Notes

1 The word 'surface' might be rather ambiguous since nuclei are groups of particles of only few Å in size.

2 For a given mineral M at a given temperature T (16)

$$\bar{N} = dn/dT = K_M n_0 \exp(-K_M t)$$

where

K_M = a constant depending on the specific nature of M,

n_0 = number of preferential sites for M to nucleate,

t = time.

When the activation energy is very high, K_M is small and $\bar{N} \simeq K_M n_0$; the nucleation then displays a quasi-linear variation with time

3 Case of cold-worked metals.

4 This displacement (Fig. 1.6) is caused either by gliding and reorganization of the inter-atomic bonds, or by diffusion. In the latter case, the point defects play an important role, and even more when the energy level is high (increase in Brownian motion of the atoms when T is high). The migration of an edge dislocation can propagate by climbing over the extra atomic half planes of the lattice. This creep is made faster by the fact that site vacancies move towards the crystal's frontiers when T increases (Nabarro-Hering creep). In reality, the 'climbing' of dislocations is an extremely complex process since there exist an infinite number of interferences between the various dislocations. The dislocations often zig-zag through the lattice and can sometimes become fixed.

5 Gradients directed towards the interface would exist (and possibly oscillate) since atoms belonging to the neighbouring solution have been captured by the nucleus and/or native crystal. The region would thus alternatively appear over- and under-saturated.

6 α has been calculated for a few silicates such as quartz (cristobalite) (α = 0.5), albite (α = 2.9), anorthite (= 5.3), enstatite (α = 4.1) and fayalite (α = 7.5).

7 This is not referring to polycrystalline aggregates which result from the interpenetration of several sub-idiomorphic crystals: this phenomenon is known as synneusis (Figure 2-9).

8 This fluid or interfacial solution is assumed to be an individual phase in which atoms are not influenced by the atomic charges of adjacent crystals.

9 The pressure of the fluid phase can be less than, equal to, or greater than the average pressure. If $p_f > P_M$, microcracks generated by stress could appear.

10 Dense surfaces are surfaces parallel to groups of reticular planes with low hkl indices; i.e., in a same mineral species, {101} is more stable than {002}.

11 Modal composition = relative percentage of a phase in a mineralogical association.

12 This type of microtextures is more rarely found in igneous rocks where it can represent a solid/liquid or solid/fluid late magmatic reaction.

13 The high solubility of quartz or amorphic silica in water at T > 200 °C and low pressures (3) is an extremely important process which explains many petrogenetic mechanisms.

14 Graphite can also reduce $\bar{C}$ considerably since this mineral, due to both its form and its high surface energies, will be adsorbed strongly on the surfaces of native crystals and thus reduce their growth. Graphite, considered as an impurity in metamorphic rocks, thus clearly plays an obstructive role.

15 This phenomenon, often called 'alteration', is a reaction process corresponding to a mineralogical readjustment at T, P, μH_2O conditions very different from those which lead to the formation of the unstable phase.

16 A 'hypereutectic' composition would be located to the left of E.

17 In fact the mechanism of appearance of A is not so simple or so spontaneous. Experiments in metallurgy (5) have shown that crystals A often appeared at temperatures much lower than t_1. This is due to the fact that the homogeneous nucleation of a solid phase within a liquid is quite difficult where the phases are structurally quite similar. Since the volume free-energy of a nucleus increases more rapidly than its surface free-energy, its critical radius r_c will be smaller when

the supercooling of the liquid is higher (the Brownian motion of nuclei and particles is smaller and the probability of forming stable nuclei increases). The supercooling is balanced by a spontaneous increase in temperature due to the freeing of heat at the liquid-native crystal interface (latent heat of fusion ≠ 'surfusion' heat). However, since nucleation processes in silicate melts are probably more heterogeneous than homogeneous and thus earlier, the crystallization temperature ends up being quite close to t_1.

18 The principal silicates of metamorphic and igneous rocks often are bound solid solutions, they are very seldom continuous.

19 As was explained on p. 45 the vapour phase is a fluid essentially made of water or of water + CO_2 (with occasionally some HCl, O_2 etc.). Because of the high solubility of Si^{4+}, the feldspars and ferromagnesian minerals which precipitated at high temperatures will alter and thus allow the growth of late-magmatic 'deuteric' phases or of minerals of metasomatic origin crystallizing in late-magmatic dikes.

20 From an Australian grass with thorns (Troda spinifex)

21 Geochemical data show that reactions in solids often occur by mass transfer (ionic solutions (48) (49)), over distances ranging from several mm to several cm; reacting minerals and products are very seldom found at a same point in the rock.

22 Bivariate equilibrium: the equilibrium (I, J)M = (I, J)N can only be defined if two of the three variables (T, P, X) of the metamorphic system are fixed, e.g. at T = const, $X^A_{(I,\ J)}$ and $X^B_{(I,\ J)}$ vary with T, i.e. T will only be known if P and one of the ratios $X^A_{(I,\ J)}$ or $X^B_{(I,\ J)}$ are given.

23 This is not an absolute rule, especially in low grade metamorphic rocks, since many examples of primary crenulation, either simple or conjugated, are known (4) (52) to limit microlithons which include orientated minerals of clastic origin such as floating phyllosilicates which represent pre-existing surfaces of sedimentary (S_0) rather than tectono-metamorphic origin or eventually can be diagenetic.

24 This word does not imply that the inclusions define a spiral-like microstructure.

25 One can assume that S_i corresponds to an early stage of the progressive formation of S_e (= S_{n+1}); in that case, the blasts are 'eokinematic' and their helicitic inclusions are either sigmoidal, in the same direction in the internal or external part of the fold, microfolded or in spiral.

26 S_1 may be perpendicular to σ_1 at the beginning of the deformation and could tend to form angles of 135° (45°) with the direction of the principal strain axis if it remains fixed during the deformation (Fig. 5.14).

27 In this model, it can be assumed that σ_1 was almost perpendicular to S_1 at the beginning of the deformation and that the limiting angle of $S_{1_{final}}$ intersects σ_1 at roughly 135°; S_1 then becomes an infinite shear surface (left inclosure in Figure 5.14).

28 If a sphere rotates within a homogeneous medium, there is a relationship between the shear angle λ and the rotation angle Ω of the sphere; If Ω is measured in radians, $\Omega = -1/2\lambda$ (Rosenfeld (63) - Fig. 5.14A) or $tg\Omega = -1/2\lambda$. In Fig. 5.14A, λ = 180°, so Ω = 143° (63). The rotational flattening (Fig. 5.14C) is 45°.

29 The microslots would have been induced by a fracture mechanism related to local fluid suppressions (in particular H_2O); they would be hydraulic extension slots due to compressive stress (68).

30 The synkinematic character of these minerals is supported by the existence of 'windmill' crystallization fringes formed by rotation of the blast during its late stages of growth, or to a late-kinematic rotation of the matrix (70).

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