Chapter 2

METHODOLOGY AND ROCK CLASSIFICATION

2.1 Mapping Methodology

Geological mapping was conducted during the 1985, 1986 and 1988 field seasons (MacDonald et al., 1985; 1987; 1988). Mapping commenced along all-weather and logging roads and easily accessible lakes and streams. Foot traverses were then used to supplement outcrop coverage in areas with poor access, diverse rock types or complex geology and helicopter traverses were also used in remote regions. Several regions are uniformly blanketed by regional ground moraine and consequently have a very low outcrop density. Geological boundaries in these regions were partly or entirely delineated using till clast distribution in the ground moraine (Graves and Finck, 1988) and/or the results of airborne gamma-ray spectrometric surveys, in particular equivalent U/equivalent Th (O'Reilly et al., 1988).

Geological information recorded in the field included: (1) grain size, texture, colour and modal mineralogy of the major rock type(s); (2) orientation, size, spacing and type(s) of dykes, veins, joints, shear zones and faults; (3) orientation and degree of development of primary fabrics or mineral alignment(s); (4) presence and style of mineralization and hydrothermal alteration; and (5) abundance and type of xenoliths (both metasedimentary and igneous). Large hand samples (approximately 2-10 kg) were routinely collected at approximately 1-2 km intervals along traverses in homogeneous rock units and more closely in heterogeneous rock units or when more than one rock type was encountered. Approximately 2500 samples were collected, all samples were slabbed and most were stained for alkali feldspar using sodium cobaltinitrate solution. Approximately 1500 of these 2500 samples, were subsequently point counted (400-1000 points/sample) using a binocular microscope and/or petrographic microscope. The entire sample collection has been archived in Nova Scotia Department of Natural Resources storage facilities in Stellarton, Nova Scotia.

Data were recorded in the field on 1:10,000 scale colour air photos and compiled in the field onto 1:15,840 (1"=1/4 mile) scale Nova Scotia Department of Lands and Forest base maps. This information was subsequently compiled on 1:50,000 scale National Topographic

Series planimetric base maps for publication. A total of fourteen bedrock geology maps have been released as Nova Scotia Department of Mines and Energy published and/or open file maps. The locations of these map sheets along with the respective authors are given in Figure 2.1. Full citations for each map are given in the References at the back of this report.

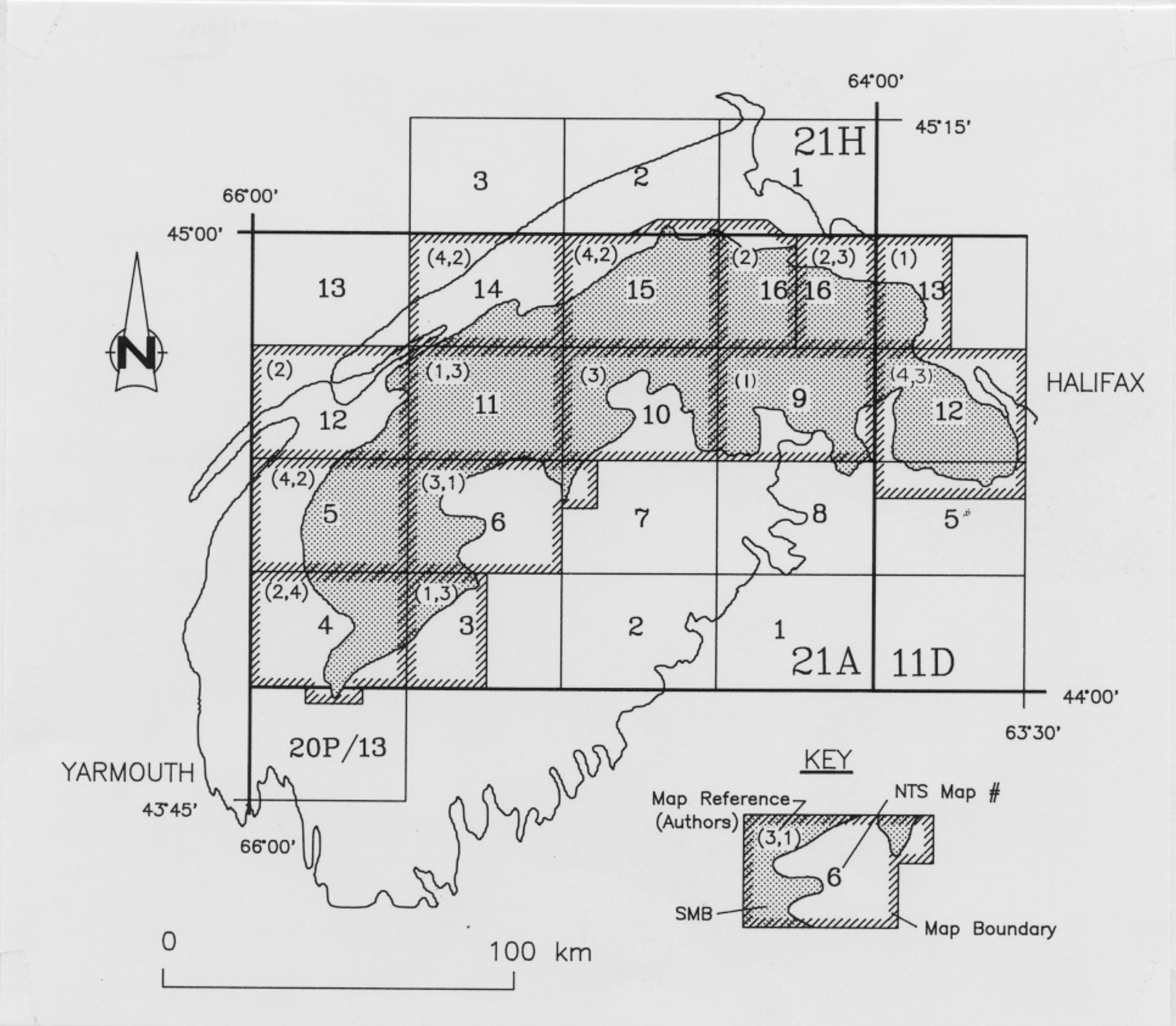

Figure 2.1 Reference map for the fourteen 1:50,000 scale geological maps produced during the 1984-1989 South Mountain Batholith mapping project. The location of the batholith is outlined with a stipple pattern. Map boundaries for each of the National Topographic series maps are indicated with hatch marks. Additional information includes the respective author(s) and the year the map was published. Full citations are given in the references. Note that authors were ordered alphabetically and coded with numbers, including: (1) M.C. Corey; (2) L.J. Ham; (3) R.J. Horne; (4) M.A. MacDonald.

2.2 Rock Classification Scheme

One of the first tasks for this project was to establish a rock classification scheme. The most important aspect of this scheme is the suitability for field use. Previous mapping in the batholith utilized a myriad of rock names. For example the rocks termed monzogranite on the provincial geological map (Keppie, 1979) were previously referred to as: biotite granite and muscovite granite (Taylor, 1969); porphyritic quartz monzonite (Smitheringale, 1973); muscovite-biotite granite (Smith, 1974); and adamellite (McKenzie, 1974). Clearly there was a need for a standard system for classifying granitic rocks.

Previous classification schemes for the batholith (Table 1.1) were mostly based on the relative proportions of quartz, alkali feldspar and quartz whereas some also considered texture and grain size (e.g. Smitheringale, 1973) and/or the relative proportions of muscovite and biotite (e.g. McKenzie, 1974; Smith 1974). Some schemes also employed the anorthite content of plagioclase feldspar as a criteria for rock classification.

This study used the classification scheme of Streckeisen (1976; Figure 2.2) which is the most universally used scheme for igneous rocks. This method is based upon the modal proportions of quartz, alkali feldspar and plagioclase and is particularly useful in igneous terranes with widely ranging compositions. For example, in the Sierra Nevada Batholith of California where compositions range from gabbro to leucogranite (Bateman, 1988), or in the Coastal Batholith of Peru where rock types range from gabbro to monzogranite (Cobbing et al., 1981). Previous studies of the batholith (Smith, 1974; McKenzie and Clarke, 1975) noted a comparatively restricted range from granodiorite to monzogranite. Strict adherence to the classification scheme of Streckeisen (1976) would yield only two rock types in most of the batholith. Therefore, a modified Streckeisen (1976) classification scheme was developed based upon the results of preliminary and past mapping projects (MacDonald, 1985; Table 1.1). Granitic rocks are divided on the basis of: (1) the modal proportions of quartz, alkali feldspar and plagioclase; (2) grain size (fine <0.1 cm; medium 0.1-0.5 cm; coarse >0.5 cm); (3) texture; and (4) the modal proportion of muscovite and the combined mafic minerals (biotite, cordierite, garnet; Table 1.1).

Several terms have been adopted and/or modified from Streckeisen (1976) previous mapping projects in the batholith for use in this project. These include the compositional terms:

leucomonzogranite - mostly monzogranite, and subordinate syenogranite, containing 2-6% combined mafic minerals; and leucogranite - monzogranite, syenogranite or alkali feldspar granite with <2% combined mafic minerals. The use of the prefix 'leuco' for igneous rocks with <6% combined mafic minerals is consistent with Streckeisen (1976); and the textural terms megacryst (adj. megacrystic) - a non-genetic term for a large (generally 2.5-7 cm) crystal (mostly alkali feldspar and lesser plagioclase) in a medium- to coarse-grained rock; and porphyry (adj. porphyritic) - a granitic rock with predominantly fine-grained groundmass and medium- to coarse-grained phenocrysts.

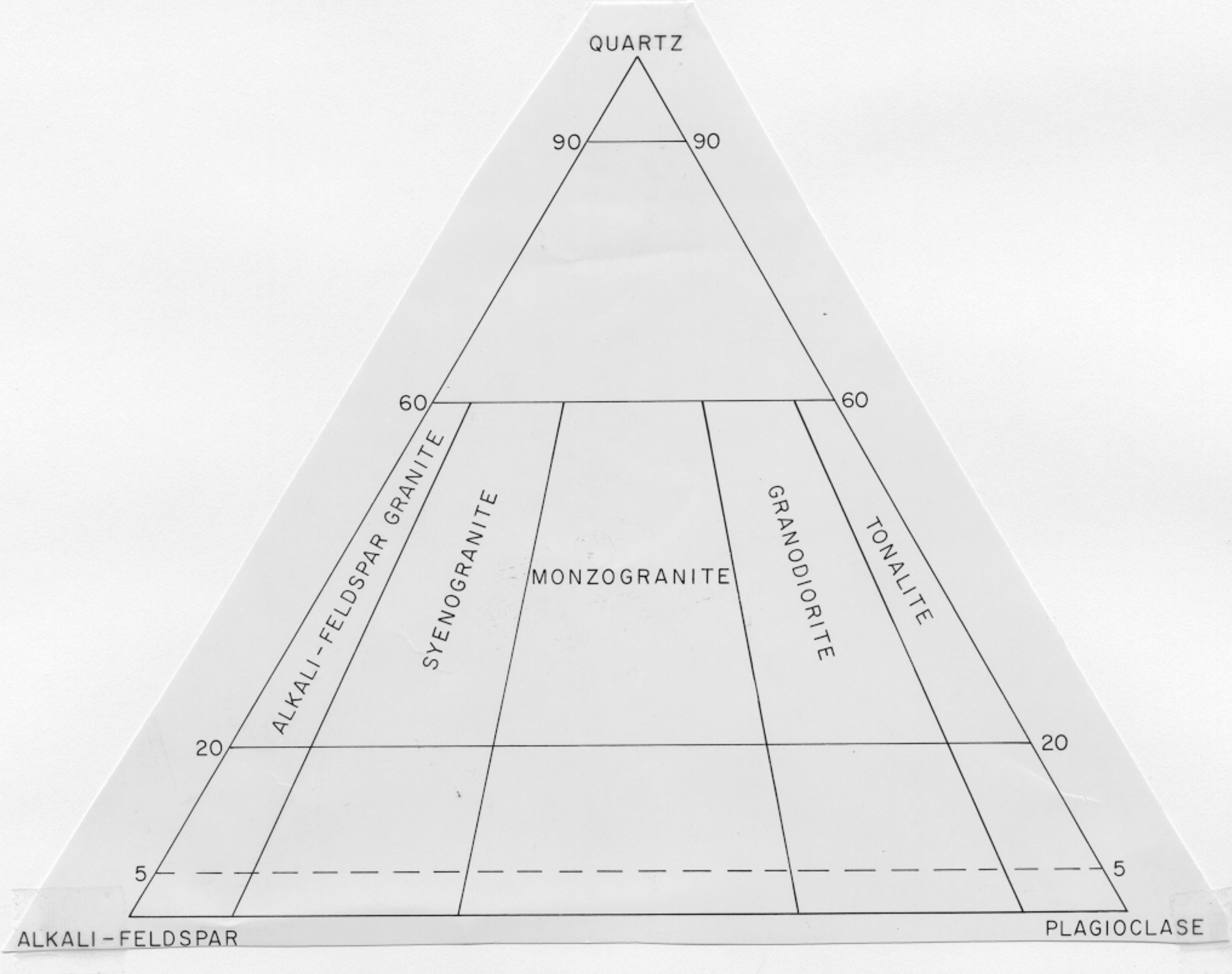

Figure 2.2 Ternary quartz-alkali feldspar-plagioclase (i.e. QAP) classification diagram (after Streckeisen, 1976) for granitoid rocks showing the location of tonalite, granodiorite, monzogranite, syenogranite and alkali feldspar granite fields.

Streckeisen (1976) suggested that plagioclase with $An_{<5}$ should be grouped with alkali feldspar. Some previous workers in the batholith used the term alaskite for leucocratic rocks with albitic feldspar. Some previous workers in the batholith used the term alaskite for leucocratic rocks with albitic plagioclase (McKenzie, 1974; Smith 1874). It should be stressed, however, that albitic plagioclase with $An_{<5}$ is present in many rocks and may vary from minor modal amounts in some leucomonzogranites to the only plagioclase feldspar in some leucogranite bodies (MacDonald et al., 1992). Determination of the exact modal amounts in the various rock units in the batholith would require vast amounts of microprobe data. Clearly this would be beyond the scope of a useful "field" classification scheme. Therefore for the purpose of this project all plagioclase compositions are grouped together.

The batholith was divided into six main rock types using the above classification scheme. These include biotite granodiorite, biotite monzogranite, muscovite-biotite monzogranite, coarse-grained leucomonzogranite, fine-grained leucomonzogranite and leucogranite. In addition to the six main rock types, several small bodies (<100 m^2-1 km^2) of fine-grained, often porphyritic, granodiorite and monzogranite with a high percentage of biotite and common metasedimentary xenoliths, termed mafic porphyry, have been delineated.

2.3 Organization of Rock Units

The batholith comprises more than two hundred separate mappable granitic bodies that must be organized before larger problems, such as emplacement history or petrogenesis, can be dealt with effectively. In general, the grouping of granitic rocks requires vast quantities of petrological and geochemical data. However, since the data available for this report are quite limited, the current organization of granitic bodies must be considered somewhat provisional and are hence subject to future modification.

Geological mapping projects in other worldwide granitic terranes have employed various schemes for organizing rock units. Pitcher and Berger (1972) assigned the various granitic rock types in the Donegal region of Ireland into eight plutons based upon field relations, including mode of emplacement, and compositional variations within these rock units.. Cobbing et al. (1981) established a scheme for classification of granitic rocks of the western Cordillera of northern Peru. The basic mappable granitic body in their scheme was "pulse". These were subsequently grouped into "units" which in turn were amalgamated into "plutons". Major magmatic episodes, based mostly upon geochronological data, which were represented by numerous plutons, were termed "super units". Bateman (1988) established a hierarchial scheme that, in increasing order, included "pluton", "lithodeme", "intrusive suite" and "super suite". Prior to the present study, most mapping projects in the South Mountain Batholith simply used rock types with no classification scheme (e.g. Taylor, 1969; Smitheringale, 1973). However, McKenzie (1974), McKenzie and Clarke (1975), and later Smith and Turek (1976) and Smith (1979) established adamellite (re monzogranite) plutons that were considered to intrude an envelope of biotite granodiorite. These plutons contained several textural variations such as megacrystic and porphyritic monzogranite (McKenzie, 1974). An essential consideration, when the organizational scheme for the batholith was established, was at least a partial retention of the term pluton and, where possible, the preservation of previously published pluton names (e.g. Davis Lake, New Ross and Halifax Plutons). The chief motive for this was the minimizing of unnecessary confusion that an entirely new scheme would create. The following section outlines the system for organization of granitic rocks of the South Mountain Batholith.

2.3.1 Map Body

A single body of intrusive rock that is continuous is termed a map body. The map body of this study is equivalent to the "pulse" of Cobbing et al. (1981), "pluton" of Bateman (1988) and "member" among stratified sedimentary rocks (Table 2.1). Contacts with surrounding igneous rocks are either intrusive or gradational whereas contacts with metasedimentary and metavolcanic country rocks are ubiquitously sharp and intrusive, with the exception of some mafic porphyry bodies (see discussion below). The relative ages of adjacent map bodies are generally difficult to establish due to poor outcrop exposure in much of the batholith and thus a lack of exposed contacts. However, in some locations it was possible to determine sequences of intrusion based on cross-cutting relationships of dykes, presence of inclusions of older map bodies in younger, or by truncated fabrics, aplite dykes or metasedimentary xenoliths in older map bodies. There is a paucity of chilled contacts, as manifest by reduction of grain size or textural changes, between adjacent granitic map bodies. The author favours an explanation whereby most map bodies were emplaced during a narrow time interval, thus later map bodies were emplaced before early bodies were cooled significantly. The entire batholith then cooled as a coalesced mass. This proposition is supported by geochronological evidence as discussed in Chapter 8.

Table 2.1. Summary of the organization of rocks in the South Mountain Batholith. Organizational schemes from the western cordillera of northern Peru (Cobbing et al., 1981), the Sierra Nevada Batholith of California (Bateman, 1988) and stratified sedimentary rocks are also included.

SMB	# Present	Cobbing et al. (1981)	Bateman (1988)	stratified sedimentary rocks
Map Body	260	pulse	pluton	member
Map Unit	49	unit	lithodeme	formation
Pluton	13	pluton	intrusive suite	group
Stage	2	super unit	super suite	super group

Most map bodies are not continuous sensu stricto because of the presence of glacial moraine which blankets much of the batholith. Map bodies are therefore inferred to be continuous based upon available outcrop and glacial till clast information (Finck et al., 1989). Geological mapping during this project has delineated 260 individual map bodies, ranging in size from <1 to >1,000 km^2, within the contiguous South Mountain Batholith. Some map bodies are characterized by homogeneous texture and grain size, such as the Cloud Lake monzogranite (MacDonald and Ham, 1992), whereas others display diverse textural variations, such as the Tantallon leucomonzogranite (MacDonald and Horne, 1987). Similarly, some map bodies are mineralogically and geochemically homogeneous whereas others are compositionally zoned from one side or end to the other, such as the Davis Lake leucomonzogranite (MacDonald et al., 1992).

2.3.2 Map Unit

The term "map unit" in this study is defined as a mappable unit of granitic rock and is a term that is equivalent to "formation" among stratified sedimentary rocks and corresponds to the "unit" of Cobbing et al. (1981), and the "lithodemes" of Bateman (1988; Table 2.1). Map units consist of a place name or prominent geographical feature, followed by a rock type that denoted the average modal composition of the rock, for example the Tantallon leucomonzogranite (MacDonald and Horne, 1987) or the Salmontail granodiorite (Ham and Horne, 1987). Note that the full rock type is generally not given, for example the Sandy Lake monzogranite is actually a biotite monzogranite whereas the Harrietsfield monzogranite is actually a muscovite-biotite monzogranite. This convention was adopted for sake of brevity. Two or more intrusive bodies composed of similar texture, grain size, modal mineralogy and composition (i.e. modal quartz-alkali feldspar-plagioclase) with similar field relations with surrounding igneous rocks in approximately the same geographical region are assumed to belong to the same map unit. It is assumed that map bodies of the same map unit crystallized from a common magma and may in fact have been connected at depth at the time of their intrusion. A few map units consist of a single map body (generally >100 km^2), for example the Whale Lake monzogranite (Horne, 1987). The assignment of map bodies to map units is entirely based upon field criteria and subsequently may be subject to future modification as additional geochemical, isotopic and geochronological data become available.

Fourty-nine (49) map units were identified in the batholith. The distribution of these map units is given in Figure 2.3 (in pocket at back of report). A full description of the textural/mineralogical aspects and field relations of the 49 map units are given in the fourteen 1:50,000 scale geological maps with marginal notes as outlined in Figure 2.1.

2.3.3 Pluton

The term pluton in this study is defined as a group of related granitic rocks and is equivalent to "group" among stratified sedimentary rocks. Pluton of this study corresponds to the "pluton" of Cobbing et al. (1981) and "intrusive suite" of Bateman (1988; Table 2.1). Map units were assigned to plutons on the basis of the following criteria: 1) map units must be located in the same general region of the batholith and, in general, are contiguous; 2) map units may share unique or characteristic textural, mineralogical or geochemical features; 3) megacrystic units of individual plutons may display normal and/or reverse compositional zoning which is manifest by mineralogy and/or major, trace and isotopic geochemistry; 4) map units may be arranged concentrically, particularly in some zoned plutons such as the Halifax Pluton (MacDonald and Horne, 1987); 5) map units of younger plutons may be in intrusive or fault contact with those of older plutons; 6) younger plutons may truncate compositional zoning patterns of older plutons. The assignation of map units to plutons is dependant on an extensive petrographic and geochemical database. At present, the database is limited to specific regions of the batholith. Consequently, the number and specific boundaries of the plutons are tentative and may be revised as additional data become available.

Thirteen plutons were outlined in the batholith. A description of the geological features of plutons is given in Chapter 3. A map showing their locations is given in Figure 2.3 (in pocket at back). The thin lines within individual plutons in Figure 2.3 are generalized compositional isopleths (no units of measure) determined from point counting and whole rock geochemistry. The arrows that are oriented perpendicular to the isopleths indicate increasing differentiation index. The plutons can be divided into early Stage I, comprising mostly granodiorite and monzogranite, and late Stage II, comprising monzogranite, leucomonzogranite and leucogranite. The two stages are equivalent to the "super-units" of Cobbing et al. (1981), "super suites" of Bateman (1988) and "super group" among stratified sedimentary rocks.