nium from the magma could be demonstrated for hornfels inclusions derived from the Gunflint Iron-formation.

James and Jackson (*1*) described and figured hornfels textures of a number of lunar samples including sample 10017. Despite some basic differences that are not too difficult to accept, the lunar samples are not necessarily completely different from terrestrial rocks. Although the Duluth hornfels differs particularly in Fe_2O_3 and in relatively high percentages of Na_2O and P_2O_5, the composition is nevertheless similar in many respects to that of the lunar fines (sample 10084, Table 1). The lunar dust appears to be a rock mixture; hence some basaltic material of lower titanium content is indicated, and this is supported by preliminary chemical data for Apollo 12 samples (*13*).

Magmatic and metamorphic processes that are commonly elaborated to explain the variations within terrestrial rocks should serve equally well, with modifications, for those of the moon. At the same time earth-bound petrologists may profit by taking a closer look at terrestrial basaltic rocks.

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23 November 1970

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Polymer Whiskers Grown from Methyl 2-Cyanoacrylate Vapor

Abstract. *Filaments of methyl 2-cyanoacrylate polymer were developed from the vapors of the monomer. While growing, the fibers seem to be chemically more active at their ends than along their sides, with this chemical specificity leading to a linearly ordered polymer structure. The number and character of the fibers are a function of the surface from which the fibers emanate and of the concentration of the monomer.*

I observed whiskers of methyl 2-cyanoacrylate polymer while preparing replicas of ice crystals by means of the "resin vapor" replication technique (*1*). In this technique ice crystals collected on a cold glass slide are exposed to the vapors of the monomer which move down a temperature-concentration gradient sustained by another glass slide, originally at room temperature, coated with liquid monomer and spaced approximately 1 mm above the collector slide. Samples of profuse growths of polymer whiskers (Fig. 1) can be obtained simply by extending the exposure time from the 10 or 15 seconds desirable for ice crystal replication to 60 seconds or more, but without the presence of the ice particles.

The whiskers are often from 0.5 to 1 μm in diameter and from 50 to 500 μm in length. Their diameters have been observed to range from less than 0.1 μm to several micrometers. Whiskers have been seen to have lengths of up to several millimeters. They do not, in general, follow the vapor concentration gradient but appear to wind about in random patterns, sometimes finding their way back to the glass surface. It was observed that whiskers would occasionally associate with one another but never coalesce. In some samples bundles of up to five whiskers were seen, but in every case the fibers retained their individual identities.

Odencrantz *et al.* (*2*) have observed long straight whiskers associated with "resin vapor" replicas of ice particles. The relation, if any, between these and the present whiskers is uncertain.

The monomer polymerizes by a base-catalyzed ionic mechanism, and polymerization can be initiated at low temperatures by even such a weak base as water. Acidic substances, such as SO_2 or CO_2, exert an inhibitory effect on the polymerization (*3*).

The nucleation of the polymer whiskers is not fully understood. A necessary condition for nucleation is certainly initiation of the polymerization. It is possible, as in the case with a wet (water or ice) or polyethylenimine-treated (*4*) slide, for a surface to contain such a high density of initiator

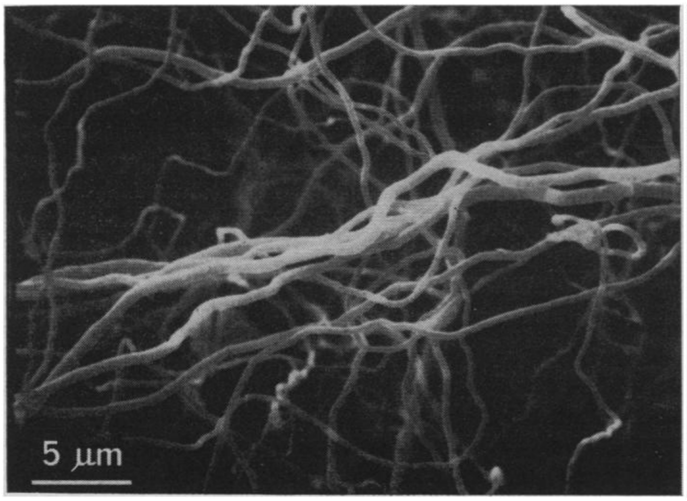

Fig. 1 (left). Fibers of methyl 2-cyanoacrylate polymer.

Fig. 2 (right). Fiber which developed a ball at its tip after divinyl sulfone vapor was added to the flow of methyl 2-cyanoacrylate vapor.

that a polymer film of uniform depth is developed rather than highly nonuniform deposits (that is, whiskers). A clean glass surface apparently contains about the right amount of initiator (in the form of surface water or basic elements of the glass itself, or both) to allow formation of whiskers. An experimental demonstration of the effect of initiator density can be easily accomplished by exposing to the monomer vapors a glass surface supporting a number of small ice crystals (20 to 30 μm in diameter). The ice crystals, being composed of pure initiator, develop a uniform coating of polymer (this fact, indeed, is what permits the successful replication of ice particles) while the glass surface, even in the immediate area of the ice, allows formation of the whiskers.

It is believed that the polymer grows in the form of filaments (once properly nucleated) because of a greater chemical specificity for the monomer at the ends of the whiskers than over the sides. If there were no differences in chemical specificity over the surfaces of the whisker, then, in order to explain its growth in that geometry, some physical transport mechanism would be necessary. One hypothesis might be that surface tension forces would tend to draw condensed liquid monomer on the fiber surfaces (which would have a certain lifetime before polymerizing) to a spherule at the end of the fiber, which would then generate further growth of the filament. In fact, spherules have been observed on several samples of whiskers. But in all cases, these spherules at the whisker tips were associated with inhibited, not enhanced, fiber growth. For instance, in experiments in which the monomer vapor gradient was increased sufficiently, spherules formed on the tips and the linear growth of the filaments stopped.

Thus it is suggested that the ends of the whiskers have a chemical specificity for the monomer. This specificity would entail a general alignment of the molecules along the growth direction of the whiskers, so that at the exposed ends the very basic unreacted carbanions would provide an attractive site for further polymerization.

Examination in a polarizing microscope revealed that the fibers were too small to give reliable birefringence results. However, the ice crystal replicas exhibited a clear birefringence, indicative of an ordering of the polymer molecules (*1*).

The growth of the cyanoacrylate whiskers is reminiscent of systems of "living polymers" (*5*) in which termination of the polymerization is avoided. These living polymers were developed from solution, whereas in the case reported here the polymer growth occurs by addition of monomeric units from the vapor. Moreover, termination is avoided only as long as the concentration of monomer vapor in the vicinity of the tip is relatively high, and during this time the filament is growing. When the monomer vapor density decreases sufficiently, termination sets in, possibly through capping by hydronium ions.

It is easily demonstrated that the activity of the ends has a finite lifetime after removal of the monomer source. If the flow of monomer vapor is interrupted for 10 seconds, the whiskers lose their ability to grow. Instead spherules form at the tips, as well as here and there along the length of the fiber. It is thought that, during the 10-second interval during which there is no flow of monomer vapor, the fiber ends terminate. Then when the flow of vapor resumes, the monomer condenses as a liquid, forming spherules as a result of surface tension, before polymerizing.

When the source of monomer is removed slowly, the diameter of the growing fiber, having been nearly constant up to that point, gradually diminishes to possibly 10 percent of its original value before terminating. If the monomer supply is removed quickly, the ends of the whiskers may develop a number (on the order of ten) of very small (about 0.1 μm in diameter) fibers. Apparently several areas on the tip remain active longer than others, giving rise to the subsidiary whiskers.

Certain monomers, such as divinyl sulfone, can profoundly alter the growth of the whiskers. In one experiment the vapor of divinyl sulfone was introduced after 10 seconds of whisker growth on a cold slide without removal of the monomer source. The resulting particles showed bulbous formations on top of short whisker stalks (Fig. 2). Since divinyl sulfone can readily copolymerize with the methyl 2-cyanoacrylate, it is believed that the three-dimensional bulbous structures resulted from a cross-linking between the polymers. This cross-linking would disrupt the ordered linear growth of the filaments.

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2 November 1970; revised 21 December 1970 ■

Disjunct Foliar Veins in Hawaiian Euphorbias

Abstract. *Isolated segments of veins occur in the leaf mesophyll of several Hawaiian species of* Euphorbia. *These anomalous structures appear to consist entirely of tracheids and are a normal feature of the anatomy of species native to mesic and wet areas, but not to xeric, dry habitats.*

The foliar venation of several endemic Hawaiian species of *Euphorbia* (subgenus *Chamaesyce*) is characterized by numerous isolated disjunct veins. This unusual feature has not been reported previously, although on occasion the sporadic occurrence of isolated veins has been reported for stems, leaves, flowers, and fruits of other plants. The two types previously reported in mature angiospermous leaves include: (i) an isolated vein ending associated with a continuous phloem strand (*1*), and (ii) a completely separated vein (*2, 3*).

Ontogenetic studies of the foliar vascular tissue of several families have shown an initial acropetal development of both xylem and phloem, followed by a subsequent basipetal wave of differentiation resulting in the formation of major lateral veins of the lamina. The minor veins develop last, completing the familiar reticulate pattern common to dicotyledonous leaves. Characteristically, the phloem differentiates sequentially, but the differentiation of the xylem frequently tends to be disjunct. Eventually a normal, complete reticulum results (*4*).

The differentiation of the minor veins of the Hawaiian euphorbias is erratic,