bodies, a few kilometers in diameter (the width of several of the rings), may produce detectable variations in the brightness of background stars.

Occulations of stars by the orbits of Jupiter's galilean satellites are rare because of the slight angle of tilt of those orbits to our line of sight, resulting in a small occultation cross section; but, if the relatively high inclination outer satellites produced such rings, the potential for discovering more outer jovian satellites would be great indeed. Moreover, the considerable gap between Miranda and the ϵ ring is likely to contain additional satellites.

On the other hand, the satellite system of Neptune seems to have been disrupted in the remote past; the chances of finding any surviving ring-producing satellites around this planet, other than Triton and Nereid, seem minimal. As for Saturn's many satellites, the probability of the existence of a ring in each orbit depends primarily upon the nature of the mechanism for producing the gaseous material, since Saturn seems to have only perhaps 10 percent of Jupiter's magnetic field. Titan, which is known to be losing the hydrogen in its atmosphere into space, would be a good candidate for a possible ring.

The model presented here reinterprets the rings of Uranus as gaseous material shed by single orbiting satellites into their orbits, which spreads and dissipates rapidly. The primary advantage of this model is that it provides a simple visualization for understanding the puzzling dynamical properties of the rings as well as their apparent failure to reflect a reasonable amount of sunlight. Moreover, it leads to the interesting and easily testable speculation that some other satellites in the solar system may likewise produce rings.

Note added in proof: (i) The reported "pictures" of the rings of Uranus (*11*) should be interpreted with caution, and may represent only scattered light from material near Uranus. The direction of intensity maximum in the pictures differed from the predicted direction for the rings; and 2 percent albedo material is still very difficult to explain physically. (ii) Observations of material in satellite orbits have now been reported for Europa and possibly Amalthea, in addition to Io (*12*). (iii) A model equivalent to the one proposed here would consist of material everywhere in near-Uranus space except for tunnels continuously cleared out by a few satellites.

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Chesterton Soil Concretions: Ilmenite and Not Iron-Manganese Cementing Matrix

Abstract. *Dark reddish-brown spherules are common in soils of the Chesterton soil series of a high marine terrace in southern California. The spherules are concretionary in structure and are bound by ilmenite rather than by an iron-manganese complex. The spherules have been mislabeled both with respect to structure and mineralogy.*

The Chesterton soil series is found primarily in San Diego County, California. The series occurs on the Linda Vista terrace, an old marine terrace, and is comprised of sandy materials derived from what appear to be ancestral beach ridges. Reddish-brown spherules ranging in size from pinheads to 3 cm occur within the surface horizons (A11 and A12) and in some cases on the surface. The A horizon is commonly 20 to 25 percent spherules (by weight). There has been much speculation about the true nature of these spherules, whether they are pebbles, nodules, or concretions (*1*). Pebbles are the product of physical rounding from some larger original specimen. Nodules are basically heterogeneous throughout. Concretions display concentric growth binding (*2*). There is also a question about the nature of the cementing agent. Are the quartz, sand-sized grains held in a matrix of largely ferromagnesium minerals or in some other iron-rich mineral assemblage?

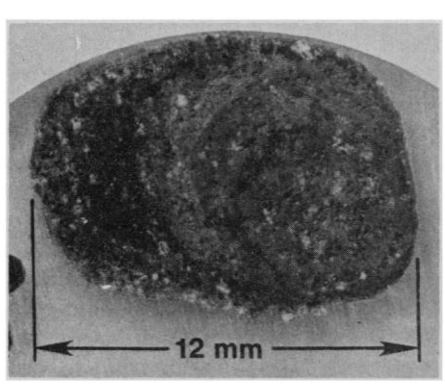

Fig. 1. Slice of one of the reddish-brown spherules in the Chesterton soil series.

I prepared spherules for macro- and microscopic examination by impregnating the samples with low-viscosity plastic under vacuum and slicing them upon polymerization with a diamond saw. The resultant slices display concentric bands to the naked eye (Fig. 1). I coated several samples with a thin layer (20 nm) of gold-palladium prior to examination in a scanning electron microscope (SEM) (JEOL JSMU-3) equipped with an energy-dispersive system (EDS).

No magnesium or manganese was detected in any samples examined by x-ray microanalysis. Silicon was detected in dense discrete concentrations which match the locations of the quartz grains. Iron was found in relatively lower concentrations than silicon. Both elements, when displayed in elemental dot maps, reflect a roughly concentric pattern. Using the same system and frame locations, I analyzed for titanium. The titanium clusters were of a lower concentration than the iron. The map, however, still displayed discrete clusters of titanium which closely overlie the iron concentrations. The failure to detect magnesium and manganese could possibly be due to the detection limits of the EDS system. Therefore, I used destructive chemical analysis with three different procedures (*3*). All procedures yielded results indicating less than 0.5 percent manganese and 1 percent magnesium on the basis of MnO and MgO. Both of these oxides are found in the lattice work of minerals which occur in low concentrations within the spherule. Thus the manganese and magnesium should not be considered part of the cementing matrix of the sphe-

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rule, although there may be small amounts present as replacement of ferrous iron. Depending on the chemical procedure, titanium comprised from 0.1 to 4 percent of the total spherule.

As chemical and x-ray electron energy analysis does not fully answer the question of elemental associations, I used an electron probe microanalyzer (JEOL Superprobe 733) to analyze for silicon, iron, titanium, and aluminum along a single transect (Fig. 2). The elemental combinations indicate an aluminosilicate and ilmenite matrix surrounding the quartz grains. Silicon is found at the highest concentrations and aluminum at lower concentrations, with iron and titanium at background levels, when the beam is impinging on a quartz grain (Fig. 2a).

When the electron beam scans past the quartz grain, one of two elemental combinations occurs. Either both aluminum and silicon concentrations drop to low values and the iron and titanium peaks rise to approximately 65 percent of the peak for pure silicon (Fig. 2b), or the aluminum peak rises to 45 percent of the peak for pure silicon with the silicon decreasing to 35 percent and iron and titanium remaining at background levels (Fig. 2c).

The presence of high concentrations of iron and titanium and the low concentrations of aluminum and silicon (Fig. 2b) is the second indication of an iron-titanium mineral. Such minerals were difficult to morphologically characterize with the SEM. To identify the iron-titanium mineral, I powdered an entire spherule in a disk mill grinder (Angstrom). The powder was randomly packed in an aluminum box mount for x-ray diffraction analysis with a Phillips diffractometer with a Cu Kα tube and a curved crystal monochromator. The resulting diffractogram displayed peaks for several minerals, but the first two peaks of ilmenite were present. Using tetrobromoethane (specific gravity, 2.96), I then separated the constituents of the powder sample. The heavy mineral complex was packed into an aluminum box mount and reanalyzed on the diffractometer. The resulting diffractogram clearly displayed the first seven powder file peaks for ilmenite (*4*). The only other recognizable mineral was a small amount of quartz.

The other elemental combination of a 45 percent aluminum peak, a 35 percent silicon peak, and low concentrations of iron and titanium (Fig. 2c) I interpret as translocated aluminosilicate clay. Colloidal clay can be carried into the spherule by groundwater during wet periods of the year, and a residual amount will remain when the groundwater is withdrawn during the dry season. An alternate hypothesis is that the clay is an inclusion present during spherule formation.

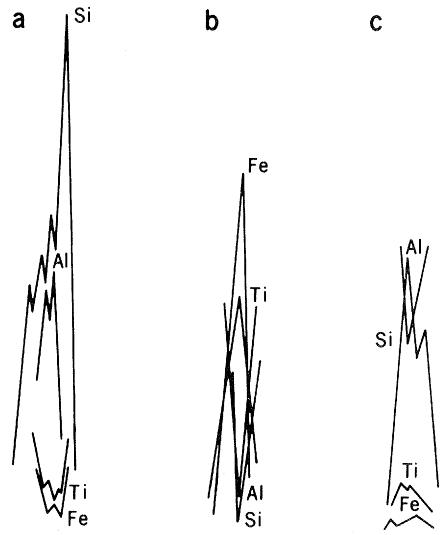

Fig. 2. Results of an electron probe microanalysis of a spherule: (a) pattern obtained when the beam scans the quartz grain; (b and c) two patterns that occur when the beam scans between the quartz grains.

On the basis of these analyses and petrographic microscope investigations, the spherules can be considered quartz-ilmenite concretions. The concentric pattern of reddish-brown to dark reddish-brown bands is visible to the naked eye. The band pattern is also present in SEM micrographs and in petrographic thin section. The binding agent for the concretion is ilmenite, not an iron-manganese complex. There is also a small amount of aluminosilicate clay, which may aid in the binding of the concretion. The spherules are true concretions cemented by an iron-titanium complex dominated by ilmenite.

This work suggests that caution be exercised in the terminology used for opaque spherules found in soils and sediments. Nodules and concretions are commonly termed ferromanganiferous; in this work the concretions are primarily iron in an ilmenite structure.

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Efficiency of Convection in Variable Stars and the Sun

Abstract. *Observed changes in the pulsation periods of Cepheid variables can be used to place an upper limit on changes in convective efficiency in their outer layers. This limit implies changes no larger than those recently suggested as occurring in the sun.*

In a recent report Dearborn and Newman (*1*), developing an idea of Ulrich (*2*), suggested that small fluctuations in the luminosity of the sun could be caused by variations in the efficiency of convection in its outer layers. They demonstrated that a sudden change in efficiency would result in a rapid readjustment of the density distribution on a dynamic time scale, but that the luminosity would readjust more slowly (on a thermal time scale). Although it is normally impossible to detect such changes in other stars, an indirect indication of a change in convective efficiency may be obtained from observed changes in the periods of variable stars. In the case of Cepheid variables, which have surface temperatures similar to that of the sun, the periods, which range between 2 and 40 days, are often determined to a few parts in 10^5 or better. The following discussion shows that the changes proposed by Dearborn and Newman, were they to occur in a Cepheid variable, could be detected.

The pulsation period, P, of a variable star is given by

$$P = Q\left(\frac{R^3}{M}\right)^{1/2}$$

where R is the radius and M is the mass of the star; Q depends on the structure of the outer envelope of the star and can be thought of as a function of the density gradient for a given value of R^3/M. Calculations have been carried out (*3*) which show how, for a given mass and radius, the pulsation periods of models of Cepheids in both thermal and hydrostatic equilibrium change as the efficiency of