pected to be determined with high accuracy from the lunar laser retroreflector data [J. D. Mulholland and E. C. Silverberg, Moon , 155 (1972)].

- 11. The laser ranging experiment is expected to yield a significant improvement in the lunar ephemeris.
- 12. With this differential technique, relevant numerical data are displayed instantaneously and can be checked, for example, by means of a telephone conversation between the sta-tions; with conventional very-long-baseline interferometry no such information is avail-

Short-Range Order and Crystallinity?

The substance of the report of Konnert et al. (1) is stated in their conclusion that "the comparisons with the functions calculated from crystalline phases of nearly the same density as the glasses imply a great similarity between glasses and crystals on the atomic level." Essentially this same conclusion was reached by Zachariasen (2) 40 years ago and experimentally supported very shortly after. In his abstract of a 1933 paper Warren (3) stated: "On the random network hypothesis it is postulated that the atoms are bound together in the same way as in the crystalline forms of silica, but forming a continuous noncrystalline network.'

In the intervening years controversy has periodically raged, and silica glass has been called quartz-like, cristobalitelike, and now, by Konnert et al., tridymite-like. One wonders what agreement might be found between their data and broadened Bragg diffraction peaks of keatite, a silica polymorph of known structure (4) with a density between that of quartz and that of cristobalite and a thermal expansion coefficient more nearly like that of vitreous silica. We are disquieted by the fact that fitting the x-ray data according to the tridymite model required a mixture of 11-Å and 20-Å particle sizes of a crystal whose unit cell size is about $82 \times 10 \times 17$ Å. Even more disquieting is the fact that the cristobalite structure must be added since "details at large r [interatomic distance] suggest the possibility of a small amount of cristobalite-like ordering." Konnert et al. have therefore proposed a crystallite model of at least two different sizes for regions having at least two different kinds of crystallites. This model is less satisfying to us than a random network model in which the Si-O-Si angle is the only structural variable. Random network models have been built and reported upon (5). It is clear that they can be extended indefinitely and that they may have an average density of 2.2 g/cm³. It is also

able until after the tape recordings are brought to a common location and processed. 13. Provided by I. M. Salzberg, personal com-

munication. 14. Supported by contract NAS 5-11947 with the MASA Goddard Space Flight Center. We are indebted to J. Ryan, I. M. Salzberg, and W. Stonesifer of Goddard; J. McAllister of the Bendix Corporation; and personnel of the STDN for their essential contributions to these experiments.

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clear that peaks in the distances between Si-O, O-O, and Si-Si atoms taken in pairs in the largest of these models extend up to at least 12 Å (6). Mozzi and Warren (7) used a technique which eliminated the troublesome Compton scattering, thus allowing them to collect usable data over a larger range of data collection s than Konnert et al. They did not report structurally significant detail beyond 12 Å.

This lack of detail beyond 12 Å suggests that the extra detail comes from the data reduction procedures. Clearly then, either the procedures of Konnert et al. are a significant advance or the extra detail is spurious. It would therefore be of interest to know just how this detail changes with physically reasonable changes in the constraints imposed. In particular, will it change if the distance between near-neighbor Si pairs is allowed to vary as it does in the random network hypothesis? It is also of interest to inquire how the differences in fine detail, at all values of r, arise between the silica glass radial distribution function of Konnert et al. and that first published by Konnert and Karle (8).

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We find the comments of Evans et al. to be a serious misrepresentation of the existing literature. On the one hand, they question the validity of the analysis of our experimental results and, on the other hand, they improperly attribute a significant portion of our results [the details in the pair function or radial distribution function (RDF) between 7 and 12 Å] to other investigators. In addition, they incorrectly imply that early investigators were aware of our new experimental results and the resulting implications concerning glass structure. We shall demonstrate here that Evans et al. have both quoted the literature inaccurately and have neglected to fully quote from pertinent sections of the cited work.

In our report (1) we showed that with the use of careful data collection and data reduction procedures we have been able to detect significant details in the RDF's of silica and germania glasses at considerably larger interatomic distances (to at least 20 Å) than have been previously reported by other investigators. This new detail is not compatible with the current concept of a complete random network, which, according to (2), could probably not produce detail in the RDF beyond 7 Å. Our diffraction data, however, are compatible with a structure in which the atoms are ordered over distances up to about 20 Å in arrangements similar to those found in the crystalline polymorph tridymite. No new experimental or theoretical data are presented by Evans et al. for comparison with our results.

We now point out a misleading citation of the literature. Evans et al. state that the authors of (2) report no structurally significant detail beyond 12 Å. This, we believe, implies that these authors reported significant detail out to 12 Å. This they did not do. They state that ". . . the vitreous silica curve showed no detail beyond about r [interatomic distance] = 7 Å. . . ." They also state, "This seems to be the last peak [the peak at r = 6.4 Å in the RDF for their random network model] which could be produced in the random type of network which we have been considering, and in fact no further peaks are observed on the measured pair function distribution curve."

Another inaccurate citing of the literature is the reference of Evans et al. to the model random network constructed by Evans and King (3). Evans et al. cited this reference to indicate that this random network model, which is an aggregate of atoms with a total diameter of only about 18 Å, produced an RDF with significant detail out to 12 Å. Examination of this reference shows that no RDF is displayed and no mention is made of any distances beyond the first Si-Si distance $(\sim 3.1 \text{ Å})$. We are, however, familiar with an article by Evans and King (4)that is not mentioned in the technical comment by Evans et al. This work (4) does display the RDF calculated from their model. Evans and King state (4) that, for their model RDF, "significant information regarding coordination is being obtained from the geometrical centre of the model out to at least 9 Å and the model density is essentially continuous, with statistical fluctuations, between 12 and 18 Å." There is little similarity between this model and our experimental results beyond 7 Å. Evans and King (4) state that "we would be grateful for accurate experimental data that can be compared with computations made from the model coordinates."

In the first paragraph of their technical comment, Evans et al. have only partially quoted the pertinent concepts contained in the early research on the structure of glass, and the part that is omitted is quite significant to this discussion. They imply that early workers in the field were aware of experimental results such as ours and with resulting implications concerning glass structure. They quote from (5): "On the random network hypothesis it is postulated that the atoms are bound together in the same way as in the crystalline forms of silica, but forming a continuous noncrystalline network.' Let us continue this quote for three more sentences: "Each silicon is tetrahedrally surrounded by 4 oxygens, and each oxygen shared between two tetrahedral groups. Each tetrahedral group has 4 nearest neighbors at 3.1 Å, and 12 next nearest neighbors at 5.0 Å. Beyond this the distances are indefinite." It is evident that an RDF with detail out to 5 Å is quite different from one with ordering out to 20 Å (or even 12 Å). It should be further emphasized that the early investigators cited (5, 6) considered the similarity between crystals and glasses to be limited to the shortest interactions such as bonded distances and next nearest neighbors.

There is one further comment. Evans et al. introduce the term "crystallite"

in describing the ordered regions which are implied by our experimental results. We find the term crystallite to be unsuitable, since it implies that periodic ordering is to be expected which extends over at least several unit cells. The type of ordering that we have observed seldom, if ever, extends in any one region over the length of even a single unit cell of tridymite. It may be useful to consider the construction of a random network, not in the usual sense by beginning with the tetrahedron as the basic unit, but by starting with various groups of atoms up to 20 Å in dimension with the bonding topologies found in the tridymite structure. These larger groupings would then be attached to one another in an efficient, noncrystalline manner.

In response to the question raised by Evans *et al.* concerning keatite, we have considered the crystalline polymorph keatite and found its associated RDF incompatible with those of silica and germania glasses. Details concerning the reliability of our experimental results will be contained in a forthcoming article on the procedures of data reduction and error analysis (7). We urge the interested reader to consult the cited literature.

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Waste Paper Used for the Cleanup of Oil Spills

Oil may be removed from a body of water by dispersing over the oil layer fiberized paper falling within a specific fragment size range. The fiberized paper sorbs (1) or collects in excess of 27 times its weight in oil and is capable of holding the oil on the water surface as an oil-fibrous paper matrix or agglomerate for extensive periods so that it can be easily skimmed and recovered. Oil can be expressed from the oil-paper mass, and the paper mass can be refiberized and reused repeatedly to sorb or collect additional oil.

Paper materials which can be used include newspaper, cardboard, waterproof paper fiber containers, and wastepaper. The paper is fiberized, by means of a commercial type of hammer mill, to a size ranging from 0.01 to 0.1 mm in diameter and from 0.75 to 10.0 mm in length.

The most critical element of the process is fragment size and geometry. Laboratory experiments have been carried out with three separate samples of paper from the same source but of different fragment size. When shredded to approximately 1 mm in diameter and 8 to 23 cm in length, the paper collected twice its weight in oil; ball-milled paper having a maximum dimension of not more than 0.05 mm sorbed approximately its equivalent weight in oil; fiberized paper ranging from 0.01 to

0.05 mm in diameter and 0.75 to 2.0 mm in length sorbed approximately 28 times its weight in oil.

In the patent literature (2) are descriptions of a number of sorbent materials that have been used to sink oil or to immobilize it on the water surface. Straw, sawdust, and clay sorb only relatively small quantities of oil. Some of these materials will sorb water as or more readily than oil. Fiberized paper is much more oleophilic than hydrophilic. After the first use the expressed paper will be hydrophobic as well as oleophilic. At this point it could be refiberized and used for collecting oil that has washed up on the beaches or it could be spread on the beaches before the oil slick reached the shore. The oil-recovery system using fiberized paper has been tested in a small lagoon with a man-made oil spill and found successful. Larger scale tests are planned. J. FRED OESTERLING

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Notes

- 1. The expression "sorb" or "sorbent" is used to refer to the quality or property of taking up and holding a substance whether by adsorption, absorption, or physical entrapment in a fiber matrix.
- 2. U.S. Patent Nos. 3,681,237, 3,676,357, and 3,674,683.

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