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.

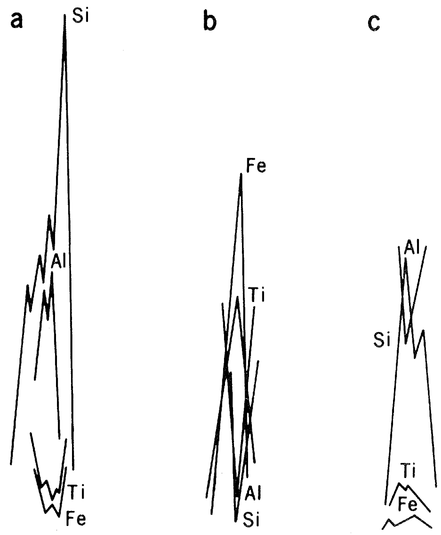

Fig. 2. Results of an electron probe microanalysis of a spherule: (a) pattern obtained when the beam scans the quartz grain; (b and c) two patterns that occur when the beam scans between the quartz grains.

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 convection is increased. (The efficiency is measured by α, the ratio of the convection mixing length to the pressure scale height. As in most stellar structure calculations, the convection has been modeled by the mixing-length formalism.)

The present discussion is concerned with relatively small changes in the structure of the outer layers of the star, which contain only a small fraction of the total mass. What is required is not the change in period with α for models of the same mass and radius, but rather the change in period for models with the same total mass and same structure in the deep interior. To fulfill the second requirement I have interpolated in the grid of models (*3*), so that the comparison is made between models for which the radius at a chosen mass fraction at the base of the envelope, $M_r/M = 0.55$, is the same.

From the results of stellar evolution calculations, such as those of Becker *et al.* (*4*), one can determine masses and luminosities appropriate to Cepheids of a given period. From a series of models with $M = 6.5\ M_{\odot}$ (the subscript $\odot$ denotes the sun), luminosity given by log $L/L_{\odot} = 3.6$, and $\alpha = 1.0$ or 1.5, which have periods between 6 and 13 days, I have obtained

$$0.006 \lesssim -\frac{d \log P}{d\alpha} \lesssim 0.04$$

The effective temperatures of these models are between 5750 and 5130 K, compared to that of the sun, which is 5700 K. The lower limit of the above derivative applies to the hottest models, where convection is relatively unimportant, so that it may be taken as a minimum value for the influence that changes in convective efficiency will have on the pulsation periods. Upper limits to the dynamic and thermal time scales of the convection zones of these models may also be obtained. The former is less than the pulsation period; the latter is less than 6 years and in most models at least an order of magnitude less.

Photometric observations of many Cepheids over more than 50 years have provided abundant data for the determination of pulsation periods and their change with time (*5*). This has been done by observing the time of maximum light, often to an accuracy of 1 percent of the period, and comparing this with the time predicted by an ephemeris based on a fixed period. From the more than 50 Cepheids that have been investigated in this manner, various patterns of period change emerge. Some stars show no measurable change in period over several thousand cycles. Others exhibit one or more abrupt changes, which occur over a time interval shorter than can be resolved from the data (1 or 2 years). In some cases the change in period appears to happen continuously over 1000 cycles or more.

Period changes resulting from changes in convective efficiency would appear abrupt, since the dynamic time scale is so short. From the published data (*5*), one can obtain an upper limit to the size of abrupt period changes in Cepheids whose periods are in the same range as the models discussed above

$$\Delta \log P \lesssim 1.5 \times 10^{-4}$$

where P is measured in days. From this upper limit and the lower limit of the theoretical derivative, one can infer an upper limit to the changes in α in Cepheid variables

$$\Delta\alpha = \left(\frac{d \log P}{\alpha}\right)^{-1} \Delta \log P < 0.025$$

This may be compared with the value of $\Delta\alpha = 0.02$ which, in Dearborn and Newman's models, produces a change of 1 percent in the luminosity of the sun. Of course, the observed period changes may be due to some other cause entirely, such as the evolution of the star or loss of mass by some ejection process. In that case, the above limit still holds unless changes in convective efficiency occur so rarely as to have never been observed.

Cepheid variables differ from the sun in several important aspects. Although the surface temperatures are similar, the surface gravities of Cepheids are smaller by a factor of 200 or more. (However, Cepheids with higher surface gravities tend to have smaller period changes.) In addition, the hydrodynamic motion of pulsation almost certainly interacts with the convection, and this might affect the possibility of abrupt changes in convective efficiency. Nevertheless, it is of some interest to realize that in these stars any rapid changes of the convective efficiency are most probably smaller than those proposed by Dearborn and Newman for the sun.

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Nitrite Promotes Lymphoma Incidence in Rats

Abstract. *Rats were exposed to sodium nitrite in food or water at concentrations of 0, 250, 500, 1000, and 2000 parts per million. Lymphoma was increased in all groups fed nitrite; the overall combined incidence was 5.4 percent in 573 control rats and 10.2 percent in 1383 treated rats. The mechanism of cancer induction did not appear to be through the formation of nitrosamines but through a more direct effect of nitrite on the lymphocyte.*

A few years ago we found a significant increase in tumors of the lymphoreticular systems of rats fed nitrite (*1*). We felt that this observation (made in the course of an investigation designed primarily to compare the effects of preformed *N*-nitrosomorpholine with those of nitrite plus morpholine) warranted further attention. We designed a study to investigate the effects on the lymphatic systems of rats of nitrite alone and nitrite fed in various concentrations and in different vehicles.

Eighteen groups of rats (Sprague-Dawley CRCD, Charles River Breeding Laboratories) were housed singly in screen-bottom, stainless steel cages with free access to food and water. Groups 1 to 5 received 0, 250, 500, 1000, or 2000 parts per million (ppm) sodium nitrite, respectively, in a semipurified agar gel casein diet, which was described previously (*2*). Groups 6 and 7 were given the same diet, but the nitrite (1000 or 2000 ppm) was administered in the drinking water. Group 8 was a positive control, receiving 2000 ppm urethane in the agar diet. Groups 9 to 11 ate commercial chow (Ralston Purina) containing 0, 1000, or 2000 ppm added sodium nitrite; group 12 was an additional positive control, receiving 2000 ppm urethane in the chow. Groups 13 and 14 were given the same agar gel casein diet as groups 1 to 5, except that it was in a dry form with 0 or 1000 ppm nitrite. Diets in groups 1 to

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