METAMORPHISM, FOLDING AND PLUTONISM IN THE WAGGA METAMORPHIC BELT OF N.E. VICTORIA

R.J. Rogerson

Department of Geology and Geophysics,
University of Sydney, NSW 2006

Structural and metamorphic studies carried out in N.E. Victoria show that the classic low-pressure metamorphism described previously by Vallance (1953, 1967), Joplin (1942, 1944, 1947) and Guy (1968) consisted of a complex interaction of metamorphic events, compressional periods and granite intrusion. Large gaps exist on maps showing the geographical distribution of zonal index minerals due to burial by younger rocks and lack of study (Fig. 1).

At least three regional metamorphic events and five periods of deformation affected N.E. Victoria and S.E. New South Wales during the Benambran Orogeny (Fig. 2). Deformation

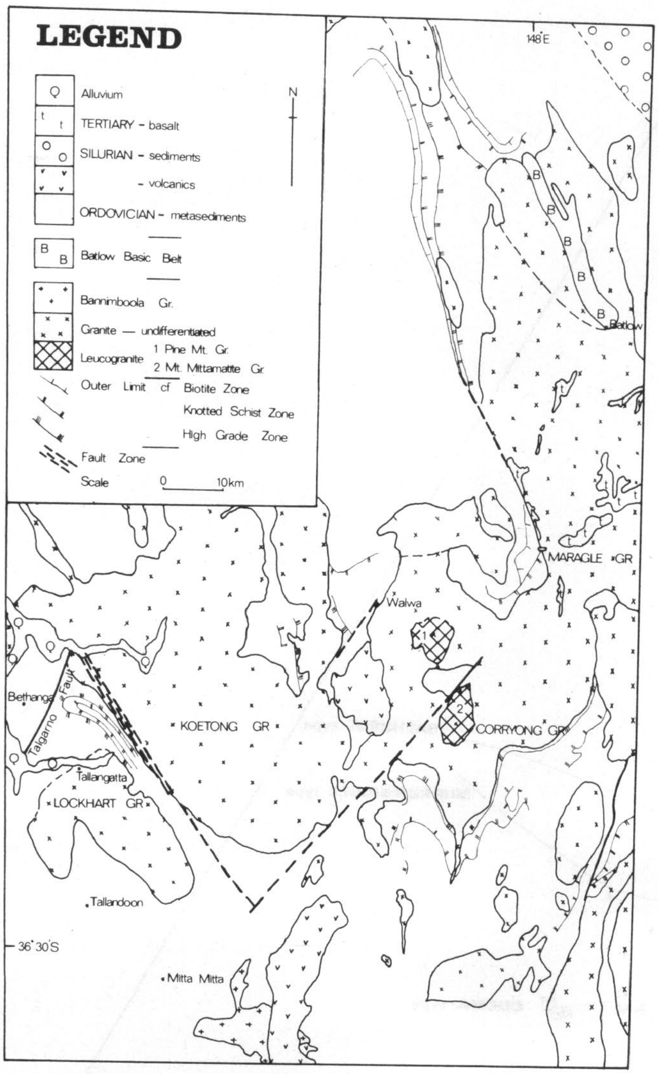

FIGURE 1
A map showing the areal distribution of granitic rocks, metasediments and M_1 metamorphic zones in the Wagga Metamorphic Belt in S.E. New South Wales and N.E. Victoria using the nomenclature of Vallance (1967). The Koetong, Corryong and Maragle Granites are local names for a continuous granite mass.

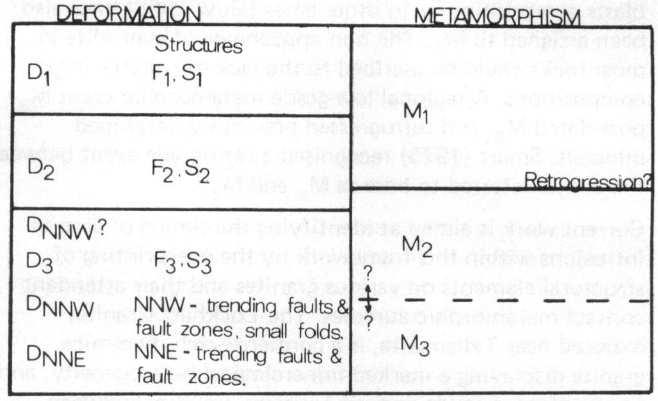

FIGURE 2
Relative timing of deformation periods and metamorphic events. The boundary between M_2 and M_3 is undefined in relation to D_3.

D_1 produced tight to isoclinal 080°-trending F_1 folds which were overprinted by 150°-trending F_2 folds referable to the second deformation D_2. F_2 folds are marked by a strong axial-plane crenulation cleavage S_2, and an isoclinal style. The F_2 trend is dominant in the Ordovician rocks of the Wagga Metamorphic Belt, but F_1 trends are preserved in a number of localities, including Albury (Hellman, 1973), and in the Tallandoon area of N.E. Victoria. D_3 produced microcrenulations and kinks with axes trending roughly east-west. Deformation D_{NNW}, consisting of faults trending NNW, overprinted S_2 and affected the Corryong, Koetong and Lockhart Granites. D_{NNE} produced faults trending to the NNE, which in places separate rocks of markedly different metamorphic grade. The Talgarno Fault has this trend and affects Upper Devonian rocks. The three compressive deformations D_1, D_2 and D_3 are recognized by overprinting criteria exhibited regionally in N.E. Victoria, but it is not known whether D_1 occurred contemporaneously throughout the whole region. Furthermore, although D_{NNW} overprints structures referable to D_2, the relationships between D_{NNW} and D_3, and between D_{NNW} and D_{NNE} are incompletely known at present.

Textural relationships observed in thin-section indicate that two prograde events, and at least one retrograde metamorphic event, affected N.E. Victoria. M_1, the principal metamorphic pulse, produced andalusite and cordierite at medium grades, and at several localities, *viz.* east of Bethanga (Williams, 1969; Rogerson, 1974), Batlow (Bradley, 1968) and Tallandoon (Rossiter, 1973), staurolite has been described from iron-rich schists. The Bethanga schists exhibit staurolite porphyroblasts with a syntectonic F_2 spiral form and pressure shadows which frequently contain pinitised cordierite porphyroblasts, while the other cordierite porphyroblasts in the same thin-section clearly overprint S_2. The poikiloblastic nature of the cordierite grains in the pressure shadows suggests they nucleated late in the development of the pressure shadows, or afterwards. Both these occurrences of cordierite are assigned to a second metamorphic period M_2, which may have been of lower pressure than the first if staurolite became unstable in post-D_2 times. Some marginal breakdown of staurolite to muscovite has occurred, and, in addition, it is probable that mineralogical adjustments to the matrix occurred also to facilitate the nucleation of M_2 products. Andalusite, cordierite, biotite and chlorite porphyroblasts overprinting S_2 in other areas (Guy, 1968) have also been assigned to M_2. The non-appearance of staurolite in most rocks could be ascribed to the lack of suitable initial compositions. A regional low-grade metamorphic event M_3 post-dated M_2, and retrogressed previously developed minerals. Smart (1975) recognised a retrograde event between the events referred to here as M_1 and M_2.

Current work is aimed at identifying the timing of granite intrusions within this framework by the overprinting of structural elements on various granites and their attendant contact metamorphic aureoles. The Lockhart Granite, exposed near Tallangatta, is a cordierite-rich, two-mica granite displaying a marked mineralogical heterogeneity, and, in one place, a crude gneissic foliation trending between 060° and 100°. Cataclastic effects attributable to D_{NNW} occur along part of its eastern margin, but most of the mass away from this area is dominated by a flow foliation trending 150°. This granite has the chemical features of the *Cooma-type* granites of Vallance (1969). Six kilometers east of the Lockhart Granite is the areally large and massive Koetong Granite, which is continuous (Guy, 1969) with the Corryong-Maragle Granites, forming a single granite mass some 100 kilometers in length. The Koetong Granite is overprinted by a D_{NNW} fault in the Walwa area, and in places possesses a weak flow foliation trending 150°. Chemical data show that these latter granites are different chemically from the Lockhart, Albury, Cooma and Omeo Granites (Fig. 3), but as yet no data relating the relative intrusion times of these two granite types have been uncovered. White *et al.* (1974) contended that the whole of the Koetong-Corryong-Maragle mass is a *contact aureole* granite. The apparent change in grade from biotite zone to sillimanite zone rocks in less than 1.5 kilometers in schists bordering the Koetong Granite suggests a geothermal gradient far steeper than that implied by the metamorphic zonation at Cooma, Albury or the Kiewa Valley area. Arndt (1969), Singer (1974) and Smart (1975) demonstrated that contact metamorphism is quite widespread around parts of the Koetong-Corryong Batholith.

Several leucogranites, including the Pine Mountain Granite

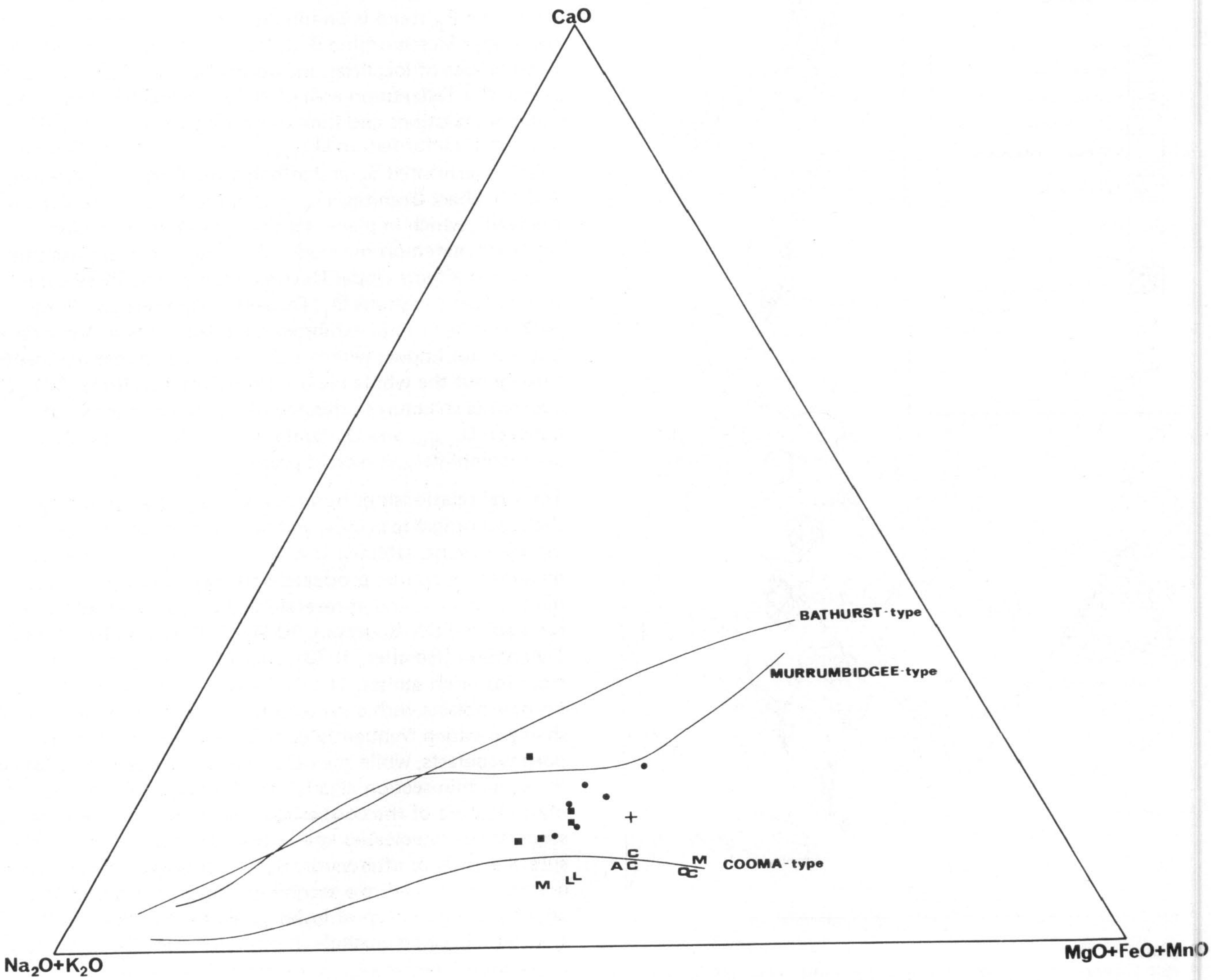

FIGURE 3
Chemical variation diagram (after Vallance, 1967) showing the separation of analyses of the Koetong ▪, Corryong •, and Maragle + Granites from analyses of the Omeo M, Lockhart L, Albury A and Cooma C Granites.

and the Mount Mittamatite Granite, intrude the Koetong-Corryong Batholith. Brooks and Leggo (1972) and Kolbe and Taylor (1966) summarised the essential features of these granites which are similar to leucogranites that are part of the Murrumbidgee Batholith (Snelling, 1960; Joyce, 1973). Small contact aureoles are present around the former bodies. East of Mitta Mitta, a hornblende-bearing granodiorite, the Bannimboola Granodiorite, crops out on the western flank of Mount Benambra. In road cuttings in this area, the granodiorite boundary is seen to be dipping shallowly outwards from the centre of the mass, and a contact aureole having an outcrop width of six kilometers is developed in low-grade regional metasediments to the west and south of the granodiorite. This granodiorite has most of the features of the *Bathurst-type* granites of Vallance (1969).

MINERALIZATION OF THE LUCKY HIT COPPER MINE, MERRILLA MINE AND GURRUNDA BARITE DEPOSIT, NEW SOUTH WALES

F.I. Roberts

Geology Department,
University of Wollongong,
PO Box 1144, Wollongong, NSW 2500

B. Mutton

Mt Isa Mines Ltd.
Mount Isa, Qld. 4825

See Programme and Abstract Volume of Conference.

ANTIMONY MINERALIZATION IN VICTORIA — A CASE FOR REGIONAL ZONING?

M. Hill

Geological Survey of Victoria,
107 Russell Street, Melbourne, Vic. 3000

See Programme and Abstract Volume of Conference.

6. SPECIALIST STUDIES

$^{34}S/^{32}S$ RATIOS IN SOME SULPHIDES OF THE LACHLAN FOLD BELT

M.S. Burns and J.W. Smith

CSIRO Division of Mineralogy,
PO Box 136, North Ryde, NSW 2113

Over geological time a distinct pattern in the distribution of the isotopes of sulphur has resulted from the combined effects of a variety of natural processes. The processes which lead to this isotopic fractionation are becoming increasingly understood and accordingly offer wider opportunities for the application of isotopic measurement to geological problems.

Sulphides from a number of localities in the Lachlan Fold Belt are being investigated as part of a wider study. The expectations are that these measurements might eventually reveal mineralization patterns, sources of sulphur, centres of volcanic activity and directions of flow of mineralizing solutions. It is yet too early to attempt the interpretation of the very limited data in all these directions, but the preliminary isotopic data for sulphides from the Lachlan Fold Belt, selected where possible from main ore bearing horizons (Fig.1), reveal a considerable range of $\delta^{34}S$ values.

Although the genesis of ores of the Kuroko type sulphide deposits is still subject to some doubt, it is generally agreed that seawater sulphate, either coeval or fossil, is the principal sulphur source in a submarine, hydrothermal process operating at a temperature of 250-300°C. Typical metal sulphide and sulphur isotope distribution patterns have been described with ^{34}S contents decreasing from +10°/oo and +8°/oo in underlying pyritic veins through values of +6°/oo to +3°/oo in the ore zone. In the uppermost layers where contact with Miocene ocean water occurred, barites with $\delta^{34}S$ values of +22°/oo to +23°/oo are found.

Sulphides from deposits at Woodlawn and Colo Creek have distributions and isotopic compositions which generally correspond closely with the Kuroko values and which also suggest equilibration temperatures approaching 300°C. Only in respect of the ^{34}S contents of the barites is there a significant difference. Those from the Lachlan Fold Belt appear to be more enriched in the heavier isotope, a difference in composition which correlates well with the increased ^{34}S content of the ocean sulphate during the Silurian.

A similar isotopic relationship, indicating the same equilibration temperature (250-300°C), also exists between the sulphides from Mount Bulga and Currawang, although all samples are depleted in the heavier sulphur isotope. Similarly depleted are the three remaining sulphide deposits of similar age, that is those at Copper Hill, Lime Kilns and Basin Creek, but, since only chalcopyrite and pyrite were examined or were present in these, comparisons with other sulphides become less meaningful.

Thus, whilst isotopic fractionations between sulphides from the same deposit all seem to be in general accord, quite marked differences in the ^{34}S contents of sulphides from different deposits are seen. Two alternative explanations for this latter effect are either that varying ^{34}S contents reflect the relative contribution of sulphur from volcanic and ocean water sources, or that the sulphur source and reservoir remain unchanged and decreasing ^{34}S values in the sulphides reflect increases in pH or oxygen fugacity.

Interest in the Devonian samples from E. Gippsland centres largely on the associated barite. The isotopic composition of this as given in Fig. 1 is in accord with the values generally accepted for Devonian ocean sulphate.