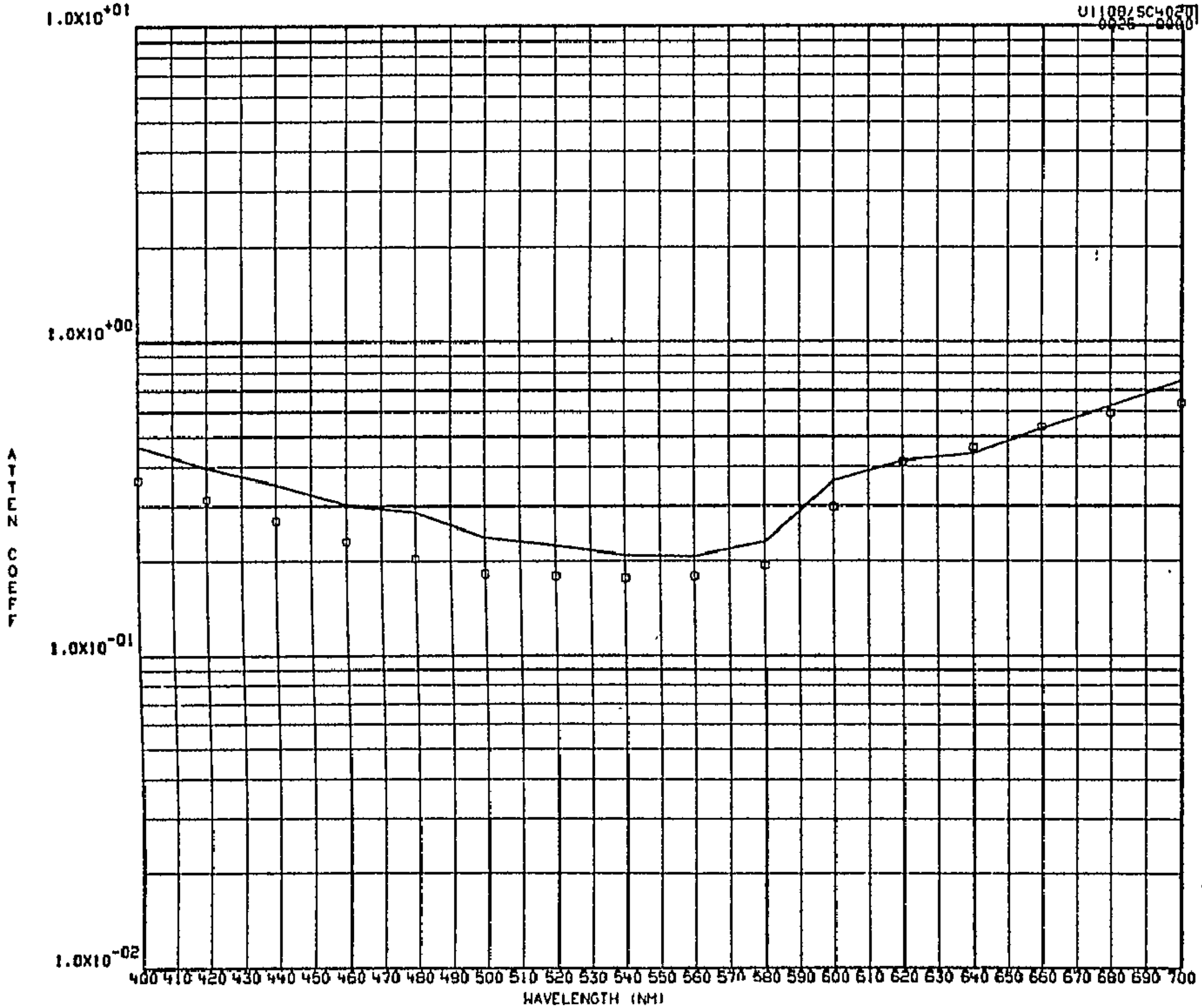
RUN TITLE- STATION 43



CHI SQUARE = 2.83×10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 3.65

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$2.985\times10^{+03}$	$3.543\times10^{+04}$	$7.856\times10^{+01}$	$5.002\times10^{+00}$	8.128×10^{-04}	$1.752\times10^{+00}$
MODE DIAM			0.20	1.50	9.25	
ALPHA			6.00	6.00	6.00	
GAMMA	2.85	6.00	0.38	0.40	0.70	

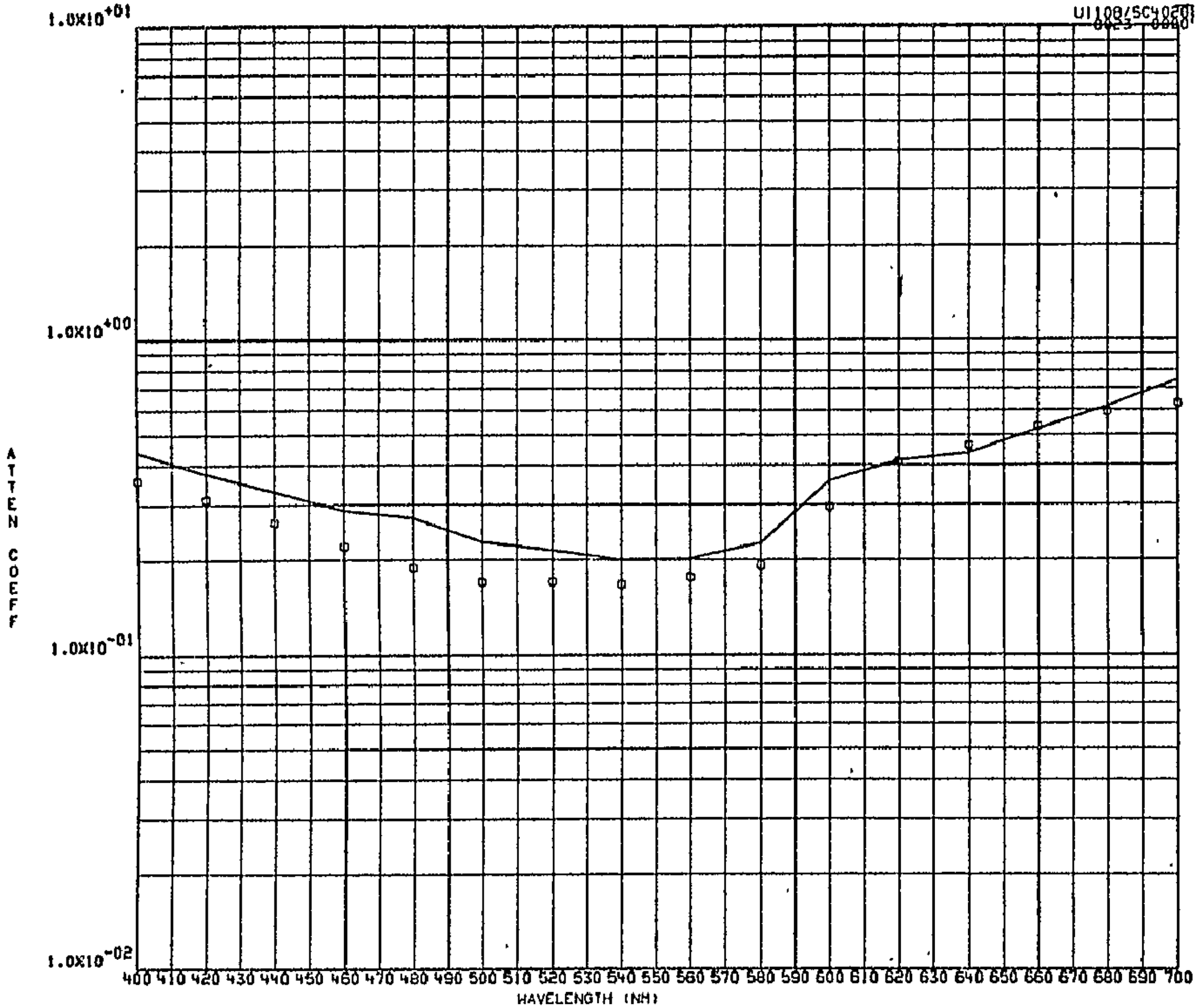
RUN TITLE- STATION 43



CHI SQUARE = 3.83×10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 10.97

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$1.237 \times 10^{+03}$	$3.520 \times 10^{+04}$	$1.787 \times 10^{+02}$	$5.799 \times 10^{+00}$	1.716×10^{-01}	9.060×10^{-01}
MODE DIAM			0.20	1.50	9.25	
ALPHA			6.00	6.00	6.00	
GAMMA	2.85	6.00	0.38	0.40	0.70	

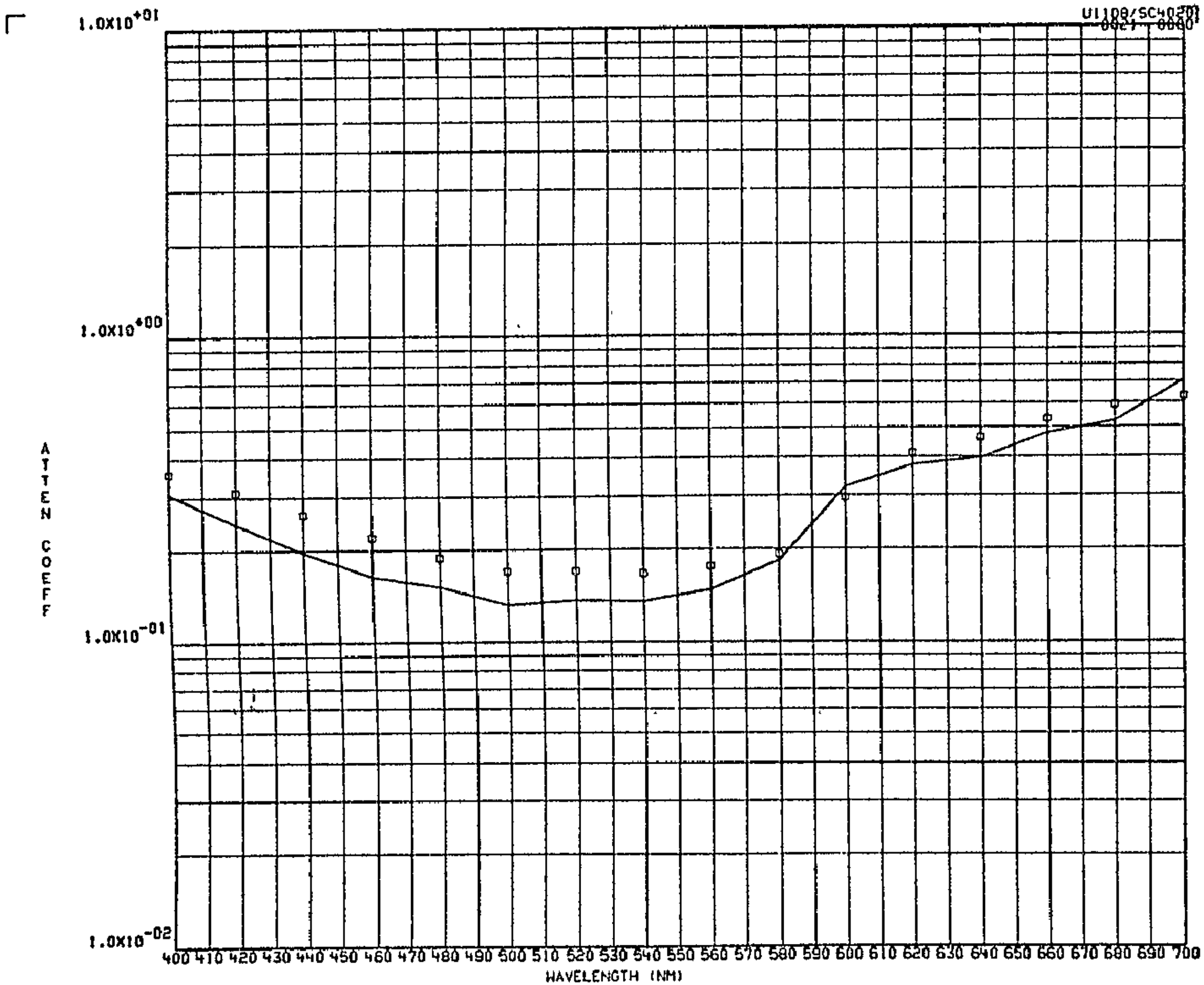
RUN TITLE- STATION 43



CHI SQUARE = 5.71×10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 10.97

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$1.202 \times 10^{+03}$	$3.651 \times 10^{+04}$	$3.454 \times 10^{+02}$	$5.831 \times 10^{+00}$	1.569×10^{-01}	8.653×10^{-01}
MODE DIAM			0.20	1.50	9.25	
ALPHA			6.00	6.00	6.00	
GAMMA	2.85	6.00	0.38	0.40	0.70	

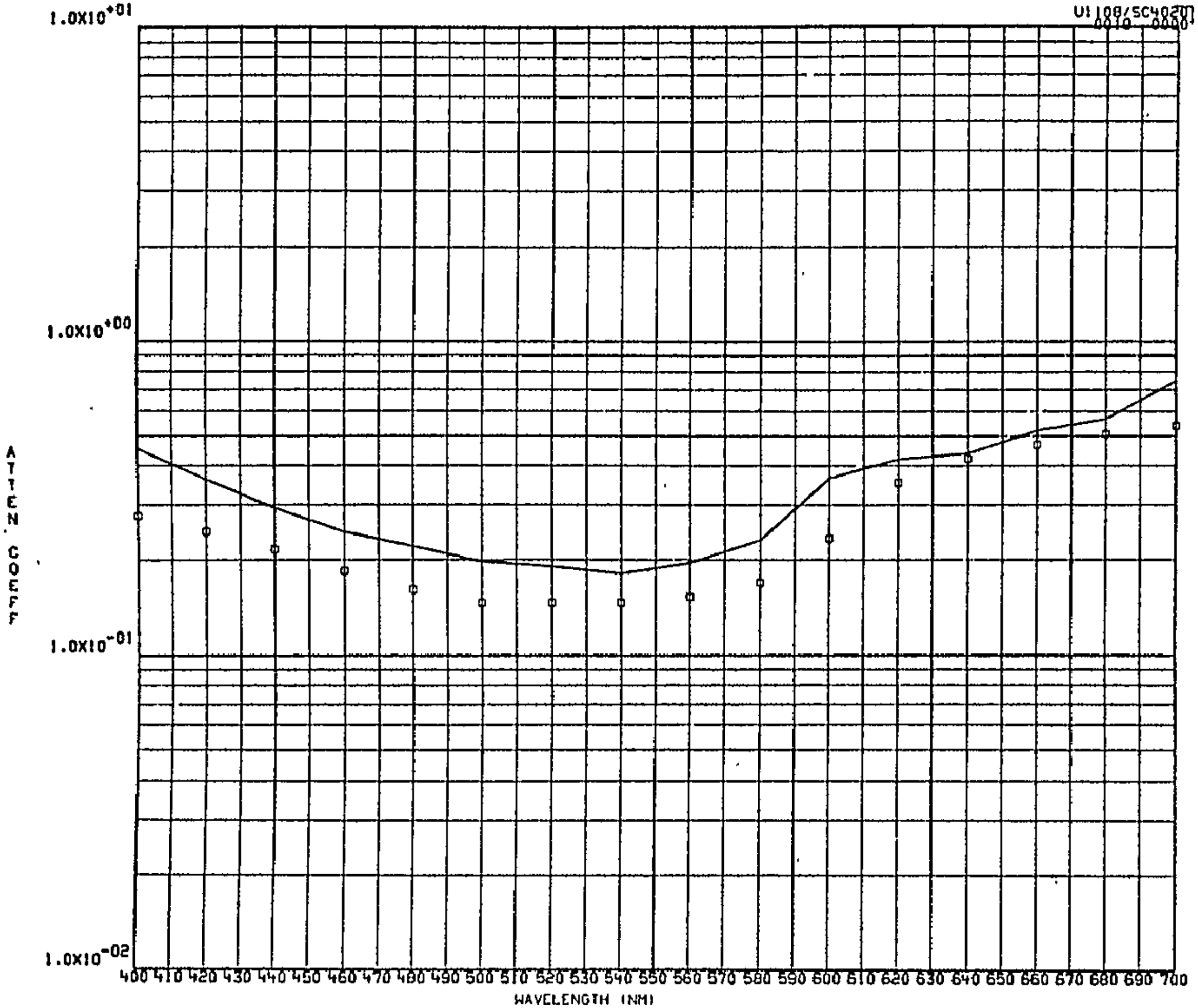
RUN TITLE- STATION 43



CHI SQUARE = 3.38×10^{-04} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 10.97

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$2.063 \times 10^{+02}$	$4.032 \times 10^{+04}$	$1.711 \times 10^{+02}$	1.220×10^{-01}	1.543×10^{-02}	7.567×10^{-01}
MODE DIAM			0.20	1.50	9.25	
ALPHA			6.00	6.00	6.00	
GAMMA	2.85	6.00	0.38	0.40	0.70	

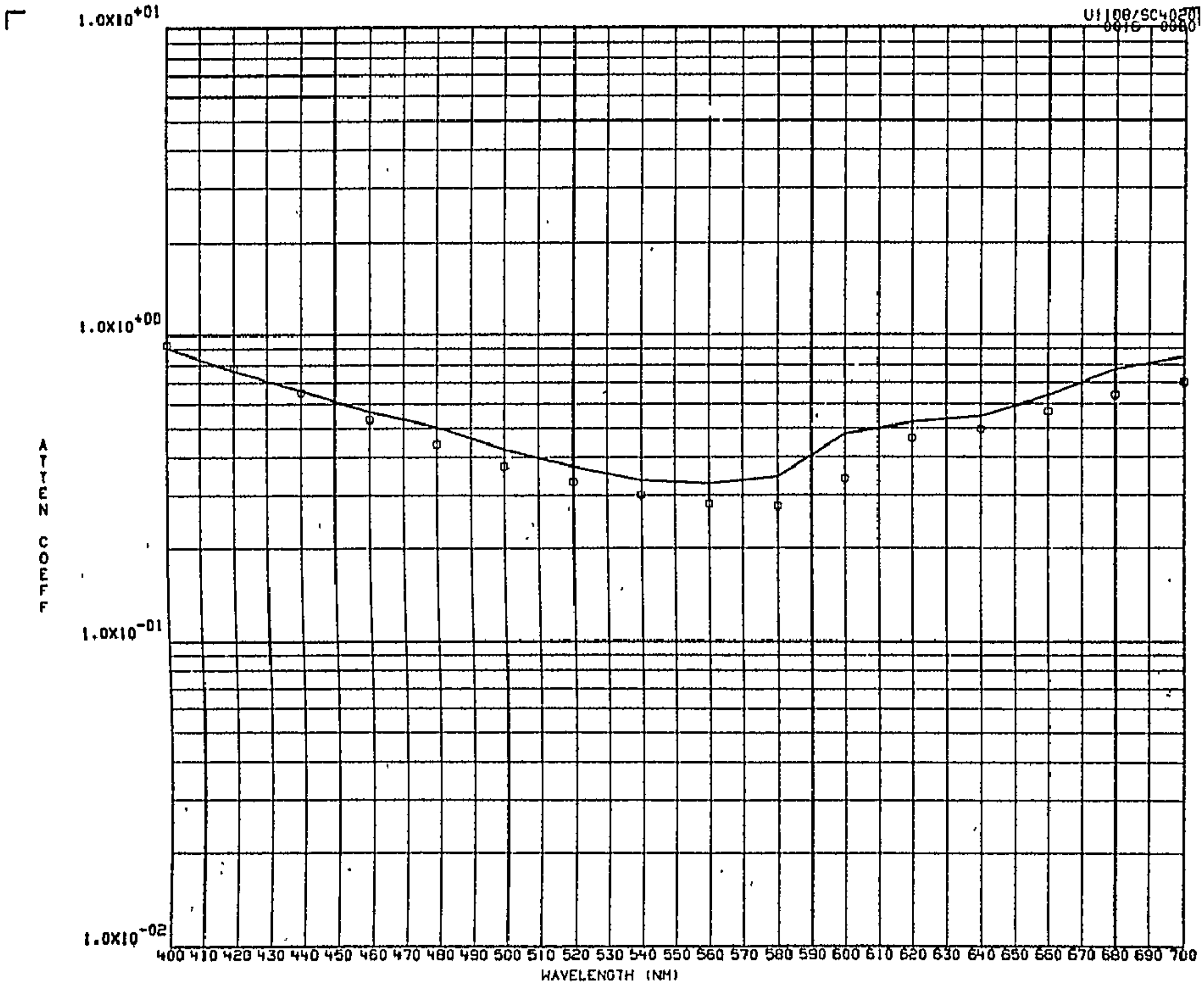
RUN TITLE- STATION 43 (BASED ON VSF FIT RESULTS)



CHI SQUARE = 9.14×10^{-06} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 14.93

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$3.277 \times 10^{+03}$	$1.630 \times 10^{+04}$	$2.922 \times 10^{+02}$	$2.083 \times 10^{+01}$	1.941×10^{-02}	$1.130 \times 10^{+00}$
MODE DIAM			0.47	1.51	15.00	
ALPHA			6.00	6.00	6.00	
GAMMA	2.99	7.00	0.37	0.80	0.80	

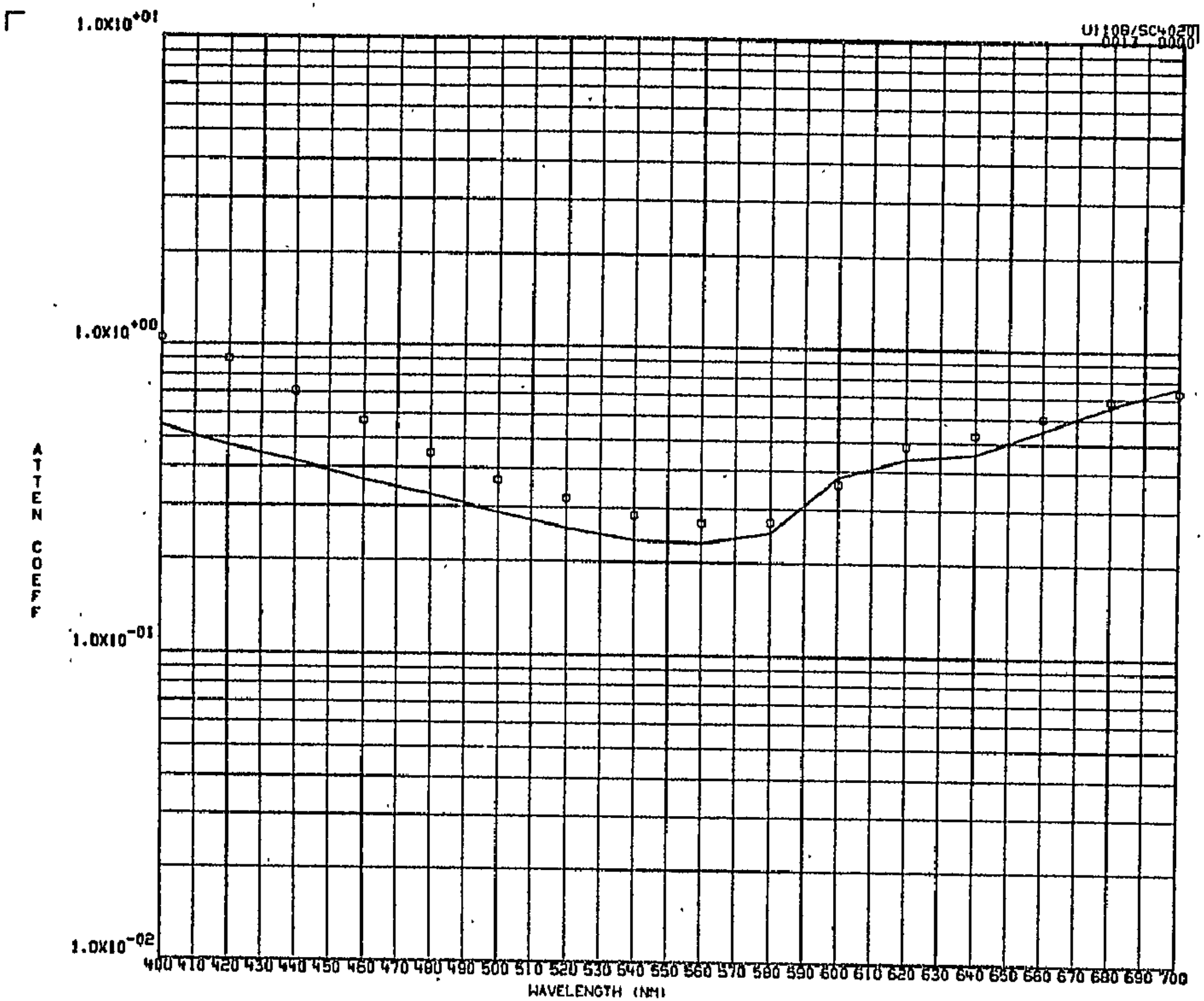
RUN TITLE- STATION 13



CHI SQUARE = 1.59×10^{-05} DEPTHS(M) IRRAD 2.13, RAD TOP 2.13, RAD BOT 4.26

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$1.348 \times 10^{+01}$	$9.598 \times 10^{+02}$	$6.723 \times 10^{+02}$	$1.638 \times 10^{+00}$	2.378×10^{-01}	$2.033 \times 10^{+00}$
MODE DIAM			0.29	1.51	15.00	
ALPHA			6.00	6.00	6.00	
GAMMA	6.00	2.85	0.29	0.40	0.70	

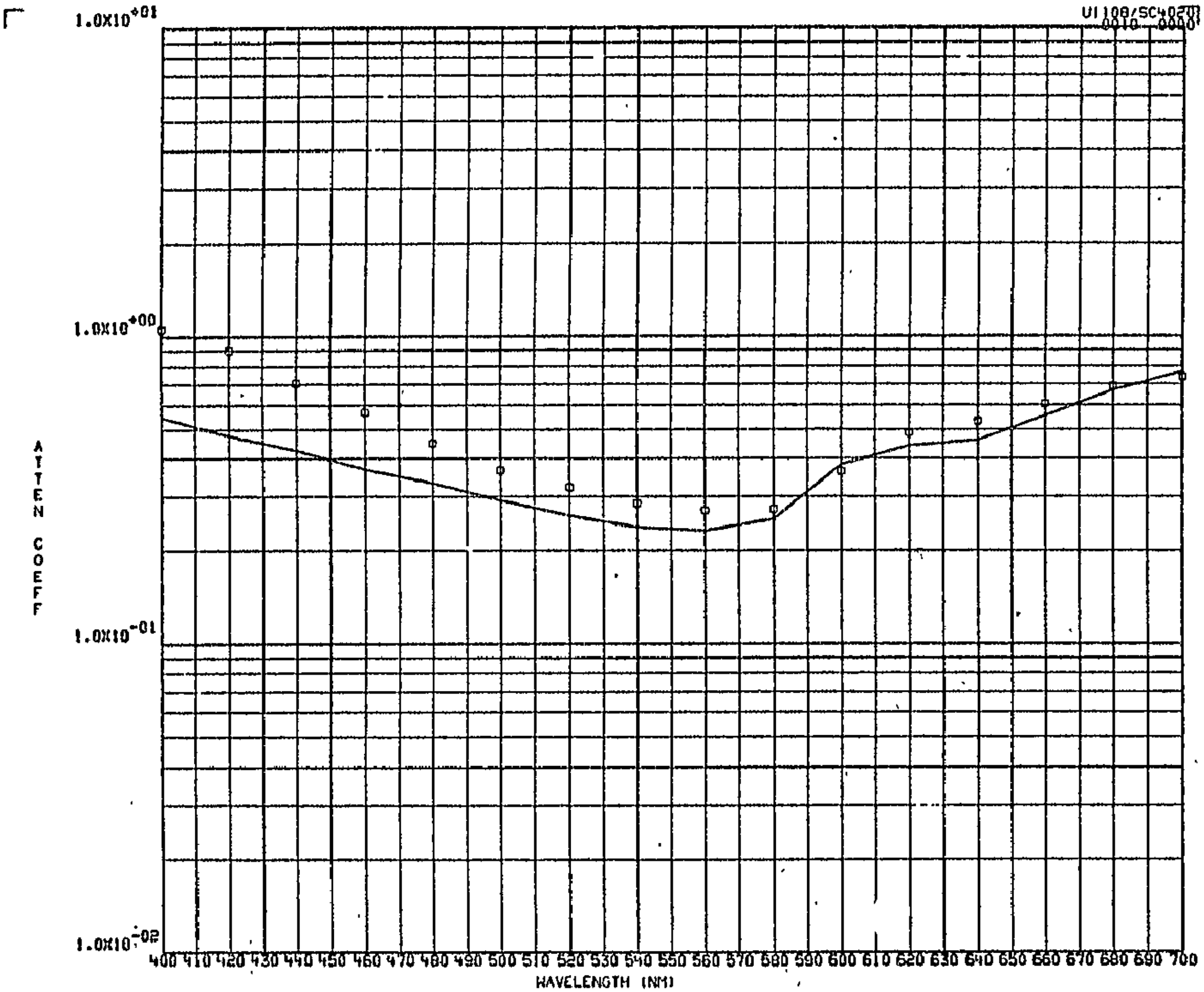
RUN TITLE- STATION 12



CHI SQUARE = 2.17×10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 2.13

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$1.356\times10^{+02}$	$5.419\times10^{+02}$	$8.761\times10^{+02}$	$3.593\times10^{+00}$	1.940×10^{-01}	$1.071\times10^{+00}$
MODE DIAM			0.29	1.51	15.00	
ALPHA			6.00	6.00	6.00	
GAMMA	6.00	2.85	0.29	0.40	0.70	

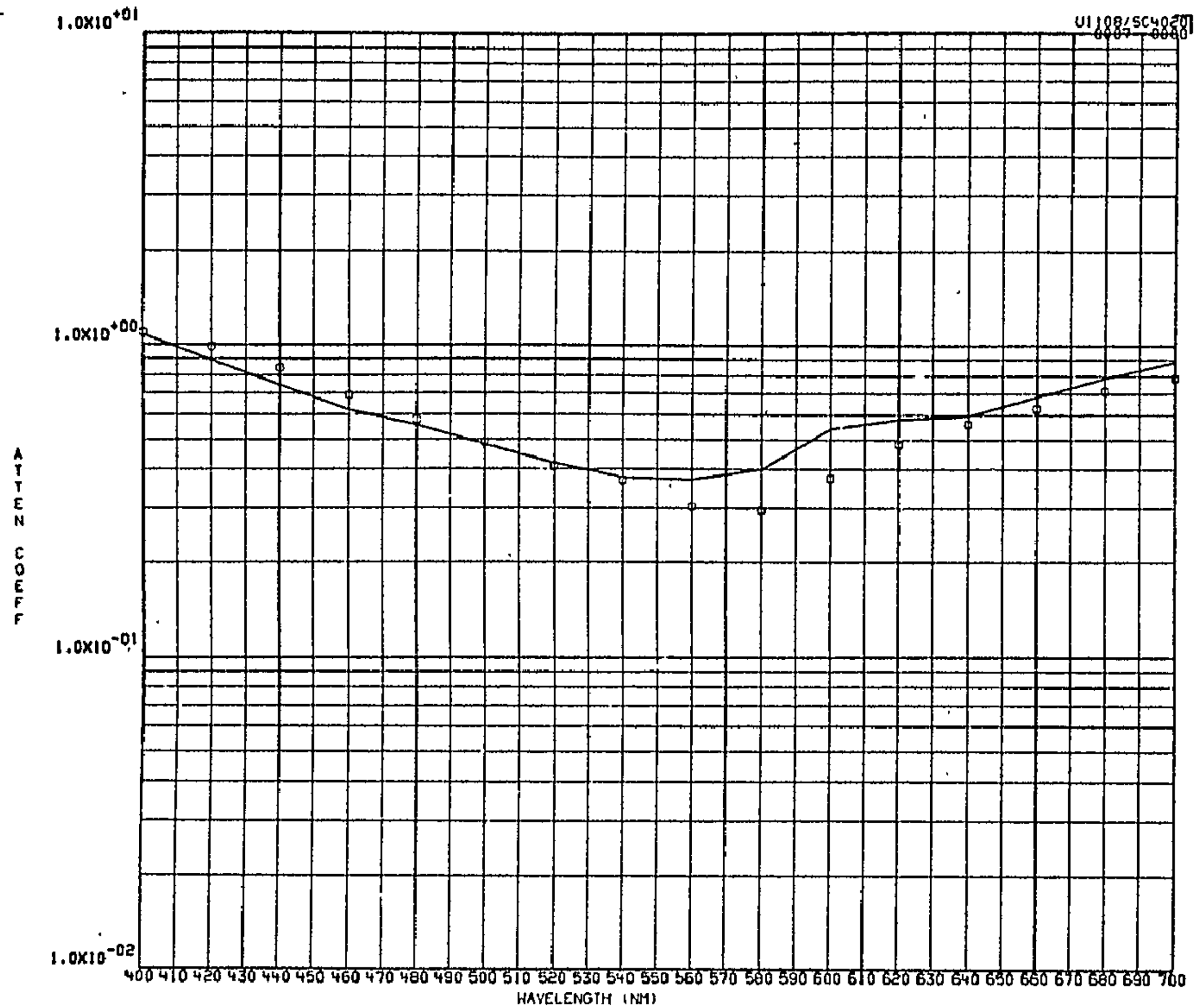
RUN TITLE- STATION 12



CHI SQUARE = 2.30X10^{-05} DEPTHS(M) IRRAD 0.91, RAD TOP 0.91, RAD BOT 2.13

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	1.014X10^{+02}	6.320X10^{+02}	9.417X10^{+02}	4.399X10^{+00}	2.040X10^{-01}	1.043X10^{+00}
MODE DIAM			0.29	1.51	15.00	
ALPHA			6.00	6.00	6.00	
GAMMA	0.00	2.95	0.29	0.40	0.70	

RUN TITLE- STATION 12



CHI SQUARE = 8.64×10^{-05} DEPTHS(M) IRRAD 0.00, RAD TOP 0.00, RAD BOT 3.04

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS	GELBSTOF
POPULATION	$3.046 \times 10^{+02}$	$5.149 \times 10^{+03}$	$3.844 \times 10^{+02}$	$1.847 \times 10^{+02}$	2.002×10^{-01}	$2.603 \times 10^{+00}$
MODE DIAM			0.23	1.37	23.00	
ALPHA			6.00	6.00	6.00	
GAMMA	5.00	3.09	0.21	12.23	0.70	

RUN TITLE- STATION 8 SURFACE

APPENDIX E

PARTICLE SIZE DISTRIBUTION

PREDICTED FROM SPECTRAL ANALYSIS

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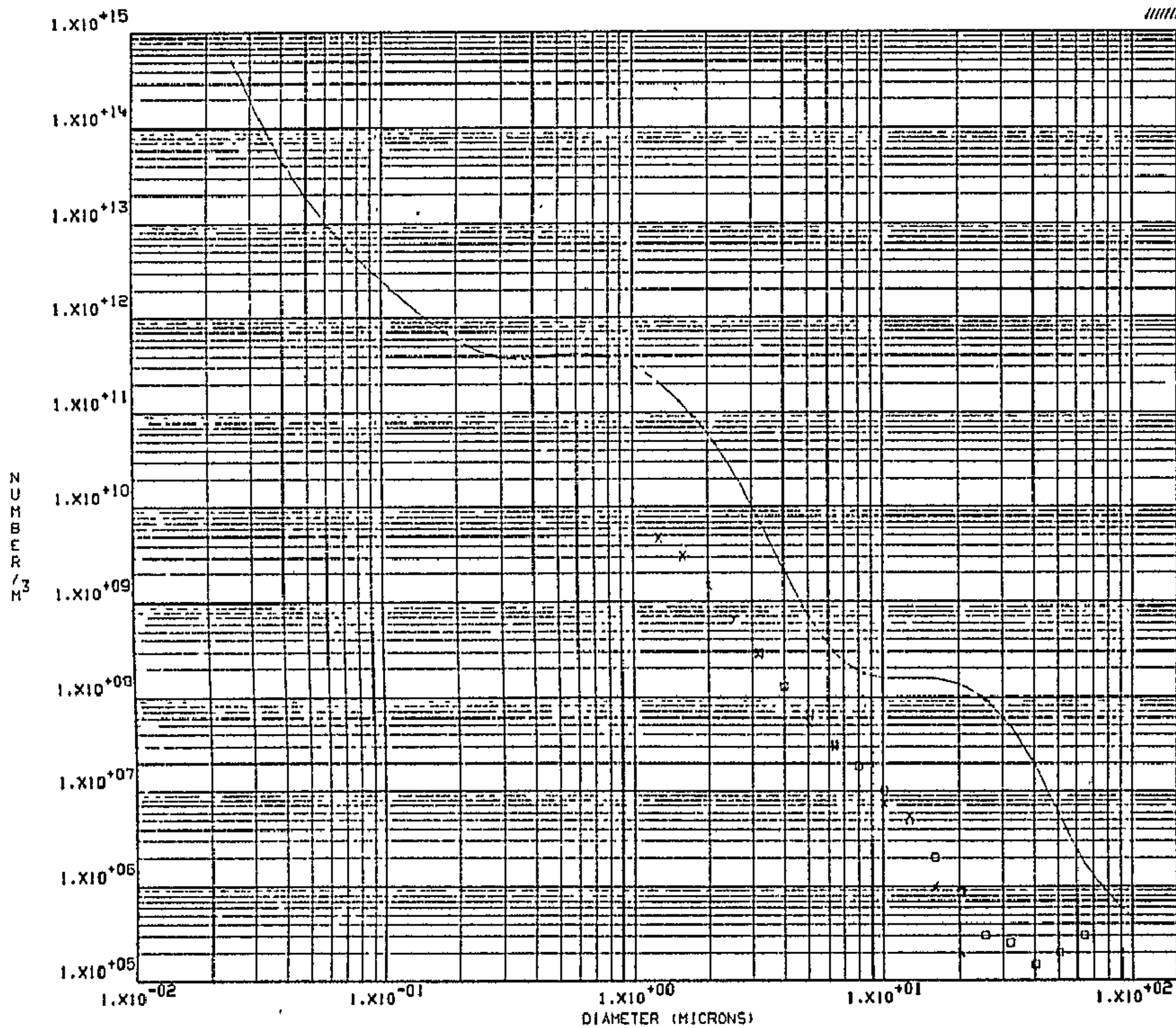
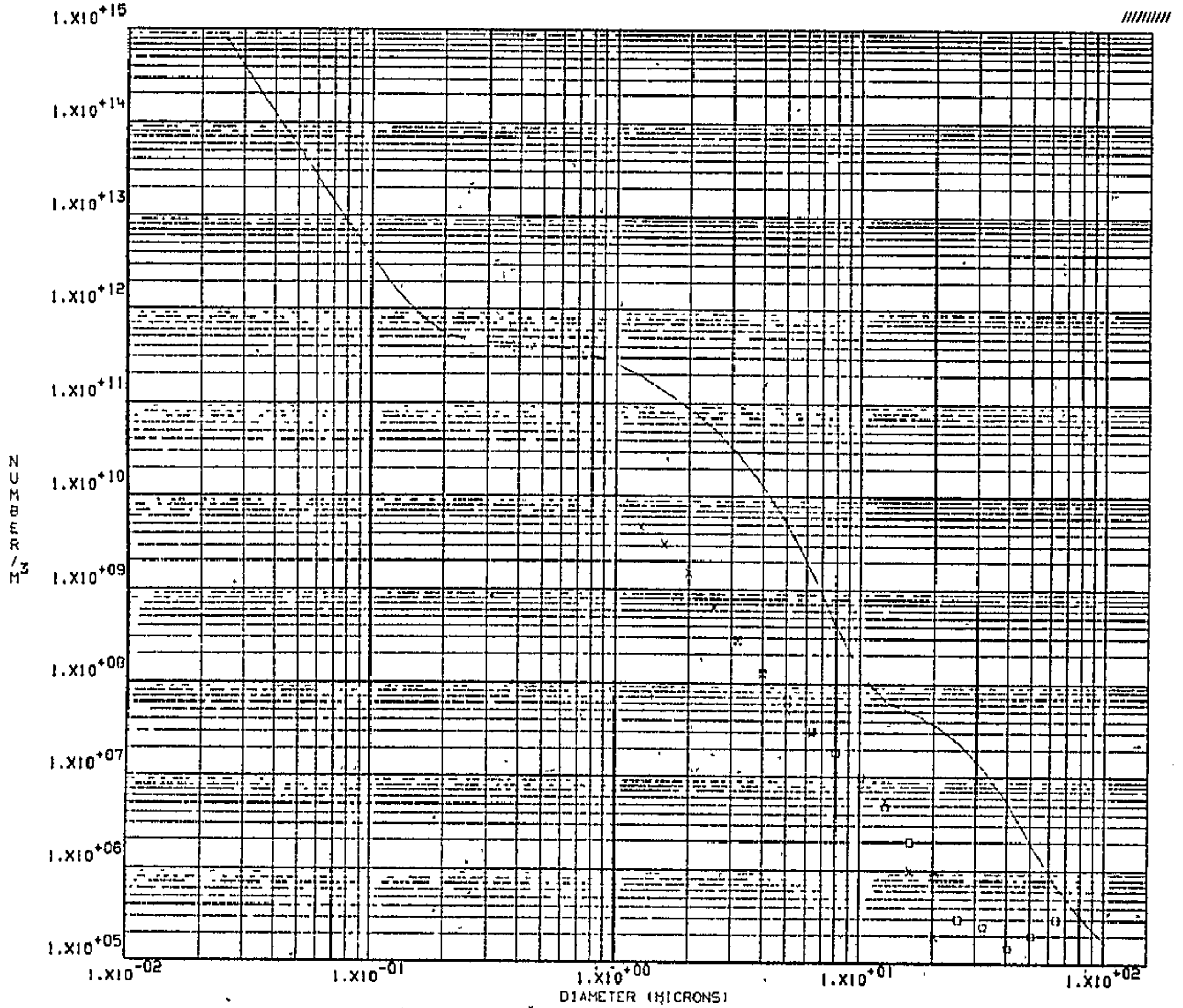


STATION 9 (FROM UPWELLING SPECTRUM)

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
o	139-3	07/22/77	9	SURFACE	1607	10	200	2.00	1.000
X	139-3	07/22/77	9	SURFACE	1607	10	50	.50	1.000

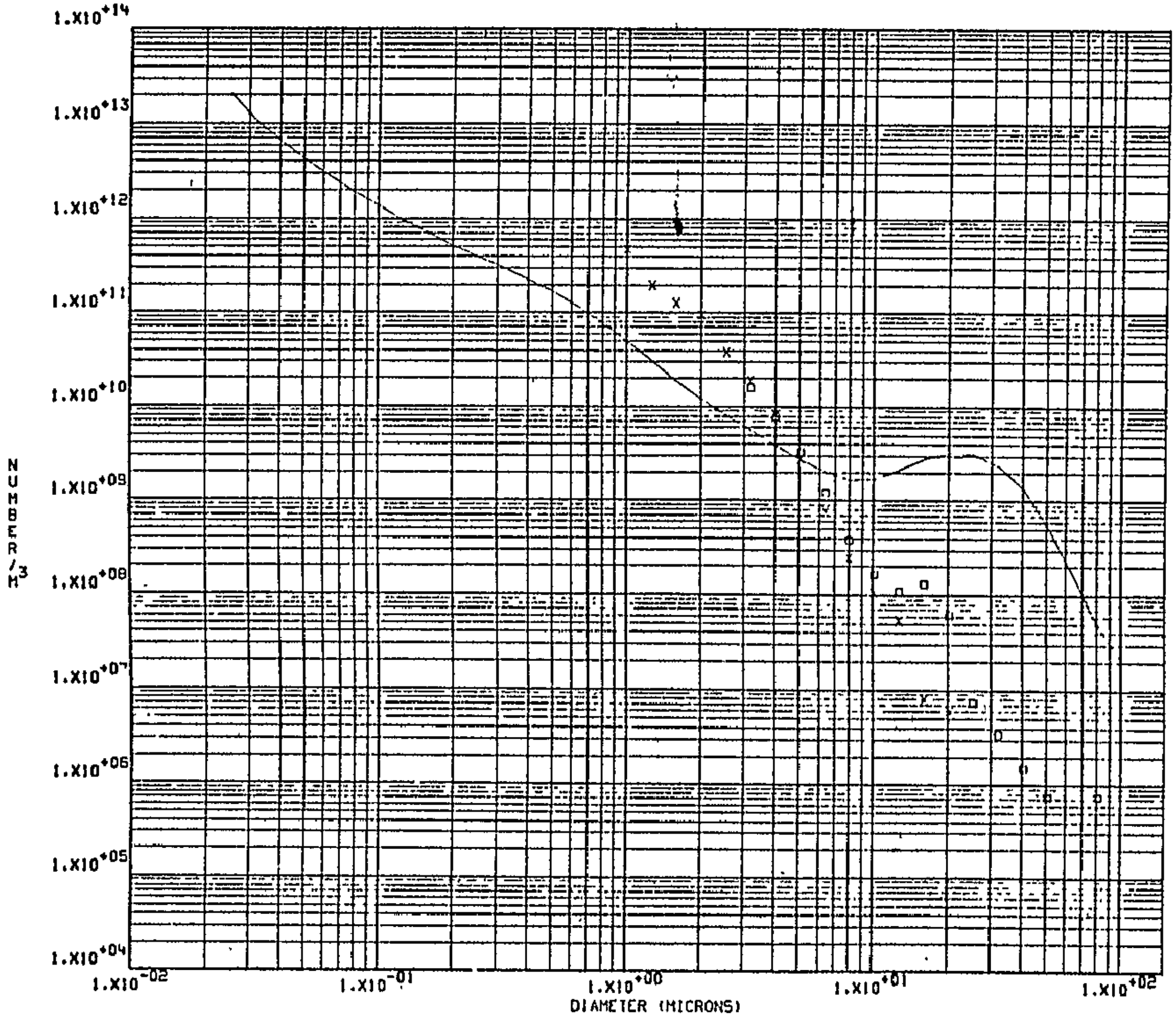
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$5.771\times10^{+13}$	$1.079\times10^{+14}$	$5.628\times10^{+09}$	$2.464\times10^{+12}$	$6.627\times10^{+08}$
MODE DIAM	0.00	0.00	1.00	0.50	15.00
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	3.23	7.00	0.40	0.40	0.70



STATION 9 (FROM UPWELLING SPECTRUM) INFINITELY DEEP, UNIFORM

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	139-3	07/22/77	9	SURFACE	1607	10	200	2 00	1 000
X	138-3	07/22/77	9	SURFACE	1607	10	50	.50	1.000

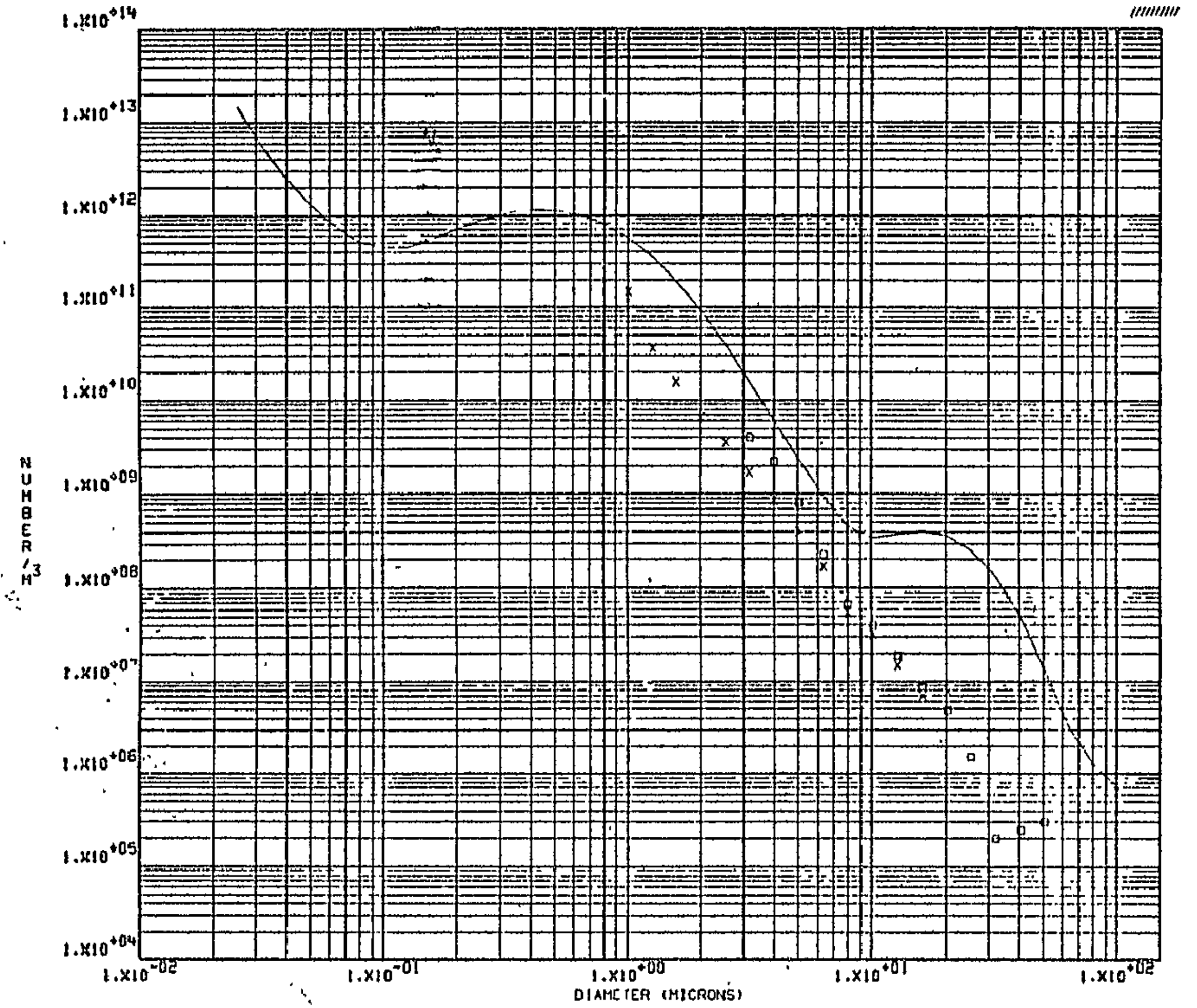
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$3.443\times10^{+14}$	$3.913\times10^{+12}$	$3.679\times10^{+12}$	$1.676\times10^{+11}$	$2.517\times10^{+08}$
MODE DIAM	0.00	0 00	0.23	1.37	11.16
ALPHA	0.00	0 00	6.00	6.00	6.00
GAMMA	4.94	3 00	0 21	0 50	0.50



STATION 11 (FROM UPWELLING SPECTRUM)

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-4	09/18/77	11	SURFACE	1549	10	200	2.00	.200
X	138-4	09/18/77	11	SURFACE	1549	10	50	.50	.200

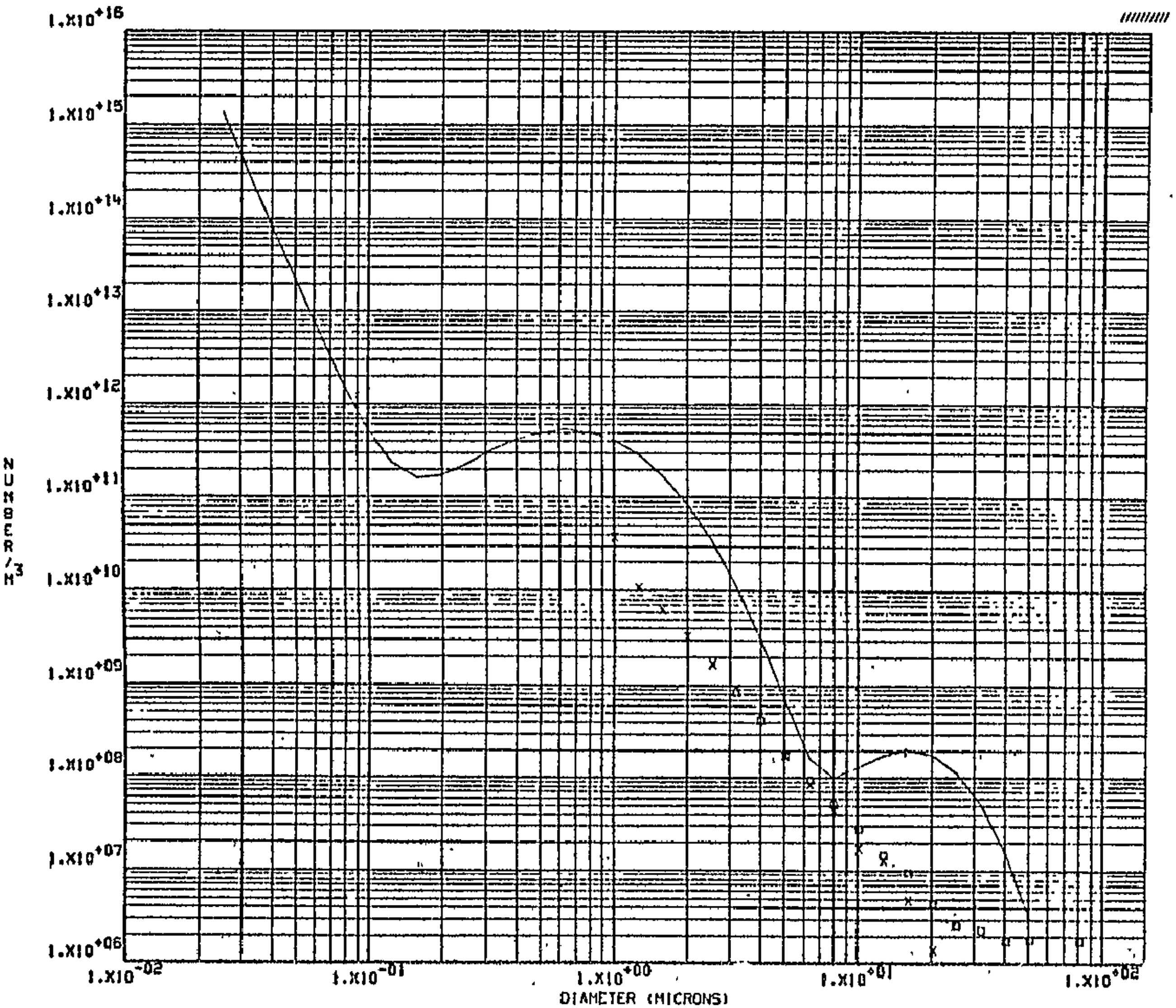
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$2.470\times10^{+13}$	$2.632\times10^{+12}$	$7.200\times10^{+11}$	$4.610\times10^{+09}$	$1.565\times10^{+10}$
MODE DIAM	0.00	0.00	0.19	1.50	20.00
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	2.61	6.00	0.29	0.30	0.70



STATION 12 (FROM UPWELLING SPECTRUM)

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-4	09/18/77	12	SURFACE		10	200	2.00	1.000
X	138-4	09/18/77	12	SURFACE		10	50	.50	1.000

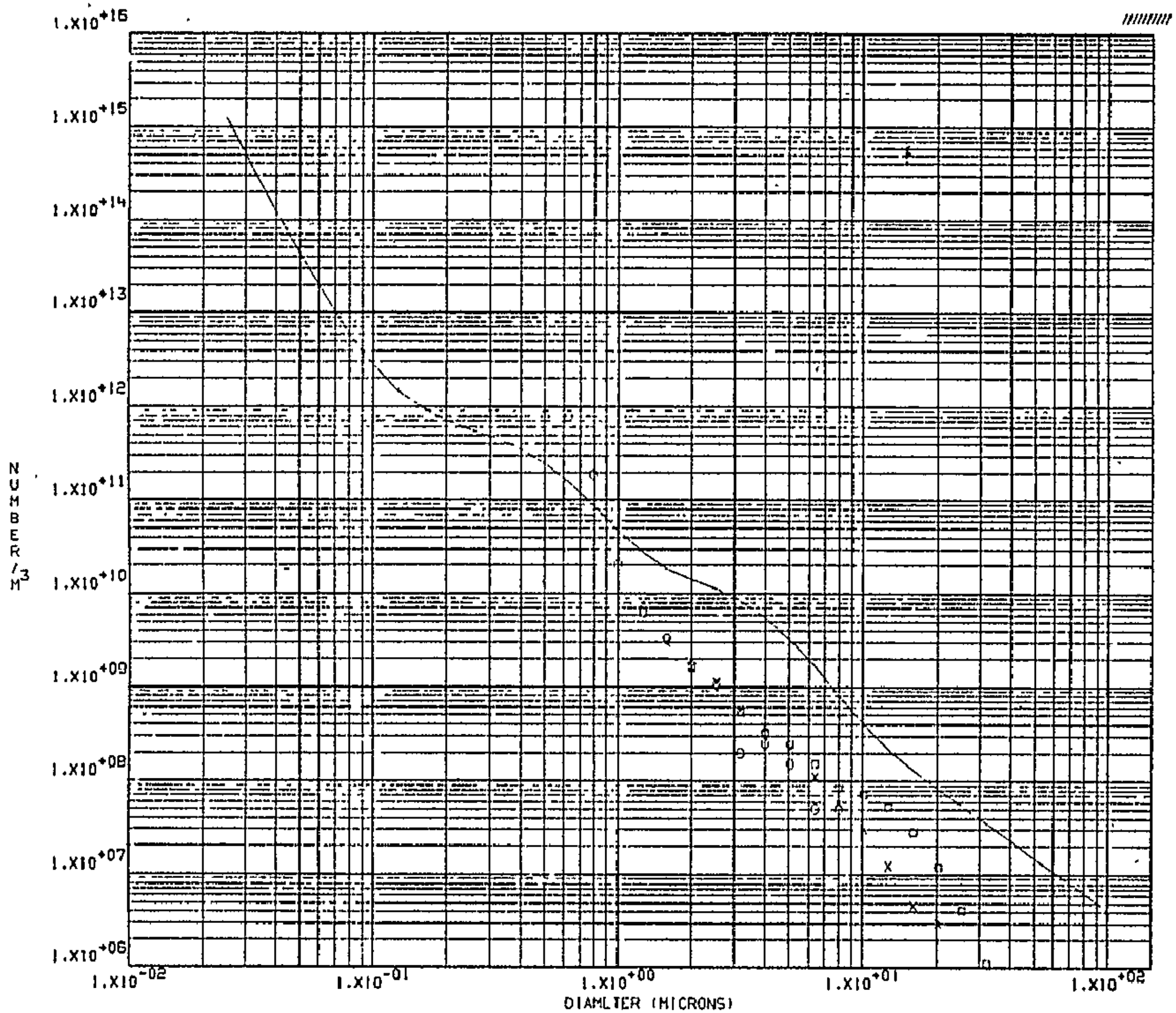
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$3.368 \times 10^{+12}$	$5.349 \times 10^{+12}$	$8.654 \times 10^{+12}$	$3.468 \times 10^{+10}$	$1.933 \times 10^{+09}$
MODE DIAM	0.00	0.00	0.29	1.51	15.00
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	6.00	2.85	0.29	0.40	0.70



STATION 13 (FROM UPWELLING SPECTRUM)

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-4	09/18/77	13	SURFACE	1920	10	200	2.00	1.000
X	138-4	09/18/77	13	SURFACE	1920	10	50	.50	1.000

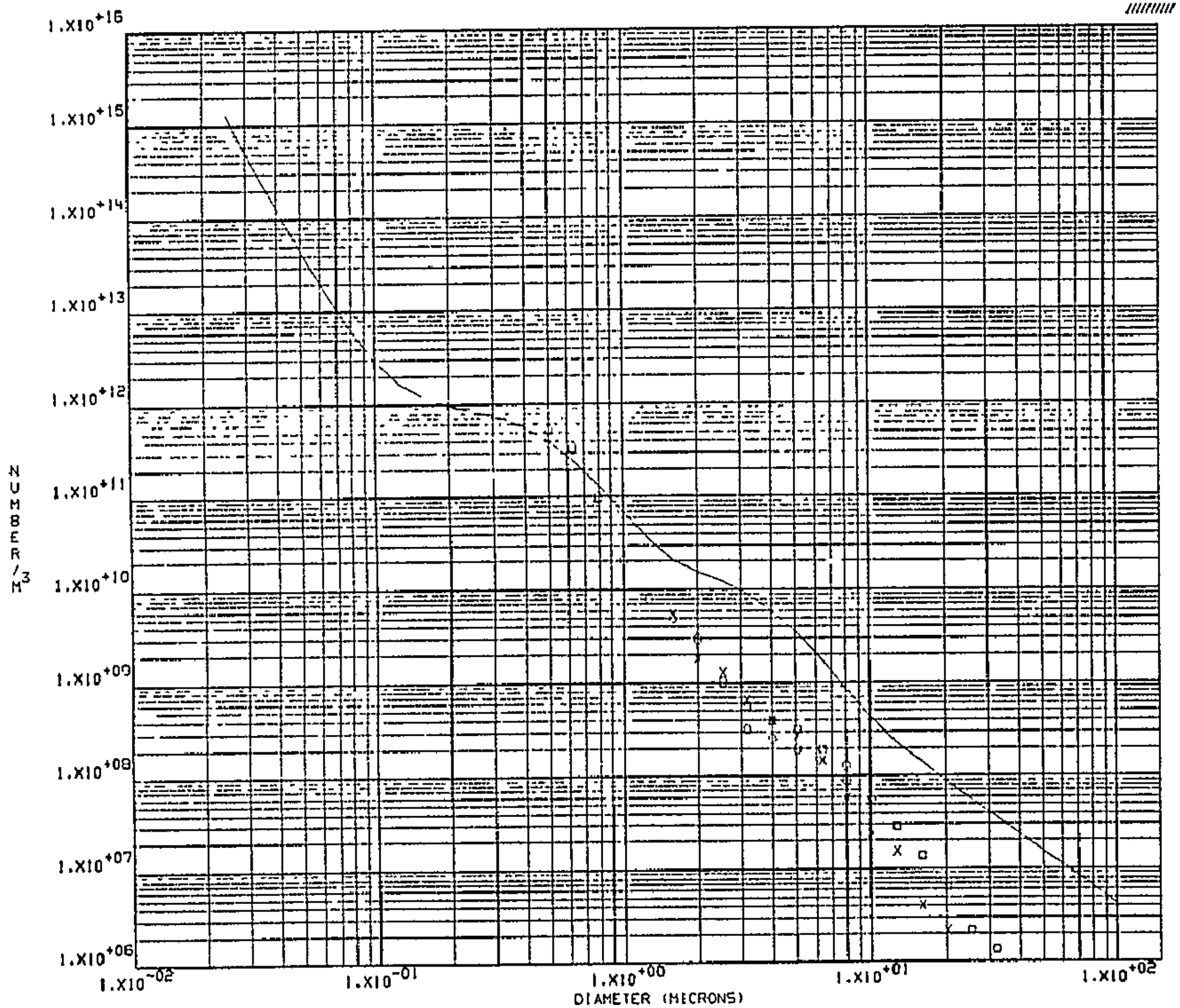
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$3.945X10^{12}$	$3.063X10^{14}$	$3.614X10^{12}$	$8.399X10^{09}$	$9.267X10^{08}$
MODE DIAM	0.00	0.00	0.47	1.51	15.00
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	2.89	7.00	0.37	0.80	0.80



STATION 43 (FROM UPWELLING SPECTRUM) DEPTH, 2 METERS

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-8	14 AUG 78	43	6 FT	2120	10	200	2.00	1.000
X	138-8	14 AUG 78	43	6 FT	2120	10	70	.50	1.000
O	138-8	14 AUG 78	43	6 FT	2120	10	15	02	.100

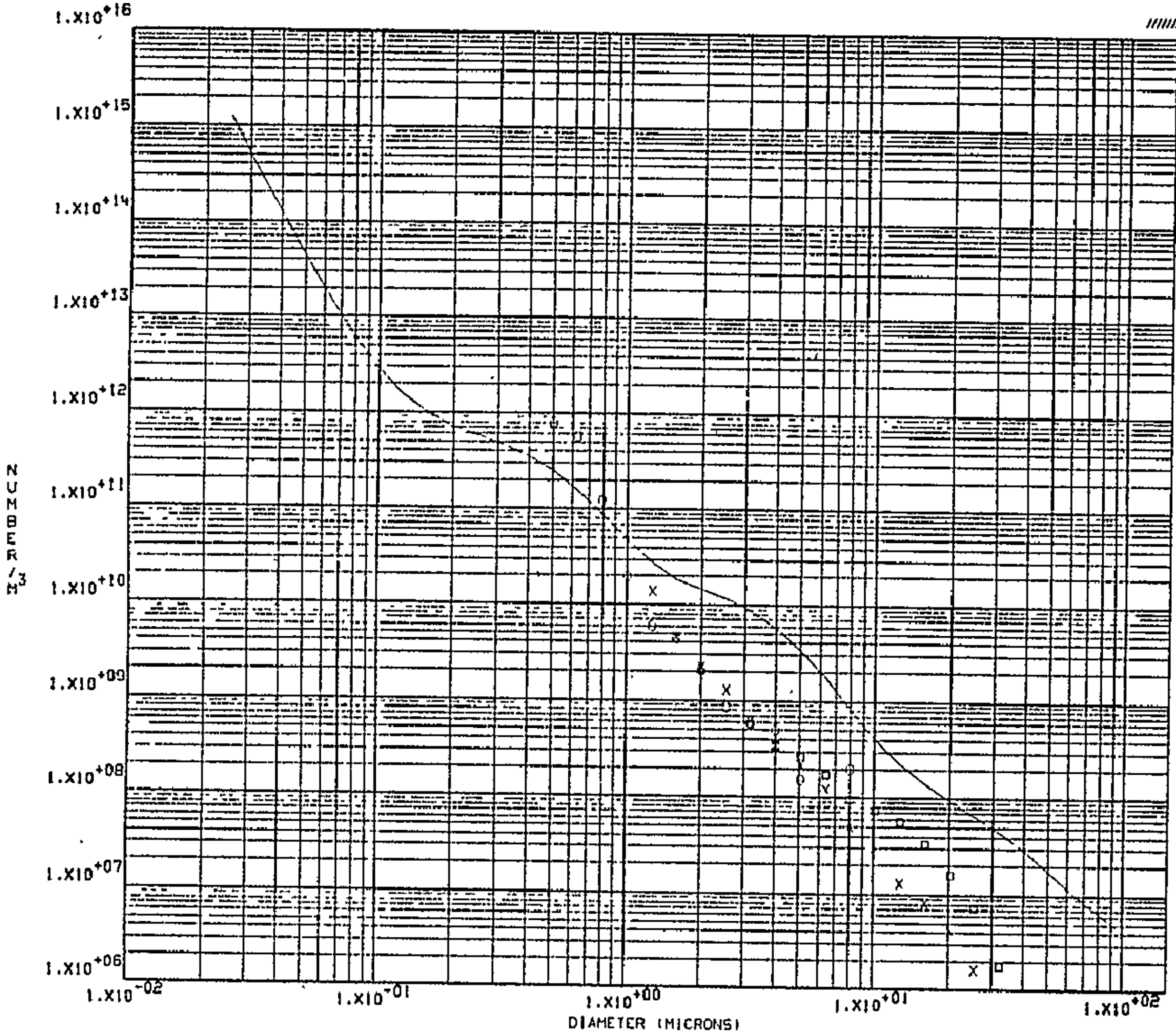
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$3.029X10^{+13}$	$3.616X10^{+14}$	$1.982X10^{+12}$	$5.316X10^{+10}$	$1.980X10^{+07}$
MODE DIAM	0.00	0 00	0.20	1.50	9 25
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	2.85	6.00	0.38	0.40	0.70



STATION 43 (FROM UPWELLING SPECTRUM) DEPTH 7 METERS

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-8	14 AUG 78	43	30 FT	2126	10	200	2.00	1.000
X	138-8	14 AUG 78	43	30 FT	2126	10	70	.50	1.000
O	138-8	14 AUG 78	43	30 FT	2126	10	15	.02	.100

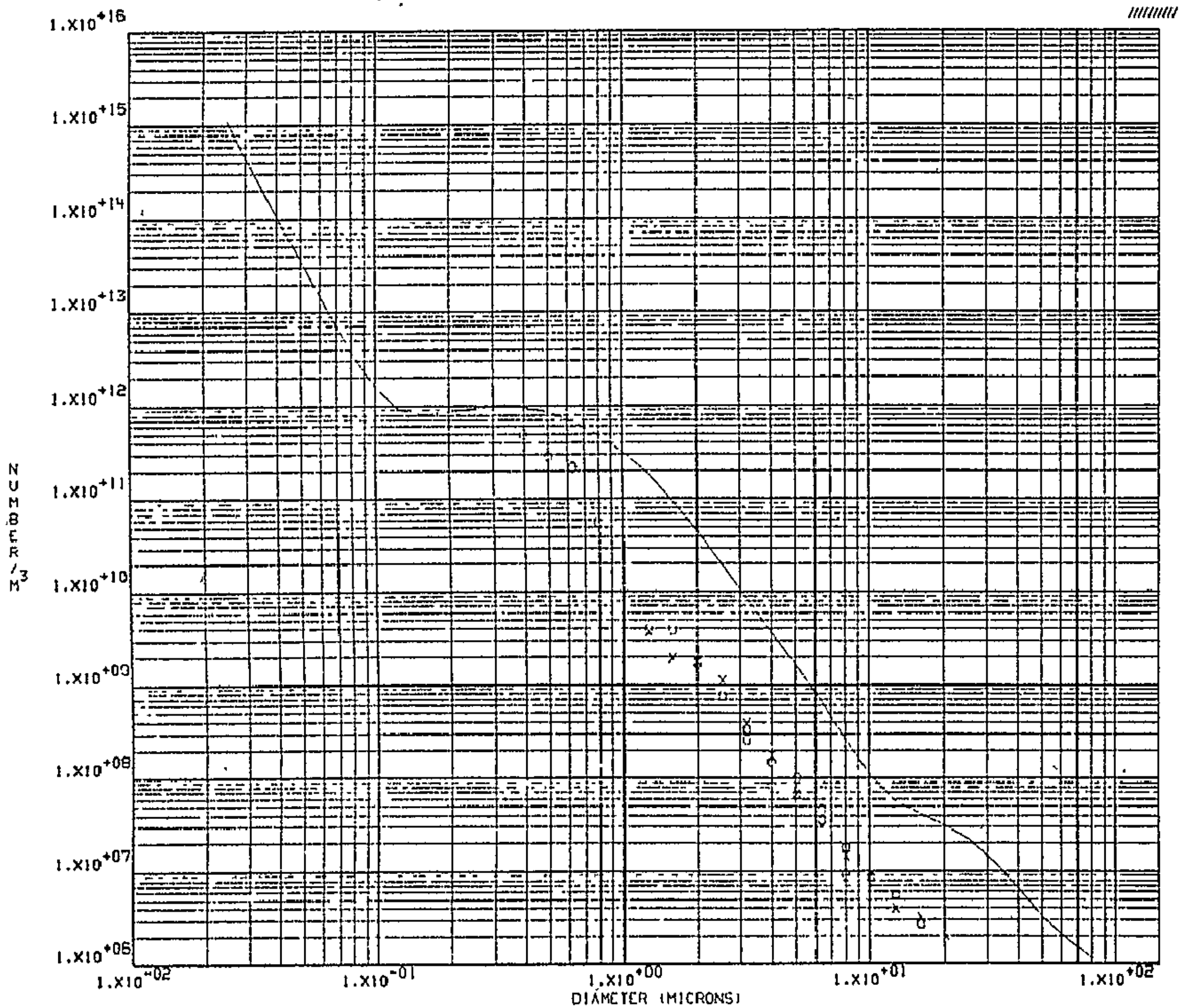
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$3.097 \times 10^{+13}$	$3.729 \times 10^{+14}$	$3.716 \times 10^{+12}$	$5.834 \times 10^{+10}$	$6.938 \times 10^{+07}$
MODE DIAM	0.00	0.00	0.20	1.50	9.25
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	2.85	6.00	0.38	0.40	0.70



STATION 43 (FROM UPWELLING SPECTRUM) INFINITELY DEEP, UNIFORM

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
D	138-B	14 AUG 78	43	SURFACE	2042	10	200	2.00	1.000
X	138-B	14 AUG 78	43	SURFACE	2042	10	70	.50	1.000
O	138-8	14 AUG 78	43	SURFACE	2042	10	15	02	.100

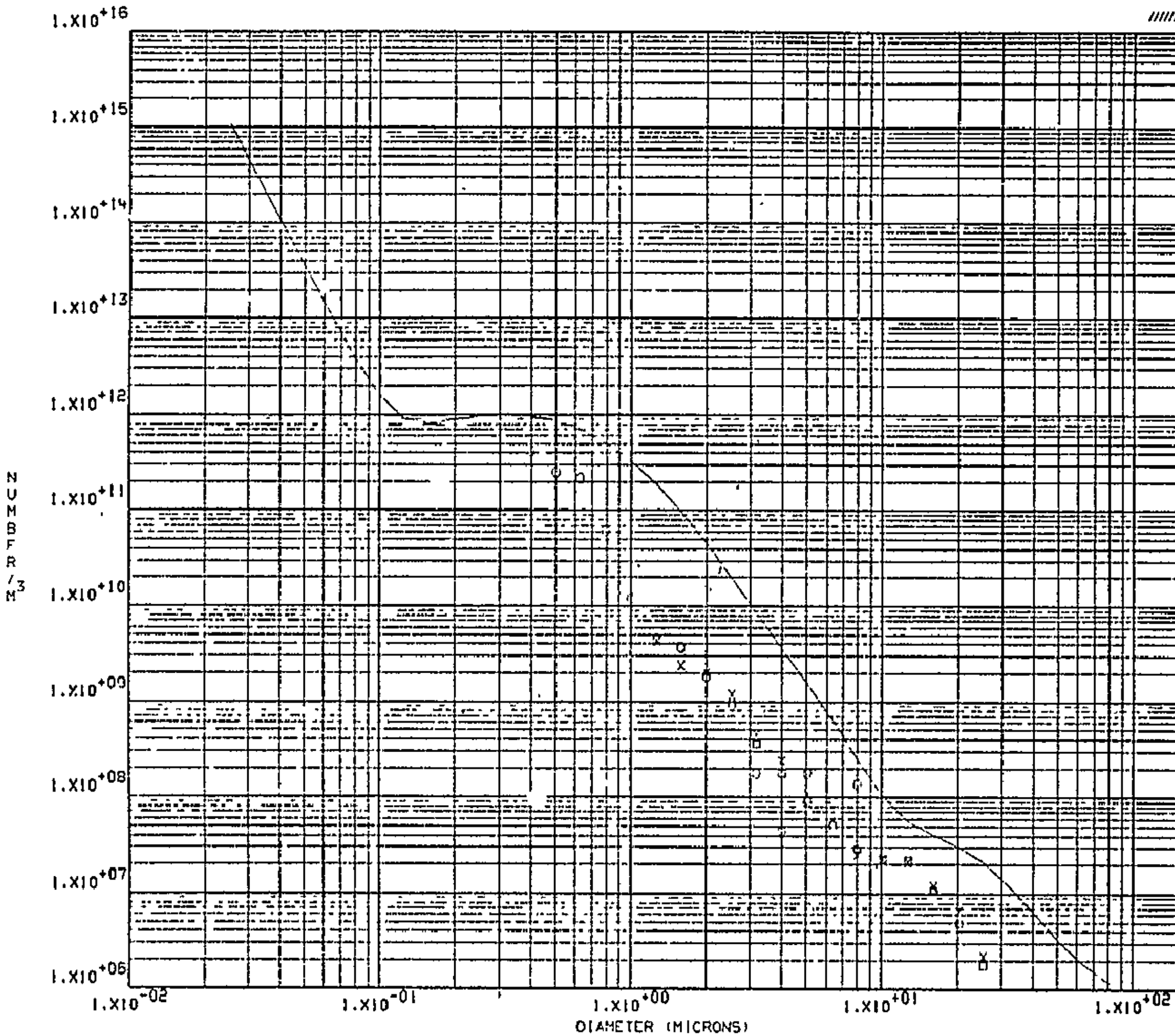
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	3.063X10+13	3.620X10+14	1.963X10+12	5.538X10+10	5.971X10+07
MODE DIAM	0 00	0 00	0.20	1 50	20.73
ALPHA	0.00	0 00	6.00	6.00	6.00
GAMMA	2.85	6.00	0.38	0.40	0.70



STATION 44 DEPTH 2 METERS (FROM UPWELLING SPECTRUM)

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
o	138-8	15 AUG 78	44	SURFACE	1430	11	200	2.00	1.000
X	138-8	15 AUG 78	44	SURFACE	1430	10	70	.50	1.000
0	138-8	15 AUG 78	44	SURFACE	1430	10	15	.01	1.000

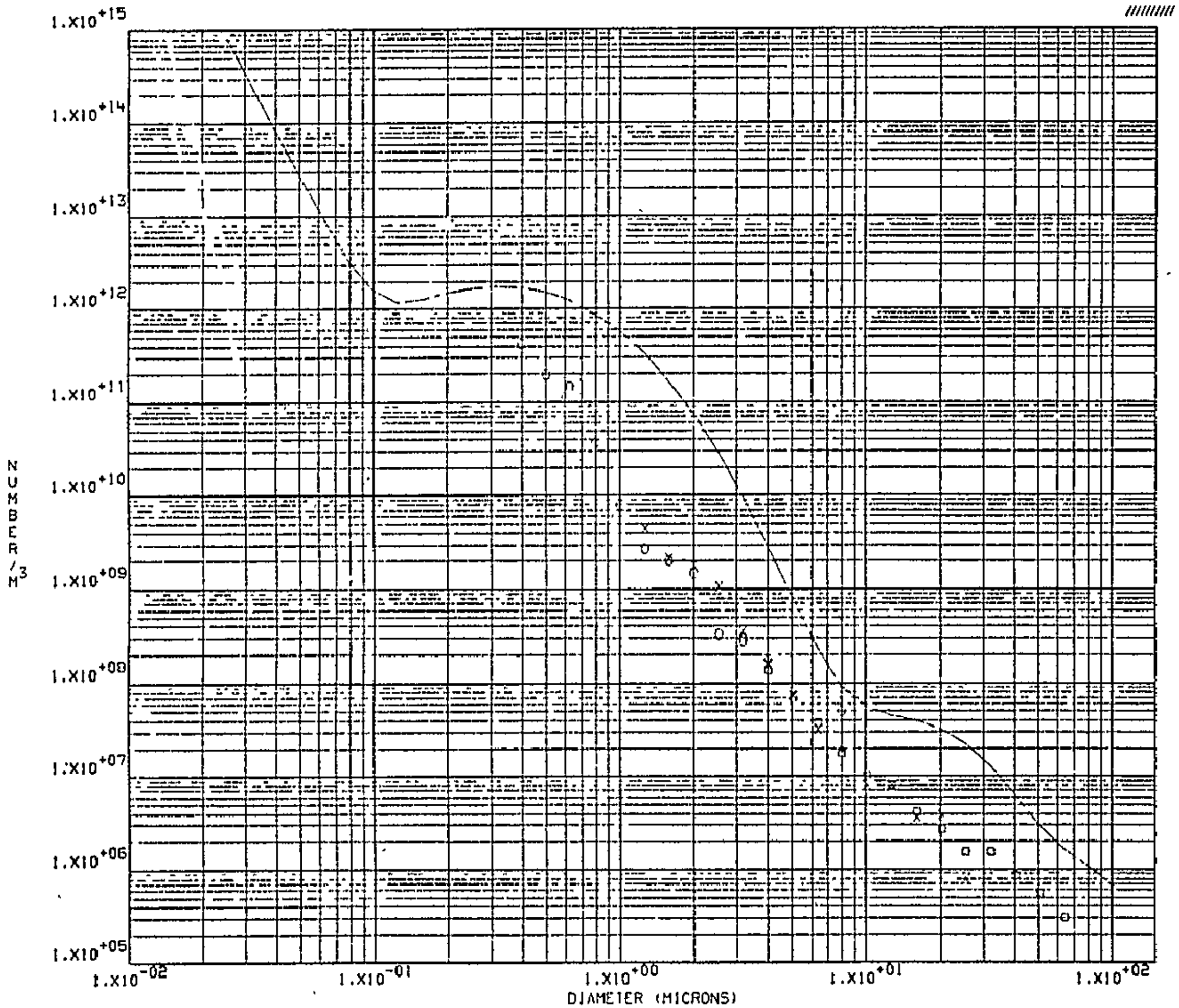
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$3.002 \times 10^{+12}$	$3.261 \times 10^{+14}$	$8.047 \times 10^{+12}$	$2.709 \times 10^{+10}$	$9.759 \times 10^{+07}$
MODE DIAM	0.00	0.00	0.20	1.50	15.07
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	2.76	6.00	0.25	0.40	0.70



STATION 44 DEPTH 5 METERS (FROM UPWELLING SPECTRUM)

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-8	15 AUG 78	44	18 FT	1455	10	200	2 00	1.000
X	138-8	15 AUG 78	44	18 FT	1455	10	70	.50	1.000
O	138-8	15 AUG 78	44	18 FT	1455	10	15	01	.200

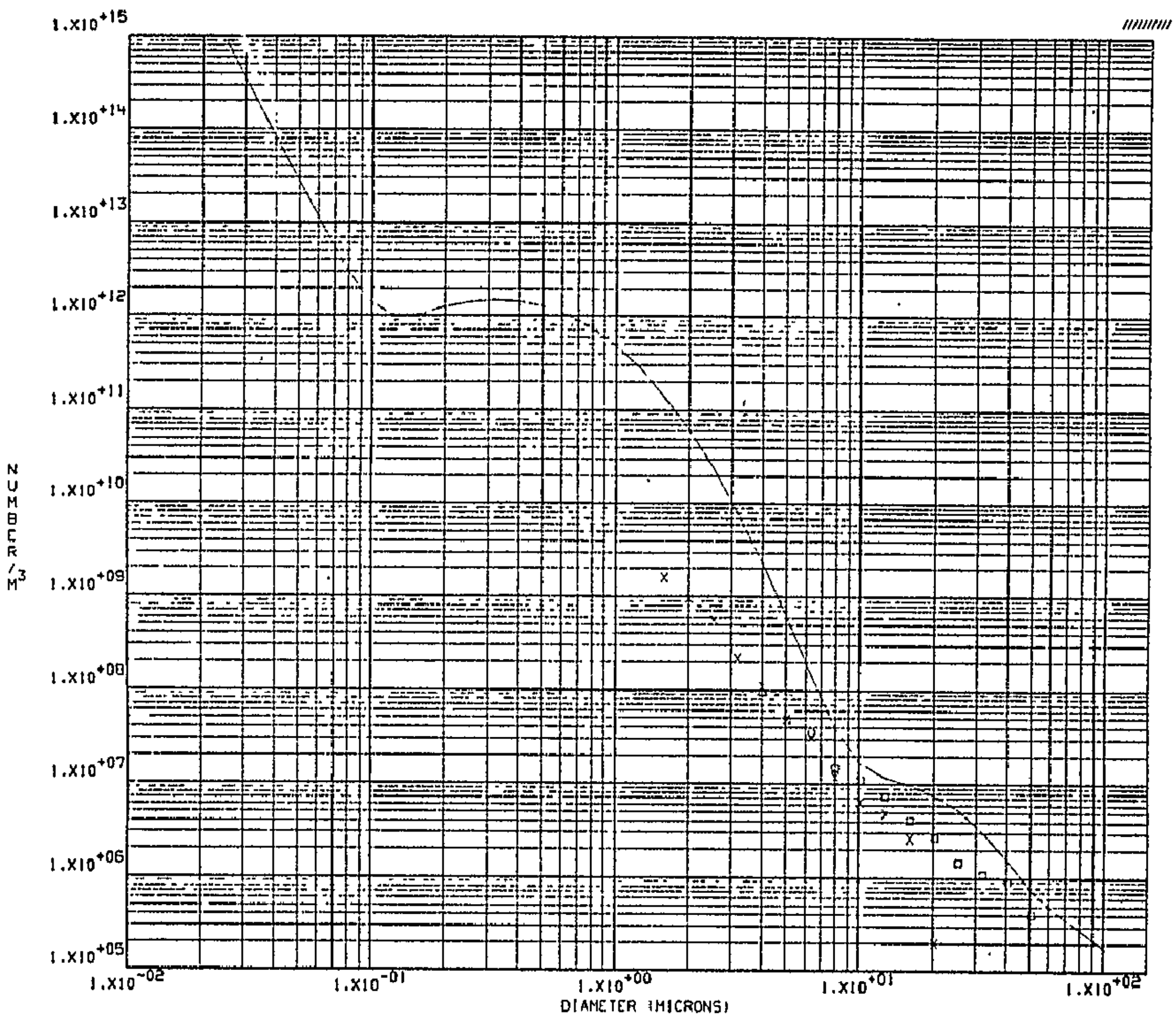
	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$2.933X10^{+12}$	$3.255X10^{+14}$	$8.167X10^{+12}$	$2.547X10^{+10}$	$9.405X10^{+07}$
MODE DIAM	0 00	0.00	0.20	1.50	15.07
ALPHA	0 00	0.00	6 00	6.00	6 00
GAMMA	2.76	6.00	0.25	0.40	0.70



STATION 44 DEPTH 10 METERS (FROM UPWELLING SPECTRUM)

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-8	15 AUG 78	44	31 FT	1511	10	200	2 00	1.000
X	138-8	15 AUG 78	44	31 FT	1511	10	70	.50	1.000
O	138-8	15 AUG 78	44	31 FT	1511	10	15	.02	.200

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	$2.644 \times 10^{+12}$	$2.539 \times 10^{+14}$	$1.446 \times 10^{+13}$	$4.400 \times 10^{+08}$	$1.092 \times 10^{+08}$
MODE DIAM	0.00	0.00	0 20	1.50	15.07
ALPHA	0.00	0 00	6 00	6.00	6.00
GAMMA	2 76	6.00	0 25	0.40	0 70



STATION 44 DEPTH 12 METERS (FROM UPWELLING SPECTRUM)

	MISSION	DATE	STATION	SAMP NUM	TIME	NUM TRIALS	TUBE APER	TEST VOL	CONC
□	138-8	15 AUG 78	44	43 FT	1527	10	200	2.00	1.000
X	138-9	15 AUG 78	44	43 FT	1527	10	70	.50	1.000

	INORGN 1	INORGN 2	PL FRG 1	PL FRG 2	DIATOMS
POPULATION	6.922X10+11	2.539X10+14	1.221X10+13	4.400X10+08	2.469X10+07
MODE DIAM	0.00	0.00	0.20	1.50	15.07
ALPHA	0.00	0.00	6.00	6.00	6.00
GAMMA	2.76	6.00	0.25	0.40	0.70

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16. ABSTRACT

Optical radiation from the sea is influenced by pigments dissolved in the water and contained in discrete organisms suspended in the sea, and by pigmented and unpigmented inorganic and organic particles. This technical memorandum addresses the problem of extracting the information concerning these pigments and particulates from the optical properties of the sea, the properties which determine characteristics of the radiation that a remote sensor will detect and measure.

The results of the application of the volume scattering function model to the data collected in the Gulf of Mexico and its environs indicate that one can reasonably predict the size distribution of the concentrations of particles found in the sea from measurements of the volume scattering function. Furthermore, with the volume scattering function model and knowledge of the absorption spectra of dissolved pigments, the radiative transfer model can compute a distribution of particle sizes and indices of refraction and concentration of dissolved pigments that give an upwelling light spectrum that closely matches measurements of that spectrum at sea.

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