matters arising

How did barium titanate particulates stick together in the Nebula?

MASUDA and Tanaka[1] in their recent letter have raised this question. Seeking explanation in the ferroelectric (FE) properties of $BaTiO_3$ we should ask now more specifically whether FE particles, similar to magnetic particles[2], may provide preferred nuclei for accretionary processes.

A FE particle acquires charge densities ($\sim 10^{-4}$ C cm^{-2}) much greater than is found with ordinary electrostatic charging, for example, that arising from the termination of crystal structure in unsaturated and dangling bonds which become rapidly screened by adsorption. To produce the kind of homogeneous polarisation which FE particles develop at their Curie temperature T_C (393 K for $BaTiO_3$) in an ordinary dielectric would require fields of 10^6–10^8 V cm^{-1}. The distorted surface layers observed on sub-μm FE particles[3] indicate that the particles do not find it easy to screen their surface charges by adsorption or internal electrical conduction. Moreover, T_C of particles $< 1 \mu$m may exceed 700 K. We may thus expect the potential corresponding to a FE particle to be much greater than the 1–30 V considered feasible for normal electrostatically charged interplanetary grains[4,5].

The potential energy of a small uniformly polarised $BaTiO_3$ crystal, represented by a doublet p_i, outside a complex formed by a collection of many uniformly polarised crystals and additional charge distributions corresponding to non-FE constituents, is determined by the normal component p_n at the surface of the complex. To determine the capture cross section[6] we consider a complex of radius r and surface polarisation p_n moving with velocity u. A doublet p_i with mass m_i and velocity v makes its closest approach at distance R from the centre of the complex and is captured in a grazing orbit. On the supposition of conservation of energy and momentum we obtain for the ratio $K = (\pi R^2)/(\pi r^2)$

$$K \simeq 1 + \frac{p_i p_n (1+3\cos^2\theta)^{1/2}}{4\pi r^3 m_c v^2}$$

Taking p_i and p_n to be of the order of $\simeq 5\times10^{-5}$C and $v \simeq 1.5$ cm s^{-1} gives $K \simeq 5\times10^7$ for a 0.15 μm particle.

The micrographs, presented by Masuda and Tanaka[1], show a large number of small composite particulates with a narrow size distribution around 0.15 μm and two conspicuous clusters of $\sim 5 \mu$m. If we were to interpret the latter as records of enhanced capture cross sections of $BaTiO_3$ in the early environment within the nebula, then these would suggest enhancement factors between 1.7 and 10^3 and $\sim 10^7$ depending on the size of the initial condensates.

While an enhanced capture cross section may explain why FE particles will stick together when available, it does not explain the high Ba abundances found in eucrites and in the Allende meteorite[7,8] as such. In view of the wide gap between the condensation temperature of $\sim$1,680 K and T_c those high $BaTiO_3$ concentrations which lie well above statistical fluctuations suggest selective spatial separation and enrichment. On account of the very high dielectric constant, even above T_c, the radiation pressure on $BaTiO_3$ condensates must have been greater than for most other particles of similar density and cross section. (Reflectively coefficient for carbonaceous chondrites is $\sim$0.04–0.07, (ref. 8) for $BaTiO_3 \sim 1$.) For particles of $\sim 0.1 \mu$m the force due to radiation pressure outweighs by far the gravitational attraction. Assuming the latter to be balanced by the centrifugal force in the orbital motion, the spatial distribution of condensates will be determined primarily by the radiation pressure and the Lorentz forces due to a solar or interplanetary magnetic field[10,11].

Considering conditions at 4 a.u. and assuming a moderate particle potential of 100 V in a uniform magnetic field of 5×10^{-5} gauss we obtain, in Table 1, for the forces due to radiation (f_R), gravitation (f_G) and Lorentz forces (f_L) the following values for particles of 0.125, 1, and 5 μm.

Table 1 Forces acting on FE particles

	0.125 μm (μ N)	1 μm (μ N)	5 μm (μ N)
f_R	2.6×10^{-14}	1.8×10^{-12}	4.5×10^{-11}
f_G	1.7×10^{-14}	1.1×10^{-11}	1.4×10^{-9}
f_L	8.5×10^{-13}	5.4×10^{-12}	1.3×10^{-11}

We may thus infer that FE particles up to 1 μm may settle out preferentially towards the inner part of the solar nebula. As particles aggregate into clusters of 5 μm, however, the radiation pressure wins out and depending on growth and ablation, larger particles are thus likely to equilibrate at 4 a.u. or to be swept out to greater distances.

At distances $\geq$ 1.75 a.u. with grain temperatures $<$300 K a $BaTiO_3$ grain should be in its orthorhombic or rhombohedral modification. It would, therefore, be interesting to determine the crystal structure of $BaTiO_3$ grains in the Allende meteorite. Moreover, the small dispersed particles as well as the larger clusters should exhibit FE polarisation and hysteresis[11–13] and it would thus be instructive to determine their *in-situ* Curie temperature. Structure and transition temperatures may give away further clues as to how $BaTiO_3$ grains came to be a vastly enriched constituent in the composite matrix forming the Allende meteorite.

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Diversity of deep-sea benthos

THE remarkable diversity of the deep-sea benthos is now well known, and Wolff[1] has contrasted two theories to explain this. One is Sanders'[2] theory of niche specialisation, the other is Dayton and Hessler's[3] theory of biological disturbance, including disturbance by predators. One point that may discriminate between theories explaining diversity is that it seems that many deep-sea benthic forms have long life expectations and low reproductive rates[1]. I point out here that these life history characteristics are found in another quite distinct group of high diversity, which also lives in a habitat with very little seasonal change—tropical forest birds. Snow[4] reviews much of what is known of the population dynamics of such birds, particularly the fruit-eating ones. The life history seems to be characterised by small clutch size and yet a very high early mortality, particularly of eggs and nestlings, and a low mortality thereafter. This early mortality is caused by predators. Snow says "Once a bird has survived the early weeks of life, the tropical forest is a