radiation, and damage to vegetation. These effects would be observed not only at the time of release of DEHA into the atmosphere but also at least 6 hours downwind from the release sites. In the same way, use of DEHA at 0.5 ppm would greatly exacerbate smog symptoms at locations from 1 hour to at least 5 hours downwind (see Fig. 2). Furthermore, DEHA's odor threshold level (0.5 ppm) prohibits its introduction into polluted atmospheres at concentrations of 0.5 ppm or more (we do not consider here the possible toxicity of DEHA and its reaction products).

Our results confirm that DEHA, at sufficiently high concentrations, acts as an inhibitor of photochemical smog. However, this result cannot be extrapolated to conditions prevailing in ambient polluted atmospheres. Clearly, experimental validation of proposed techniques for the control of photochemical smog by chemical additives must be conducted at ambient pollutant levels.

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14. Ambient air was introduced into the chamber less than 1 hour after the local morning peak of automobile traffic.
15. Control experiments were conducted simultaneously in the two compartments of the chamber with ambient air and the HC surrogate mixture without added DEHA. Identical NO, NO_2, O_3, PAN, nuclei, and b_{scat} profiles were obtained in the two compartments throughout the 6-hour irradiation periods. The possible contamination by reactive species formed in an earlier experiment and adsorbed on the chamber walls was also investigated. Since DEHA was added to the same compartments in all experiments except experiment 2, one may argue that the observed increase in O_3, PAN, and b_{scat} with the addition of DEHA may be due in part to contamination from earlier experiments. We tested this possibility in experiment 2, where DEHA was added to the compartment usually used for ambient air alone, and vice versa. The results of this experiment were in no way different from the results of the other experiments.
16. These experiments were conducted in another chamber with Teflon and plexiglass walls housing a Fourier-transform infrared spectrophotometer with a base path of 22 m and a total optical path of 1.1 km. The DEHA concentration was measured on the basis of its known absorptivity at 931 cm^{-1}.
17. Ozone was measured with a chemiluminescent instrument calibrated by the ultraviolet photometry method (W. Simmons, filing sheet amending Section 70200, "Table of standards applicable statewide," of Title 17 of the California Administrative Code, Sacramento, 15 May 1975).
18. We thank P. Johnson for help in carrying out the experiments. We thank Dr. E. Tuazon, Dr. A. Winer, and R. Easton for carrying out the DEHA half-life measurements described in (*16*). This work was supported in part by NSF Research Applied to National Needs (RANN) grant ENV73-02904-A03. Initial results of this study were presented at the NSF RANN 2 meeting, Washington, D.C., 7 to 9 November 1976.

21 December 1976

High-Frequency P_n Phases Observed in the Pacific at Great Distances

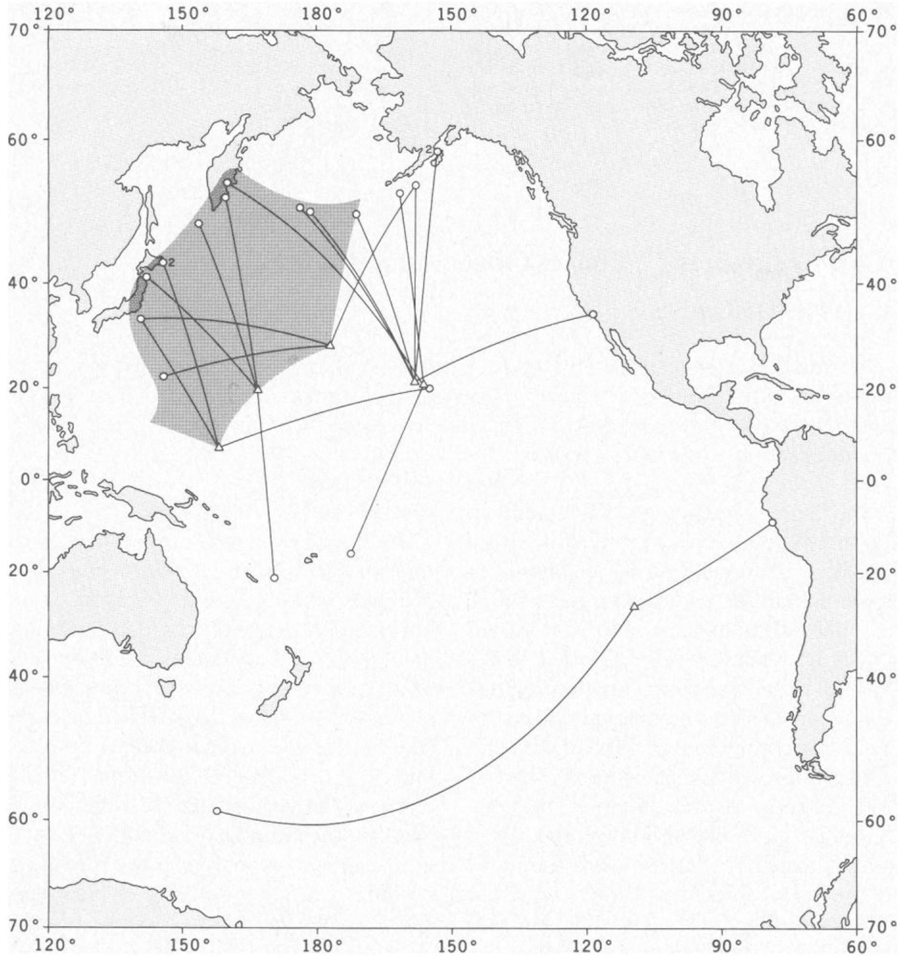
Abstract. *Earlier observations of a seismic waveguide in the northwestern Pacific with a velocity of 8.3 kilometers per second to distances of approximately 30° are complemented by suggestions of a possible waveguide with a velocity of 7.8 kilometers per second to distances well in excess of 30°.*

The high-frequency P_n waveguide in the mantle underlying the northwestern Pacific is characterized by velocities of about 8.3 km/sec and frequencies as high as 6 hertz to distances of 30° (*1*). Waveguides with similar velocities (8.1 to 8.3 km/sec) have been found in other regions of the earth (*2*), with observations out to 35.07° for continental travel paths (*3*) and to 37.84° for oceanic travel paths (*4*). Recently, however, P_n arrivals for distances greater than 30° in both the North and northwestern Pacific were found (*4*) to have significantly lower apparent velocities (approximately 7.9 km/sec) than the P_n arrivals with velocities of 8.3 km/sec or 8.1 to 8.3 km/sec. Suggested interpretations were that low signal-to-noise ratios prevented the observation of the actual first arrival corresponding to the 8.3-km/sec energy or that an additional waveguide was present. The second interpretation implies that the slower waveguide, although masked by phases from the faster waveguide at distances less than 30°, is actually more efficient, resulting in the observation of 7.9-km/sec arrivals at distances greater than 30° and the corresponding absence of 8.3-km/sec arrivals.

The suggestion of a second waveguide prompted a reexamination of existing earthquake data (seismograms and hydrophone recordings from Midway, Wake, and Hawaii; seismograms from Ponape and Easter islands) for travel paths in the Pacific. Thus far, a total of 23 suspected waveguide phases have been found for travel paths generally in excess of 30° (*5*). Travel paths and a travel time curve for these phases are shown in Figs. 1 and 2, respectively. The travel time curve [$T = X/(7.76 \pm 0.18) - 15.7 \pm 11.7$, where T is the observed travel time in seconds and X is the epicentral distance in kilometers] is based on all but two of the data points in Fig. 2; these data points (at distances of 33.88° and 68.42°) represent poorly recorded phases at Easter Island. The travel time curve (Fig. 2) for P_n arrivals observed at distances of less than 30° illustrates the differences between the curves for the 8.3- and 7.8-km/sec phases. Sample seismograms and hydrophone power level recordings are shown in Fig 3. [The generally higher apparent velocities (that is, X/T) of Fig. 3 relative to the value of 7.76 km/sec determined from Fig. 2 are a result of the large negative intercept (− 15.7 seconds) of the travel time curve. This intercept may not be statistically significant because it has a large standard deviation (± 11.7 seconds).]

Occasionally, depending on epicentral distances and focal depths, arrival times of the suspected waveguide phases correspond to the expected arrival times of either *PP* (a wave reflected once from the surface), *PPP* (a wave reflected twice from the surface), or *PcP* (a wave that bounces off the core) phases, or scattered precursors of these phases. These phases and their precursors are generally characterized by short wavetrains, consisting of only a few cycles with periods longer than their first-arriving *P* phase, and the phases suspected here as being guided arrivals are generally characterized by wavetrains of extremely long duration (a common characteristic of guided waves) and frequencies higher than that of the *P* phase (frequencies higher than 3 hertz are generally observed for more than a minute; Fig. 3). For these reasons the waveguide interpretation appears somewhat more reasonable.

Moreover, the suggestion that the 7.8-km/sec phases may actually be later arriving portions of 8.3-km/sec phases is weakened by the fact that some 7.8-km/sec phases display strong, abrupt onsets (that is, approximately 8 of the 23 phases observed had distinct onsets with signal-to-noise ratios of > 3 : 1; most of the re-



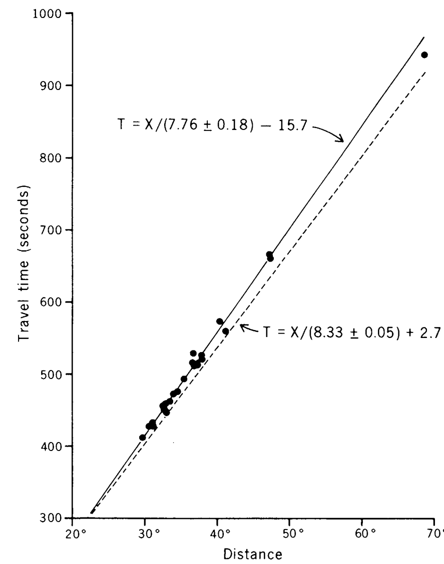


Fig. 1 (left). Great circle travel paths for waveguide phases recorded in the Pacific at distances greater than 30°. Shading indicates those portions of the northwestern Pacific Basin which transmit 8.3-km/sec phases out to distances of 30°. Fig. 2 (above). Travel time curve for waveguide phases observed in the Pacific at distances greater than 30° (solid line). The travel time curve for the 8.3-km/sec waveguide phases observed at distances less than 30° is also plotted (dashed line).

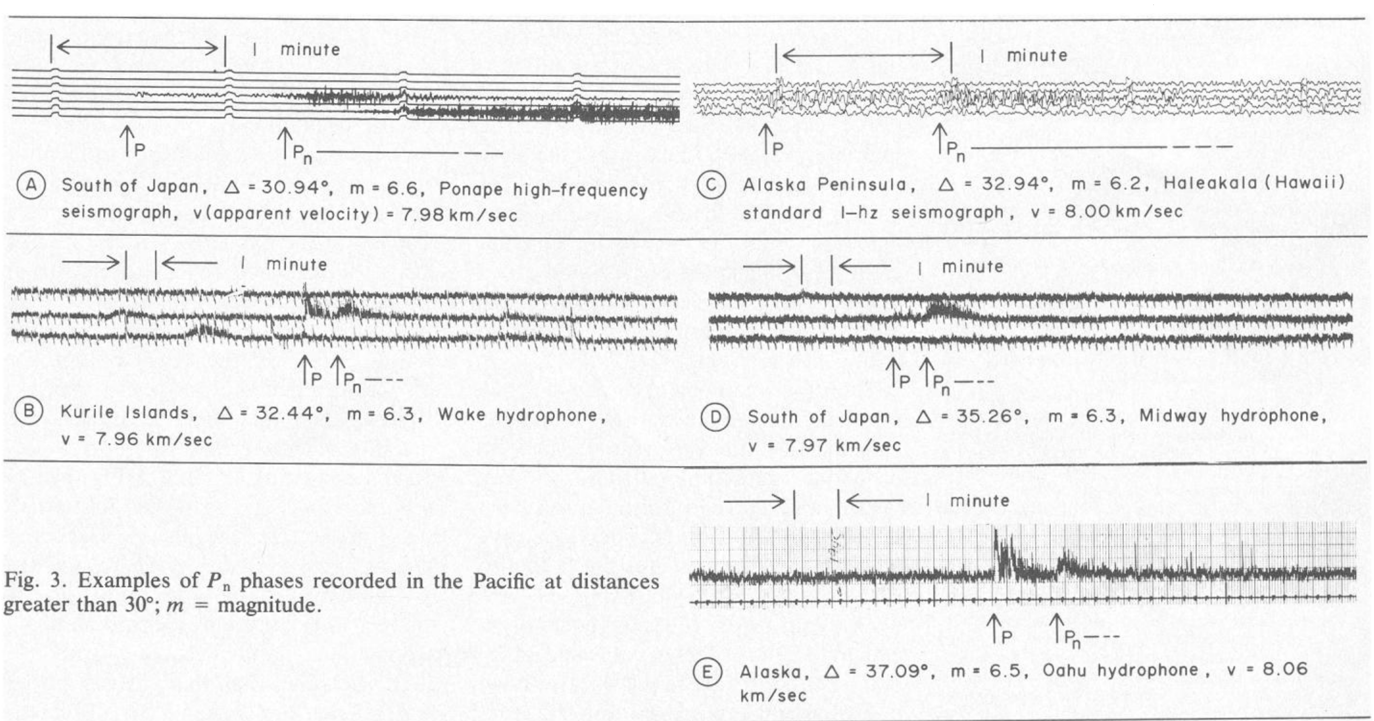


Fig. 3. Examples of P_n phases recorded in the Pacific at distances greater than 30°; m = magnitude.

maining phases also had distinct onsets but signal-to-noise ratios of $< 2:1$). Since many of these phases had travel paths entirely within portions of the northwestern Pacific Basin already known to have an 8.3-km/sec waveguide (shaded area of Fig. 1), two major waveguides seem to be suggested for this part of the Pacific. Concerning the possible presence of the 7.8-km/sec phase for distances less than 30°, it seems reasonable that this phase would begin to make its appearance as the 30° distance is approached. Unfortunately, the only data available in the distance range of 19° to 30° were recorded on low-speed, rectified power level recordings of hydrophones. Later arriving phases on these recordings are extremely difficult to evaluate (*6*).

Although data relevant to the existence of a waveguide in the North Pacific comparable to the northwestern Pacific's 8.3-km/sec waveguide do not exist (because of a lack of stations at appropriate epicentral distances), worldwide observations suggest that such a waveguide should be present for that area as well as for large areas of the South Pacific. At this time, the extension of a dual waveguide hypothesis to the South Pacific, however, would not be reasonable since the 7.8-km/sec waveguide for this region would be based on only two poorly recorded phases at Easter Island.

Propagation of the 8.1- to 8.3-km/sec phase has generally been thought to occur along a discontinuity surface or within a waveguide which is close to the Mohorovicic discontinuity. Recently, explanations involving thin high-velocity layers have been proposed for this waveguide, as well as for additional upper mantle waveguides suggested by long-range seismic refraction observations in France (*7*). Such explanations may also be applicable to the suspected 7.8-km/sec waveguide reported here.

Having now obtained evidence for high-frequency guided phases to distances well in excess of 3300 km (perhaps to 7600 km), it is my hope that the thought expressed in the following statement will receive additional, well-deserved attention: "It will be the challenge to both explosion and earthquake seismology for the coming decade to find an answer to the question of how *P* and *S* transmission can occur within the lower lithosphere over distances of more than 1000 km with nearly constant velocity of first arriving energy" (*8*).

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3. See Båth (*2*).
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5. The criterion used in selecting these 23 phases was merely the fact that they had distinct onsets. The phases are the only ones having such onsets in the currently available data set consisting of several hundred seismograms and hydrophone power level recordings. Of the 23 phases suspected as being guided arrivals, 16 were recorded by only one station; four were from two earthquakes, each recorded by two stations at distances in excess of 30°; and three were observed by single stations at distances beyond 30°, but also recorded at distances less than 30°. Of these three observations at distances less than 30°, two have arrival times corresponding to a higher velocity 8.33-km/sec waveguide; the remaining observation is found close to the crossover point of the 8.33- and 7.76-km/sec travel time curves ($\approx 18.6°$).
6. At distances less than 19° where the 7.76-km/sec phases would begin to arrive earlier than the 8.33-km/sec phases (because of the large negative intercept), several arrivals corresponding to the 7.76-km/sec phase have been observed on a seismograph at Ponape (*4*). However, these observations may not be too meaningful because of the large standard deviation of the 7.76-km/sec line.
7. See Hirn *et al.* (*2*); R. Kind, *J. Geophys.* **40**, 189 (1974); K. Fuchs and K. Schulz, *ibid.*, in press. Hirn *et al.* (*2*) stated that thin, high-velocity strata could only be proposed if thin zones of low velocity were also included in the model implying "drastic modifications of current petrological models of the lower lithosphere" and modifications to current estimates of the strength of the lower lithosphere.
8. See Hirn *et al.* (*2*), p. 381.
9. I thank the staff of Honolulu Observatory for providing records from their Haleakala seismograph, and R. Johnson for hydrophone recordings. I thank G. Sutton and M. Odegard for reviewing this report, and E. McAfee for editorial assistance. Illustrations were provided by C. S. McCreery. Contribution No. 832, Hawaii Institute of Geophysics. This research was supported by the Office of Naval Research and NSF grant DES 75-14814.

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High-Resolution Soft X-ray Microscopy

Abstract. *X-ray micrographs of biological materials have been obtained with a resolution better than 100 angstroms by using x-ray resist as the recording medium. A high-resolution scanning electron microscope with a short-focal-length final lens, operating in the "low-loss" mode, is used to make the smallest features in the x-ray replica visible.*

A resolution better than 1000 Å has recently been demonstrated by soft x-ray contact micrography by using polymethyl methacrylate (PMMA) resist for recording and a scanning electron microscope (SEM) for magnified viewing of the resist replica (*1*). We present here some new results which demonstrate a resolution better than 100 Å.

In PMMA breaking of bonds reduces the molecular weight and increases the dissolution rate in a proper solvent (*2*). Development in this solvent produces a relief replica of the object, where the higher elevations correspond to a higher absorption of the specimen. The limit of the resolution of an x-ray resist is the effective range δ of secondary electrons which are produced in the resist by soft x-ray absorption (*3*). Measurements have shown that this range increases linearly with the energy *E* of the incident x-rays and that a value $\delta \approx 50$ Å is obtained for carbon Kα ($E = 277$ ev) x-rays (*4*). The highest resolution to be expected is for the wavelength range around 50 Å. For shorter wavelengths (higher energies) the resolution decreases because of the increasing range of secondary electrons; for longer wavelengths the resolution decreases because diffraction effects become dominant.

For our high-resolution experiments we have used carbon Kα radiation (wavelength $\lambda = 44.8$ Å) and radiation from the DESY synchrotron in Hamburg, which was operating at an electron energy of 7 Gev and a current of 5 ma. The spectrum of the DESY synchrotron radiation was modified by reflecting it from a gold mirror at a glancing angle of 4° to eliminate the hard radiation with $\lambda < 25$ Å. The effective exposure spectrum of the resist under this condition extends from about 30 to 44 Å (*5*).

Figure 1 shows a scanning electron micrograph of the resist replica obtained from a section of a salivary gland chromosome of *Drosophila* with carbon Kα radiation. The micrograph was obtained in a commercial SEM, and the finest details visible correspond to the resolution of this instrument (~ 250 Å).

Figure 2 shows the x-ray images of a section of the retina pigment epithelium