lens, in the whole sky, having a magnitude corresponding to the range $0.15 \leq Z \leq 0.3$. If one integrates to see how many gravitational lenses can be found, and if one uses a telescope powerful enough to penetrate until $Z = 2$, the answer is 40 galaxies for $q_o = 1$; 65, for -1; and 3, for 2.5. These numbers were found by use of the arbitrary assumption that all galaxies at distance are so compact that their radii are no greater than 2×10^{19} cm. Clearly this assumption maximizes these numbers.

If one wishes to confine himself to instances in which the amplification is so great that the total flux received is of the order of 50 times greater than the flux received from one normal galaxy, the deflecting galaxy should be 50 times smaller in radius than our model galaxy. Therefore the probability of finding a galaxy behind it is reduced by a factor of 2500, and the total number of galaxies that are 50 times more luminous than a normal galaxy over the entire sky becomes 2×10^{-2}!

One is tempted to explain the apparent large amount of energy emitted by quasars, and their fluctuations in luminosity, as results of accidental alignment, along the line of sight, of two normal galaxies in such a way that the light from the distant one is amplified by the gravitational-lens effect of the nearer. But the probability of such an alignment has just been calculated to be so small that such event cannot be found. One's conclusion is that quasars are not demonstrations of gravitational lenses unless additional assumptions are made: for example, if the density of galaxies increases much more rapidly with increasing distance, the probability of alignment increases. But this is an arbitrary assumption lacking theoretical or observational backing; such an assumption was made by Barnothy (*9*) who claimed that 3000 Seyfert galaxies can be found behind each other and act as gravitational lenses.

Another assumption that I would like to contemplate is the following: Let us assume that most of the galaxies in the universe come in doublets. Let us assume the distance between each two components to range between 10^{21} and 10^{22} cm (3 to 30 kiloparsecs) (the separation between the optical doublet of Cygnus A is of that order of magnitude), and the radius of each galaxy to range from 10^{17} to 10^{18} cm. When the line connecting the two galaxies is normal to the line to Earth, nothing significant happens, but, if one galaxy is behind the other, amplification may occur. (For $d = 10^{28}$, the angular separation of the doublets is no greater than 0.2 second.) The amplification in this instance is (for $d \gg d_1$)

$$A = \sqrt{\frac{4\,GMd}{a^2c^2\,[1 + (d/d_1)]}} \cong \sqrt{\frac{4\,GMd_1}{a^2c^2}}$$

$$= 25 \text{ for } a = 10^{18},\ d_1 = 10^{22}$$

$$= 79 \text{ for } a = 10^{17},\ d_1 = 10^{21}$$

The probability of finding one component behind the other is $2\ (a^2/d_1^2) = 2 \times 10^{-8}$. Therefore, of 1.6×10^9 galaxies over the entire sky up to a distance of $Z = 2$ (for $q_o = -1$ or 1, 2×10^9 for $q_o = \frac{1}{2}$), 32 are aligned—a number that is comparable to number of quasars found (*10*). This model can explain the great luminosity emitted by quasars, and the variation recorded (if the relative velocity between the two components in 10^3 km/sec, variations having short periods can occur, as I have just explained). But it fails to explain other characteristics of quasars, such as the excess of short wavelengths (blue) in the visible spectrum of quasi-stellar sources, the two sets of red shifts found for some of them, or the greater flux of radio emission from quasi-stellar sources than from normal galaxies. In order to obtain a number comparable to the number of observed quasars, I was forced to make assumptions that are unsupported by observation.

Another interesting idea follows: Every two galaxies in the universe define a line; there are approximately $(10^9)^{10^9}$ such lines. The density of photons on each line is higher than outside the lines because of the gravitational-lens effect. We have just calculated that the probability of finding a third galaxy on this line is very small; but, if there exist in the universe thin clouds of highly ionized material happening to be on this line, these can behave like mirrors and reflect the light toward us. Thus a cloud that is undetected under normal conditions becomes visible and reflects the properties of the distant two galaxies (like the red shift and the fluctuations). Here again are assumptions that are unsupported by observations, because we must assume that these clouds are as large as galaxies and that their densities are much greater than those of galaxies. Thus we conclude that quasars are unlikely to be amplified normal galaxies; that instead they are real entities having large masses, small radii, and intrinsically high luminosities.

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10. This is the order of magnitude of quasars for which red shifts have been found. The absolute number of quasars, according to sample survey, is of the order of 10^4. I should emphasize that when one allows the distance between the two galaxies d_1 to be 10^{20}, the number of gravitational lenses increases to 3200.
11. Supported by NSF grant GP 6823. The author, now on leave from the University of California and the University of Tel-Aviv, thanks John Hayes of the Naval Research Laboratory, Washington, D.C., for discussion.

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Undersea Penetration by Ambient Light, and Visibility

Abstract. *Undersea observations from various submersibles reveal penetration by ambient light to depths as great as 700 meters. The range of horizontal viewing under ambient light in offshore tropic and subtropic areas varies from 5 to 6 meters (estimated) at 300-meter depth to more than 60 meters at 183-meter depth. Such observations indicate that ambient light may be usable for undersea tasks to greater depths than was anticipated.*

Before Beebe's dives by bathysphere in the 1930's (*1*) information was sparse concerning ranges of visibility at water depths much beyond 30 m. In Beebe's era this information was neither deemed necessary nor even so envisioned. Recent years, however, have witnessed a surge of interest in undersea operations, and concomitant growth of technology has made possible the employment of deep-diving manned submersibles.

Apart from Beebe's in situ observations, the major emphases in underwater illumination have been on measurements of the beam-attenuation coefficient (α) or the diffuse-attenuation coefficient (K). Empirical data on penetration by ambient light have come from use of the Secchi disc; sky reflection and complex refraction effects resulting from water waves, however, complicate interpretation of the results.

A major consideration in undersea surveys or research from submersibles is the observer's range of visibility, which depends on penetration by ambient light, intensity and configuration of artificial light sources, water clarity, "viewport" (window) characteristics, and, obviously, the observer's personal vision. In particular I shall now deal with the empirical data resulting from the above factors: How great is the observed penetration by ambient light? What is the range of visibility under ambient light? Although the α and K coefficients can and have been used to calculate the limiting range at which a swimmer (with face mask) can sight a specific underwater object (*2*), such calculation is uncommon and yields no appreciation of underwater range in visibility.

Since 1964 the U.S. Naval Oceanographic Office has conducted more than 60 dives with submersibles operating at depths from 30 to 1900 m. The observed penetration by ambient light has been totally unexpected.

At 305-m depth due east of Miami, Florida, the bottom could be viewed an estimated 5 to 6 m from *Aluminaut* under illumination resembling moonlight. Because of reduced scattering, the viewing range was greater from *Deepstar-4000* by use of ambient light instead of artificial light at a depth of 183 m, west of San Diego, California. Similarly, at a depth of 183 m in the Tongue of the Ocean, Bahamas, horizontal visibility ranged from 9 to 15 m (estimated) from within the Perry *Cubmarine.*

During recent operations with *Star III* off Key West, Florida, the greatest visibility ranges yet encountered were observed. Ascending from the bottom at 190 m, one could observe the bottom from an altitude of 55 m. One of the more surprising aspects of this operation was the difference between true and estimated ranges of near-bottom horizontal visibility. Before emplacement of a camera-target array, the pilot and I reconnoitered the bottom at 183-m depth and estimated the range of visibility at 15 to 18 m; after the emplacement, the scene was photographed (Fig. 1). The array consisted of a rack holding a 35-mm camera, a strobe light, and batteries; beyond were targets (4-liter Clorox bottles) spaced at 3-m intervals out to 30.5 m. Ten of the targets are visible in the photograph, the photographer being approximately 9 m from the rack. The resultant depth of field of this photograph, taken under ambient light (0.5-second exposure, 160-ASA Ektachrome, *f*/1.8), exceeds 30 m. By use of the targets as a basis for comparison, a range of visibility exceeding 60 m was estimated. This estimate, against a known and measured reference, contrasts significantly with the initial estimate of 15 to 18 m, without a reference base. This experience gives rise to speculation as to how many estimates of visual ranges have been in error during other operations in submersibles.

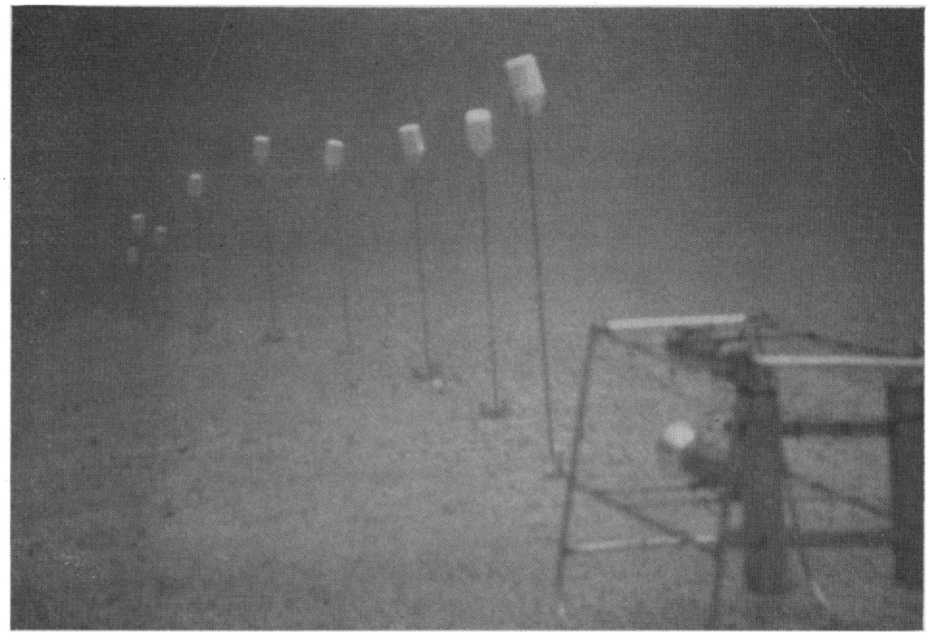

Fig. 1. A camera and a line of targets, 4-liter bottles spaced 3 m apart, photographed at a depth of 183 m under ambient light; the depth of field exceeds 30 m.

One known problem in estimation of ranges from a submersible is the magnification and distortion inherent in the design of viewports. For example, normal magnification by *Alvin*'s viewports is 4 : 3; beyond a solid viewing angle of 70 deg, both magnification and distortion increase quickly to almost unusable proportions (*3*). In the extreme, if a vertical wall is observed through a forward-looking viewport, it appears as an overhang because of window distortion. The result of these effects is difficult to evaluate, especially when estimation of range is of unknown accuracy under optimum conditions. On the basis of the meager data available, it appears that estimates of range from within the submersible are short by at least ⅓, and that the size of objects is overestimated by the same amount. Obviously a rapid and accurate method for determination of these parameters from a submersible is required; meanwhile such estimates of range and size must be taken at face value.

The vertical limits of penetration by visual ambient light were indicated during operations with D.S.R.V. *Alvin* in the Tongue of the Ocean. A small viewport located in *Alvin*'s hatch allows direct vertical observation; the hatch is surrounded by a sail (fairwater) that is open at the top and free-flooding, and the sail outline can be seen through this port as long as visible light prevails. At a depth between 640 and 700 m the sail outline finally disappears not uncommonly in tropic and subtropic waters, and *Alvin*'s pilots generally consider 700 m to be the limit of visible light.

These observed ranges of penetration by visible light are only indications of the transmissibility of ambient light in the open ocean; more extensive observations are required before generalizations can be made. Nevertheless, observations indicate that penetration by and intensity of visible light are really greater than earlier studies indicated. Usable ambient light may be available to submerged observers and ocean engineers at significant depths.

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21 August 1967

Deformation Lamellae Parallel to (10$\bar{1}$3) and (0001) in Quartz of the Coeur d'Alene District, Idaho

Abstract. *Deformation lamellae oriented parallel to the (10$\bar{1}$3) and (0001) crystallographic planes in quartz have been considered to be deformation structures unique to shock metamorphism induced by meteorite impact. Rocks of the Belt Supergroup of the Coeur d'Alene district, Idaho, contain quartz with deformation lamellae parallel to both (10$\bar{1}$3) and (0001). All available evidence indicates a geotectonic rather than an astrotectonic origin for the deformation lamellae of the district. Therefore, the uniqueness of these orientations to astrotectonic deformation is doubtful.*

Recently there has been considerable interest in establishing petrographic criteria for the recognition of structures formed by meteorite impact. Experimental deformation of rock specimens by hypervelocity shock waves has produced what are considered to be unique indicators of shock deformation (*1*). Among these unique indicators are multiple sets of planar lamellae in quartz, with preferred orientation parallel to (10$\bar{1}$3) and, less strongly, parallel to (0001) crystallographic planes. The uniqueness of these deformation structures is based largely on the failure to produce lamellae of these orientations in experimental deformation of quartz under low rates of strain and on the absence of reports of similar orientations from geotectonically deformed rocks (*2*).

Accepting the uniqueness of (0001) and (10$\bar{1}$3) lamellae, French (*1*) argues that their presence in quartz of the Onaping Formation at Sudbury, Ontario, is evidence that the Onaping was deposited immediately after a meteorite impact that formed the Sudbury basin.

I report here that orientation of deformation lamellae parallel to the (10$\bar{1}$3) and (0001) planes of quartz was found in rocks having no apparent meteorite impact history. Clearly, the scarcity of available reports on deformation lamellae makes arguments based on negative evidence rather tenuous. By this presentation I hope to encourage additional studies of geotectonic structures before the uniqueness of the criteria for recognition of astrotectonic structures is accepted.

The microfabric of the rocks of the Belt Supergroup in the Star Mine, Coeur d'Alene district, Idaho, was examined by me in 1964–65 to provide data for a study of deformation around mine openings (*3*). During the microfabric study, I became aware that, contrary to the report of Carter (*4*), deformation lamellae were occasionally oriented parallel to the basal plane (0001) of quartz. Deformation lamellae are predominantly parallel to (10$\bar{1}$3) of quartz in the samples from the Star Mine. At the time, the observation by itself did not appear to warrant reporting; but now the lack of available reports of such lamellae has led writers to conclude that these orientations are not to be found in geotectonically deformed rocks. The rocks of the Coeur d'Alene district have been complexly deformed and, despite the long history of mining in the area, no extensive microfabric-megafabric structural analyses have been made. However, in the available studies of the megastructure, the most recent of which is Hobbs *et al.* (*5*), no evidence is presented to suggest any extraterrestrial effect.

Samples from the Star Mine were collected from the walls of mine openings. Therefore, all samples had been affected by relatively low-velocity shock during blasting. Because of the limited nature of the study, the degree of deformation attributable to blasting was not determined directly. The statistical pattern of quartz lamellae paralleled the patterns of healed and unhealed microfractures in quartz and the major joint sets in the area. Therefore, it is thought probable that the lamellae are geotectonic rather than blasting features.

Of the samples examined, approximately 10 percent of the quartz grains studied contained deformation lamellae. Of 160 planes measured, five were parallel to (0001) and 48 were parallel to (10$\bar{1}$3). The accuracy of measurement is considered to have been $\pm$ 4°.

It is beyond the scope of this report to explain why basally oriented quartz lamellae are present in the rocks of the Coeur d'Alene district and apparently absent in other areas. One might observe that in sections containing basally oriented lamellae more orientation planes are represented, with a consequent reduction of the frequency of the (10$\bar{1}$3) plane. This suggests that under certain combinations of preferred quartz orientation and subsequently applied stress, easy directions and planes of translation in quartz are inopportunely oriented, and stress is accommodated on planes of greater resistance.

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Radiocarbon Content of Marine Shells from the Pacific Coasts of Central and South America

Abstract. *The radiocarbon content of contemporary pre-bomb marine shells from the region of upwelling of the Pacific coast of South America has been determined and found to be somewhat similar to the content of shells from the coast of California and the west coast of Mexico. Deviations of up to −8.5 percent with reference to the contemporary biospheric carbon-14 standard have been observed for the Peruvian coast. Values of from −0.35 to −4.04 percent have been obtained for marine shells from the Galápagos group. Problems associated with radiocarbon dates based on shells are discussed.*

In an earlier investigation the content of radiocarbon in contemporary pre-bomb marine shells from the region of upwelling of the California coast and the west coast of Mexico was determined in order to estimate the general magnitude of the upwelling effect as expressed by the apparent radiocarbon age (*1*). A knowledge of this fictitious age is also of considerable consequence in the application of radiocarbon dating to marine shells found in archeological sites, provided oceanic conditions since ancient times have not changed markedly.

This study has now been extended to the Pacific coasts of Central and