Table 2. Compositions of stanfieldite (*10*) in percentages by weight. The six pallasites were Santa Rosalia, Albin, Finmarken, Imilac, Mount Vernon, and Newport. In parentheses are ranges in values for all pallasites; Na_2O was not above background.

Component	Estherville	Average from six pallasites
CaO	24.6	26.6 (26.2-27.2)
MgO	12.9	21.0 (20.1-21.6)
FeO	13.8	2.5 (2.2- 2.7)
MnO	1.4	0.4 (0.4- 0.5)
P_2O_5	46.6	50.4 (50.3-50.5)
	Totals	
	99.3	100.9

10.00 ± 0.02 Å; *c*, 22.88 ± 0.04 Å; *β*, 100° 15′ ± 10′. The powder data are not indexed because of the multiplicity of possible relections for each line, which reflects the large cell size. Two possible space groups are *Pc* and *P2/c*. The space group $P2_1/c$ is eliminated by the presence of a weak 050 reflection on the single-crystal photographs. The powder patterns for the mineral from Estherville and from all pallasites are identical, corresponding closely with those listed for the synthetic compound $Ca_4Mg_5(PO_4)_6$ on ASTM card 11-231. The calculated x-ray density for the molecule $Ca_4Mg_3Fe_2(PO_4)_6$ is 3.15 g/cm³ for $Z = 8$; the density by the sink-or-float method is 3.15 ± 0.01 g/cm³. The hardness is greater than 4 and slightly less than or equal to 5.

The chemical composition (Table 2) was determined by electron-microprobe methods. Greater substitution of iron for magnesium is observed in the Estherville occurrence; this finding is also characteristic of the associated olivine and orthopyroxene. Analysis of Estherville stanfieldite yields the formula

$$Ca_{4.02}(Mg_{2.91}Fe_{1.74}Mn_{0.18})_{4.83}(PO_4)_6.$$

If one takes into consideration the analytical error of 2 percent of the amount present and adds manganese to iron, this formula may be written $Ca_4Mg_3Fe_2(PO_4)_6$. The average composition for stanfieldite from all pallasites gives the formula

$$Ca_{4.02}(Mg_{4.41}Fe_{0.30}Mn_{0.06})_{4.77}(PO_4)_6,$$

or ideally,

$$Ca_4Mg_5(PO_4)_6.$$

The iron-free mineral has been synthesized by heating a mix, prepared according to the last formula, at 800°C for several days in a platinum crucible in air. The optical properties and x-ray powder pattern of the single-phased product are identical with those for the mineral in the Santa Rosalia meteorite.

The phase diagram of the synthetic system $Mg_3(PO_4)_2$–$Ca_3(PO_4)_2$ at 1 atm, reported by Ando (*9*), contains three crystalline phases: the end members have the ideal compositions of the minerals farringtonite and whitlockite, respectively; and a third phase has an intermediate composition close to that of stanfieldite. For comparisons, the mineral compositions are considered to be free of iron and manganese. Ando's diagram for 900°C shows a two-phased region extending from a Mg:Ca atom ratio of 0.08 (corresponding to whitlockite) to one of 0.91 (corresponding to stanfieldite). However, stanfieldite in the pallasites has by analysis a Mg+Fe+Mn:Ca ratio of 1.19, which ratio is apparently independent of the mineral's coexistence with whitlockite and greater than the 0.91 given by the phase diagram. The diagram shows a single-phase region, equivalent to stanfieldite, extending from 0.91 to 1.02; however, since I have synthesized stanfieldite as a single phase at 1.19, it appears that the published phase diagram is not sufficiently accurate to delineate the stability fields of these three phosphate minerals. Although study of the ternary system $Fe_3(PO_4)_2$–$Mg_3(PO_4)_2$–$Ca_3(PO_4)_2$ would be more applicable, Ando's work does suggest that farringtonite and whitlockite will not coexist in a meteorite formed under equilibrium conditions.

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References and Notes

1. Stanfieldite is named after the late Stanley Field, former chairman of the board of trustees of the Field Museum of Natural History. Together with O. C. Farrington, former curator of geology, he added most of the present meteorite collection of the museum, one of the world's largest. The mineral has been approved by the Commission on New Minerals and Mineral Names of the International Mineralogical Assoc.
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8. The x-ray powder pattern of stanfieldite from Mount Vernon contains an impurity line at 6.7 Å; that from Finmarken has extra lines at 6.7 and 7.9 Å. The farringtonite pattern from Phillips County contains three extra lines at 7.9, 6.7, and 2.68 Å. These lines are characteristic of many hydrated phosphate compounds, but no specific identifications were attempted. Microprobe results for some spots on these phosphates were lower than for adjacent spots and were deleted from the analyses reported in Table 2.
9. J. Ando, *Bull. Chem. Soc. Japan* **31**, 201 (1958).
10. The electron-microprobe analyses were performed on carbon-coated, polished, epoxy-resin mounts of from four to six grains of each mineral removed from the meteorite; the instrument was made by Applied Research Labs. Analyzed apatite, olivine, and farringtonite were used as standards. Compositions were corrected for dead time, background, absorption, fluorescence, and atomic number according to Smith (*11*). Deviation of individual grains was within the analytical error of from 1 to 2 percent of the amount of each calculated oxide.
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12. Work performed under the auspices of the AEC. I thank E. Olsen (Field Museum of Natural History, Chicago) and G. Reed (Argonne National Laboratory) for the meteorite samples, E. Olsen for assistance in correction of the microprobe data, S. Siegel and J. Whitaker (Argonne National Laboratory) for the single-crystal x-ray results, G. Montet (Argonne National Laboratory) for critically reviewing the manuscript, and C. Knowles (Department of Geophysical Sciences, University of Chicago) for operation of the electron microprobe.

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Seismic Refraction Profile in Coral Sea Basin

Abstract. *A refraction profile near the south edge of Coral Sea Basin shows sediments, "second layer," and oceanic crust all thicker than normal for an oceanic station; normal mantle lies at a depth of 19 kilometers.*

In October 1960 we made a reversed refraction profile (station MN5) in the southwestern part of Coral Sea Basin, using the R.V. *Argo* and its boat with previously described methods (*1*). This is the only refraction profile so far reported from the Coral Sea, one of the very few from the southwest Pacific (*2*).

Lack of previous soundings resulted in location of the profile closer to the continental slope in the southwest flank of the basin than one would have desired. One end of the line was on the abyssal plain in water 4.45 km deep; the other end was in 3.50 km of water on the continental rise of Queensland Plateau (*3*), a shoal area, 1 to 2 km deep, resembling in many ways Blake Plateau off the eastern United States (Fig. 1). Because of the large change in depth and the break in slope along the

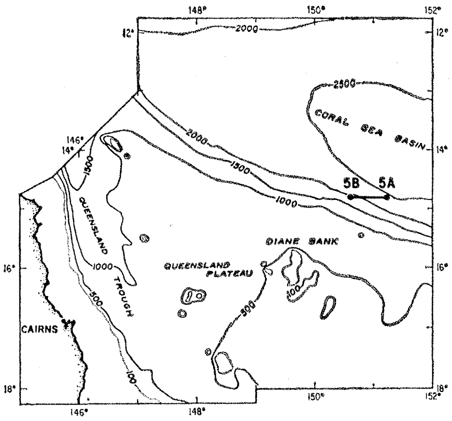

Fig. 1. Location of station on the west side of the Coral Sea. Depths are in fathoms (after Krause).

profile, it was necessary to correct the data for topography as well as for water delay; all travel times were therefore corrected to basin-floor datum at 4.45 km below sea level by the method of Sutton and Bentley (*4*). Two sets of corrections were made: the first on the assumption that all irregularities were in the first (sedimentary) layer; the second on the assumption that the first layer was a uniform blanket covering an irregular second layer. The scatter of travel times was least in the first solution (Fig. 2), which fact implies that the small-scale irregularities in the sea floor were due to erosion or to differential deposition of the sediments, rather than to uniform deposition over preexisting rough topography.

Results of a conventional analysis of the data appear in Fig. 2 and Table 1; some discussion of the nature of and validity of the data is in order. Reflection data at short ranges were sought in the records, but no reflection arrivals were sufficiently strong to permit correlation from record to record on the evidence of amplitude alone, and the shots were too widely spaced to permit phase correlation of the records. Velocities used for the first layer are therefore based on sets of secondary arrivals, received at both stations, that are here interpreted as signals refracted within the sedimentary section. If they were in fact refracted at the sea floor, the travel times for this layer would have a zero-distance intercept of 0.00; the fact that they do not implies that these arrivals were either refracted from an interface within the sedimentary section, or were low-angle reflections from the layer below. The choice of these alternatives is not clear; if the first is true, the velocity given is that of a discrete layer within the sediments; if the second, it lies between the interval velocity and the maximum velocity in the sedimentary section.

Data for the second layer were recorded on run 5B, but on run 5A they were represented only by a single early arrival and the reverse point. Arrivals from the "oceanic layer" were well recorded on both runs. Mantle arrivals were recorded only as a set of strong secondary arrivals on run 5B.

Despite the slope of the sea floor, the base of the low-velocity sediments and the base of the second layer are horizontal; the slight difference in depth between the two ends of the profile is less than the error of determination. The velocity of the second layer found here is near the lower limit of velocities for the "second layer" in the Pacific basin; the layer here could therefore consist of older sediments. The records were therefore carefully examined for evidence of a "masked layer" having a velocity intermediate between 4.1 and 6.9 km/sec; such a layer could represent either the oceanic "second layer" or continental material (depending on velocity). No such evidence was found; if a layer having the velocity of the continental crust (near 6 km/sec) does exist here, it must be extremely thin.

The determination of mantle depth, based on second arrivals on one run only, was necessarily made on the assumption that the interface was horizontal. One cannot therefore attach importance to the exact value of the velocity determination, since a small dip would cause considerable error. One can place some reliance on the determination of depth; it shows unusually great depth to the mantle for such depth of water. The thickness of the oceanic layer (11 km) is one of the highest values we have measured anywhere.

On the basis of these data one can derive a few tentative conclusions about structure and geological history: The slope on the north side of Queensland Plateau is partly depositional, and considerable sedimentary material has been derived from the plateau to build the rise at the foot of the slope and to help fill Coral Sea Basin. This finding does not, however, rule out Krause's conclusion (*3*) that much of the fill comes from the northwest from Papua Plateau. The thickened second layer suggests additional filling of the basin by either sediments or volcanic rocks. The velocity of the third layer, very close to that found under the ocean basins, but well above values normally found at such depths under continental areas, argues that the basin originated as a separated area of oceanic structure. The most unusual feature of the

Table 1. Signal velocities and depths to bases of layers at station MN5. Value in parentheses is unreversed.

Layer	Velocity (km/sec)	Depth (km) at station MN5B	Depth (km) at station MN5A
Water	1.526	3.55	4.47
Sediment	2.11	5.0	5.3
"Second layer"	4.16	7.5	7.8
"Oceanic"	6.94	18.8	18.8
Mantle	(8.07)		

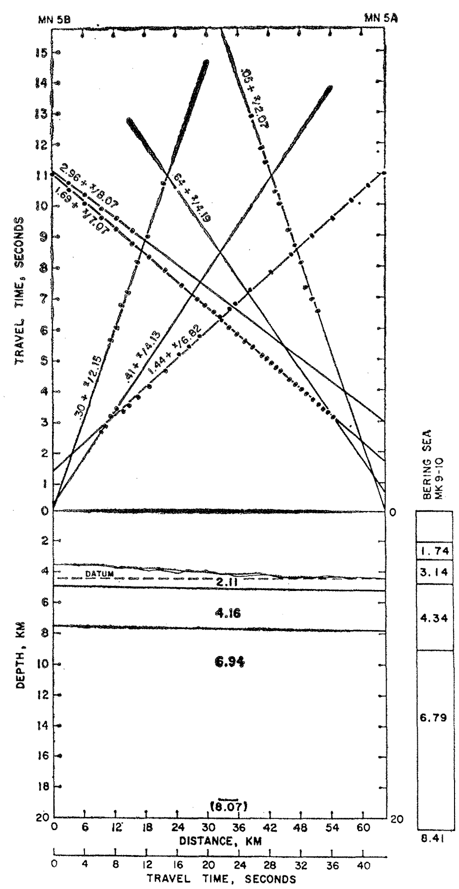

Fig. 2. Travel times; refracted arrivals are corrected to datum at 4.45 km, the depth of the flat floor of the basin. Station MN5A is at the right. A structural column for station MK9-10, in a similar location in the Bering Sea, is included for comparison.

station, the great thickness of the third layer, or "oceanic layer," would be startling if one assumed that it represented the structure under the entire basin. We have found stations like this before, however; the one that it resembles most is station MK9-10, lying in a similar topographic position on the continental rise on the east side of the Bering Sea (*5*), a similar small ocean basin separated from the main basin of the Pacific. The average of reversed profile MK9-10 is plotted to the right of that of station MN5 in Fig. 2 for comparison. In the case of the Bering Sea, the thickened "oceanic layer" is found only at the margins of the basin; the central portion has a normal oceanic crust overlain by greatly thickened sedimentary and "basement" layers, with the mantle depressed accordingly.

The zone of thickened "oceanic layer" may be of considerable significance if it is normally found at the margins of enclosed basins. Unfortunately, stations are rarely made in this topographic position, and, when they are, the large vertical exaggeration used in making crustal sections makes them less noticeable. They may demonstrate part of the process by which a piece of ocean can be converted into continent: the sedimentary section thickens by deposition at the top at the center of the basin, and the crustal section thickens by conversion or addition from below at the edges. Such a possibility (among others) has been suggested in Menard (*6*).

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Paleomagnetic Field Reversals and Cosmic Radiation

Abstract. *Faunal changes observed in association with reversals of the geomagnetic field have been attributed to increased radiation dosages produced by cosmic rays when the field intensity is greatly reduced. However, at currently observed cosmic ray and solar particle intensities, the additional dosages produced at sea level during a period of complete removal of the geomagnetic field are negligible. Furthermore, even complete dumping of the energetic particle in the radiation belts would not give rise to the necessary increased dosages.*

Paleomagnetic studies of rock samples taken from many parts of the world have provided strong evidence that the geomagnetic field undergoes occasional reversals of polarity. Measurements based on simultaneous paleomagnetic and radiometric studies of lava flows have traced at least four major geomagnetic field reversals in the past 4 million years, together with indications of several short periods of reversed magnetic polarity (*1*). Similar results have been obtained [Opdyke *et al.* (*2*)] from paleomagnetic studies of sediments in Antarctic deep-sea cores. These authors also examined the marine protozoan radiolarian species in these sedimentary cores and found striking faunal boundaries that were related to field reversals observed in the same cores. A correlation of paleomagnetic and paleontological evidence from the Cambrian to the Recent present (*3*) also suggests that field reversals strongly influence population trends. From these coincidences or near coincidences of the faunal changes with the field reversals it has been suggested (*2*) that there must be a causal relation between the two effects. The nature of this causal relation has been the subject of speculation. In particular, it has been pointed out that during a magnetic field reversal the intensity of the geomagnetic field most probably decreases temporarily to essentially zero. As a consequence, the earth's surface would have been exposed to a greater cosmic ray intensity than normal. The resulting increase in the radiation dosage is assumed to be responsible for the observed faunal changes, most probably due to an enhanced mutation rate that strongly affects the evolutionary development of individual species (*4*).

I now point out that the increased radiation dosages that would be experienced at sea level as a consequence of a complete removal of the shielding effect of the geomagnetic field would be so small that a significant effect on population levels would be extremely unlikely.

The effect of reducing the intensity of the geomagnetic field to zero on the radiation dosages experienced at sea level may be regarded as threefold. First, there will be an increase in dosage due to the additional cosmic ray particles allowed to make an impact on the top of the earth's atmosphere in regions previously shielded. Second, those particles intermittently emitted by the sun will be able to reach all parts of the upper atmosphere with full intensity and thus produce increased radiation. Third, it is possible, although rather unlikely, that some or all of the particles stored in the radiation belts might be "dumped" into the earth's atmosphere. Each of these effects are considered after a discussion of the role of energetic particles falling on the top of the earth's atmosphere in determining the total radiation dose experienced by organisms at sea level.

The earth's atmosphere is so thick that essentially none of the corpuscular radiation falling on it can reach the surface without having suffered several nuclear interactions. For energetic protons, which make up a major fraction of the incident particles and are the most penetrating, this thickness corresponds to approximately ten interaction mean free paths. Thus, the probability of a proton reaching the earth's surface without having interacted is less than 5×10^{-5}. Similarly, the heavier nuclei, with their shorter mean free paths, have a still smaller probability of not interacting. The radiation dose at sea level is thus almost entirely due to the secondary particles created in the atmosphere, and sensible contributions to this dosage are only made by incident particles having sufficient energy to produce secondary particles capable of penetrating to sea level. Incident protons with energies below a few Bev are thus incapable of affecting the direct radiation dose at sea level. How-