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

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

where

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

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

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

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 which the liquid can be subcooled. Alternatively, when the value of T_c is known, the equation can be solved for the interfacial tension, σ.

Consider, for example, the freezing of water, for which the value of T_c is known to be $T_c = -38°$ C. Taking $T_0 = 273°$ K, $T_c = 235°$ K, $\Delta H_v = 80$ cal/cc $= 3.34\ (10)^9$ ergs/cc, the value of the ice-water interfacial tension, σ, determined from equation (5) is

$$\sigma = 32.8 \text{ ergs/cm}^2. \quad (6)$$

By using this value of σ in equation (1), the rate of nucleation, $\dot{n}$, can be obtained as a function of T:

T° C	$\log_{10} \dot{n}$
0	$-\infty$
−33	−10.89
−34	− 8.33
−35	− 5.98
−36	− 3.82
−37	− 1.84
−38	0
−39	+ 1.70
−40	3.27
−41	4.74
−42	6.10
−43	7.37

It is of interest to note that the rate of nucleation changes by a factor exceeding 10^{18} in a 10° temperature range including T_c as midpoint. T_c, therefore, resembles a critical temperature, in that water cooled to a few degrees above T_c can persist as liquid for many years on account of the small rate of nucleation of ice. However, on lowering the temperature from a few degrees above T_c, the rate of nucleation increases so rapidly that subcooling below T_c is highly improbable.

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The Reduction of 2,3,5-Triphenyltetrazolium Chloride by *Penicillium chrysogenum*[1]

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The use of the tetrazolium salts, especially 2,3,5-triphenyltetrazolium chloride, to indicate cell viability is aparently well established. Triphenyltetrazolium chloride (TTC) has been used to indicate the germinability of seeds (*3*), and as a histological agent and a reagent in rapid penicillin assays with *Staphylococcus aureus* (*4*). Its use as a reagent in physiology depends upon the enzymic reduction of the soluble colorless triphenyltetrazolium salt to an insoluble carmine red formazan. At this laboratory TTC has been used in studies on the physiology of the penicillin-producing strains of *Penicillium chrysogenum.*

Penicillium chrysogenum Q176 was grown in shaken flasks of 2% corn steep solids–2% lactose medium after the manner described by Koffler, *et al.* (*2*). After harvesting, the pellets were washed free of pigments and nutrients, suspended in M/15 phosphate buffer, and torn apart by a 5-sec treatment in a Waring Blendor. After blending, a buffer solution of the dye was added to give a final concentration of 0.5% TTC. The buffer used throughout was at pH 7.2–7.4, because the reduction of the dye was retarded at a lower pH and was virtually stopped at pH 6.

Under these conditions the most active mold cells would reduce the dye to a deep red color in 20 min at 30° C. Table 1 shows the relative ability of *Penicillium chrysogenum* Q176 of different ages to reduce the dye to a colored formazan and gives the penicillin yields at the time of harvest.

TABLE 1

A Correlation Between the Rate of TTC Reduction and Penicillin Yields by Mycelium of *Penicillium chrysogenum* Q176 at Different Ages

Age of mycelium (Days)	Color	Penicillin yield (Oxford units/ml)
1	deep red	0
2	deep red	0
3	red	0
4	pink-red	0
5	pink-red	42
6	yellow-pink	294
7	yellow-pink	440
8	yellow (color of mycelium)	310

These experiments have been repeated on other penicillin-producing molds with the same results. Thus, if TTC reduction is an indicator of cell viability, it is evident that young nonpenicillin-producing cells (1–3 days old) are much more viable than the older penicillin-producing cells (5–7 days old). In other words, penicillin is formed by the mold when its metabolic state is considerably reduced. That penicillin is formed by the mold when its metabolic state is low or abnormal has been suggested (*1*). These findings with TTC have been checked with the vital stains Nile blue sulfate and neutral red. The cytoplasm of young cells that readily reduced TTC stained deeply and homogeneously, while cells 5 to 7 days old stained unevenly and showed the granules and vacuoles typical of aged cells.

TTC was reduced only inside the cells and the addition of glucose did not change the rate or site of reduction; apparently the endogenous activity of the mycelium was more than sufficient to reduce the dye. The inhibitor KCN inhibited reduction at M/100 final concentration

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