The spatial distribution of salt particles at cloud levels in Central Queensland

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ABSTRACT

Large hygroscopic particles in the size range 0.5–200 $\mu\mu$g were collected on flights in central Queensland. The particles crystallized into distinct cubic shapes and were sized according to the volumes of these cubes. The concentrations so obtained showed only small variations in the vertical from 200 m to 1000 m and the shapes of the cumulative mass curves were similar to those measured near Hawaii. At cloud base levels (typically 1000 m), the concentrations decreased only slowly with distance inland—a penetration of 1100 km reduced the concentrations by a factor of five. It was found that the vertical and horizontal variations in the concentrations could be fitted to Tanaka's model quite well provided that the decrease associated with the pressure dependence on altitude was recognized. Preliminary chemical tests showed that the particles were mostly chloride with a small fraction of sulphate, and between 50 and 80 per cent contained some nitrate.

1. Introduction

Although the large and giant hygroscopic particles are known to constitute only a small fraction of the total CCN (Hobbs, 1971; Twomey, 1971), they are nevertheless thought to be influential in the rain production processes of some clouds, although the question of which is the most important size range still remains unanswered (Woodcock et al., 1971; Takahashi, 1974). The results of the Indian cloud seeding experiments of Biswas et al. (1967) lend support to the ideas that the giant particles are important, yet such basic information as normal background concentrations of these large particles is lacking. Early workers in the field (Woodcock, 1953; Blanchard & Woodcock, 1956; Moore & Mason, 1954) established the essential features of the oceanic source distribution—the production mechanism and the dependence on wind speed and altitude—but measurements of concentrations at cloud levels, particularly in continental situations, are rare.

In Australia, Twomey (1955) sampled salt particles at cloud levels in southern maritime air masses, but was unable to discern any consistent trends with distance inland. He concluded, however, that even pronounced depletion effects could have been masked by orographic interference and the mixing of air streams of different origins. Byers et al. (1955), in a series of flights in the Mississippi Valley, established that concentrations of salt particles at cloud levels were comparable with those measured in maritime situations, even at distances of 1000 km from the coast. This contrasts with the ground-based measurements of Okita (1962) and Lodge (1955) who found reductions of 3 orders of magnitude in 100 km; these figures are further substantiated by the more recent work of Semonin (1972) and Rossknecht et al. (1973).

The present paper is concerned with concentrations of salt particles at cloud levels, and how they change with penetration inland. In addition, some measurements of vertical profiles are given, together with results of some preliminary chemical tests on the hygroscopic particles.

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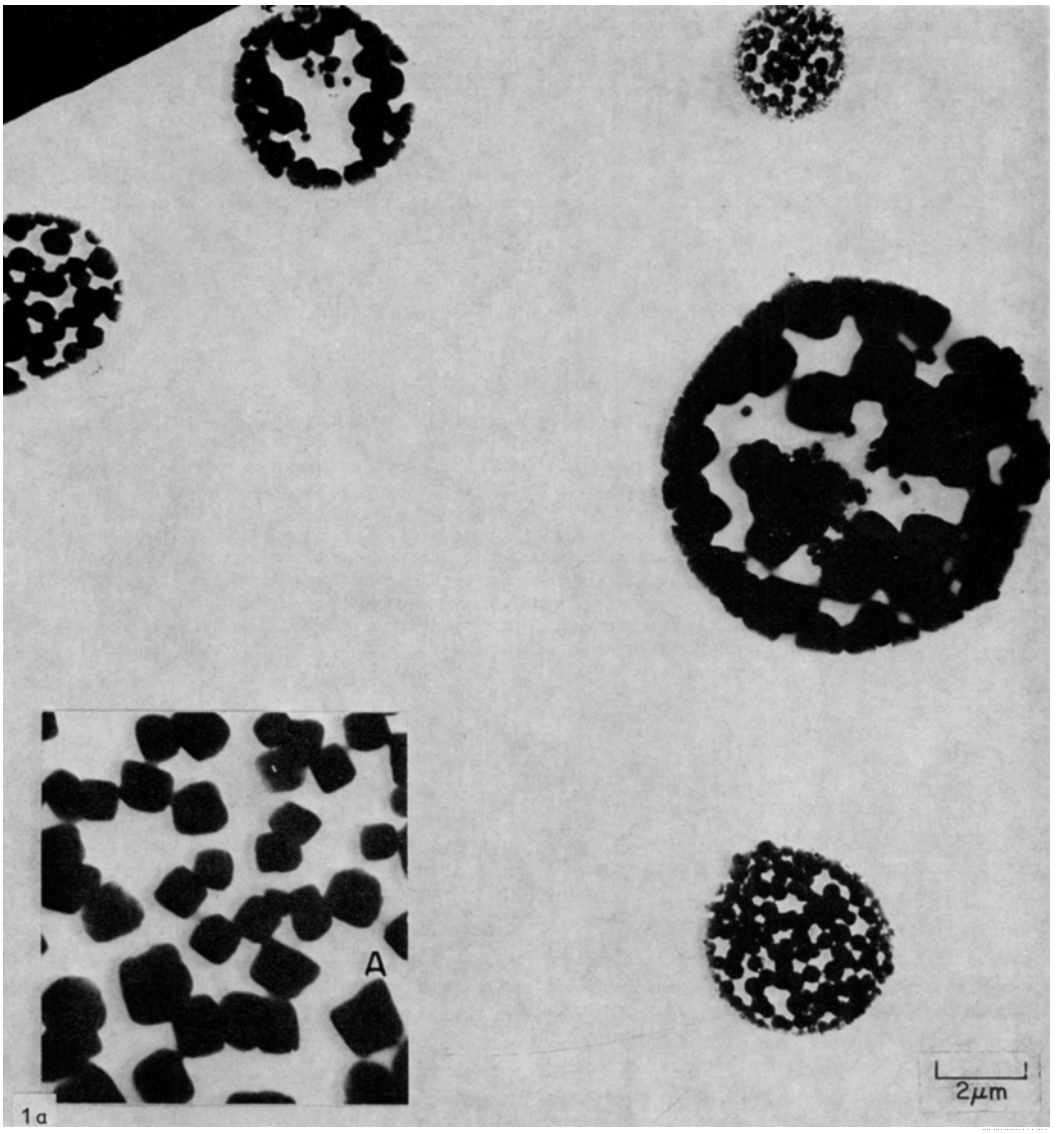

Fig. 1. Electron micrographs of crystallized salt particles collected on grids coated with nitro-cellulose. (*a*) Transmission electron micrograph. The insert is twice the magnification of the remainder.

2. Method

Particles were collected by impaction on standard 3-mm electron microscope grids which were coated with a thin film of nitro-cellulose. Groups of four of these grids were attached to brass slides of 3 mm width, and the slide exposed to the airstream from a light aircraft. Immediately after exposure, the slide was sealed in a gelatin capsule and removed only for examination under the electron microscope. The collection and examination system was designed as an adjunct to the chemical studies of submicron particulate matter as described by Bigg et al. (1974), and usually 3 of the 4 grids were pre-coated with suitable chemicals as part of this study.

Fig. 1*a* shows an electron micrograph of a portion of a grid exposed for 5 minutes at 70 m s^{-1}. Most of the particles were collected just

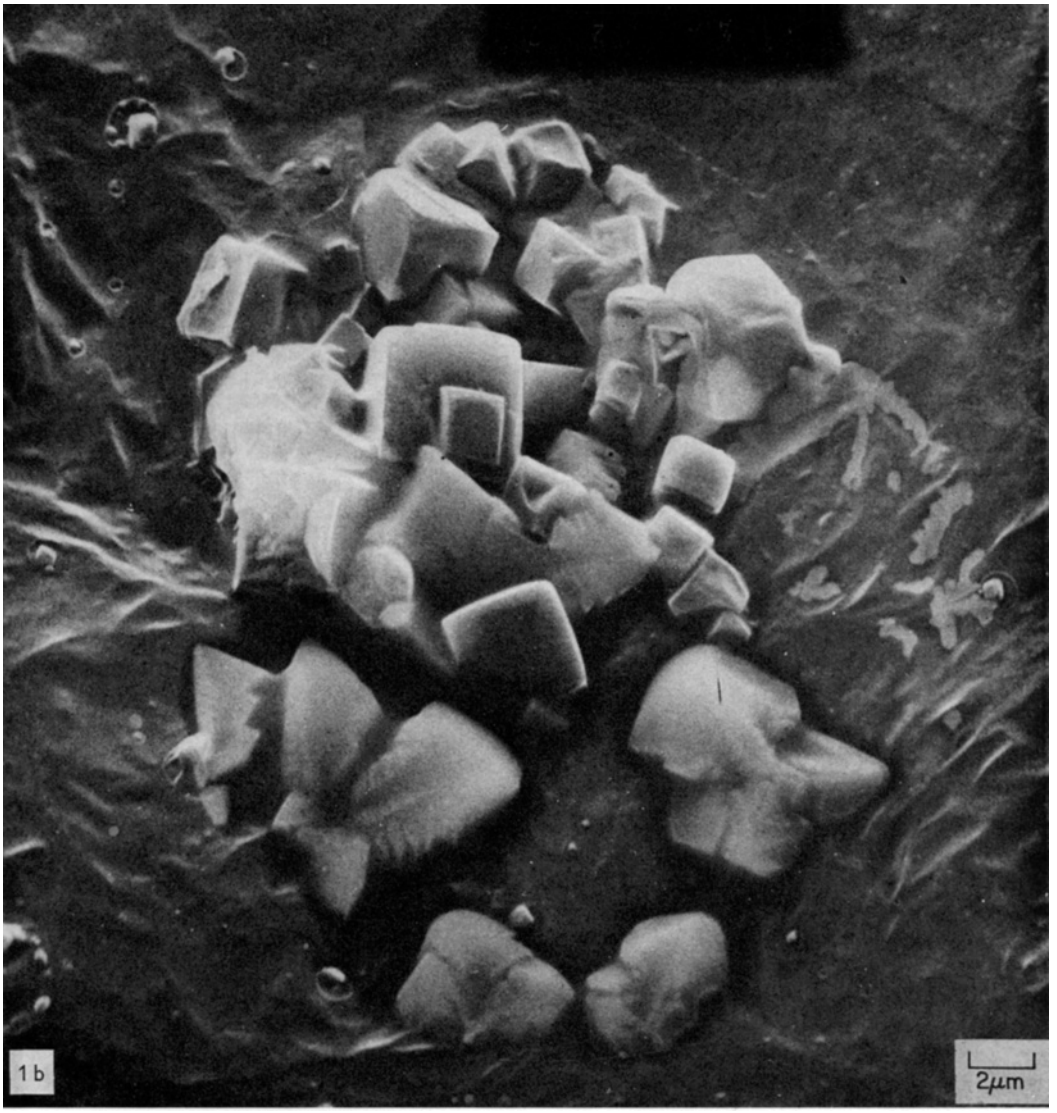

Fig. 1b Scanning electron micrograph. Note the way in which the cubes crystallize with their diagonal planes on the film.

below cloud base where the high relative humidities ensured that they were captured as solution droplets. In Fig. 1*a*, the fairly definite boundary around each group of crystals corresponds to the diameter of the spread droplet, and the total mass of the crystals contained therein is the mass of concern to us. Very few dry particles, i.e., solid and non-hygroscopic, were collected. This is not surprising, and is in accordance with Winkler's (1974) finding that, in collection by impaction, moist particles are collected preferentially because of their better adhesion. The exposure time for the grids was a compromise between the need to obtain sufficient numbers of particles and the danger of damaging the fragile nitro-cellulose film; five minutes was found to be the maximum possible exposure time. In an airstream at 70 m s^{-1}, it was found that the 3-mm grids collected particles down to about 0.5 $\mu\mu$g. This compares favorably with the recent measurements of collection efficiencies by Jaenicke and Blifford

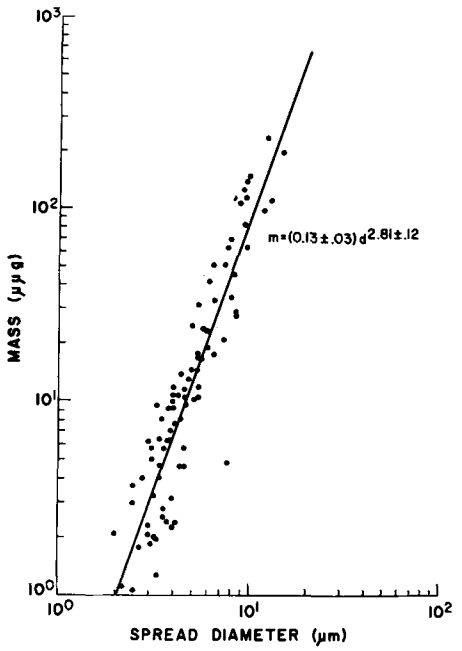

Fig. 2. Calibration curve of mass-diameter relationship for NaCl contained in droplets impacted on electron microscope grids.

(1974). According to their results, a 3-mm slide impacting salt particles from an atmosphere of 80 per cent relative humidity at 70 m sec^{-1} should collect 0.7 $\mu\mu$g particles with 50% efficiency, with a rapid decrease in efficiency for particles smaller than this. To avoid some of the uncertainties in concentrations associated with assumptions about collection efficiencies, only data for masses greater than 1$\mu\mu$g are presented in the following sections. According to the Jaenicke and Blifford measurements, the collection efficiency for a 1 $\mu\mu$g under impaction conditions mentioned above is 0.93. The five minute sampling time, in conjunction with the smaller concentrations of larger particles, restricted the useful upper size limit to 200 $\mu\mu$g. (The size limits of 1 $\mu\mu$g and 200 $\mu\mu$g correspond to dry radii of 0.46 μm and 2.6 μm, respectively.)

The droplets spread on impact, forming a shallow dish in the film. This feature was a disadvantage since the usual electron-microscope technique of shadowing with a heavy metal could not be used to determine the volume of the crystals. Nonetheless, the distinctly cubic form in which the salts crystallized enabled the masses to be established. Scanning electron micrographs of the grids [see Fig. 1*b*] show that the crystals, whilst cubic in shape, form such that the "diagonal" plane of the cube rests on the film surface, i.e., the salt particles crystallize in the shape of triangular prisms. The base of this prism is a square of side a, as viewed in the transmission electron micrograph of Fig. 1*a* The volume of such a portion of a cube is

$$V = a^3/2\sqrt{2} \tag{1}$$

It should be noted that the volume is not a^3, as one might at first suspect from an examination of the transmission photograph alone. Use of the geometric relationship (1), together with the assumption that the crystals are NaCl (partly justified by chemical tests to be described later), enabled the mass of salt in a cube to be calculated. Comparison of the number and size of cubes counted in this fashion with the diameter of the spread droplet produced the points of the calibration curve of Fig. 2. The line of best fit is drawn in, describing the relation

$$m = 0.13d^{2.81} \tag{2}$$

where d, the spread diameter, is measured in microns, and m, the total mass of salt in the drop, is measured in $\mu\mu$g. The uncertainty in the exponent was calculated at 0.12, bringing the relation (2) very close to a cubic dependence, which is what is expected physically if the depression in the film forms part of a sphere and the depression angle of the film remains constant.

The calibration described by (2) was obtained from the examination of grids containing particles collected approximately 100 m below cloud base, where the relative humidity varied between 70 and 80%. A different calibration would be required for particles collected in much drier air, since the same mass of salt would have less condensed water associated with it and the spread diameter would probably be reduced. This effect was not examined. It is also possible that the calibration would be affected by variations of the film thickness or its method of preparation. In practice, this is not a severe limitation since several hundred grids can be prepared simultaneously, and the method is reproducible (Hall, 1953, p. 313). Again, experiments aimed at elucidating this point were not undertaken.

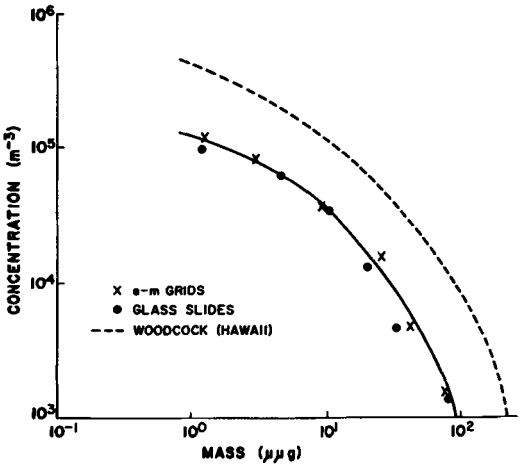

Fig. 3. Typical cumulative mass distribution for the Central Queensland region, showing a comparison between concentrations obtained from the e–m grids and glass slides.

During the course of the operation, numbers of particles were collected in the liquid form on cloudless days when the relative humidity was as low as 40%, indicating that the droplets can exist in the supersaturated phase for several hours at least. Such effects are not new, having been noted by Junge in the course of laboratory experiments in 1952, but the time scale of concern here is considerably longer.

On some occasions, even at high humidities, the salt particles did not crystallize into discrete cubes, but remained opaque and diffuse when viewed under the electron microscope, rather similar to the photographs shown by Kuroiwa (1951, his Fig. 2). There is some tentative evidence that (2) may be used to describe the masses in these situations as well, in that mass distributions obtained from sets of grids of the diffuse nature were in reasonable agreement with the more usual discrete types. This seems reasonable, since the spread diameter probably depend more on the dynamics of the impact, whilst the mode of crystallization would be primarily influenced by the relative humidity history experienced by the particles after collection.

For comparison purposes, 3-mm glass slides coated with a hydrophobic film were also exposed. These were developed isopiestically over a 250 g l^{-1} NaCl solution as suggested by Toba (1966). As mentioned previously, collection efficiencies were calculated according to the theory of Jaenicke & Blifford (1974). Because the glass slides and electron-microscope grids were the same width, the corrections for collection efficiencies were identical for both so that any comparison of concentrations so obtained is unaffected by uncertainties in the computed collection efficiencies.

3. Results

3.1. *Comparison with glass slides*

Fig. 3 shows a cumulative mass distribution (i.e., the ordinate is the concentration of particles whose mass is greater than the abscissa) for a sample collected just below cloud base near Emerald in Central Queensland (23°30′ S, 148°08′ E) on 20 March 1974. The comparable slide distribution is also shown in Fig. 3. The agreement between the concentrations obtained from the glass slides and electron microscope grids is reasonable, vindicating the use of the calibration relation (2).

Woodcock's (1953) results for the oceanic distribution near Hawaii in winds of force 4 (approximately 5–8 m s^{-1}, typical of those encountered) are shown in Fig. 3. The similarity in the numbers and shapes of the curves indicated that the air over Emerald, 280 km from the coast, is still strongly maritime in character in terms of the salt particle concentrations. Total masses of salt in the size range considered

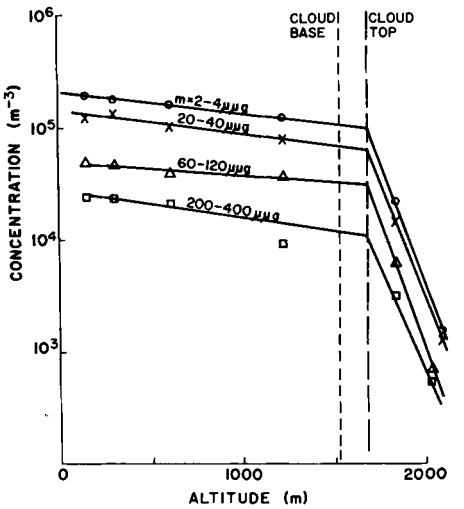

Fig. 4. Variation of the concentration of salt particles with height at Keppel Sands.

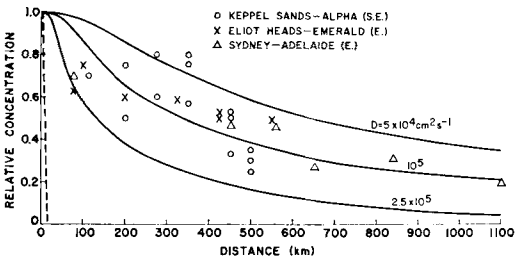

Fig. 5. Relative concentration of salt particles of mass greater than 1 $\mu\mu$g as a function of inland penetration for 3 different onshore wind situations. The full lines are theoretical curves for various diffusivities, and the dashed line shows typical concentration at ground level as measured by Lodge (1955).

were typically 8 to 12 μg m^{-3}, which is comparable with values compiled by Junge (1963, p. 162) for wind force 4.

3.2. *Height variation*

Fig. 4 shows how the concentration of selected logarithmic mass classes varied with altitude at Keppel Sands on the Central Queensland coast (23°22′ S, 150°42′ E). The rapid decrease in concentration above the cloud-top inversion level, first noted by Woodcock in 1953, is clearly evident. Below cloud base the concentrations can be fitted fairly well to an exponential decrease with height, $\theta = \theta_0\, e^{-\alpha z}$. From Fig. 4, the decay coefficient, α, was 5.6×10^{-6} cm^{-1}, and fairly insensitive to the mass class. Values of α in the five locations in which vertical profiles were measured, ranging from the coast to 500 km inland, were all in the range 3 to 9×10^{-6} cm^{-1}. This is in reasonable agreement with the theoretical and experimental conclusions of Toba (1965). Synthesizing the data of Woodcock (1953) and Durbin & White (1961), Toba showed that the vertical distribution over oceans is characterized by a decay coefficient of

$$\alpha = w/D + g/RT \qquad (3)$$

where w is the terminal velocity of the particle, D the eddy diffusivity, g the gravitational acceleration, R the universal gas constant, and T the absolute temperature. Toba was able to show that this height decay was consistent with theoretical expectations. In his theory, turbulent diffusion transports material from lower to higher levels, while sedimentation produces a flux in the reverse direction. In the steady-state of Toba's model, the balance of these two processes is characterized by the first term of (3). The second term of (3) can be regarded as the equilibrium height decay in the absence of sedimentation. As in all diffusion processes, the driving force is the gradient of the mixing ratio (i.e., the ratio number of aerosol particles to number of air molecules in a given volume). Since the density of air decreases with altitude with a decay constant of g/RT, there is a similar decrease in the equilibrium concentration of the aerosol.

Inserting some typical values in (3) we find (for 80% relative humidity and an eddy diffusivity of 10^5 cm^2 s^{-1}) that $w/D \simeq 10^{-7}$ for a 1 $\mu\mu$g particle and 2.4×10^{-6} cm^{-1} for a 100 $\mu\mu$g particle. Since $g/RT \simeq 1.2 \times 10^{-6}$ cm^{-1}, we see that α is dominated by the density term of (3), and changes only by a factor of 3 in the range 1 to 100 $\mu\mu$g, even though the terminal velocity varies by a factor of 25. It is therefore not surprising that only small changes of α with mass were detected from the measurements.

It should also be noted that the theoretical expression (3) was derived for an atmosphere which extends to an infinite height. The existence of a strong inversion capping the lower mixing layer would tend to ensure more uniformity in the vertical. In the limit, a constant mixing ratio would be achieved such that α should tend to g/RT.

3.3. *Inland penetration at cloud levels*

Particles were collected in three different onshore air streams: (1) southeasterly from Bundaberg (24°50′ S, 152°21′ E) to Emerald (23°30′ S, 148°08′ E), (2) easterly from Keppel Sands (23°22′ S, 150°42′ E) to Alpha (23°37′ S, 146° 37′ E), and (3) easterly from Sydney (33°55′ S, 151°10′ E) to Adelaide (34°55′ S, 138°35′ E). The first two are in Central Queensland and the latter in Southern Australia. To be classed as a particular air stream, the wind direction had to be consistent for a full day prior to sampling Average wind velocities were typically 5 m s^{-1}. For each flight, the aerosol was sampled at the coast line, and usually at three or four other points on the flight path.

Although the total number of salt particles decreased with distance inland, the cumulative mass distributions were essentially parallel to each other and to that of Fig. 3. This result is in accordance with Twomey's (1955) findings, and enables the distribution to be characterized by a single parameter, which we have taken to be

the number of particles of mass greater than 1 $\mu\mu$g.

The results for all three air streams are shown in Fig. 5, where the concentrations of particle at a given distance inland is shown relative to the concentration at the coast. The data used were those for a height of 1 000 m above ground level, and the inland distances were computed from crude air trajectory analyses. Although it might be expected that residence times in the air and the relative humidity history of the air mass could play important roles in determining fall-out of the larger particles, the fact that the observed decreases were insensitive to the particle mass indicated that these effects were probably not important and consequently were not considered. Changes in the height of the mixing layer over the length of the flight path were of the order of 15%. Variations in the particle concentration due to this effect were therefore not considered.

It is apparent from Fig. 5 that a significant decrease in the concentration of particles at cloud levels occurred only after the air mass had penetrated several hundreds of kilometers inland. This result can be compared with what is expected from the theory advanced by Toba (1965) and restated and modified by Tanaka (1966). The theory has a similar theoretical framework as the Toba (1965) one outlined in section 3.2, except that transport of matter can also be effected by horizontal advection as well as diffusion and sedimentation in the vertical. The assumed initial distribution (at $x = 0$) is $\theta = \theta_{00}\, e^{-wz/D}$, i.e., the particles are considered so large that sedimentation/diffusion effects are more important than the natural decrease associated with the fall-off in air density with altitude. This distribution is modified as the air mass moves inland, mostly by removal of the aerosol by impaction on vegetation at ground levels. Under the assumption of uniformity of horizontal wind, vertical diffusion, and surface terrain, the theory predicts that the relative concentration of particles of a given mass class is given by

$$\theta/\theta_{00} = 1/2\ \mathrm{erfc}\ (\sqrt{\xi} - \zeta/2\sqrt{\xi})\, e^{-2\zeta} - 1/2(1 + 1/\gamma)\ \mathrm{erfc}\ (\sqrt{\xi} + \zeta/2\sqrt{\xi}) + \frac{(2\gamma + 1)\ \exp\ [-(\sqrt{\xi} + \zeta/2\sqrt{\xi})^2]}{2\sqrt{\pi}\gamma\,[(1 + 2\gamma)\sqrt{\xi} + \zeta/2\sqrt{\xi}]} \qquad (4)$$

where erfc is the complementary error function:

$$\mathrm{erfc}(x) = 1 - \mathrm{erf}(x) = 1 - \frac{2}{\sqrt{\pi}} \int_0^x e^{-s^2} ds \qquad (5)$$

ξ and ζ are dimensionless distances and heights respectively, $\xi = w^2x/4Du$, $\zeta = wz/2D$, w and D have the same meaning as noted earlier, u is the horizontal wind velocity, θ_{00} is the concentration at $x = 0$, $z = 0$, and γ the ratio of the diffusive to sedimentary particle fluxes at ground level:

$$\gamma = \frac{D\partial\theta/\partial z}{w\theta} \quad \text{at } z = 0 \qquad (6)$$

For the ranges of distances and particle masses of interest to us, it can be shown that $\zeta/2\sqrt{\xi} \gg \sqrt{\xi}$. Under the further assumption that $\gamma > 10$ (a reasonable one in terms of the results of Semonin (1972) and Rossknecht et al. (1973)), then the expression for the concentration at a distance ξ relative to that at the coast (both measured at the same height ζ) is determined from (4) as

$$\theta(\xi, \zeta)/\theta(0, \zeta) = (1 - e^{2\zeta})/2 + \mathrm{erf}(\zeta/2\sqrt{\xi})\ (1 + e^{2\zeta})/2. \qquad (7)$$

The dominant term of this expression is erf $(\zeta/2\sqrt{\xi})$, which can be rewritten using the definitions of ζ and ξ, as erf $(z\sqrt{u}/2\sqrt{Dx})$. Since the terminal velocity w does not appear in the argument of this expression, the implication is that the concentrations should be independent of the particle mass, a result corroborated by the experimental observations. It is also not a surprising result since the theoretical assumption that γ is large is tantamount to stating that diffusion dominates over sedimentation. The relative concentrations predicted by (7) have been plotted with the experimental observations in Fig. 5 for a wind velocity of 5 m s^{-1}, and eddy diffusivities of 5, 10 and 25 $\times$ 10^4 cm^2 s^{-1}. The line of "best fit" to all the data points, which is not of great significance considering the theoretical assumptions and uncertainties in measurement techniques, wind velocity and air trajectories, is obtained for $D = 10^5$ cm^2 s^{-1}. This is in reasonable agreement with the value found using a similar method by Semonin (1972) and from turbulence measurements (see Priestly, ly, 1959, p. 100).

Concentrations at the surface were not measured at any time, but typical decreases at ground levels as found by Lodge (1955) in Puerto Rico, Okita (1962) in Japan, and Kline (1972) in Hawaii, are also shown in Fig. 5 for comparison purposes. Although the vegetation and ground cover in Central Queensland (open grass and woodland) is less dense than that of the three locations mentioned above, it seems unlikely that concentrations at surface levels would be significantly different from those shown in Fig. 5. As pointed out by Byers et al. (1955), it is apparent that impaction of the aerosol on trees and vegetation reduces the concentrations very rapidly, and for this reason, ground-based measurements are not particularly relevant in assessing the importance of the large hygroscopic particles in processes which occur at cloud levels.

In relation to ground-based measurements, it is probably worth pointing out that because surface concentrations do depend on the mass of the particle, the full differential equation describing the diffusion and sedimentation should be solved. This is (Toba, 1965)

$$u\frac{\partial\theta}{\partial x} = w\frac{\partial\theta}{\partial z} + D\frac{\partial^2\theta}{\partial z^2} + \frac{gD}{RT}\frac{\partial\theta}{\partial z} \qquad (8)$$

As pointed out in section 3.2, the final term of (8) arises from the decrease of density with altitude, and because it is small for particles of 100 $\mu\mu$g or larger, is normally neglected, as was the case when Tanaka (1966) modified Toba's theory. For particles of mass less than about 10 $\mu\mu$g (depending on the eddy diffusivity), it should be considered, however, and can simply be incorporated into the Tanaka theory by replacing w by $w+gD/RT$. This fact helps explain why Rossknecht et al. (1973) were able to obtain a good fit of their data to the Tanaka theory for all but their smallest class size, which was $2.2\ \mu\mu\text{g} < m < 5\ \mu\mu\text{g}$.

3.4. *Chemical tests*

Chemical tests for micron-sized particulate matter have been fully described by Bigg et al. (1974), and will not be detailed here. It is sufficient to state that the test reagent is vacuum deposited over the particles collected on electron microscope grids and followed by a "development" process in the vapor of a suitable solvent, usually ethanol or water. Examination of the shape of the reaction products provides identification of the anion of the collected particles. These tests are still only qualitative, although it is hoped to make them quantitative in the future.

3.4.1. *Silver sulphate tests.* This is a test for the chloride ion, in which the reaction products are saber-like silver chloride needles. An extreme example of a reaction, in which only the chloride needles are left, is shown in Fig. 6*a*. Approximately 95% of the individual droplets gave positive reactions, indicating the presence of chloride in almost all of the droplets, and partly justifying the assumption that the cubic crystals are NaCl. The needle-like shape of the silver-chloride crystals precluded any accurate estimates of volumes, and consequently masses, of chloride content of the particles.

3.4.2. *Barium chloride tests.* This is a test for sulphates, and typical reaction products are shown in Fig. 6*b*. Again, almost all of the droplets gave a positive reaction. In this case, the extent to which the reaction proceeded radially, together with a knowledge of the thickness of the barium chloride deposit, enabled crude calculations of the amount of sulphate present to be made. This can be compared with the amount of chloride in the inner circle, and typical values for the SO_4/NaCl ratio were around 4%. This is considerably less than the ratio for sea-water (9%), and values found by Junge (1956), which were close to the sea-water values. The most likely source of error arises from estimating the thickness of the barium chloride deposit, which could easily be in error by a factor of 2.

3.4.3. *Nitron tests.* This is a standard test for nitrates, the characteristic reaction product being long needle-like crystals, and an example is shown in Fig. 6*c*. Of the grids examined, between 40 and 80% gave positive reactions, the exact proportion depending on the location, but there were no consistent trends with distance inland. This need not be at variance with Junge's (1956) results, because although he found an increase in NO_3^- content with penetration inland for some aerosols, these situations were usually associated with higher NO_2 concentrations as well. It is thought that the nitrate forms when HNO_3, a product of the hydrolysis of NO_2, reacts with the chloride:

$$NaCl + HNO_3 \rightarrow NaNO_3 + HCl$$

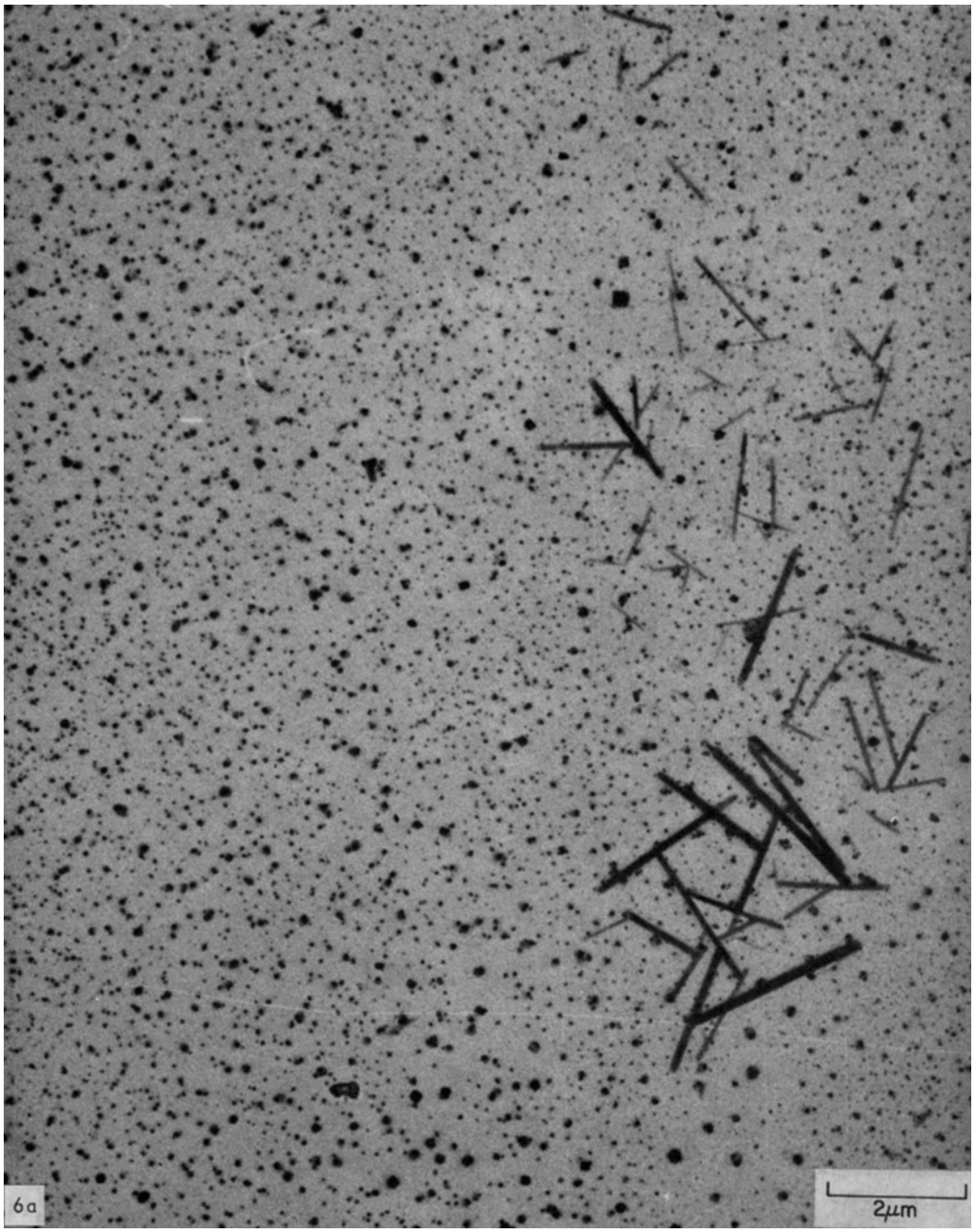

Fig. 6. The products of reactions between individual aerosol particles and related reagents. It should be noted that the size of the reaction region is not the size of the original particle, and in most cases, bears no simple relation to it. (*a*) An extreme chloride reaction: all of the original chloride crystals have reacted. The stippled background is the silver sulphate deposit, and the needles are silver chloride.

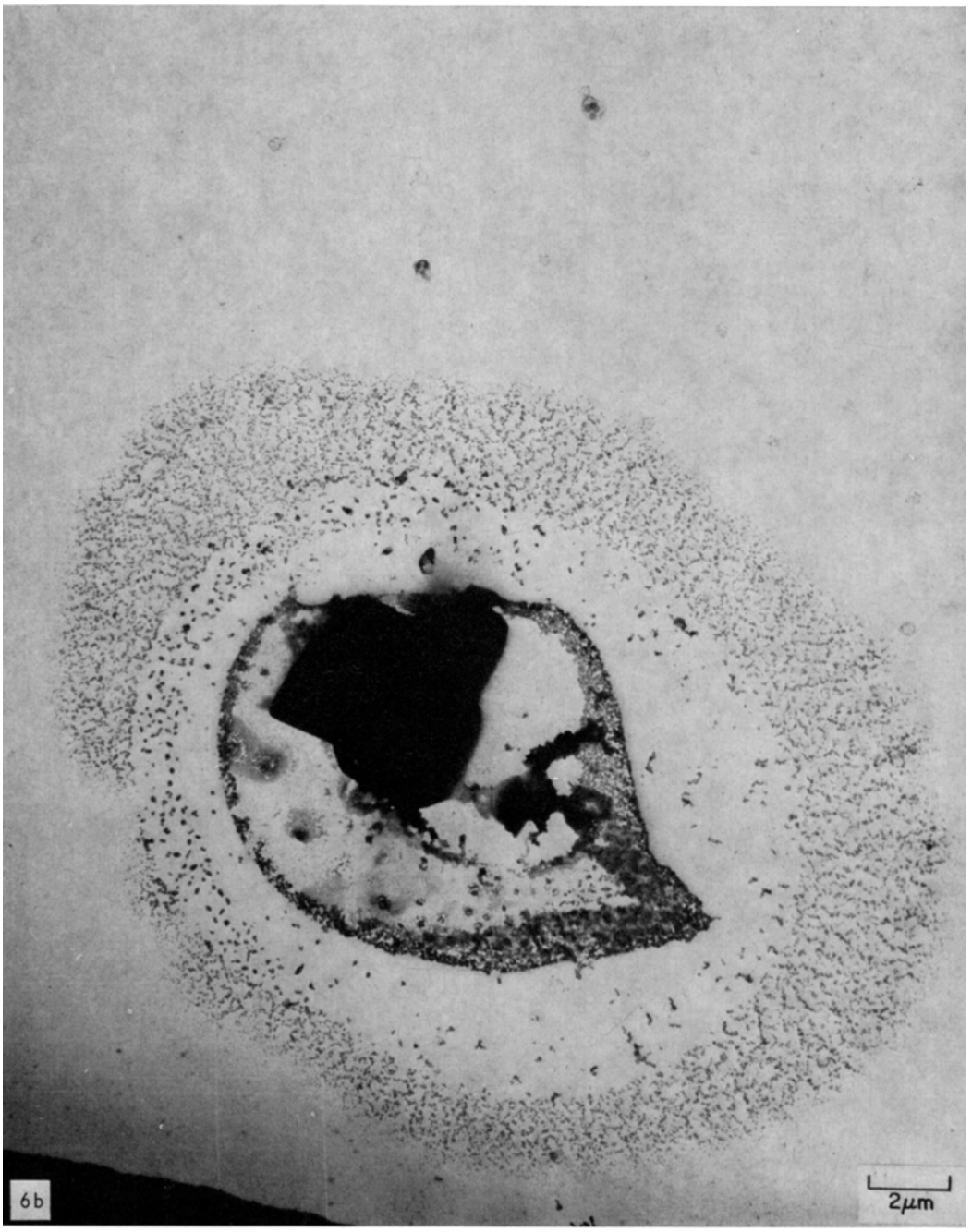

Fig. 6b. A typical sulphate reaction. The dark mass in the central region is unreacted sodium chloride, while the sulphate in the particle has reacted with the barium chloride deposit to form a halo of barium sulphate.

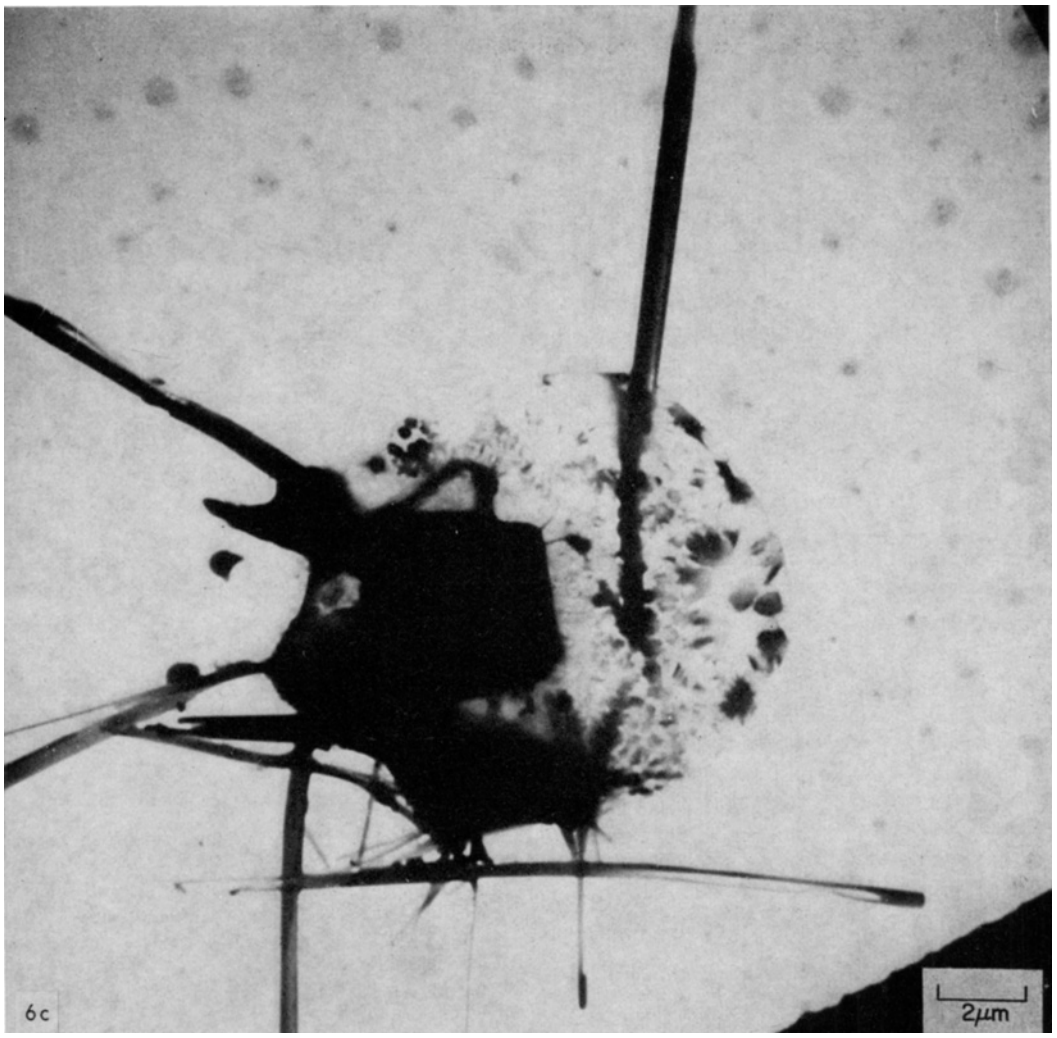

Fig. 6c. A nitrate reaction. The reagent is nitron, and any nitrate in the particle forms long nitron nitrate needles.

It is difficult to imagine how sufficient quantities of NO_2, usually associated with combustion products and pollution, can be found in the predominantly rural area around Emerald. The evidence supporting lightning as an important source of atmospheric NO_2 is still marginal (Viemeister, 1960), and lightning activity was not frequent in the region during the sampling period anyway. There is also a possibility that the NO_2 results from the denitrification of soils. This process is favored in the anaerobic conditions of warm, wet soils containing decaying vegetation (Black, 1968). Since large areas of Central Queensland had experienced severe flooding 8 weeks prior to the period in which sampling took place, this possibility cannot be overlooked, although the magnitude of the effect is unknown.

3.5. *Conclusions*

Impaction on electron-microscope grids provides a convenient method for collecting large salt particles in the range 0.5–200 $\mu\mu g$. The distinct cubic morphology of the crystals enables their masses to be determined, so together with

the more detailed chemical tests described by Bigg et al. (1974), it forms a fairly powerful tool for analysis of aerosols in this size range. The rather low upper size limit of 200 $\mu\mu$g is a disadvantage, but this can be alleviated to a certain extent by sampling for longer periods. Although it is simple to construct thicker and more robust nitro-cellulose films to withstand the buffeting associated witth longer exposure times, the opacity of the film to the electron beam limits the usefulness of this solution. The need to calibrate the mass against spread area of the droplets is also a disadvantage, and more work is required to establish the range of conditions under which the calibration relation used in this paper is valid.

In terms of aerosols, the main feature which arises from this study is the uniformity and persistence of the salt particle concentrations. Variations in the vertical, from 200 m to cloud base, amounted to a factor of 2 at most, and concentrations at cloud levels decreased by a factor of 5 going from the coast to 1100 km inland. Taking the measurements as a whole, we can say that the ambient concentration of particles of mass greater than 1 $\mu\mu$g is of the order of 10^5 m^{-3} at cloud levels and the mass dependence is similar to that found by Woodcock (1953).

Further work on the concentration of particles in the size range 100–1000 $\mu\mu$g under different wind and terrain conditions, together with more detailed chemical tests, is currently being pursued in this laboratory.

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ПРОСТРАНСТВЕННЫЕ РАСПРЕДЕЛЕНИЯ ЧАСТИЦ СОЛИ НА УРОВНЕ ОБЛАКОВ В ЦЕНТРАЛЬНОМ КВИНСЛЕНДЕ

В полетах над Центральным Квинслендом собирались большие частицы в интервале весов от 0,5 до 2 000 10^{-12} *г*. Частицы кристаллизировались в четкие кубические формы и разделялись согласно объемам этих кубов. Полученные таким образом концентрации проявляли лишь малые вариации по вертикали для высот от 200 до 1 000 *м* и формы кривых распределения частиц по массе были подобны тем, которые получались в измерениях вблизи Гавайских о-вов. На уровнях оснований облаков (типично около 1 000 *м*) концентрации уменьшались медленно с расстоянием от берега внутрь континента — на расстоянии 1 100 *км* концентрации уменьшались лишь примерно в пять раз. Найдено, что вертикальные и горизонтальные вариации концентраций могут быть вполне хорошо согласованы с моделью Танаки при условии учета уменьшения концентрации при уменьшении давления с высотой. Предварительные химические пробы указывают, что частицы состояли в основном из хлоридов с небольшой примесью сульфатов, а от 50 до 80 % их содержали некоторые нитраты.