CHAPTER 1

INTRODUCTION

The composite, dominantly N-S trending New England Batholith represents a prominent manifestation of Permo-Carboniferous intrusive activity in eastern Australia. Composed of at least 140 distinct, mappable units* the dimensions of this batholith, including subsurface intersections in southern Queensland, exceed 500 km in length and 200 km in width. It therefore constitutes one of the largest batholiths in the eastern Australian portion of the circum-Pacific zone of magmatism. Such extensive upwellings of granitoids and associated mafic intrusives are unlikely to represent a single consanguineous series; hence it is not surprising that at least six distinct intrusive associations may be recognised in the New England Batholith. These include the New England, Bundarra and Hillgrove (Plutonic) Suites, a suite of large, more-or-less circular, felsic plutons which essentially postdate the major intrusive activity and the associated orogenesis of the New England region, a suite of low-K granitoids which are spatially associated with the Peel Thrust, and a small but significant number of mafic tholeiitic and calc-alkaline intrusives which crop out discontinuously in a restricted linear belt along the eastern margin of the batholith.

Although fundamental mesoscopic differences between some of the granitoids from the New England Batholith have been known for some time (e.g. Andrews, 1905, 1908; Browne, 1929) mineralogical distinctions between specific granitoids were not proposed until Binns *et al.* (1967) outlined some of the more outstanding mineralogical aspects for the New England and Hillgrove Suites. Binns *et al.* showed that the voluminous plutons belonging to the New England Suite were predominantly massive, possessed sharp contacts and generally well developed thermal aureoles, usually displayed only minor or no cataclastic deformation and varied widely in composition and mineralogy. In contrast, the relatively small, often elongate plutons which comprise the Hillgrove Suite frequently conform

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* This does not include individual intrusive phases within the numerous mafic/intermediate complexes that are closely associated with the batholith, especially the Hillgrove Suite.

to the structural trend of the country rocks, display a well developed tectonite fabric, are restricted in composition to granodiorite and adamellite, and possess a mineralogy which reflects the probable sedimentary nature of the parent rock.

However, these distinctions are by no means always clear-cut because individual intrusions from both suites may show mineralogical and chemical features characteristic of either suite, i.e. some samples display features typical of the New England Suite whereas other samples *from the same intrusion* are more akin to the Hillgrove Suite.

Chappell and White (1974) classified Siluro-Devonian granitoids from the Lachlan Fold Belt (southern New South Wales) into S- and I-types and showed that the mineralogy, chemistry and Sr isotopic ratio of the granitoids reflect the nature of the inferred source rocks. Chappell (1978) extended this two-fold granitoid division to the New England Batholith and, on the basis of field, petrographic and chemical data, showed that not only are the I-type granitoids from the southern end of this batholith readily distinguished from the adjacent S-type granitoids, but they in fact comprise four distinct suites, each reflecting distinct source-rock compositions. Because the divisions between the suites of granitoids studied by Chappell were reasonably sharp on the basis of chemical data he argued that the source material for these granitoids was in all likelihood igneous, probably of tonalitic composition, and suggested that this igneous parent material resulted from subduction, presumably during the early Paleozoic, which underplated the New England region.

The implications for this sequence of events are profound and relate to a geologic conundrum which has existed for some time and which has tended to polarize geological opinion into two channels: one following Rutland (1976) and Chappell (1978) who believe that the New England Fold Belt is underlain by (at least pre-Mid Paleozoic) continental granitic crust, and the other which maintains that oceanic crust underlies the sediments (and therefore granitoids) of this Fold Belt (Leitch, 1974; Crook and Felton, 1975). One aspect of this argument which is inescapable is the presence of very extensive Paleozoic basaltic flows in southern New England (Gunthorpe, 1970) and along the entire length of the Peel Fault. These basalts, together with a belt of chemically and isotopically 'primitive' tholeiitic basalts and gabbros along the eastern margin of the New England Batholith, xenoliths of mafic granulite very depleted in LILE (chemically analogous to ocean-ridge basalts, Wilkinson *pers. comm.*) in analcimite sills, and eclogites with bulk compositions resembling tholeiitic basalts (Flood and Shaw, 1975), collectively provide strong preliminary evidence for the existence of oceanic crust under New England.

The objectives of this thesis are manifold but principally focus on two major topics: (a) the granitoids from the southeastern portion of the New England Batholith and (b) the relatively small, mafic intrusive complexes which are associated with them. The first part of this thesis is essentially a detailed investigation of granitoids belonging to the Hillgrove Suite and the adjacent New England Suite to examine whether there are indeed fundamental and unambiguous differences in field relations, textures, mineralogy, chemistry and isotopic composition between these suites as suggested by Binns *et al.* (1967), Gunthorpe (1970), Flood (1971), Neilson (1971), O'Neil *et al.* (1977) and Chappell (1978). When applied to experimentally determined phase equilibria the mineralogical and chemical data inevitably provide additional information on the melting and crystallization conditions of the respective granitoid suites and therefore provide further constraints on the question of source rock compositions.

Previous studies on the New England granitoids (authors as listed above) concentrated only on portions of one, or at most two, particular suites; consequently, a unified interpretation of New England granitoid genesis has not been presented previously. In this study I examine in detail an *entire* suite of rocks (the Hillgrove Suite) and compare it with a large number of plutons from the adjacent New England Suite. Furthermore, I also examine *all* other granitoids from the southeastern portion of the batholith, particularly those (e.g. the low-K granitoid suite) which are geographically isolated from the previous two suites, and especially those granitoids which display geological characteristics transitional to the Hillgrove and New England Suites.

This 'blanket' approach to the problem is warranted and indeed essential since it effectively eliminates the sampling bias inherent in previous studies. Only through such a breadth of sampling, combined with a wide range of analytical techniques, is it possible to convincingly demonstrate consistent differences or similarities between proposed suites of granitoids and therefore test the validity of the 'S-I' classification when this is applied to New England granitoids.

There is strong evidence to indicate that the granitoids belonging to the Hillgrove Suite are derivatives of partially melted volcanogenic sediments. Accordingly, the sedimentary rocks which are intruded by these granitoids were analyzed chemically and isotopically to test whether their characteristics are appropriate as a source material for the magmas (assuming that the exposed sediments may be chemically and isotopically equivalent to those which underwent partial melting). In addition, the rocks were dated to resolve apparent discrepancies in the depositional sequence of the sediments and to establish more precisely the time interval between sedimentation and partial melting. Using available paleontological data, Binns (1966) speculated that this interval may have been restricted to only ~ 15 m.y.

The second 'part' of this thesis is primarily a detailed documentation of a previously undescribed suite of mafic intrusives associated with the Hillgrove Suite, dealing specifically with their mineralogy, chemistry and isotopic characteristics, and applying these in an attempt not only to relate the origin of individual evolved representatives of particular complexes to specific magmatic processes such as fractional crystallization, but also to define precisely the magmatic affinities of the rocks within these complexes.

The association of small mafic complexes with granitoids is not uncommon within orogenic belts throughout the world, e.g. Scotland (Nockolds, 1940), southern California (Larsen, 1948; Best and Mercy, 1967), Sierra Nevada (Hietanen, 1951; Bateman *et al.*, 1963), Peru (Pitcher, 1978) and eastern Australia (Joplin, 1959). In most cases the close spatial association between the felsic and mafic rocks has been regarded as an indication of some genetic relationship, whether by fractional crystallization from a mafic melt or by contamination and hybridism. The rocks within the New England mafic complexes will be examined in some detail to establish whether there is indeed a genetic relationship between these complexes and the granitoids as suggested by Binns *et al.* (1967), Offenberg and Pogson (1972) and Scheibner (1976).

One very significant aspect of this association in New England is the relatively narrow belt in which these mafic complexes occur. Although small in size at the current level of exposure their frequent occurrence in this restricted belt along the entire eastern margin of the New England Batholith emphasizes the potential importance of mafic rocks in the evolution of batholiths. This study attempts to demonstrate an intimate temporal and causal relationship between the generation of specific New England granitoids and the mafic intrusives based on the premise that the upper mantle-derived mafic intrusives represent a focussing (or possibly funnelling) of heat into a major structural zone of weakness at the crust-upper mantle interface thereby triggering extensive partial melting of volcanogenic detritus.

This thesis is therefore multi-faceted, encompassing detailed investigations of a wide spectrum of rock units from the New England region of New South Wales. Unfortunately, such breadth must inevitably entail some simplification and generalization and consequently several aspects remain inadequately documented. Probably the most obvious omission is a detailed tectonic synthesis of the region. However, this was not an original aim of the investigation nor was it ever intended to involve a comparison of any length with other orogenic belts in the circum-Pacific 'ring' of magma generation, particularly since it is not possible, unlike Peru for example (Cobbing and Pitcher, 1972; Pitcher, 1978), to demonstrate with even a small degree of confidence, that the New England Fold Belt marked the locus of a convergent plate boundary.

Previous Work

Geological investigations of the New England Batholith commenced in the mid-nineteenth century following the discoveries of gold in 1849 at Baldblair Station near Guyra and shortly afterwards at Uralla and Hillgrove. Additional impetus to further investigations came from the discovery of tin near Glen Innes in 1853, antimony at Hillgrove in 1873, but especially following the diamond finds at Bingara and Copeton in 1867 and 1884, respectively. Petrological studies of the granitic rocks began with Andrews (1900, 1904,1905) and Andrews and Mingaye (1907) who distinguished several granitoid types from the batholith. In addition to describing some of the mafic intrusives from the Bakers Creek Complex, Andrews published some excellent chemical analyses (carried out by J.C.H. Mingaye) on these igneous rocks.

Benson (1914, 1918) studied the rocks associated with what is now known as the Peel Fault, but concentrated mainly on the serpentinites and their close mafic associates.

Browne (1929) formally recognized the existence of a suite of foliated granitoids around Hillgrove and speculated that these stressed bodies were older than the associated massive granitoids. This view was supported by Raggett (1938), Voisey (1942) and David (1950) who collectively considered them to be epi-Silurian by analogy to the stressed plutons of the Murrumbidgee, Kosciusko and Berridale Batholiths in southern New South Wales.

Since the mid 1960's valuable petrological information on the intrusive rocks of the New England Batholith has accumulated through numerous contributions by students from the University of New England. In particular, significant contributions were made by Vernon (1961), Ransley (1970) and Flood (1971) on rocks from the Uralla-Kentucky area,and Chappell (1966, 1978) on the granitoids from the southern end of the batholith. Gunthorpe (1970) examined the relationships between the granitoids, regional metamorphics and structure of the Tia area. Neilson (1971) studied the calc-alkaline intrusives from the Wards Mistake area and concluded that the adamellites were derived by hybridization, i.e. mixing of dioritic rock with a felsic melt. He also provided the first documentation of the mafic (tholeiitic) gabbros which he believed represented the mafic end of a spectrum of calc-alkaline rocks. Leitch (1972, 1974, 1975, 1976, 1978, 1979a, 1979b) and Mayer (1972) concentrated on structural, metamorphic and sedimentological aspects of the New England region and made valuable contributions to the understanding of crustal events during the Paleozoic.

Smaller, but nevertheless significant contributions to the geology of the southeastern portion of the New England Batholith were also made by Gentle (1960), Greaves (1960), Ransley (1964), Langham (1972) and Poole (1974) on the Hillgrove district, Street (1975) and Stolz (1976) on the Kookabookra district and Burlinson (1976) on the Dundurrabin Granodiorite. Apart from Collerson (1969), Mason (1969) and Haydon (1974) who examined the Camperdown, Mornington and Cheyenne Complexes respectively, details of the mafic intrusives are very limited. Similarly, data on the low-K granitoids are exceedingly sparse, resting on Bultitude (1965) and Moore (1974) for descriptions on the Duncans Creek and Gogs Top Trondhjemites.

Early age determinations on members of the New England Batholith and associated metamorphic rocks were by the K-Ar method (Evernden and Richards, 1962; Cooper *et al.*, 1963; Binns and Richards, 1965). Although these results (determined mainly on biotite separates) were generally consistent with field relations, doubts as to the suitability of biotite for dating when the rocks have been deformed after crystallization, were expressed by these authors. The three K-Ar ages* of 275 m.y., 264 m.y. and 257 m.y., corresponding to the Hillgrove Adamellite (Cooper *et al.*, 1963), and the Tobermory and Abroi plutons, respectively (Binns and Richards, 1965) clearly predate K-Ar ages for the relatively undeformed plutons of the adjacent New England Suite, all members of which are confined to the range 241-253 m.y. (Evernden and Richards, 1962; Cooper *et al.*, 1963; Binns and Richards, 1965; Neilson, 1971; Rowley, 1975).

Despite considerable scatter and moderately large errors, fission-track ages on sphene from the Moonbi Adamellite and apatite from the Tobermory Adamellite (Kleeman, 1975) agree with other radiometric data.

During the course of this thesis Flood and Shaw (1977) published a total-rock Rb/Sr age of 289 ± 25 m.y. and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7064 ± 0.0009 for the Hillgrove Suite, using six plutons spaced nearly 100 km apart, and concluded that members of this S-type suite, in conjunction with members from the western S-type Bundarra Suite, are coeval with the last stages of Andean-type volcanism along a belt west of the Peel Fault.

Recently, Leitch and McDougall (1979) examined the relationship between deformation and granitoid intrusion in the eastern part of the Nambucca Slate Belt by dating deformed metagreywackes, slates and phyllites and several samples of the undeformed, diapiric, felsic plutons (e.g. Carrai Granodiorite) which probably constitute the youngest intrusive suite of the New England Batholith. Leitch and McDougall concluded that although deformation of the metasediments may have resulted in some anomalous ages it is highly likely that the emplacement of the Hillgrove Suite (accompanied by metamorphism and deformation) occurred prior to the age recorded by the metasediments of the Nambucca Slate Belt (255 m.y.).

Finally, during their examination of the southernmost portion of the New England Batholith, Cooper *et al.* (1963) also dated the Barrington Tops Granodiorite with a view to elucidating its hitherto unknown petrological affinities. However, its K-Ar age of 264 m.y. is intermediate between the K-Ar ages for the New England and Hillgrove Suites and therefore ambiguous.

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* Recalculated using the revised decay constants and isotope ratios and abundances recommended by Steiger and Jäger (1977).