of a centred dipole and I used the theorem to show that the new determination[3] of the present lunar dipole magnetic field as $< 1.3 \times 10^{18}$ gauss cm³, or $< 0.05 \gamma$ at the equator (essentially negligible), is very powerful evidence for the existence of an ancient lunar magnetic field of internal origin, which had been postulated to explain the natural remanent magnetisation discovered in the lavas returned by the Apollo missions[4], and effectively excludes an external agency unless it resulted in random magnetisation.

It was shown[2] that if the maximum magnetisation of the shell at its exterior is I, then, for the dipole case, there is within its inner boundary, a uniform field of intensity $4\pi I/3$ times the ratio of the volume of the shell to that of the unmagnetised inner sphere. If the depth of the Curie point isotherm is taken as 50 km, this ratio is 0.1, and if $I = 10^{-4}$ e.m.u. g⁻¹ the uniform field is 10 γ.

I was aware that such a field, derived from the outer part of the magnetised shell, not only induces magnetisation in its interior, the point of Goldstein's communication, but would also have modified the magnetising field in which the rocks, cooling through the Curie point, acquired thermoremanent magnetisation. The resultant component of uniform magnetisation of the shell, increasing inwards, will give rise to an external dipole field, as will the departure of the Moon from sphericity, but I considered these effects and found them negligible[2]. Goldstein incorrectly quotes us in the last paragraph: we[6] stated that, for the theorem to be applicable, c, the magnetisation acquired in unit field, must be very small, of the order of 10^{-4}, not the magnetic susceptibility ($\mu - 1$) which even if it is 10^{-2}, as one analysis gives[7], produces a dipole field of much less than the observable limit. As the equatorial surface field of a shell, of uniform magnetisation I', is $4\pi I'/3$ multiplied by the ratio of the volumes of the shell to the sphere, this external field is about 0.01 γ for the Moon.

In devising a mathematical model to describe and understand the significance of experimental data, the scientist simplifies the physical situation by leaving out of consideration factors which are unimportant. Lyttleton[8] has lately reminded geophysicists of Eddington's description of the process. It is entirely legitimate for the mathematician to point out that the most general expression has not been used, but he must show quantitatively that with this added complexity, observations can be better fitted or the inferences to be drawn are thereby qualitatively changed; Goldstein does neither. But perhaps when the accuracy and reliability of magnetometers carried in spacecraft is improved by orders of magnitude, the further refinement of the theorem will be necessary. Goldstein may be drawing an analogy with the Earth— often misleading for lunar scientists—

where the induced magnetisation of geological formations is usually of the same order as the permanent magnetisation.

Institute of Lunar and Planetary Science,
University of Newcastle upon Tyne

1 Runcorn, S. K., *Nature*, 253, 701–702 (1975).
2 Runcorn, S. K., *Phys. Earth planet. Interiors*, 10, 55–62 (1975).
3 Russell, C. T., Coleman, P. J., and Schubert, G., *Science*, 186, 825–826 (1974).
4 Runcorn, S. K., *et al.*, *Geochim. cosmochim. Acta*, suppl. 1, 3, 2369–2387 (1970), Runcorn, S. K., *et al.*, *Proc. R. Soc.*, A325, 157–174 (1971).
5 Goldstein, M. L., *Nature*, 258, 175 (1975).
6 Stephenson, A., Runcorn, S. K., and Collinson, D. W., *Geochim. cosmochim. Acta*, suppl. 6, 3. (in the press).
7 Dyal, P., Parkin, C. W., and Daily, W. D., *Geochim. cosmochim. Acta*, suppl. 6, 3 (in the press).
8 Lyttleton, R. A., *Adv. Astr. Astrophys.*, 7, 83 (1910).

Effects of gallic acid on nitrosamine formation

OBSERVATIONS[1] on the catalytic effect of the naturally occurring polyphenol, chlorogenic acid, on the nitrosation of piperidine, may be supplemented by similar observations we have made during an investigation into the effect of gallic acid—an essential constituent of the gallotannins—on nitrosation of diethylamine. The possibility that such compounds could exert an influence on the *in vivo* formation of carcinogenic nitrosamines deserves careful attention.

Though early experiments[2] established the existence of an impeding effect by tannins on the formation of nitrosamines, more recent work shows that the amount of nitrosamine formed is dependent both on the pH and the concentration of the gallic acid.

We reacted concentrations of nitrite (0.075 M) and diethylamine (0.5 M) in buffered aqueous solutions, in the presence of different concentrations of gallic acid. Reaction was allowed to proceed for 30 min after which the solution was made alkaline to stop further reaction, and extracted with methylene chloride. The concentration of nitrosamine was determined using both ultraviolet spectrophotometry and gas chromatography. The concentrations of both the nitrite and the amine were chosen to give a convenient yield of nitrosodiethylamine for measurement of both systems. The relatively high concentration of amine allowed the use of a lower concentration of nitrite so that the competitive reaction of nitrite with gallic acid was not masked.

The results show (Fig. 1) that although gallic acid does exert a catalytic effect, it is extremely dependent on pH and is restricted to a narrow range in the region of pH 4. In addition, the balance between the

retarding and catalytic effect is strongly dependent on the concentration of gallic acid, as illustrated by the fact that an increase in the formation of nitrosamine related almost linearly with a decrease in the concentration of gallic acid. Similar effects were also found when solutions of tannic acid were used in place of gallic acid.

Though this tends to support the views of Challis and Bartlett[1], the idea that a catalytic effect by natural phenols can lead to the *in vivo* formation of nitrosamines, should be considered with caution. Nitrosamine formation could be dependent on the
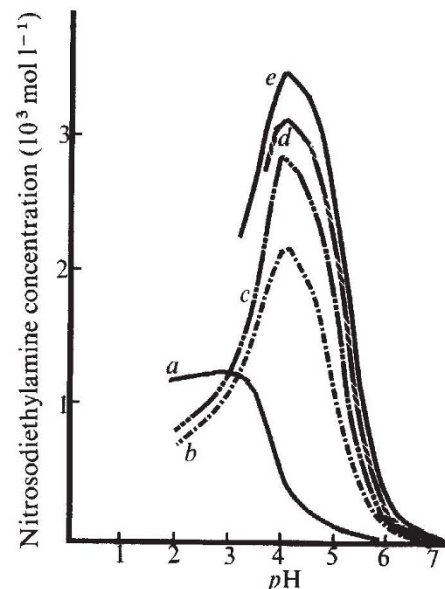

Fig. 1 Diagram demonstrating the increasing catalytic effect of gallic acid on nitrosodiethylamine formation with decreasing concentrations of gallic acid. Gallic acid concentration: *a*, 0; *b*, 0.0625 M; *c*, 0.0375 M; *d*, 0.025 M; *e*, 0.0125 M.

variable pH conditions in the digestive system and on eating and drinking habits which could regulate the simultaneous concentrations of nitrite, tannins and nitrosatable amines that may have been ingested or formed in the system.

E. A. WALKER
B. PIGNATELLI
M. CASTEGNARO

International Agency for Research on Cancer,
150 Cours Albert-Thomas,
69008 Lyon, France

1 Challis, B., and Bartlett, C. D., *Nature*, 254, 532–533 (1975).
2 Bogovski, P., Castegnaro, M., Pignatelli, B., and Walker, E. A., *N-Nitroso Compounds Analysis and Formation*, No. 3, 127 (IARC Scientific Publications, 1972).