Feldspar in Chondrites

Abstract. *Whereas most chondrites contain sodic plagioclase (or occasionally maskelynite, its glassy equivalent), a few are free of feldspar. Absence of plagioclase is correlated with the presence of calcium-poor clinopyroxene (pigeonite* sensu lato*) instead of orthopyroxene. Olivine in feldspar-free chondrites is frequently variable in composition; in feldspar-bearing chondrites this mineral has essentially uniform composition. It appears that the silicate material of most chondrites was initially an association of olivine and pigeonite (or perhaps olivine and glass), and recrystallization has produced the usual olivine-orthopyroxene-sodic plagioclase association.*

As Edwards (*1*) has shown, chondrites contain a remarkably uniform amount of sodium, about 0.7 percent. In most chondrites the sodium is present as plagioclase of albite or oligoclase composition; the plagioclase is the disordered (high-temperature) form of this mineral (*2*).

In studying the mineralogy of chondrites, I have found that it is frequently very difficult or impossible to detect feldspar in thin sections under the microscope, although the mineral may be identified in powder patterns and diffractograms obtained by x-ray diffraction, especially when it is concentrated from an acid-insoluble fraction by density separation, by means of heavy liquids. This feldspar is very fine-grained, and it is difficult to determine its refractive indices precisely by the immersion method. Meteorites having this very fine-grained feldspar also contain much clinopyroxene giving an x-ray pattern similar to that of pigeonite, together with orthopyroxene. In some chondrites I have found no feldspar, even in carefully prepared concentrates; and in these meteorites the pyroxene seems to be entirely clinopyroxene. Since the olivine structure is incapable of incorporating more than trace amounts of sodium and aluminum, the obvious deduction is that these elements are combined in the clinopyroxene, in the form of the $NaAlSi_2O_6$ component.

The chondrites with little or no feldspar are always highly chondritic; Bjurböle and Chainpur are typical examples (*3*). The feldspar-bearing chondrites always show signs of recrystallization, the boundaries of the individual chondrules merging more or less with the groundmass. The mineralogical changes are thus linked with structural changes.

It seems reasonable to postulate that the highly chondritic, feldspar-free chondrites represent a more primitive stage than the somewhat recrystallized feldspar-bearing chondrites. It is interesting that, in those meteorites with very fine-grained feldspar and appreciable amounts of clinopyroxene as well as orthopyroxene, the feldspar is almost pure albite, whereas the more recrystallized chondrites have more calcic plagioclase, usually with between 10 and 20 percent of the anorthite component. This is analogous to the increase in calcium content of plagioclase with increasing metamorphic grade in terrestrial rocks.

These facts appear to fit best in theories of chondrite formation expounded by Wood (*4*) and Anders (*5*), in which chondrules formed very rapidly as molten droplets in a primordial dust cloud, and then aggregated together with some of the dust into larger bodies (asteroids?). If, as seems likely, the aggregated bodies had an internal heat source, such as short-lived radionuclides, thermal metamorphism would take place, resulting in the recrystallization and the phase changes we observe in the individual meteorites.

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6. Work aided by NSF grant GP 1218.

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Paleontologic Technique for Defining Ancient Ocean Currents

Abstract. *Subtraction from the new data, of a quadratic surface fitted to the taxonomic diversity data of recent planktonic foraminifera yields a residual surface closely related to ocean current systems. This technique could be applied to fossil materials to develop knowledge of ocean circulation patterns during glacial and interglacial climatic episodes.*

Gradients in taxonomic diversity (the number of "kinds" of organisms present) are generally covariant with the planetary temperature gradient (*1*). This relationship, if found in fossil populations, could be used to locate past rotational pole positions and thus test the hypothesis of polar wandering (*2*). Observed taxonomic diversity gradients include both a primary response to the planetary temperature gradient and secondary responses to local conditions (Fig. 1).

It is desirable to separate these responses by mathematical calculation of a quadratic surface that best fits the observed distribution (*3*). The resulting surface isolates the response to the planetary temperature gradient and may be referred to as the "regional surface" (Fig. 2). Failure of the regional surface to fit all of the observed data results in a "residual surface" which includes all secondary sources of variation (Fig. 3). Attention was originally focused on the utility of the regional surface for defining the thermal equator. It now appears that the residual surface can be of comparable significance. Specifically, it is considered that taxonomic diversity residuals for planktonic foraminifera can be used as a reasonably accurate means of revealing past configurations of the surface circulation patterns of the oceans.

Since it can be assumed that the "regional surface" isolates the response of a taxonomic diversity gradient to the planetary temperature gradient, the "residual surface" must comprise the composite effects of all remaining factors affecting diversity. In a few groups of organisms, the factors contributing to the residual surface can be recognized as arising primarily from a single source. When such a situation occurs, the residual surface becomes an effective measure of this factor. Such a condition seems to be largely fulfilled by the planktonic foraminifera. These animals are involuntarily distributed by the motion of the water masses they inhabit. Allochthonous water masses thus carry with them an exotic population when they move from their place of origin. Because this is the case, and

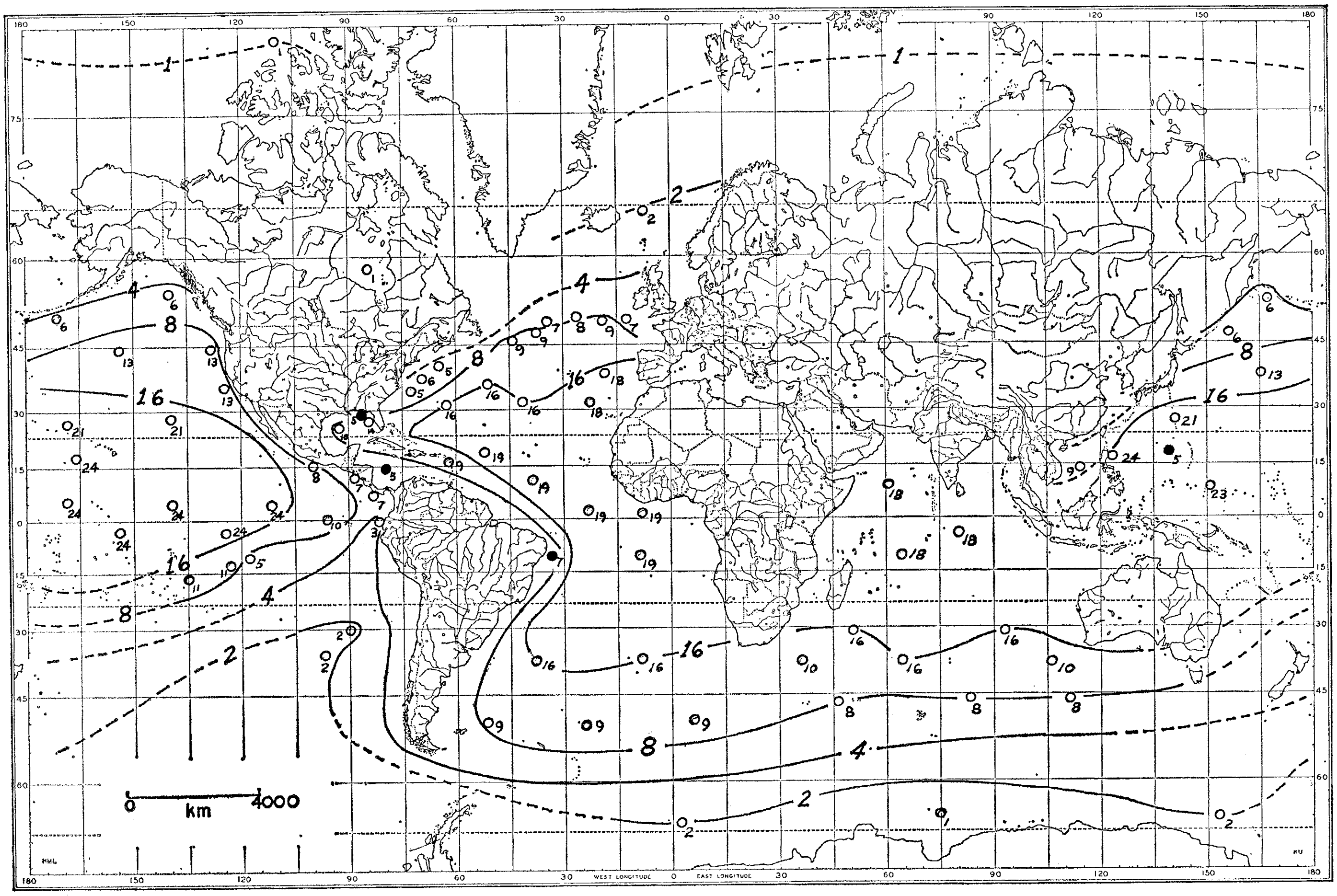
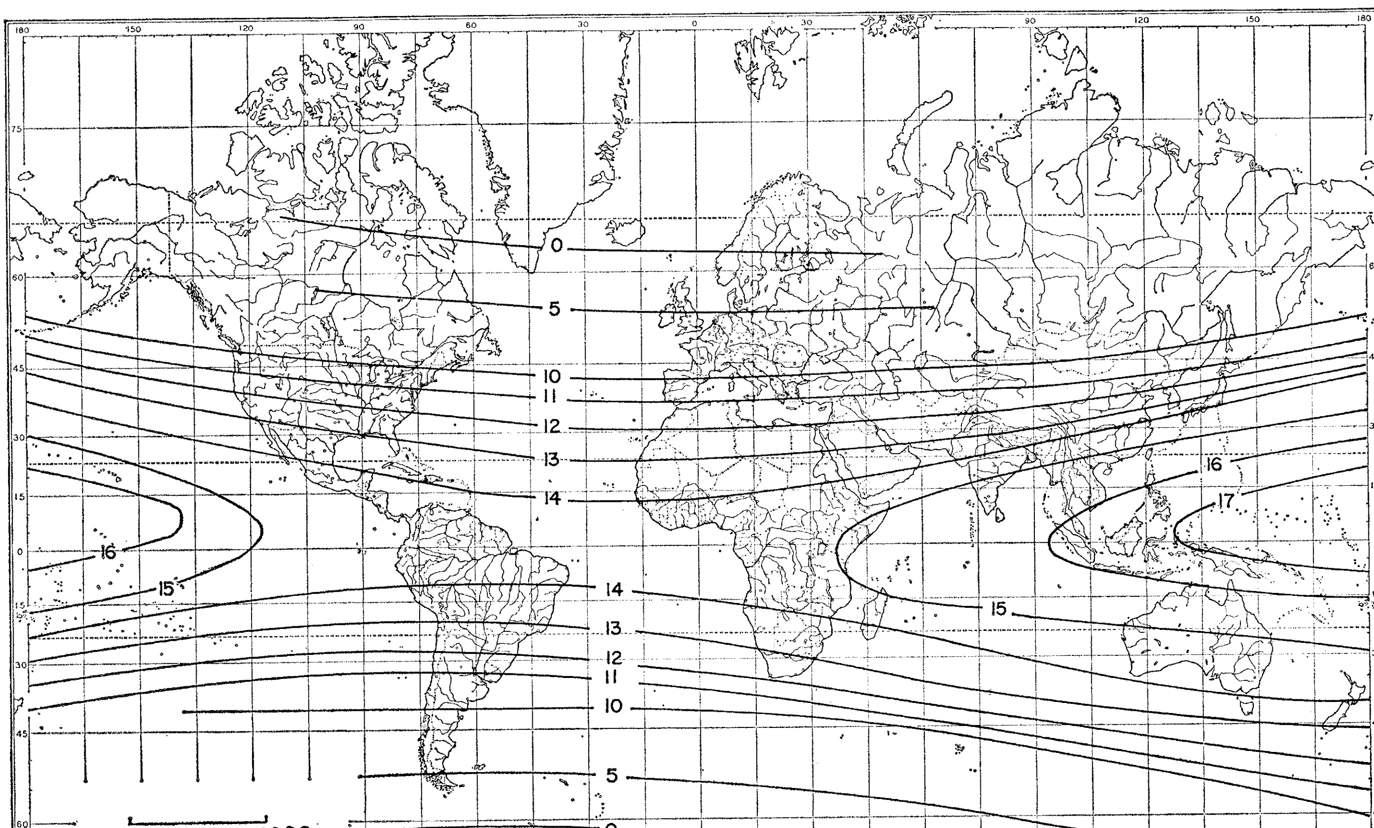


Fig. 1 (top). The distribution and diversity of Recent planktonic foraminifera (contoured according to the number of species present). Fig. 2 (bottom). Quadratic "regional surface," fitted to diversity of Recent planktonic foraminifera, shows pronounced dependence on the planetary temperature gradient.



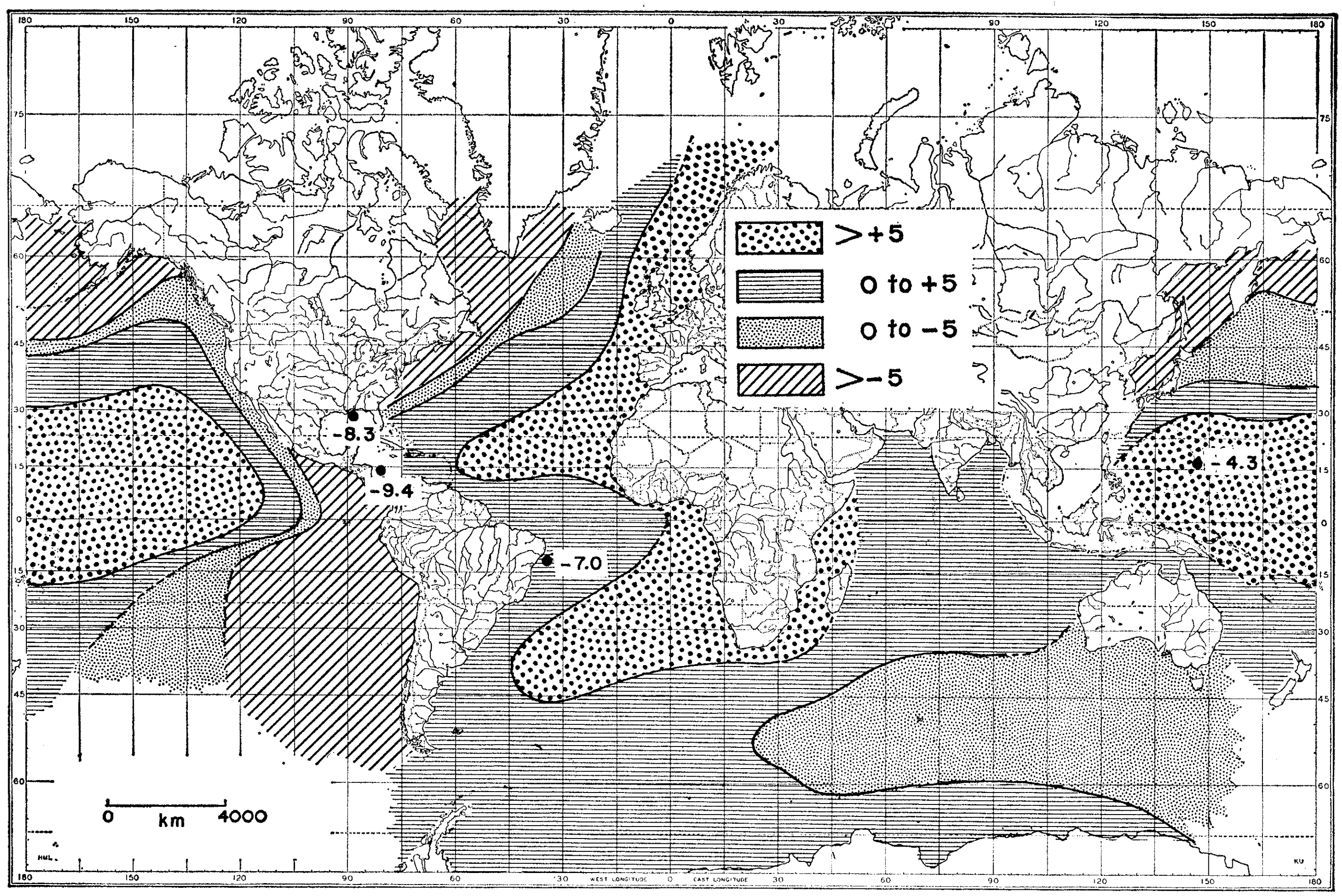
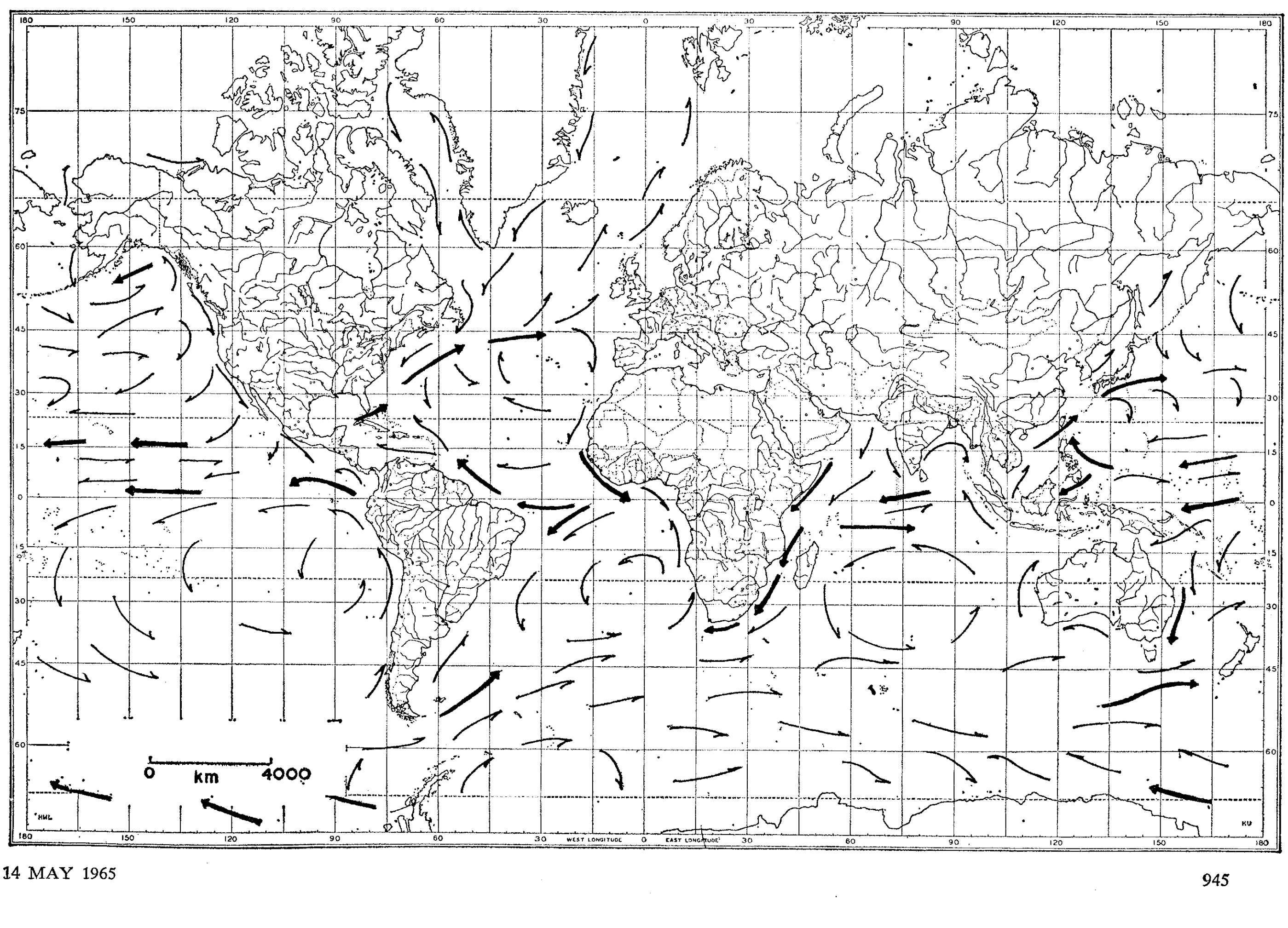


Fig. 3 (top). "Residual surface" from diversity of Recent planktonic foraminifera includes all secondary sources of variation. In this example, however, the surface principally reflects variations due to deformation of the planetary temperature gradient by ocean currents. Fig. 4 (bottom). Simplified, major ocean circulation patterns for comparison with the "residual surface" of Fig. 3. (The data were compiled from many sources; weight of arrows indicates relative strength of currents.)



because the group is reasonably well collected and studied, the diversity residuals of planktonic foraminifera can be almost wholly ascribed to distortions of the planetary temperature gradient by ocean currents (*4*).

Figure 3 shows contoured, positive (more diverse and, therefore, warm) and negative (less diverse and, therefore, cold) residuals from the computed regional surface for present-day planktonic foraminifera. The control was adequate to show the regional surface, as was originally desired (Fig. 2), but is, unfortunately, minimal for consideration of residuals (75 points for the entire world), and is poorly distributed (concentration in the North Atlantic). Nevertheless, a marked relationship to the surface circulation pattern is evident. Positive diversity residuals are divided into two arbitrary classes (greater than +5 is very warm; +5 to 0 is warm); negative diversity residuals are, likewise, divided (0 to −5 is cold; greater than −5 is very cold). A comparison of the residual surface (Fig. 3) with a simplified diagram of ocean circulation patterns (Fig. 4) shows clearly that even at the present level of resolution many of the major current systems can be recognized. All of the data were used in the original calculation of the regional and residual surfaces. In contouring the residual surface, however (Fig. 3), four points have been omitted because it is believed that they owe their value to factors other than ocean currents, such as poor collecting or deltaic influences. The four omitted points are marked with a special symbol; the residual value for each is given.

The data presented in the figures permit only a preliminary test of the technique suggested. A further and more critical test of the relationship of present-day diversity residuals and existing ocean currents is required. The preliminary test is sufficiently encouraging, however, to suggest some interesting possibilities for the method.

Planktonic foraminifera have been abundant since the late Mesozoic. Thus, it is theoretically possible to reconstruct patterns of oceanic circulation back into the Cretaceous, or for a period of about 100 million years. A practical limit is presently imposed by the extreme scarcity of oceanic cores which have penetrated early Tertiary or Cretaceous sediments. For the time being, the method could probably be applied only to Miocene and younger ages. Its greatest immediate possibilities appear to lie in detailed studies of the Pleistocene record.

Core coverage for the latter part of Pleistocene time is probably adequate for reconstruction of the oceanic circulation patterns that accompanied the extreme climates of the Pleistocene. It should be possible to recognize the circulation of both a fully glacial and a fully interglacial interval and, thus, establish boundary conditions within which other less extreme changes should be contained. It should also be possible to determine whether the Arctic Ocean has been ice-free during any part of the Pleistocene, thereby providing a test of some theories of glaciation. With a relatively few O^{18}/O^{16} paleotemperature measurements on suitable samples, it might even be possible to calibrate the residual surface for temperature.

If the surface oceanic currents bear the close relationship to atmospheric circulation suggested by Munk (*5*), a knowledge of the currents characterizing the extremes of the Pleistocene might reflect considerable information about the patterns of zonal wind circulation in the atmosphere. Such information might lead to a better understanding of the conditions attendant upon continental glaciation of the middle latitudes.

Exploration of the interesting possibilities for the use of taxonomic diversity residuals of planktonic foraminifera in the study of past patterns of oceanic circulation must await a critical and detailed test of the recent model.

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4. The diversity data used in these plots have been abstracted from a survey of available literature with the assistance of James Bugh. No attempt has been made to insure a high degree of internal consistency in the taxonomic information used. Such an attempt is being made in a detailed study now underway.
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Is There Vegetation on Mars?

Abstract. *At least some of the changes in the color of Mars at different seasons are caused by color centers produced by electromagnetic and corpuscular solar radiation in solids on the surface. Calculated radiation flux, at appropriate energies and known temperature variation, could account for seasonal formation of color centers and bleaching if a simple trap model is assumed. In certain kinds of rhyolite (SiO_2, $NaAlSi_3O_8$), which has been suggested as one of the possible constituents of the martian surface, color centers can be produced. No color centers are expected in limonite, $Fe_2O_3 \cdot 3H_2O$, the other likely constituent.*

The hypothesis that vegetation exists on Mars is based on two kinds of observations: one is the presence of infrared absorption bands of aldehyde, the other is the seasonal variation of the darkness of bluish-green areas on the otherwise orange-rusty planet. Recently (*1*) the absorption bands have been shown to be caused by heavy water, HDO, of telluric origin. My purpose is to point out the possibility that the seasonal color variations may be explicable, at least in part, in terms of the well-known phenomenon of color-center formation and bleaching by incident ionizing radiation under varying temperature conditions. According to recent estimates (*2, 3*) the martian atmosphere (total pressure 13 to 20 mm-Hg) consists of 85 percent (by volume) of N_2, 14 percent (by volume) of CO_2, and the rest being essentially argon. These data, combined with the known absorption coefficients (*4*), indicate that no significant absorption of solar ultraviolet radiation occurs for wavelengths longer than about 2000 Å ($h\nu = 6$ ev). In the range of photon energies between 4 and 6 ev the total solar flux at the top of the martian atmosphere is about 10^4 erg cm^{-2} sec^{-1}. This gives 10^{15} photons cm^{-2} sec^{-1} as an estimate of the intensity of this radiation at martian surface in the subsolar region. On Earth ultraviolet radiation in this range of wavelengths is totally absorbed by atmospheric ozone. On Mars the upper