

the low-temperature moment is positive.

The experimental results have demonstrated a high-coercivity structure-sensitive moment that occurs in supposedly antiferromagnetic hematite; this we interpret as a form of defect ferromagnetism which we consider to be due to local departures from the truly self-compensating antiferromagnetic configuration. It is maintained across the Morin transition and the Curie point, which bound the temperature range within which detectable spin-canting has been described. The defect ferromagnetism is lost only at the Neel point of hematite. This interpretation does not preclude the existence of a small spin-canted moment above the Curie point, but denies the importance of any such moment in the phenomena we have studied.

If a defect moment occurs in α - Fe_2O_3 , it is not likely to be an isolated phenomenon; for example, we would expect to find a similar moment in Cr_2O_3 , which is isomorphous with hematite. Moreover, the presence of a moment in Cr_2O_3 would more clearly demonstrate defect ferromagnetism because Cr_2O_3 has fully compensated Dzyaloshinsky-Moriya spin-canting (7). The Neel point of Cr_2O_3 is 37°C . When we attempted to observe the predicted moment at low temperature, hysteresis was seen at -196°C in a commercial powder; the remanence in the quenched state was 2.9×10^{-3} emu/g and in the annealed state, 1.7×10^{-3} emu/g.

Thus this magnetic moment in Cr_2O_3 is structure-sensitive. The recovery of the initial annealed value, after a second anneal following the quench, suggests that we are not observing changes in grain size that might otherwise explain the moment (16). We interpret the presence of a moment in Cr_2O_3 , and its structure-sensitivity, as confirmation of the idea of defect ferromagnetism in this material and in α - Fe_2O_3 .

The origin of the defect ferromagnetism is not established. We noted previously that Li (5) and Jacobs and Bean (6) considered the polarization of antiferromagnetic walls pinned by dislocations as the origin of such a moment. However, a severe objection to this mechanism is that the pinning of the walls restricts changes of net remanence to the movement of Bloch lines (6). Jacobs and Bean (6) and, more recently, Meiklejohn (17) and Roth (18) have suggested that "ferromagnetism" may occur in antiferromagnets because

of the local breakdown of antiferromagnetism in the vicinity of lattice defects. The regions of ferrimagnetism, which are held responsible for the "ferromagnetism," are considered to be in exchange coupling with the antiferromagnetic lattice.

The idea of ferrimagnetic regions coupled by exchange to the antiferromagnetic spins is attractive in hematite because it appears that memory would be a natural consequence of the proposed mechanism; when the antiferromagnetic spin configuration changes at the Morin transition, there will be a change in the spin coupling of the ferrimagnetic region to the antiferromagnet. This transition zone of perturbed spins between the ferrimagnet and the antiferromagnet could determine the variation of remanence in thermal cycles [see Iwata (19)].

Nevertheless one should note that the high remanent coercivity of the pinned regions must be due to their inherent anisotropy. Exchange anisotropy can couple the ferrimagnetic regions to the antiferromagnet, but it cannot couple the ferrimagnet tightly to the lattice because the anisotropy in the basal plane of hematite is low. We therefore conclude that stable remanence in hematite is due to small ferrimagnetic regions caused by lattice imperfections, and that memory arises because of a transition zone of spins that couple the ferrimagnetic regions to the antiferromagnet.

The geophysical significance of this work lies in the insight it may give to the NRM of rocks. It is immediately clear that, although a defect moment is magnetically stable, it is sensitive to lattice adjustments and therefore could be relatively unstable mechanically. Thus we should expect changes in remanence if the concentration or configuration of defects changes. Such change may be caused naturally during geological time by transient stress fields, radiation effects, or heating. We may learn to recover information about these factors. Moreover, although the defect moment could introduce some difficulty into paleomagnetism, it is also possible that the range of materials that may be used paleomagnetically may be extended to include antiferromagnets having suitable Neel points (for example, FeS). Defect ferromagnetism may also occur in ferrimagnets, although it would not be so evident as in the antiferromagnets or hematite.

In the light of these ideas and the reported weak remanence of alkali

halides (20), perhaps the question of which naturally occurring materials may carry interesting magnetic information should be considered in a wider setting than hitherto.

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Mitosis: On the Mechanism for Invariable Sister Chromatid Segregation

The report of Lark, Consigli, and Minocha (1) on the nonrandom segregation of sister chromatids during mitosis of embryonic mouse cells carries much significance for an ancient puzzle: What makes sister chromatids almost invariably go to opposite poles during normal mitosis?

The data of Lark, Consigli, and Minocha reveal that at, or after, the second mitosis following the administration of ^3H -thymidine to a cell culture, the radioactivity in DNA is distributed unequally and nonrandomly among progeny nuclei. Their interpretation, which seems most reasonable, is that their data reflect the following mechanism: "When the con-

served unit of a chromosome (2) is used as a template for the first time, it is attached permanently to a structure distinct from that to which its parent chromosome was attached." If the centriole produced in preparation for the next mitosis is that structure to which attachment is made by all those "conserved units" that are being used as templates for the first time, we can understand how one set of chromatids with a similar history (that is, time of synthesis) would go to one pole and the other set (the sisters of the first group of chromatids) with a different history would go to the other pole. Presumably, the "conserved units" that had been used as templates during prior replications would be associated exclusively with the pre-existing centriole.

Another way of looking at this model is to envision, as have Lettré and Lettré (3), that the chromosome and centriole, with a permanent fiber connecting the two, replicate as a unit. In the light of Lark, Consigli, and Minocha's data, this would mean that the entire chromosomal complement and the centriole, with all the permanent connecting fibers, would be duplicated as a physically integrated unit. There is, however, no need to imagine that the centrioles and the connecting fibers replicate in a semi-conservative fashion similar to that of chromosomal DNA replication.

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2. This conserved unit can be envisioned as that DNA-containing subunit, of a 2-unit chromosome, that had been synthesized at the immediately preceding replication period; its "complementary" subunit would have been synthesized during an earlier replication.
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It is, of course, natural to search for a structure to which the centromeres remain attached during a succession of cell cycles. It is also natural to choose for such a structure one which has been implicated by cytological measurements.

That this may be dangerous is exemplified by the comment of Goldstein. Recently, we have found that

nonrandom segregation of sister chromatids can be observed in *Vicia faba* and *Triticum boeoticum*. Our experiments only demonstrate that each set of chromatids appears to be attached to a structure with a centriole-like function. While Goldstein's hypothesis is a plausible one, I feel it would be premature to assign a primary role to the centriole merely because it can be seen.

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Properties of Lunar Surface Rocks

We shall assume that, in the absence of closer observations, O'Keefe, Lowman, and Cameron (1), have indeed correctly identified the Flamsteed Ring as an extrusive volcanic feature similar to terrestrial ring dikes. We shall assume further that they have derived "a reasonable value for the viscosity of the mass regarded as a single flow," of 10^{13} cgs units (poises). [It should be noted that the use of a "coefficient of thermal diffusion" (that is, thermal conductivity divided by density times heat capacity) for a nonvesicular rock ("granite") may not be appropriate for an extruded lava exposed to the hard vacuum at the lunar surface.] Clearly, however, the high value of the viscosity so derived does not allow one to conclude that the magma is highly acidic on that basis alone.

Viscosities of terrestrial lavas are dependent not only upon SiO_2 content but also upon such factors as temperature, content of volatiles such as H_2O and CO_2 , degree of vesiculation and content of crystallites. Thus, the viscosity of basaltic lavas of identical SiO_2 content may range from the very high values characteristic of the low-temperature ejecta which form spatter cones, and which essentially stick to whatever they fall upon, to the low values associated with pahoehoe flows. Indeed, the range of viscosity at the high end is essentially undefined; basaltic cinder cones are often composed almost exclusively of solid ejecta, with respect to which the concept of viscosity has little meaning. All gradations may be observed, from solids to very fluid lavas, without invoking any chemical distinctions.

As another example, in the compilation of viscosities of melted rocks by Clark (2), values from 1.7×10^5 to 4.4×10^6 are listed for obsidians. Shaw (3) states that granitic melts have viscosities of 10^5 to 10^8 poises at various temperatures above the liquidus. Values as high as 10^{13} poises are found at temperatures of the order of 500°C provided that water is present. The data of Shaw (3) show clearly the dependence of viscosity on temperature, water content, and crystal content. The value of 10^{13} poises derived by O'Keefe and co-workers (1) indicates a body with viscosity similar to terrestrial glasses at a few hundred degrees centigrade. The value is removed by several orders of magnitude from terrestrial lava flows, and certainly yields no information about the composition of the body.

Any conclusion about the acidity or basicity of the putative magma which formed the Flamsteed Ring is mere speculation as long as there is no information available on the temperature of the magma, its crystallite and volatile content at the time of extrusion, and the history of changes in these parameters (especially the volatile content) as the flow spread. One should be especially cautious about extrapolation of terrestrial observations of the behavior of lava flows to considerations of their possible analogs on the lunar surface; many terrestrial magmas are thought to have abstracted volatiles from their surroundings as they neared the surface, while lunar magmas would almost certainly lose volatiles near the lunar surface.

We differ from O'Keefe *et al.* regarding their interpretation of the gamma-ray data from the Russian Luna-10 instrument package. Vinogradov and co-workers state that not more than 10 percent of the observed activity could have been due to the presence of K, U, and Th. This indicates that the *upper* limits for the concentrations of these elements are of the same order as observed in terrestrial basalts, while even material with the K, U, and Th contents of ultramafic rocks or chondrites is not excluded. The abundances in australites [K, 1.8 to 2.1 percent; Th, 9.0 to 14.5 ppm; U, 1.9 to 3.1 ppm (4)] are several times greater than those in basalts (typically with K ~ 0.8 percent, Th 2 to 3 ppm, and U ~ 0.5 ppm). Unless there are unknown