ASPECTS OF CONTACT METAMORPHISM PRODUCED BY THE NEW ENGLAND BATHOLITH, NEW SOUTH WALES

by

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ABSTRACT

Forcefully emplaced plutons in the southern part of the New England Batholith, northern New South Wales, have produced extensive contact aureoles in Palaeozoic sediments and volcanics. This thesis describes the contact effects observed in pelitic, psammitic and impure calcareous sediments.

Four metamorphic zones are recognised within pelitic sediments around the Walcha Road Adamellite (with distances from the contact in brackets):

I) biotite zone (4 km - 1500 m);
II) cordierite zone (1500 m - 500 m);
III) cordierite + K-feldspar zone (500 m - 100 m);
IV) cordierite + K-feldspar ± garnet zone (100 m - contact).

The two outer zone boundaries are defined by discontinuous reactions, the biotite isograd being represented by the general reaction

chlorite + K-feldspar + Fe-oxides → biotite + quartz + H_2O,

and the cordierite isograd by

chlorite + muscovite + quartz → cordierite + biotite + H_2O.

Petrography and phase relations (probe data) demonstrate that, for any particular host-rock chemistry (specifically Mg/Mg+Fe ratio), these reactions can be represented as isothermal sections on divariant T-X(Fe-Mg) loops. The cordierite + K-feldspar isograd is defined by the continuous reaction

biotite + muscovite + quartz → cordierite + K-feldspar + H_2O,

which shifts both biotite and cordierite Mg/Mg+Fe ratios toward more Fe-rich values along the divariant T-X(Fe-Mg) loop. The Mg/Mg+Fe ratios of phases participating in this reaction are fixed at the temperature at which muscovite is exhausted. They remain fixed unless a further temperature increase results in intersection of the divariant T-X(Fe-Mg) loop for the continuous reaction

$$\text{biotite} + \text{cordierite} + \text{quartz} \rightarrow \text{garnet} + \text{K-feldspar} + H_2O.$$

If intersected, this reaction causes a reversal in the Mg/Mg+Fe ratios of the ferromagnesian phases, shifting them to more Mg-rich values as temperature increases. All reactions in the pelites appear to take place on divariant reaction loops, and univariant reactions defined by the intersection of two or more divariant loops are not in evidence, apparently because reactants are consumed on the divariant curves before such intersections are achieved. At estimated pressures of 1-1½ kb, temperatures across the aureole are believed to range from 350-400°C at the outer limit to 720-745°C near the contact. Such contact temperatures are consistent with the observed presence at the contact of the Walcha Road Adamellite of migmatites believed to have formed by *in situ* partial melting of the pelites.

Mineralogical and textural changes define three metamorphic zones in greywackes around the Mt Duval Adamellite:

I) blastopsammitic biotite zone (2½ km - 500 m);
II) transitional biotite zone (500 m - 150 m);
III) biotite + orthopyroxene zone (150 m - contact).

The biotite isograd is denoted by the discontinuous reaction

$$\text{chlorite} + \text{K-feldspar} + \text{sphene} + \text{Fe oxide} \rightarrow \text{biotite} + \text{quartz} + H_2O,$$

resulting in the loss of chlorite. The outer zone shows very little textural adjustment of the original sediment, and the onset of obvious textural modification defines the beginning of the transitional biotite zone. The orthopyroxene isograd is marked by the continuous reaction

$$\text{biotite} + \text{quartz} \rightarrow \text{orthopyroxene} + \text{K-feldspar} + H_2O,$$

which proceeds with an increase in the Mg/Mg+Fe ratio of both biotite and orthopyroxene. The high-grade zone is totally reconstituted, leaving little trace of original textures. Biotite compositions in the greywacke reflect the interrelated effects of paragenesis, host-composition, and structural and charge balance requirements, yielding a general decrease in Al, and increases in Ti and Mg with increasing grade. P-T conditions are not well delineated within the greywackes around the Mt Duval Adamellite. However, pressures of approximately 1 kb are suggested, and

temperatures appear to vary from 350°-400°C at the outer limit of the aureole to around 650°C at the contact.

The impure calcareous rocks comprise calcareous litharenites, impure calcirudites, impure biomicrites and stylolitic limestones with bulk rock compositions approximated by the K_2O-CaO-MgO-Al_2O_3-SiO_2-CO_2-H_2O system. Five metamorphic zones are delineated within these rocks around the Inlet Monzonite and Moonbi Adamellite:

I) biotite zone (2 km - 1100 m);
II) clinopyroxene zone (1100 m - 950 m);
III) garnet zone (950 m - 650 m);
IV) wollastonite zone (650 m - 350 m);
V) wollastonite + plagioclase zone (350 m - contact).

These zones are based on mineralogical changes in the calcareous litharenites from the northern contact of the Inlet Monzonite (distances shown in brackets are for this aureole). They are also applicable to the impure calcirudites and biomicrites, except that no garnet zone occurs in the latter. The stylolitic limestones have a distinctive mineralogy (e.g. forsterite marble near the contact) that reflects a bulk-rock composition lower in SiO_2, Al_2O_3 and K_2O than that of the other calcareous rock types studied. Petrography and probe data reveal a prograde sequence of metamorphic reactions in the calcareous litharenites, which can be represented by a series of experimentally determined univariant curves on isobaric T-X_{CO_2} diagrams for 1 and 2 kb corrected to allow for solid solution within the phases. Reactants and products of these reactions do not appear to coexist over significant temperature intervals, implying firstly that the reactions are discontinuous and secondly, that they do not buffer the pore-fluid composition. Contact metamorphic conditions in the calcareous litharenites of the northern aureole of the Inlet Monzonite are believed to have been approximately: pressure below 2 kb, X_{CO_2} in the fluid phase between 0.06 and 0.22, and temperatures ranging from around 350°C at the outer edge of the aureole (≃ 2 km from the contact) up to 700-750°C at the contact.

Three types of small-scale reaction band are developed in calcirudites located 350m from the northern contact of the Inlet Monzonite; namely between (1) marble and pelite blocks, (2) garnet-rich matrix and

pelite blocks, and (3) garnet-rich matrix and marble blocks. They are believed to have formed during contact metamorphism at temperatures between 610 and 650°C and pressures below 2 kb. The characteristic sequence of layers developed between marble and pelite blocks is

marble
garnet
garnet + clinopyroxene
felsic (K-feldspar + sphene ± clinopyroxene ± plagioclase)
clinopyroxene + feldspar + sphene
biotite + feldspar + sphene
biotite + feldspar unit
pelite (unmodified material not found)

The original contact between marble and pelite is represented by the boundary between the garnet + clinopyroxene and felsic layers. This boundary is characterised texturally by a sharp change in grainsize, and mineralogically by the lack of K_2O- and TiO_2-bearing phases on the marble side. The layer sequence developed between the garnet-rich matrix and pelite blocks is similar to that in the marble → pelite reaction bands. At contacts between matrix and marble blocks, either a monominerallic wollastonite layer, or a wollastonite + garnet + clinopyroxene layer is developed within the original marble. Chemical variations across the reaction bands, calculated from modal data and microprobe analyses, show sharp changes in composition at layer boundaries. Notably, CaO shows a stepwise decrease across the reaction band away from the marble, whereas Al_2O_3 and MgO (+FeO) decrease away from the pelite, but increase in the garnet and garnet + clinopyroxene layers respectively.

The reaction bands are believed to have developed by mass transfer of components between chemically incompatible adjacent rock types. A model is suggested whereby the components diffuse through a pore solution in response to chemical potential gradients in the solution (concentration gradients). These gradients are maintained by removal of material from solution, as solid phases in equilibrium with the fluid are formed in the reaction bands. Diffusion proceeds so as to reduce these gradients and, with time, discontinuities are eliminated and the chemical potentials of the diffusing components will vary monotonically and continuously across the reaction band. Local equilibrium is considered to be achieved at each point across the reaction band. The solid phases in local equilibrium with the diffusing components of the pore fluid can be expressed on chemical

potential diagrams. The layers develop across the reaction band as new phases become stable in response to the continuously changing chemical potentials of the diffusing components and the presence or absence of non-diffusing components. The layers represent distinct changes in mineral assemblage, and the layer boundaries mark sharp discontinuities in bulk-rock composition. The number of phases in each layer is typically less than the number of components. The relationship between the number of phases and components can be expressed by the phase rule in terms of J- and K- components (Thompson, 1970). Flux (amount of material moved) appears to be directly related to differences in the concentrations of components between the two initially chemically incompatible rock types. The relative distances to which the components have diffused across the original boundary appear to depend simply on the flux of each component and the rate at which it is used by the solid phases forming in equilibrium with the pore fluid.

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