

All of the grains examined in the samples reported on in this paper appeared to have a uniform index.

### RESULTS

The results of our investigations are shown in Figure 1.

From this figure, it can be seen that the shape of the refractive index (Nd) versus water content curves for the experimentally hydrated samples depends on the temperature at which the samples were hydrated. The lower the hydration temperature (and pressure), the closer the curve to the Ross-Smith curve (Fig. 1).

This then might be taken as an indication that the naturally hydrated glasses investigated by Ross and Smith did hydrate at low temperatures, as originally suggested by them.

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### STRESS-CORROSION FAILURE AND THE HYDRATION OF GLASSY SILICIC ROCKS<sup>1</sup>

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The steps in the hydration of glassy silicic rocks can be reconstructed from petrographic and field relations. As seen in thin section, hydrated aphyric glassy rocks typically are traversed by an interlocking network of fractures that divide the rock into innumerable equant or, less commonly, pencil- or lath-shaped bodies. In many cases the glass immediately adjacent to these curvilinear primary fractures is stained by iron oxides, partially devitrified, argillized, etc., or rendering the fractures distinguishable on a nongeometric basis from later fractures.

The blocks of glass bounded by the primary fractures contain numerous concentric perlitic fractures. The outermost of the perlitic cracks parallel the margins of the isolated blocks whereas towards the centers the fractures approach a spherical configuration. The origin of perlitic fractures as a result of secondary hydration has been conclusively demonstrated by Ross and Smith (1955), Friedman and Smith (1958), and Friedman and others (1966). Perhaps the best evidence is provided by

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marekanite—partially hydrated glassy rock in which relict cores of nonhydrated glass are present at the centers of the blocks bounded by the primary fractures. Most nonhydrated glass of Tertiary age occurs associated in this manner with hydrated glass.

Primary fractures continue to form after the hydration of the isolated blocks has begun. Very commonly an originally coherent block of glass is subdivided by an approximately planar crack which intersects early formed perlitic fractures at a high angle. The two volumes of nonhydrated glass thus formed subsequently undergo hydration independently of one another. The resultant pattern is one of a single system of large concentric perlitic fractures which enclose two or more smaller systems of perlitic fractures, and which in turn may terminate and enclose several even smaller systems of concentric cracks.

The apparent absence of primary fractures in extremely young glassy rocks suggests that primary fractures form after the glass has completely cooled. Residual stresses present in the quickly cooled glass would appear to be the most likely cause. Glasses fail at much lower stresses when exposed to a water-containing atmosphere than when in a vacuum or an inert atmosphere (e.g. Charles, 1961; Hillig, 1962; Wiederhorn, 1967) and glasses are more reactive chemically when under tensional stress than when in an unstressed state (e.g. Rothermel, 1967, and references cited therein). These and other pertinent experimental observations appear to be best satisfied by the theory of Charles and Hillig (see Wiederhorn, 1967, for a recent discussion), in which crack propagation under relatively small stresses reflects accelerated corrosive attack of the glass at the tip of the fracture. It thus appears likely that the chemical action of adsorbed water will allow cracks in rhyolitic glass to propagate even though the stresses concentrated at the tips of the fractures are very small. Crack propagation by such a stress-corrosion mechanism, although probably extremely slow by non-geologic standards, necessarily is much faster than the rate of glass hydration at room temperatures (see Friedman and others (1966) for estimates of the rate of hydration). Since temperature after cooling will be relatively constant, the average rate of propagation should be mainly a function of the amount of residual stress within the glass. The density of the primary fracture system presumably reflects the scale of the nonuniformity of distribution of the residual stresses.

Phenocryst-bearing glassy silicic rocks hydrate much more rapidly than aphyric or phenocryst-poor glassy rocks. It is the writer's experience that vitrophyres containing nonhydrated glass are found only in rocks of late Quaternary age, whereas relicts of nonhydrated glass not uncommonly are present in dense, phenocryst-free, glassy rocks of Pliocene, Miocene, and even greater age.

The primary fracture system is much finer in hydrated vitrophyric rocks. The largest fragments of glass seldom have diameters greater than 2 to 3 mm., whereas in many aphyric glassy rocks blocks greater than an inch in average diameter are not uncommon. Almost all the fragments of glass outlined by the primary fractures contain no phenocrysts, the largest of the blocks, being surrounded on all sides by intratelluric crystals. These relations are readily apparent in thin section, and in some vitrophyres can be seen on broken surfaces, the typical onion-skin structure of the perlitic cracks within the larger fragments of glass being readily visible with a hand lens.

The much smaller scale of the primary fracture system in vitrophyres is the result of local stresses set up on cooling by differences in the coefficients of thermal expansion of the crystal and glass phases (*cf.* Edwards, 1951). The presence of such stress is directly demonstrable in completely nonhydrated glassy rocks which contain scattered phenocrysts, strain birefringence being readily discernible about feldspar phenocrysts in thin sections cut 3 to 10 times normal thickness. In all cases of such strain birefringence examined, the sense of optical anisotropy indicates that the glass is under tension parallel to the crystal-glass interface and thus that the phenocrysts are under compression.

The tensional stresses produced by the included phenocrysts thus appear to be the cause of the rapid hydration of vitrophyres. The very small blocks of glass formed in vitrophyres by the primary fractures obviously will hydrate completely in a much shorter period of time than will the much larger blocks in aphyric glassy rocks. Moreover, in vitrophyres the relatively large tensional stresses produced by the included phenocrysts should allow the primary fractures to develop more rapidly than they would if the phenocrysts were absent. Since the primary fractures provide the means of access for atmospheric and meteoric waters, the earlier the formation of the primary fracture system the earlier hydration of the rock mass will begin.

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BYTOWNITE FROM CAPE PARRY, EAST GREENLAND

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The phenocrysts described originate from a porphyritic plagioclase-basalt dike in the syenitic intrusion of Cape Parry on Traill Island in East Greenland (72°25' N, 22°05' W). The intrusive center has suffered strong hydrothermal alteration; many of the dikes, however, are very fresh. The rocks belong to a volcanic association, to the well-known Brito Arctic province, and are of post-Campanian age (Donovan, 1954). The phenocrysts, which are up to an inch in size, and the dike-rock were sampled in 1957 on a short reconnaissance trip to Cape Parry by one of the authors (E. W.), who was a member of the Danish East Greenland Expeditions directed by Dr. Lauge Koch.

Clear, often idiomorphic crystals of plagioclase occur in a fine-grained doleritic matrix, composed of plagioclase An 60-90, augite  $2V\gamma=52^\circ$ , pseudomorphs after olivine, and ore. The rock is easily decomposed by the arctic weather and loose phenocrysts are scattered along the dike. All the following results were obtained from such crystals. They are twinned mainly according to the albite law, with a stepped, or curved composition "plane." In only a few cases do they consist of a single twin-group; large crystals containing smaller rounded grains are often intergrown, they both show a similar orientation. Typical for these rocks are imperfect twins. The positions of the indicatrices seldom fulfill the conditions of symmetry between the two parts of the twin, in spite of the uniform composition of the crystals, which latter condition facilitates the exact determination of the optical orientation. A wide variation of the optical-structural angle-relationships was ascertained and appears to be typical for this occurrence.