make this clear is to describe conditions and processes in the earth as determined by these facts.

If it be assumed that the earth's surface materials, to a considerable depth, at some time were not divided in zones or shells, but were approximately homogeneous, would they continue to be homogeneous indefinitely? No change is to be expected in the uppermost part, if it remains below fusion temperatures, but at some depth earth temperatures due to the normal geothermal gradient will be near fusion temperatures for the average rock materials. The radium present in the rocks will slowly raise the temperatures, since rocks are such good thermal insulators that heat will not be conducted away as fast as radioactivity produces it. Selective fusion of some parts is probable without the aid of heat derived from radioactive processes. After liquefaction (of any considerable mass) the magma thus produced will be lighter than the surrounding rocks and, even without fractures, it will therefore move slowly toward the surface. One mode of motion will be by means of rock flowage, in the same way that a balloon moves in the air, except that the motion is very much slower. After a time the magma will reach a cooler level and begin to crystallize; then (and perhaps before) differentiation will take place, leading to a gradual development of a more acid part and a more basic part. The level reached by the magma as a whole may be such that the basic part, perhaps produced by settling of the early products of crystallization, remains solid, while the acid part may remain liquid, because its crystallization temperature is about two hundred degrees lower than that of the basic part (if differentiation has produced a granitic fraction). Accordingly, the acid part will be slowly forced to a level still closer to the surface; and this process will be aided by the fact that the radium content of the original magma will be unequally divided between the differentiation products in such a way that the acid part will contain about twice as great a percentage as the basic part. Accordingly, the cooling effects of adjoining solid rocks will be more efficient in lowering (or preventing the rise of) the temperature of the basic part than in lowering the temperature of the acid part.

Ever since the beginning of the Paleozoic era such processes have affected the surface of the earth only locally—but even in this way a considerable fraction of the earth's surface has been subjected to the process. However, during the Precambrian the surface was affected more generally, so that the results of the process are to be found everywhere over the exposed Precambrian areas.

It is worthy of note that, once a mass of granitic composition is forced upward into the Sial shell, it is impossible for it to return to the underlying Sima. For, if such a mass, by subsidence or otherwise, is gradually buried toward the level of the Sima, it will liquefy at a level considerably above the basaltic substratum, since its fusion temperature is about 200° below that of the Sima, and the latter is believed to be near its fusion temperature.

Also, no granitic mass (or possible granitic differentiate) can long remain in the Sima, because, even if the Sima is not liquid or vitreous, it is believed to be at near-fusion temperatures, at which the granitic mass would be liquid and would therefore be forced toward the surface, since it would be considerably lighter than the surrounding Sima. Furthermore, such a granitic mass would contain about twice as much radium as the surrounding Sima, and would therefore gradually become hotter than the latter; so that, even if the upper part of the Sima is at a temperature level in some parts of the earth at which granite does not melt, the granitic mass would be further heated by its own radioactivity, and thus finally melt. On account of marked differences in specific gravity granitic magmas can not remain in the Sima.

It is true that, at least since Precambrian time, basaltic masses can remain indefinitely at the surface, but in the deeper and hotter portions of the earth an arrangement of rock materials controlled by gravity, and aided by radioactivity, differentiation and fusion temperatures, seems inevitable in the light of our present knowledge of the significant data on these subjects.

Such an arrangement corresponds well with the fact that seismic data require the existence of two (or more) shells with different properties near the earth's surface.

This paper has benefited by suggestions kindly offered by Professors R. A. Daly and C. K. Leith.

A. N. WINCHELL

UNIVERSITY OF WISCONSIN

COPPER IN RELATION TO CHLOROPHYL AND HEMOGLOBIN FORMATION

IT is known that chlorophyl, the respiratory pigment of plants, and hemoglobin, the respiratory pigment of the red blood cells of animals, are related chemically. One point of difference, however, is that magnesium is the element in chlorophyl corresponding to iron in hemoglobin. Under certain conditions the amounts of these pigments are decreased. A diet deficit in iron, for example, will cause a decrease in hemoglobin producing a condition known as anemia. Orange growers in Florida have recognized for a number of years that when citrus fruit trees are set on certain types of grove land—marl, for example—the leaves of the trees, instead of developing the characteristic deep green color, become spotted yellow, a condition known as "frenching." This "frenching" in trees is evidently comparable to anemia in animals. Whether "frenching" can be produced by a deficiency in magnesium in the soil comparable to the production of anemia in animals by a deficiency of iron in the diet is not known, so far as I am aware. It is known however that copper sulfate is an effective remedy for "frenching" in citrus fruit trees. When Bordeaux mixture was first used as a spray material it was observed that in addition to its insecticidal property it caused the leaves of the citrus fruit trees to turn green and put on new growth. It was soon found that this beneficial effect was due to the copper in the Bordeaux, so that copper sulfate, or bluestone, has come to be used very extensively by Florida orange growers as a remedy for "frenching."

The object of this investigation was to determine the effect of copper sulfate on the chlorophyl content of "frenched" orange tree leaves, and the following is a description of the method of procedure in carrying out the investigation. Four pounds of commercial copper sulfate, or bluestone, were scattered on the ground in a Florida orange grove around several three-year-old orange trees, whose leaves had lost most of their green color or were "frenched." In the same part of the grove several other trees whose leaves were similarly "frenched" were left untreated for controls. Four months later chlorophyl determinations were made, using the photoelectric method described by Oltman,[1] and it was found that the leaves of the trees treated with the copper sulfate contained 4.6 times more chlorophyl than did the leaves of the control or untreated trees. It should be said in this connection that the copper sulfate greatly improved the general condition of the trees. They put on much new growth and the leaves turned green, while the untreated trees put on very little new growth and the leaves remained spotted yellow or "frenched." It should also be stated that the chlorophyl of the leaves from the treated as well as the untreated trees were analyzed for copper and none was found.

Hart, Steenbock, Waddell and Elvehjem[2] were the first to show that the presence of copper, although in minute quantities, was necessary for the utilization of iron in the formation of the hemoglobin of the red blood cells of the rat, and the experiments reported in this paper would seem to indicate that copper is likewise necessary for the formation of the chlorophyl of the leaves of orange trees, thus indicating a similarity between the animal and plant kingdoms in this respect. It should be mentioned in this connection that cattle grazing on certain types of Florida pasture land develop a nutritional anemia or "salt sickness," just as citrus fruit trees set on certain types of grove land develop "frenching" and this may be cured with the use of iron and copper.

O. S. ORTH
G. C. WICKWIRE
W. E. BURGE

UNIVERSITY OF ILLINOIS

[1] R. E. Oltman, "A New Method and Instrument for the Quantitative Determination of Chlorophyll," *Plant Physiology*, 8: 2, 321–326, 1933.

[2] E. B. Hart, H. Steenbock, J. Waddell and C. A. Elvehjem, "Iron in Nutrition. VII. Copper as a Supplement of Iron for Hemoglobin Building in the Rat," *Journal of Biological Chemistry*, 77: 797–812, 1928.

THE INCIDENCE OF COLOR-BLINDNESS AMONG THE CHINESE

GARTH'S report in SCIENCE[1] of "The Incidence of Color Blindness among Races" is of considerable interest in showing that unselected white males are afflicted with color-blindness more than any one of the other racial groups reported on, *viz.*, Jews, North American Indians of various tribes, Mexicans and Negroes.

For comparison the following results obtained in an investigation of Chinese students in Chengtu may be of interest. Ishihara's color-blindness tests were used, and each chart was shown to a small group of students at one time. Each student was asked to write down the figure he saw. The students' papers were then collected and compared with the correct answers. In this way in a comparatively short time a large number of students were tested. All were males and ranged in age from students in primary schools to those in university.

Of 1,115 students 67, or 6.3 per cent., were found to be red-green blind, either complete or incomplete.

The only other report on the color-blindness of the Chinese of which we are aware is that of Chang,[2] in which he reports 80 out of 1,164 male students, or 6.9 per cent., to be deficient in color vision (either red-green blind or weak in color discrimination). In addition, he reports that 19 females out of 1,132 examined, or 1.7 per cent., showed either color-blindness or color weakness.

If these two reports are combined we have a color-blindness incidence of 6.5 per cent. for Chinese males, based on the use of the Ishihara test on a total of 2,279 students in the schools of Peiping and Chengtu, and an incidence of 1.7 per cent. for Chinese females, similarly tested on 1,132 girls in the schools of Peiping.

L. G. KILBORN
Y. T. BEH

WEST CHINA UNION UNIVERSITY
CHENGTU, SZECHWAN, CHINA

[1] T. R. Garth, "The Incidence of Color Blindness among Races," SCIENCE, 77: 333, 1933.

[2] S. P. Chang, "Statistics on Color Blindness among Students in Peiping," *National M. J. China*, 18: 806, 1932.