TECHNICAL PAPERS

Structural Control in the Formation of Gneisses and Metamorphic Rocks[1]

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Field work in the Laramie Range, Wyoming, has led to the concept of migration of chemical elements along planar features such as layering, schistosity, and subparallel, closely spaced fractures in the host rock. Gneissic structure may develop along and parallel to these planar features. Plotting the poles of these planes (as shown by strike and dip) on Schmidt hemisphere projections and plotting the composition of the rocks which the poles represent make possible an exact comparison of lithologic composition and structural attitude. A large number of such projections have been made of Pre-Cambrian rocks in Wyoming and Colorado. The results indicate a surprisingly close control of composition of the ''guest'' by structure of the host. Stress with uniform orientation over regions of hundreds of square miles during each ''intrusive'' period acted to ''open'' a set or conjugate sets of planes in the host rock. These relict planes in the guest, when projected and contoured in the structural diagrams, give the center or centers of the most open planar features. The centers of the most open structures for each of the succession of intrusions progress linearly across the diagram, indicating progressive shifts in the orientation of regional stress between intrusive periods. The schist facies display similar variations, indicating a close relation between structural attitude and facies of guest. The most open centers (pole concentrations) for the several schist facies march across the diagram roughly parallel to the line followed by the centers of the time succession of intrusions.

Detailed quantitative work on three gneisses in Wyoming gives a striking mineral variation within each one related to an angular variaton of as little as 10° to 20°. The line from basic to more acidic gneiss within each rock unit is roughly parallel to the ''time'' line of intrusions and the facies line of the schists.

It is in accord with stress-strain theory to suppose that during each spasm of stress, planes of certain attitude would have least normal pressure and thus form ''openings,'' whereas others, differently oriented, would have most normal pressure and thus be the most ''closed'' planes of the region. The latter should include the host rocks that have suffered least migration of elements. This would be the ''closed chemical system'' portion of an area, in contrast to the ''open chemical system'' in the open structure. Data available are adequate for a partly quantitative comparison of structure and composition, but the method may be made completely quantitative.

The viewpoint and method should have wide application in either field or mineral studies of rock facies. In addition to the gneisses and schists that have been mentioned, amphibolites, dolomites, and iron-formation are examples of rocks of variable composition that might be profitably studied. Regional correlation of gneissic rocks is possible. The strain pattern of a region being ''intruded'' and metamorphosed can now be studied with fairly high precision.

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Rate of Nucleation of Solid Particles in a Subcooled Liquid

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There are many instances, particularly in the nucleation of solid particles from a subcooled liquid, in which transformation appears to take place only after a critical amount of supercooling. For example, in the formation of ice from a cloud of water drops, Cwilong (*1*) and Schaefer (*3*) observe snow to form at a critical temperature of about −38° C. Above this temperature, under most conditions, practically no ice is observed, although the cloud cannot be subcooled below this temperature without rapid transformation of the water to ice. It is the purpose of this paper to show that the existence of such a critical temperature is consistent with the theory of nucleation.

According to nucleation theory (*2, 4, 5*), the rate of nucleation of solid crystals in a mol of liquid is

$$\dot{n} = (NkT/h)\ \exp\ (-\Delta F^*/kT), \qquad (1)$$

where

$$\Delta F^* = (16\pi/3)\ \sigma^3/\Delta F_v^2 \qquad (2)$$

is the local free-energy change on forming a nucleus of critical size, σ is the solid-liquid interfacial tension, and ΔF_v is the free-energy change per unit volume associated with the transformation.

Approximating ΔF_v as

$$\Delta F_v \approx \Delta H_v\ (1 - T/T_0), \qquad (3)$$

where ΔH_v is the latent heat of fusion per unit volume and T_0 is the equilibrium temperature, the value of $\ln \dot{n}$ is

$$\ln \dot{n} = \ln\ (NkT/h) - 16\pi\,\sigma^3\ T_0^2/3kT\ \Delta H_v^2\ (T_0 - T)^2. \quad (4)$$

The lowest temperature, T_c, to which the liquid can be subcooled is evidently that for which $\ln \dot{n} \approx 0$, giving the relationship

$$\ln\ (NkT_c/h) = 16\pi\,\sigma^3\ T_0^2/3kT_c\ \Delta H_v^2\ (T_0 - T_c)^2. \quad (5)$$

When the interfacial tension, σ, is known, the above equation can be solved for T_c, the minimum temperature to