

GRANITES OF NORTH QUEENSLAND

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Introduction

North Queensland comprises Palaeoproterozoic to Mesoproterozoic basement (Etheridge, Savannah, Croydon¹) provinces structurally overlain by successively younger components including Neoproterozoic-Cambrian (Iron Range, Cape River, Barnard), Cambrian-Ordovician (Thalanga) and Ordovician to Carboniferous (Broken River, Hodgkinson) provinces (Figs 1, 2). The region has been the site of long lived, episodic, widespread and voluminous felsic I-, S- and rarer A-type magmatism, spanning some 1200 Ma. Major episodes of granite formation include the Mesoproterozoic (ca 1550 Ma), the Cambrian to Ordovician (ca 480-460 Ma) Macrossan Igneous Province, the Silurian to Devonian (ca 430-380 Ma) Pama Igneous Province, and the Carboniferous to Permian (ca 330-260 Ma) Kennedy Igneous Province (Table 1; Fig. 2).

Mesoproterozoic granites

Proterozoic granites in north Queensland are dominated by the Mesoproterozoic granites of the Georgetown region (Forsyth Subprovince (Etheridge Province) and Croydon Province; Fig. 2). These differ markedly from the majority of Proterozoic granites elsewhere within Australia, being dominated by S-type granites, and also comprising Sr-undepleted, Y-depleted sodic I-type granites. The Georgetown region provides a cross-section through the crust, showing that the S-type granites range from small migmatitic bodies at higher metamorphic grades (middle-upper amphibolite) to large plutons at similar and lower metamorphic grades (Bain et al., 1997). Their potassic, LILE-, LREE-, Th- and U-enriched nature coupled with Nd-Sr isotopic data show that they were largely derived from gneissic metasediments similar to those outcropping in the region. The I-type granites, although locally associated with migmatites, more commonly outcrop as a series of higher level plutons. They are characterised by felsic (>68% SiO₂), low- to medium-K, high Al₂O₃, low LILE, LREE and HREE compositions, consistent with an origin from a basaltic composition source derived at high pressure (garnet stable). All granites give similar ages, within error, of ca 1550 Ma (see Bain et al., 1997).

Late Cambrian-Ordovician granites of the Macrossan province

Granites of the Macrossan Province are largely confined to the Charters Towers region (Hutton et al., 1997; Fig 2; Table 1), though also include units within the Barnard Province (Bultitude et al., 1997) and the Georgetown region (Withnall et al., 1997). The Macrossan Province is dominated by I-types of largely granodioritic to granitic composition, but also includes interpreted S-type granites (Hutton et al., 1997). Ages range from Late Cambrian to Mid Ordovician, with granites of the latter age the most common. Hutton & Crouch (1993) showed that the I-type granites are felsic (>65% SiO₂ mostly), are Sr-depleted, and mostly Y-undepleted, and range from medium- to high-K, with K₂O contents increasing in a systematic regional manner south to north. These workers suggested that the granites were predominantly crustal in origin, though indicated that the Late Cambrian to Early Ordovician members may be (continental) arc-related. The interpreted S-types appear to be spatially and/or temporally associated with high grade metamorphism and migmatites. At least some of the 'S-types' are

¹ All province and region names are as defined by Bain & Draper (1997).

characterised by sodic compositions with high $\text{Na}_2\text{O}/\text{K}_2\text{O}$ (1.4-2.0; Hutton & Crouch, 1993), suggesting they are, in part, contaminated I-type granites.

Silurian-Devonian granites of the Pama Igneous Province

Granites of the Pama and the younger Kennedy Igneous Provinces, dominate magmatism in north Queensland. Pama Igneous Province granites outcrop principally in the Georgetown, Coen and Charters Towers regions (Fig. 2, Table 1). Granite geochemistry varies on a regional scale, with each region having its own distinctive signature. The oldest, the largely Silurian granites of the Georgetown region, are dominantly tonalitic & trondhjemitic I-types, but range to locally garnetiferous peraluminous granites. Units are characterised by medium- to high-K, Sr-undepleted Y-depleted compositions, with an expanded silica range (60-75% SiO_2) and, like the Proterozoic I-types of the same area, have a chemistry consistent with the involvement of garnet. In direct contrast, the younger (ca 410-390 Ma) voluminous granites of the Coen region are dominated by felsic potassic peraluminous two-mica granites, interpreted as S-types, and minor (<20%) I-type granites and granodiorites (Blewett et al., 1997). These granites represent the earliest true batholithic S-type granites in north Queensland and are similar in many aspects to S-type granites in the LFB. Granites of the Charters Towers region compositionally and temporally fall between those of the other 2 regions. They are dominated by I-types (largely granodioritic, but ranging from tonalite to granite), with lesser S-type and interpreted S-type peraluminous granites (Hutton et al., 1997). The I-type granites have an expanded silica range (<60% to >75 % SiO_2), mostly range from medium- to high-K, and have a number of similarities to Georgetown region granites, but unlike the latter are largely Sr-depleted and Y-undepleted. Chemical compositions more like Georgetown, however, appear to occur in the western part of the Charter Towers region. This difference is also reflected in the Sm-Nd data. Nd depleted mantle model ages are greatest in the Georgetown and western part of the Charters Towers regions (mostly 2.1 Ga and greater), decreasing eastwards in the central (1.7 to 2.0 Ga) and eastern parts of the Charters Towers region (Black & McCulloch, 1990; Champion, 1991; Hutton et al., 1997b). Model ages for the Coen region granites overlap those of the western and central Charters Towers region (Hutton et al., 1997b). The isotopic and chemical data indicate a significant component of pre-existing crust was involved in the genesis of the majority of Pama Igneous Province granites, either as part of the source or via subsequent contamination.

Carboniferous-Permian granites of the Kennedy Igneous Province

Granites of this age, and the significant associated volcanism, represent the most voluminous magmatic event in north Queensland. Magmatism is particularly concentrated within the Georgetown and Cairns region but is found in all regions (Table 1). Magmatism, ranging in age from ca 340 Ma to ca 260 Ma, is dominated by high-K, high SiO_2 (>70%), I-, S- and lesser A-type granites (Table 1), with common moderately to very strongly fractionated compositions. Although grouped as one province, it is evident that the magmatism can be subdivided into 3 temporal subgroups (Table 1): early Carboniferous (KP1), mid-Carboniferous to Early Permian (KP2), and early to late Permian (KP3). KP1 forms a minor component, characterised by felsic I-type magmatism (intrusive and extrusive) which appears to be localised around the margins of the Broken River Province (and perhaps related to basin formation in some manner). KP2 forms the major component of Kennedy Igneous Province magmatism, particularly concentrated along the southern half of the Palmerville fault and its extension south. Magmatism is both extrusive and intrusive, is largely I-type, dominantly monzogranite and syenogranite (rhyolitic to rhyodacitic) but includes granodiorites and lesser quartz diorite and andesite and local basalt/gabbro. Within the Georgetown and Cairns region, KP2 can be further subdivided into early (ca 325-310 Ma), typically strongly fractionated,

high silica (>72% SiO₂) magmatism and younger (ca 305-290 Ma) less siliceous, more compositionally variable magmatism. Both have identical evolved isotopic signatures (depleted mantle model ages of 1.5 Ga and older; Champion & Chappell, 1992). KP3, which may form a continuum with KP2, marks a change from dominantly I-type magmatism to more diverse I-, A- and S-type magmatism in the Permian. S-type granites are concentrated almost solely within the Hodgkinson province. A-types occur either as sub-volcanic intrusions closely associated with volcanics of similar chemistry (Mackenzie, 1993), or as generally high-level intrusions (Bultitude et al., 1997). Temporally associated I-types also typically form a similar distribution, and it is notable that a number of these have A-type affinities. Sm-Nd isotopic data for Kennedy Province granites (Black & McCulloch, 1990; Champion, 1991) shows that all granites have a significant component of older crustal material involved in their genesis. More importantly, Nd depleted mantle model ages appear to broadly correlate with provinces. This is best seen for the I-type granites which show a pronounced broad regional decrease in model ages from 1.5 Ga and older in the Georgetown region to less than 1.2 Ga along the eastern margin of the Cairns region. The S-type granites of the Cairns region also follow this trend, and notably have similar or more primitive isotopic signatures to spatially associated I-types. A-type granites overlap with I-types or extend to younger model ages. The majority of intrusion-related mineralisation in north Queensland is associated with granites of the Kennedy Igneous Province. Significant mineralisation includes: Sn and/or W deposits clearly associated with fractionated and reduced I- and S-type granites (Champion & Mackenzie, 1994); W-Mo-Bi deposits associated with more oxidised I-type granites; and Au, in a variety of settings (breccia-hosted, vein-hosted, lode gold, stockwork, skarn), interpreted to be related to I-type granites in a porphyry environment (Morrison, 1994; Blevin et al., 1996). The A-types appear to be unmineralised.

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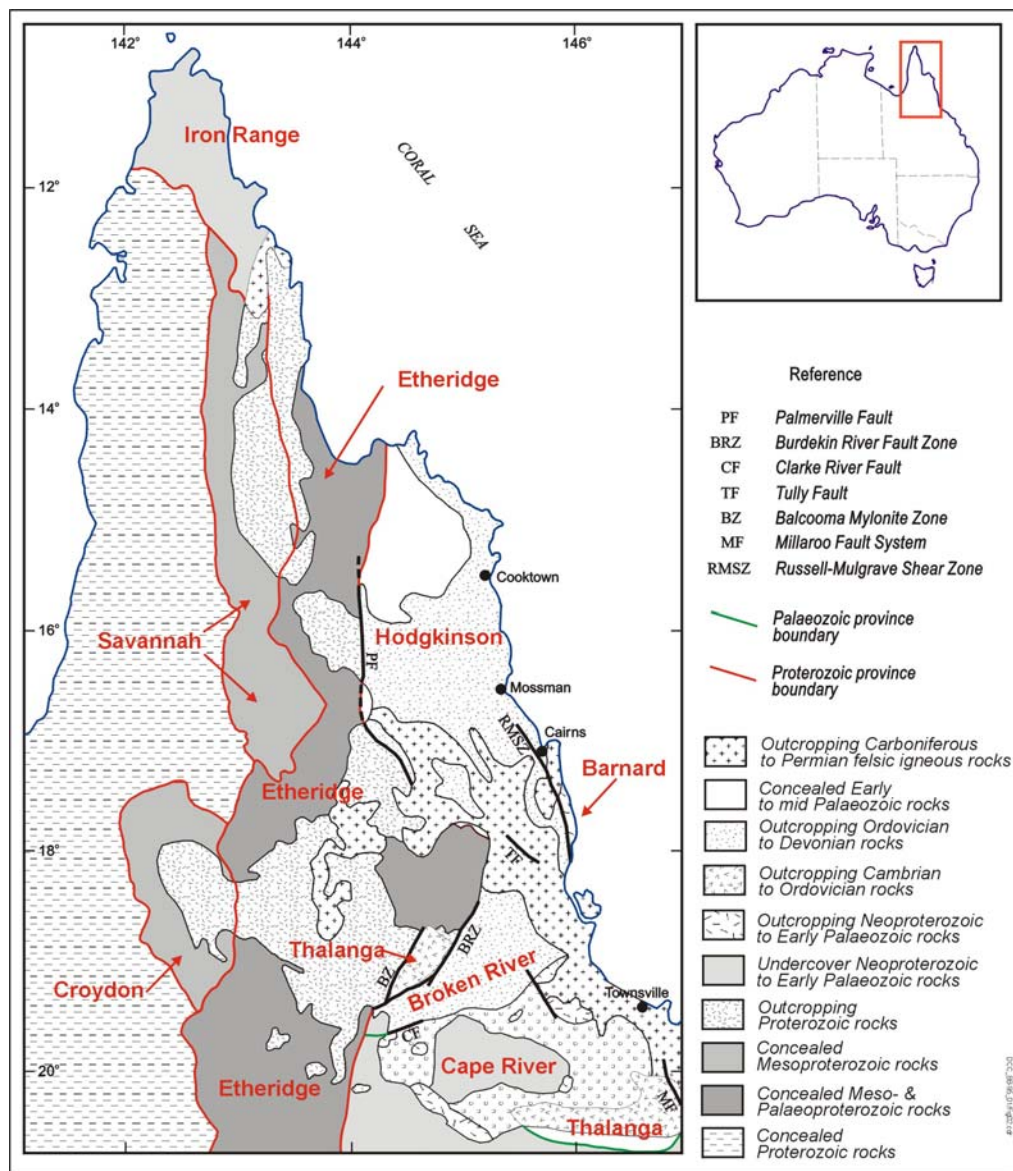


Figure 1. Geological map of the north Queensland region. Province names as defined by Bain & Draper (1997). Geology modified after Bultitude et al. (1995).

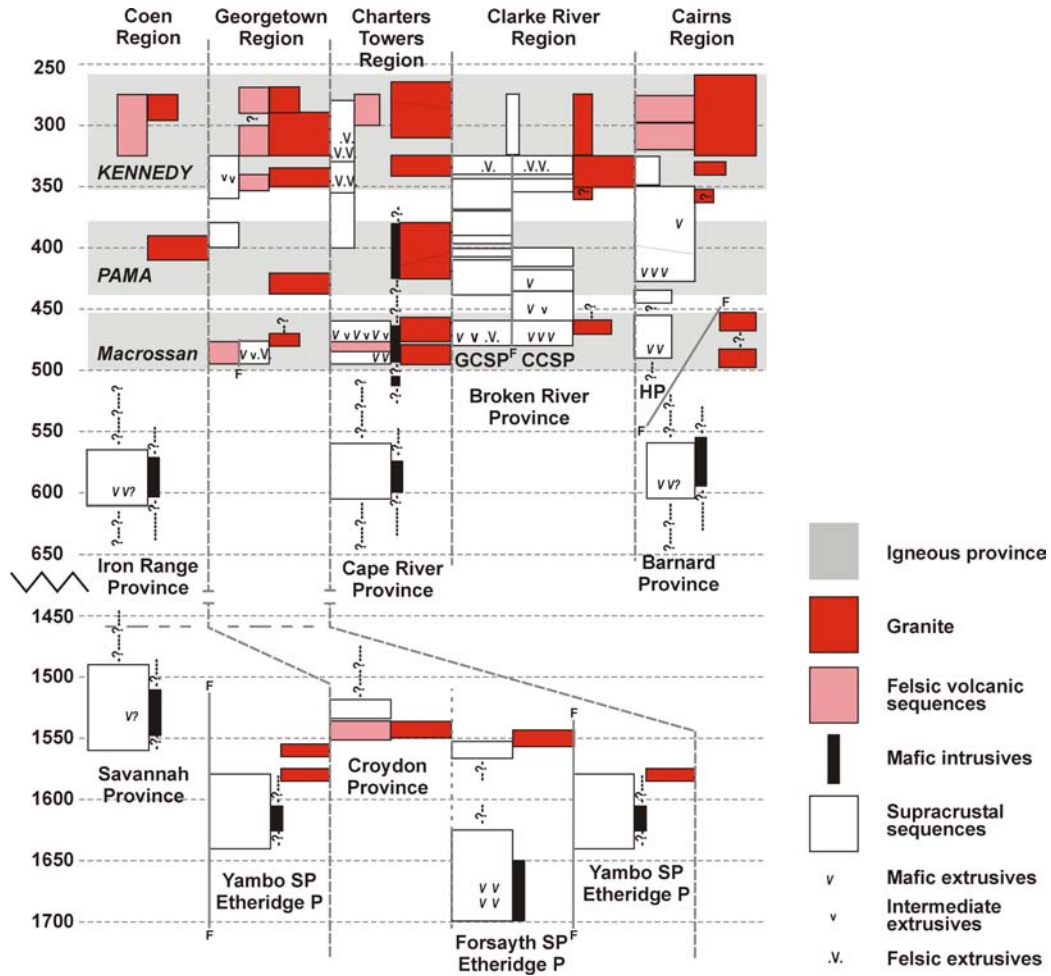


Figure 2. Time space plot for regions and provinces of north Queensland. Compiled from data in Bain & Draper (1977). HP = Hodgkinson province, CCSP = Camel Creek Subprovince, GCSP = Graveyard Creek Subprovince, SP = subprovince, P = province. Igneous province names in italics.

Age	Coen region	Georgetown region	Charters Towers	Hodgkinson region	Clarke River region
Permian	Ig If (M)	If Ig A (M)	If Ig (M)	S Ig If A	
Mid Carboniferous - Early Permian	If (Ig)	If Ig (It M)	Ig If (M)	If Ig (M)	(I?) ((S))
Early Carboniferous		If	If (M)	(If, A??)	(If M)
Early - mid Devonian	S Ig (M)		If S? Ig (M)	?(S)	
Silurian - Early Devonian		It Ig (If)	Ig If It (M)		((It))
Late Cambrian - Ordovician		(It)	Ig If S (M)	(It S (I))	
Mesoproterozoic	(Ig S)	S It			

Table 1. Granite types for geographic regions of north Queensland. It, Ig & If = dominantly tonalitic, granodioritic, or granitic (monzogranitic & syenogranitic) I-types, respectively. S = S-types, A = A-types, M = mafic rocks (largely gabbros to diorites). Items in bold are dominant granite type for that age period and region; items in single or double parentheses indicate only minor or uncommon component, respectively. Data compiled from information in Bain & Draper (1977).

GRANITES OF NORTH QUEENSLAND

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TALK OUTLINE

- Regional Geology
- Proterozoic magmatism
- Cambro-Ordovician
- Siluro-Devonian
- Carboniferous-Permian
- Conclusions

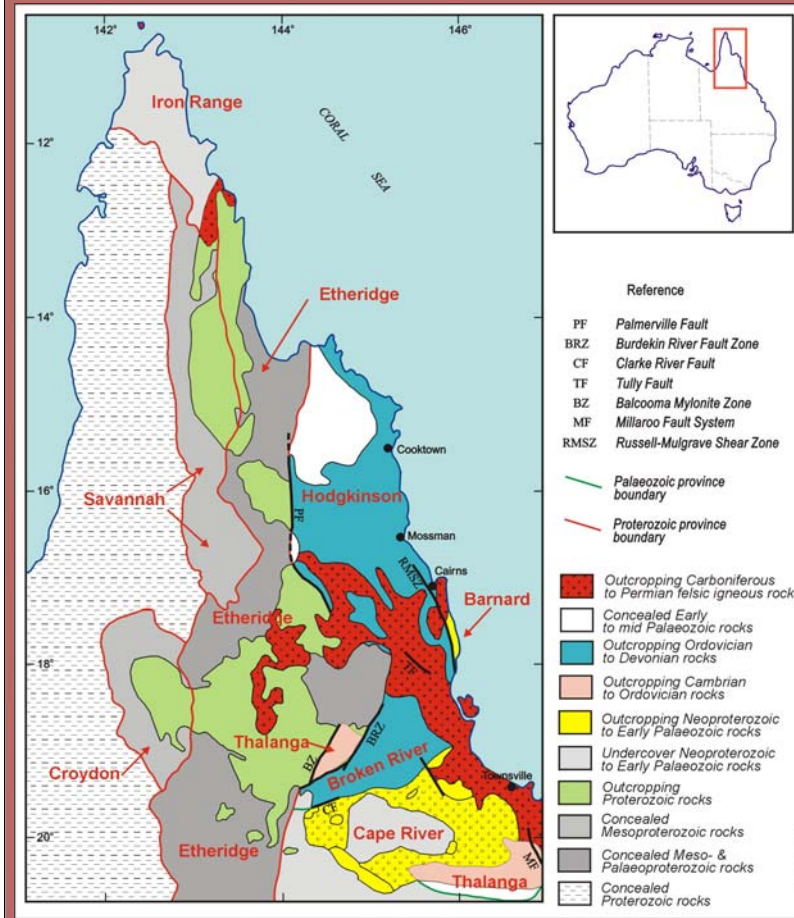


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- North Qld Geology volume (AGSO Bulletin 240/Qld Geology 9; Bain & Draper, 1997)
- North Qld 1:1 000 000 Geology Map & digital data (Bain & Haipola, 1997)

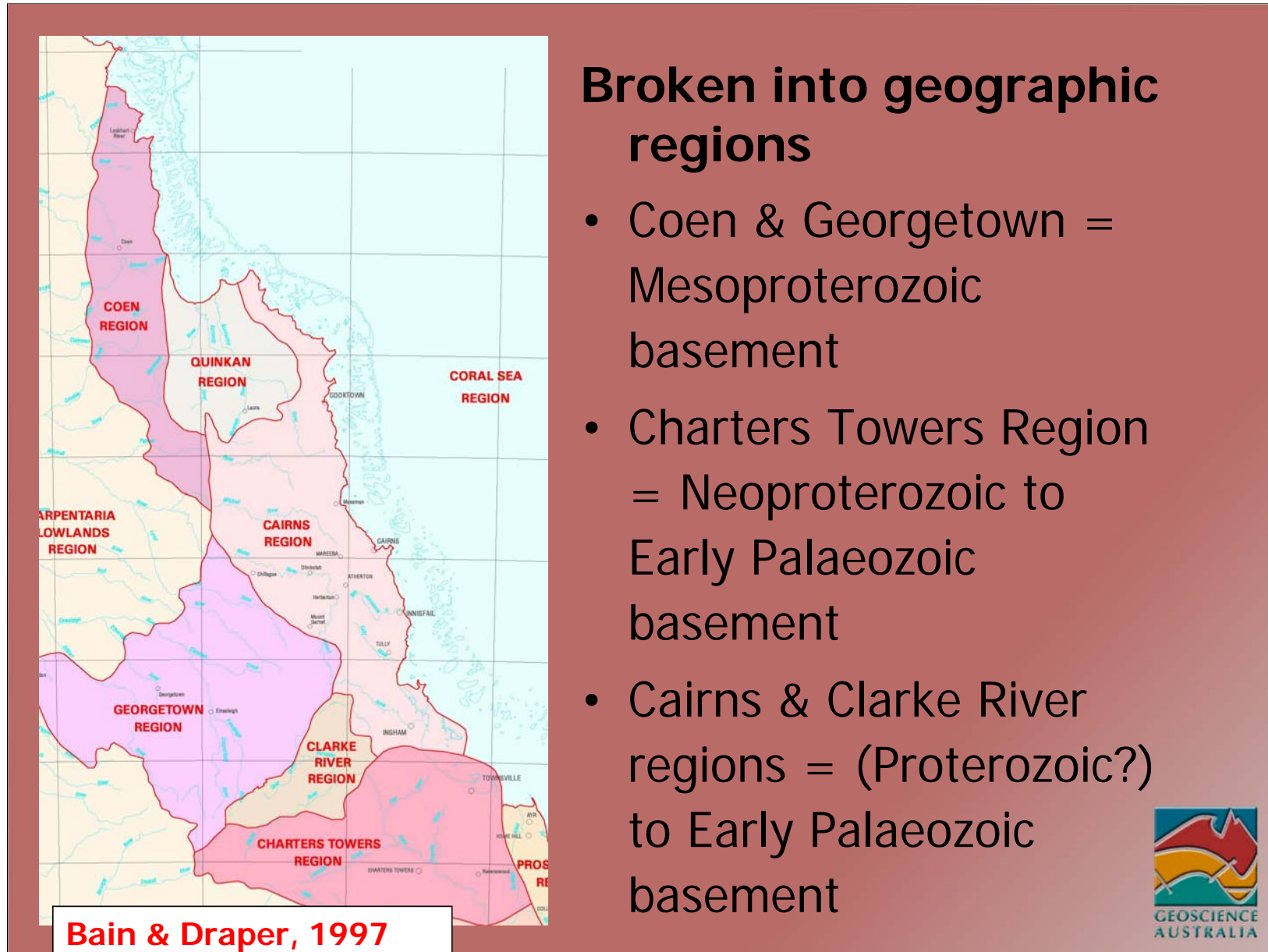


North Qld Regional Geology



- Palaeo- to Meso-Proterozoic basement: Etheridge, Savannah, Croydon Provinces)
- successively younger provinces to east: Cape River, Iron Range, Thalanga, Barnard, Broken River and Hodgkinson



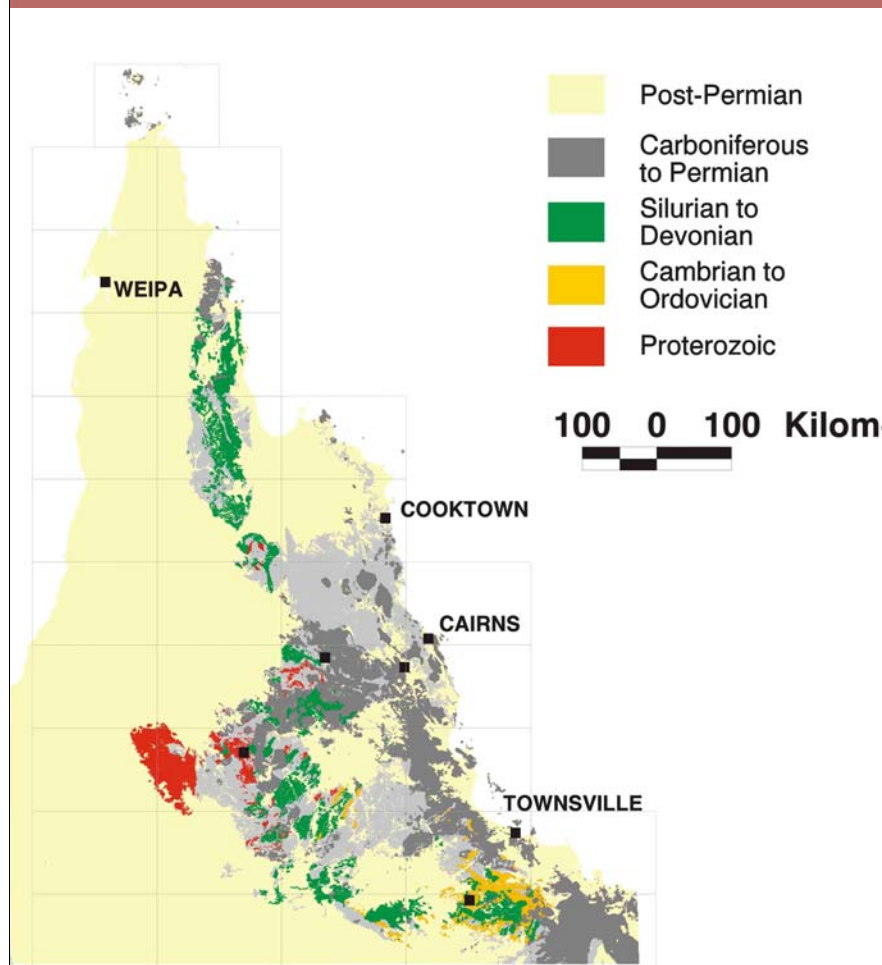


Broken into geographic regions

- Coen & Georgetown = Mesoproterozoic basement
- Charters Towers Region = Neoproterozoic to Early Palaeozoic basement
- Cairns & Clarke River regions = (Proterozoic?) to Early Palaeozoic basement



North Qld Magmatism



Modified from Bain & Haipola (1997) digital data

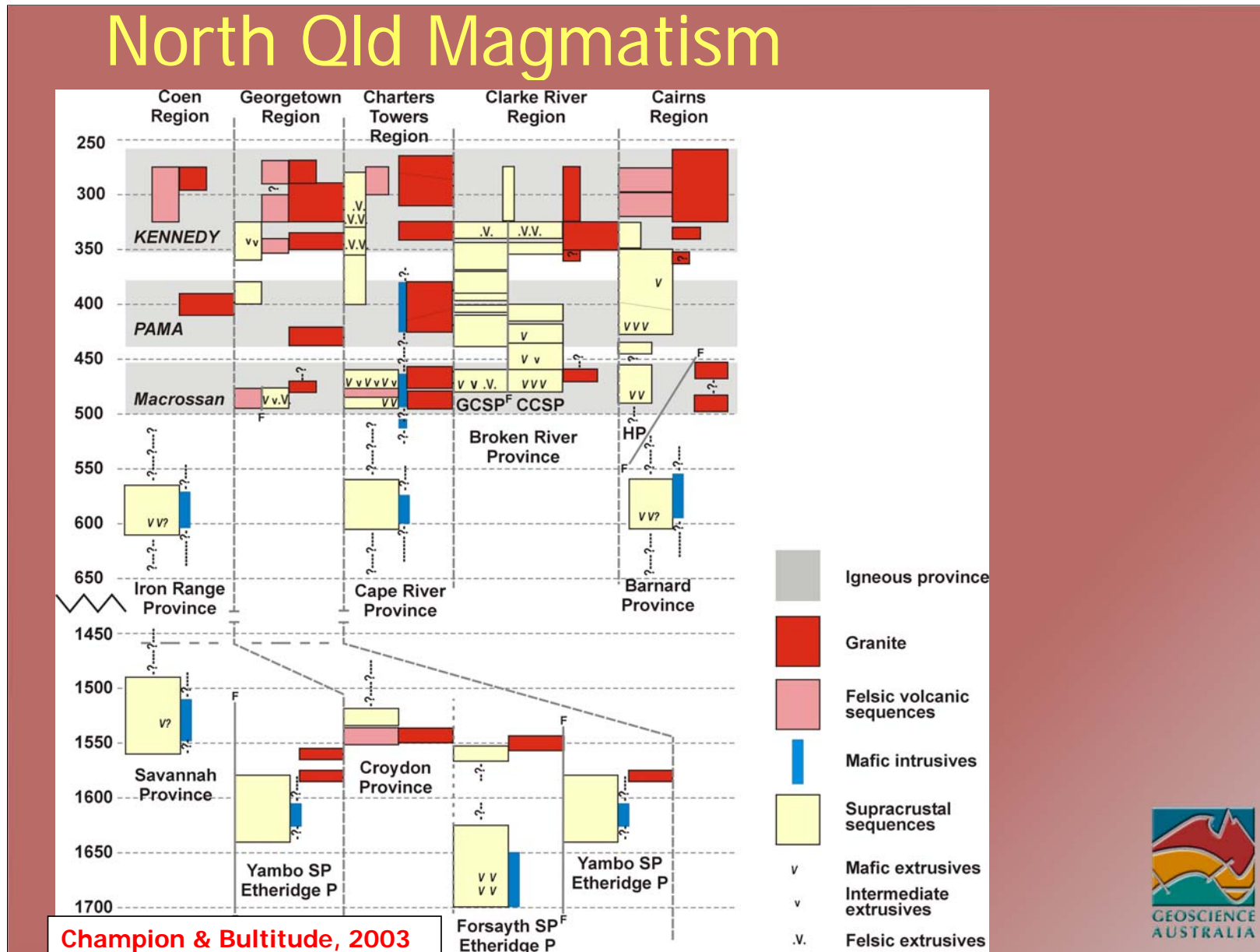
Long lived (>1200 Ma)

Episodic, 4 Main Periods:

- Mesoproterozoic
- Late Cambrian to Early Ordovician
- Silurian to Mid Devonian
- Carboniferous-Permian

Last 2 most voluminous



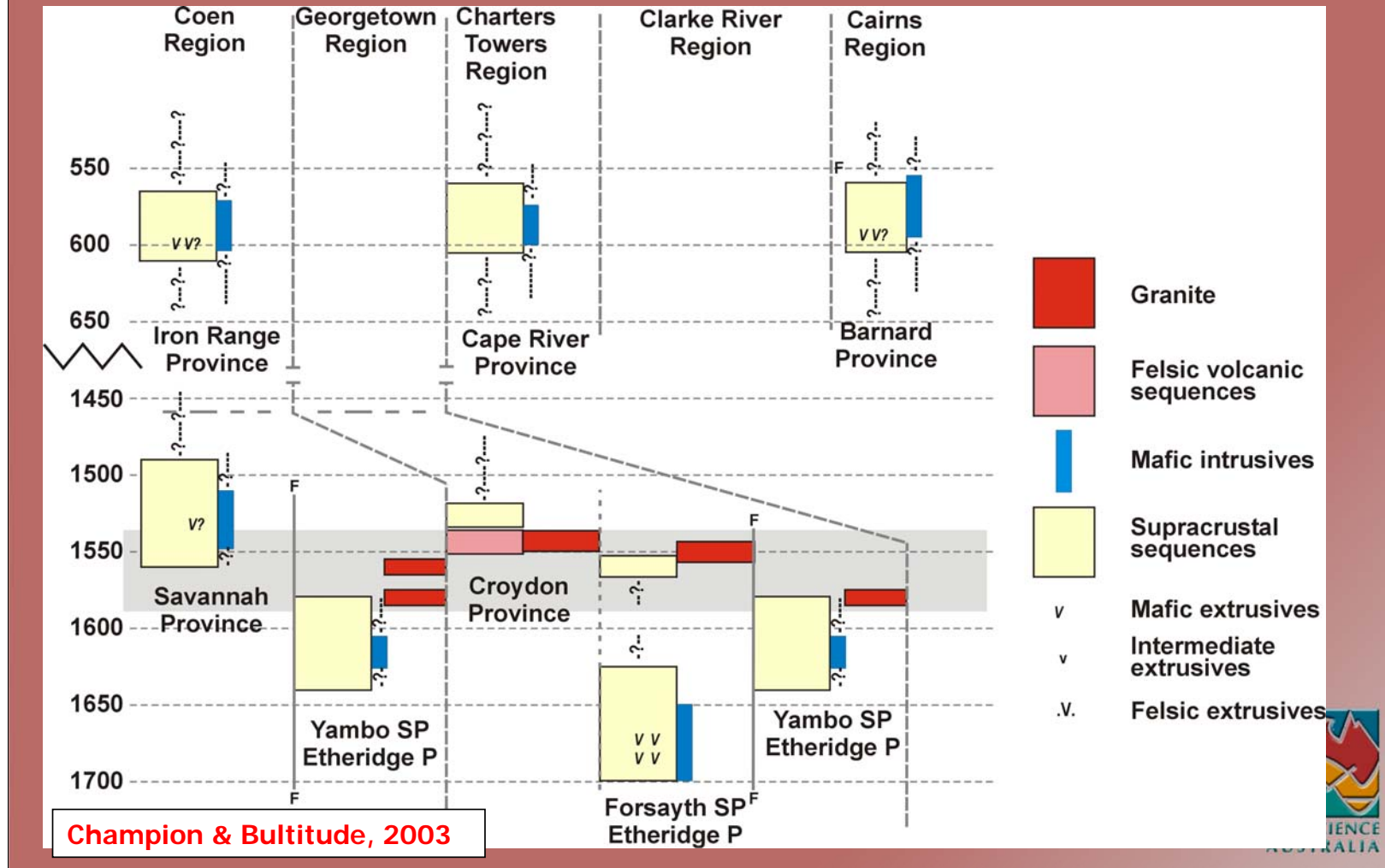


North Qld Magmatism

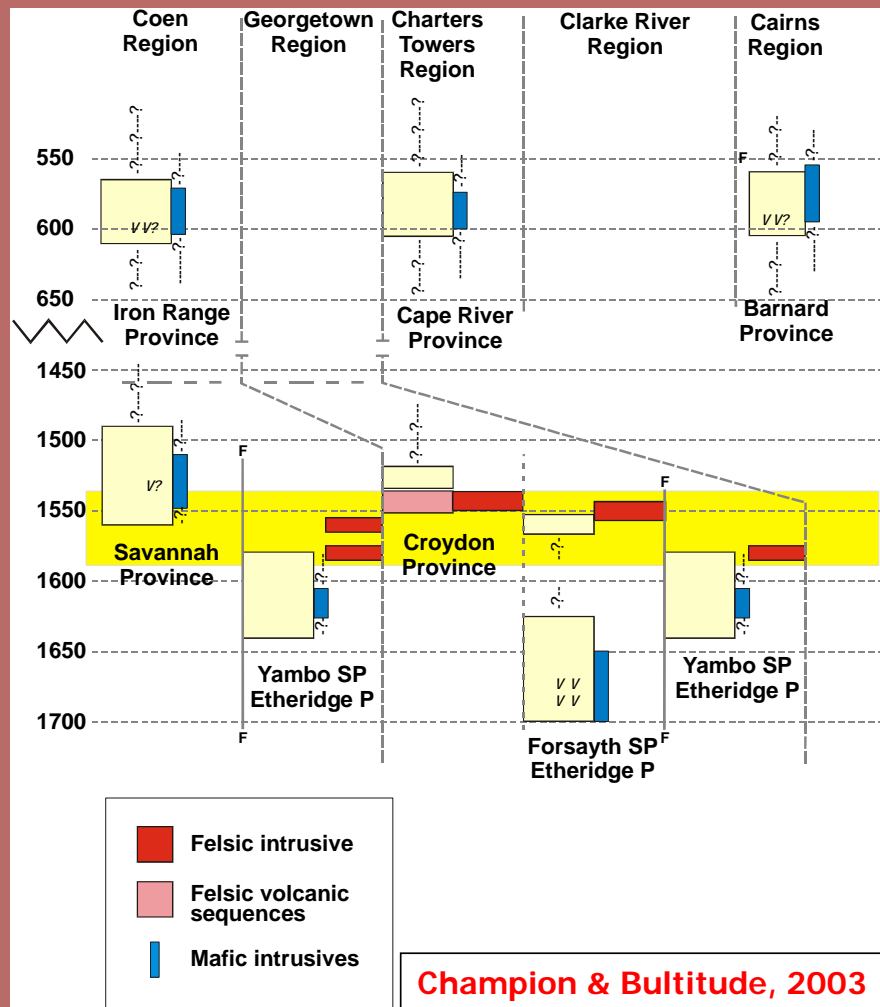
- long lived & episodic from Mesoproterozoic to Permian
- dominantly felsic: monzogranite, granodiorite and syenogranite
- largely I-type, S-types locally dominant, lesser A-types



Mesoproterozoic Magmatism



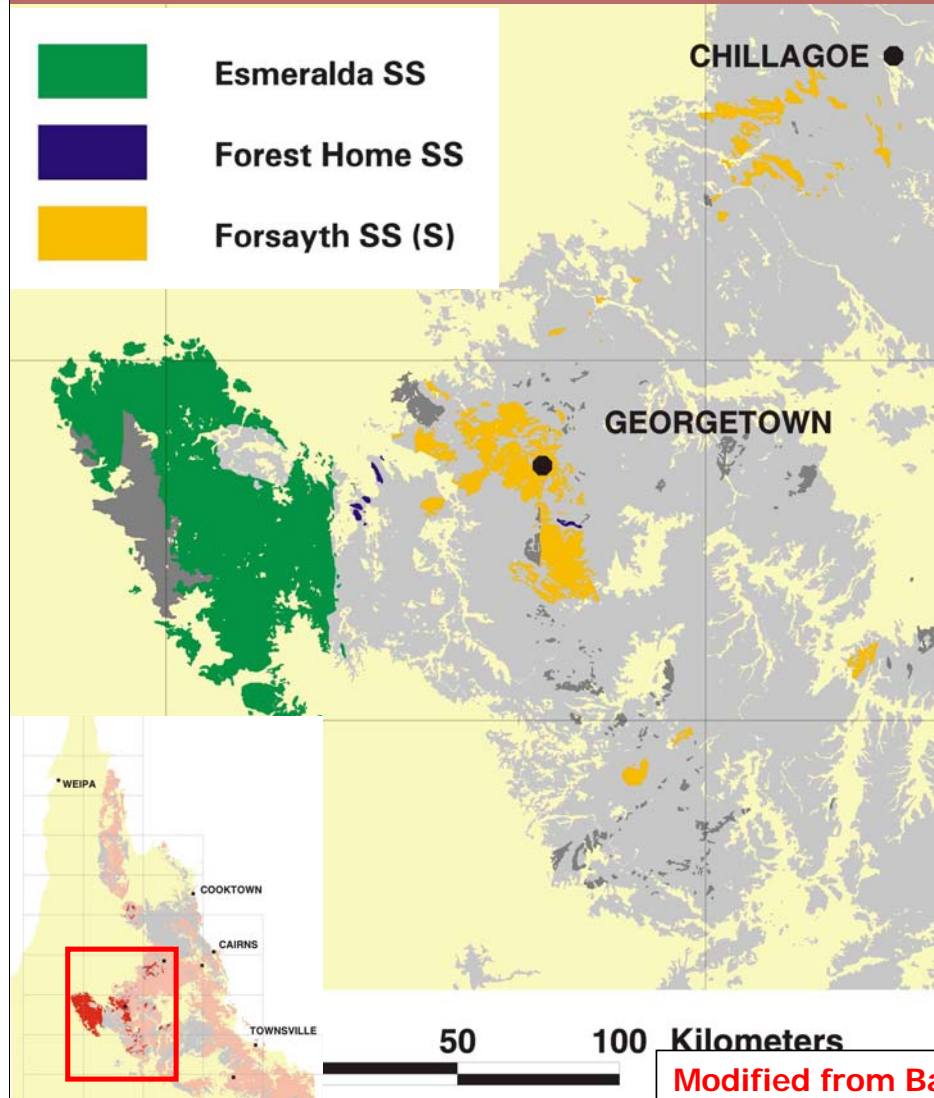
Mesoproterozoic Magmatism



- Concentrated in Georgetown region
- ca 1550 Ma
- Dominantly S-types (Forsayth SS), also I-types



Mesoproterozoic Magmatism - Georgetown

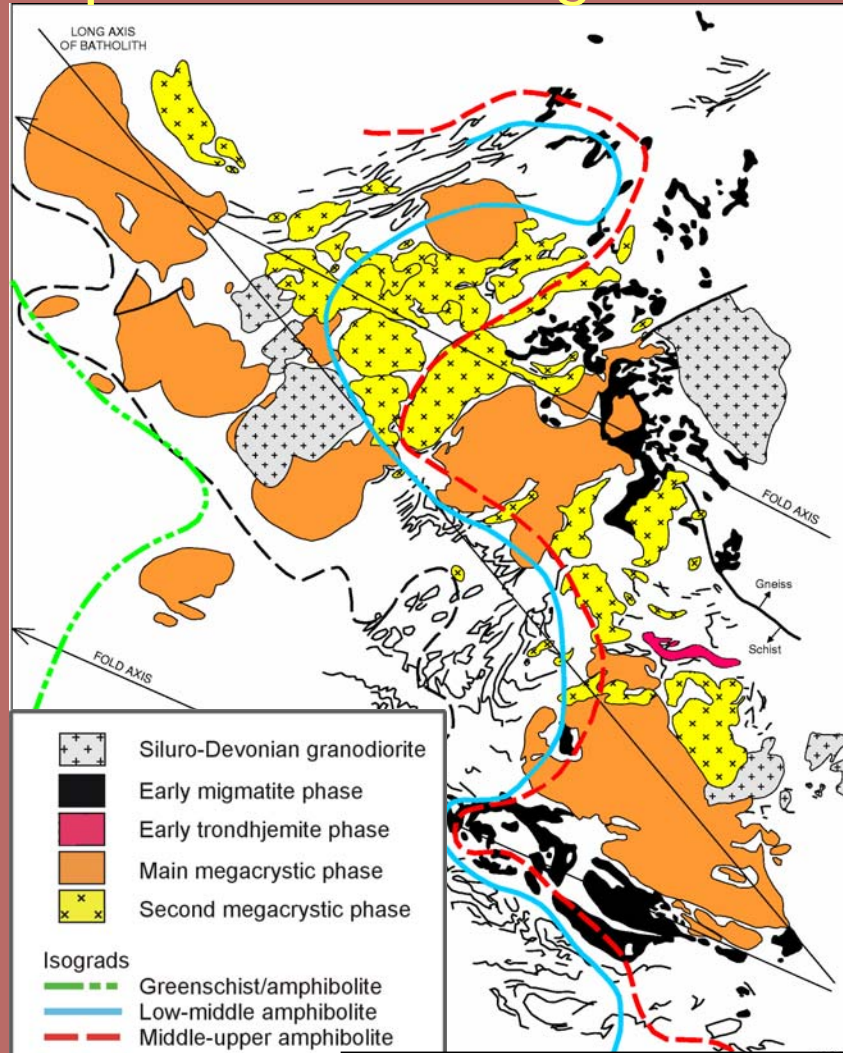


- Dominantly S-types (Forsayth SS). Migmatitic to large plutons.
- Minor sodic I-types (trondhjemites)
- possible A-types. Esmeralda SS unusual chemistry.



Modified from Bain & Haipola (1997) digital data

Mesoproterozoic Magmatism - Georgetown

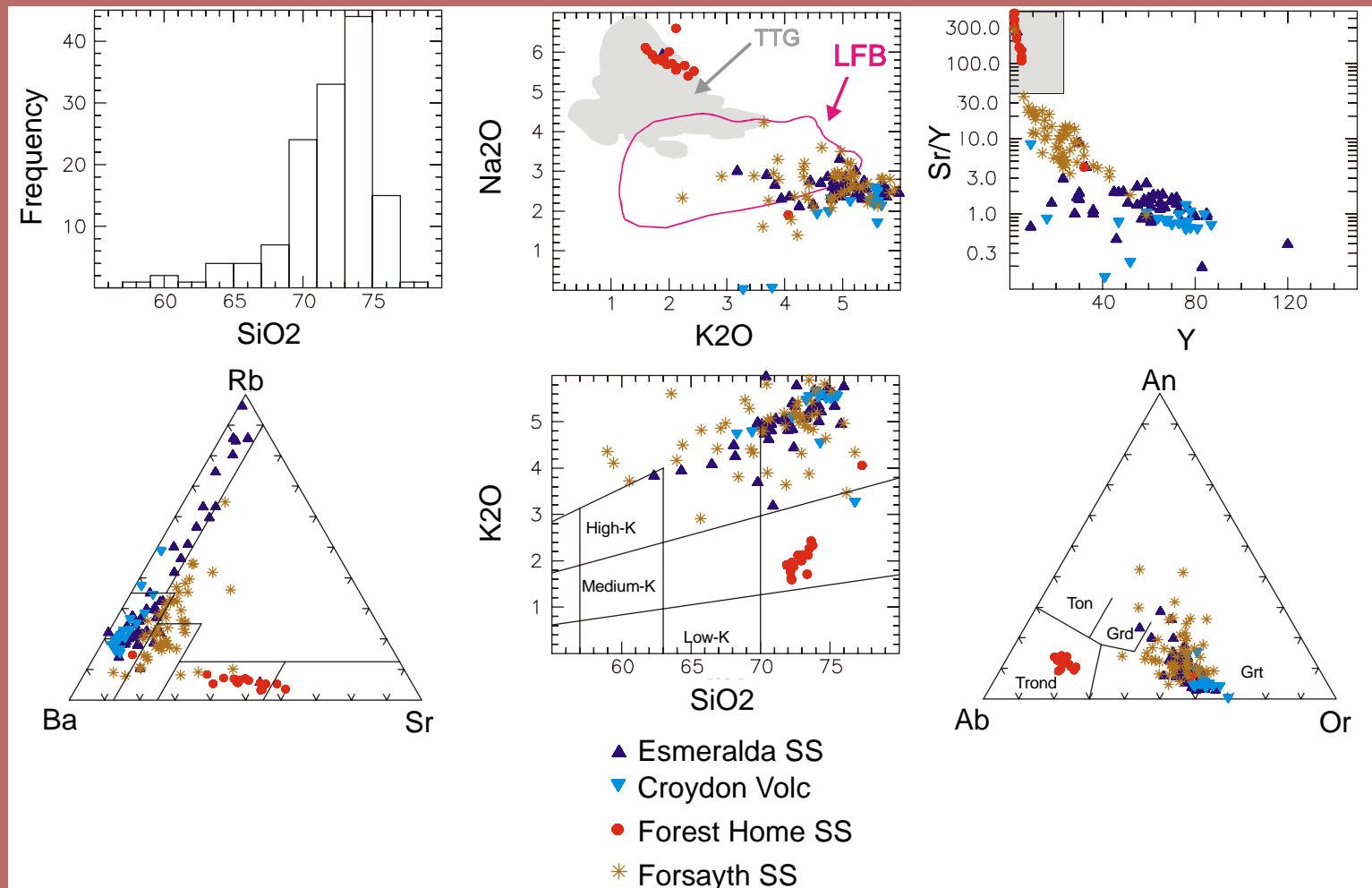


Bain & Draper, 1997

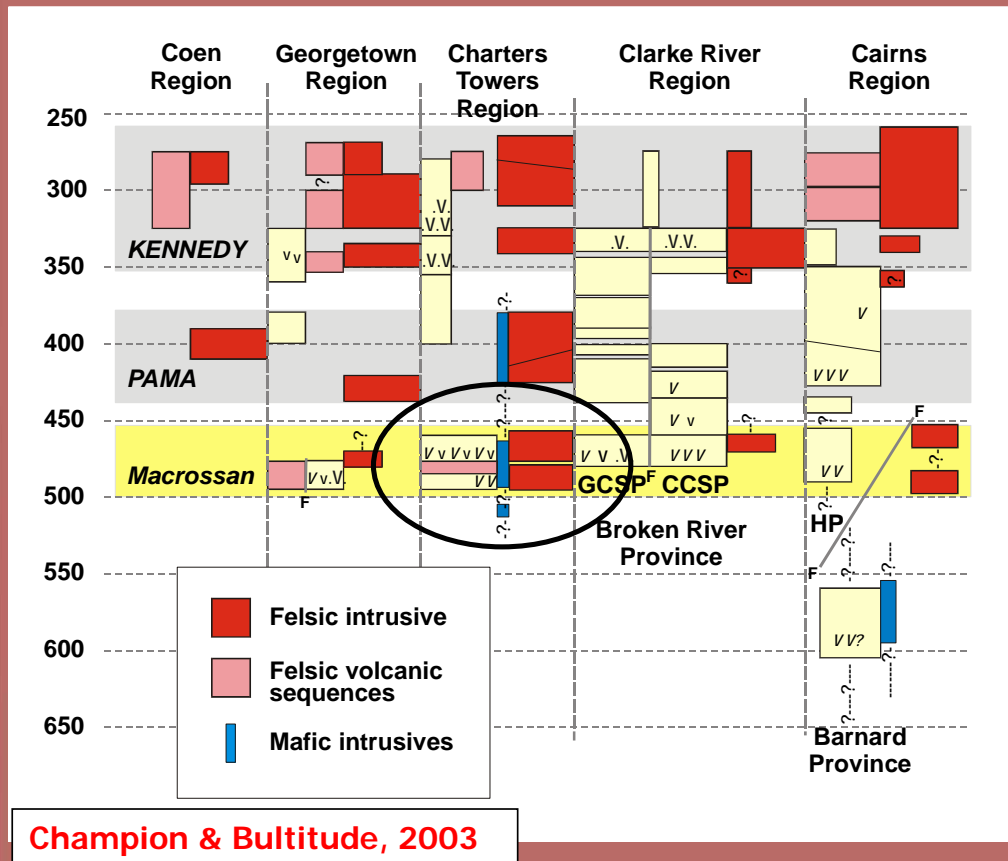
S-types range from migmatitic bodies to large plutons



Mesoproterozoic Magmatism - Georgetown



Macrossan Province: Cambrian-Ordovician

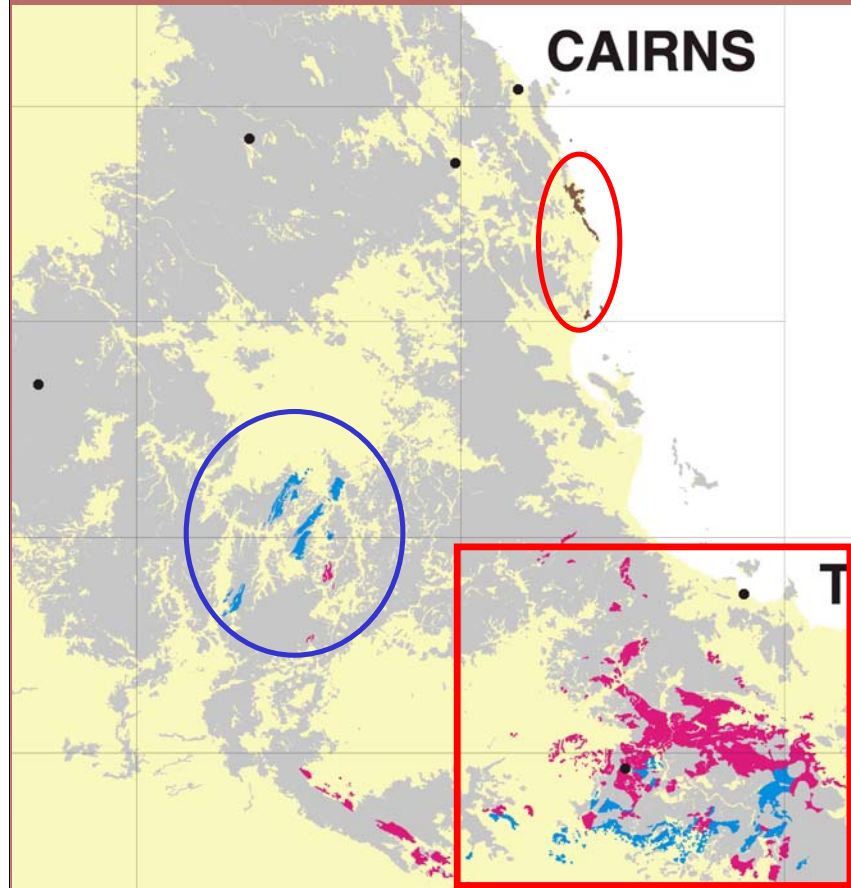


- Late Cambrian to Early Ordovician
- Early to Mid Ordovician
- ca. >480 to 460 Ma

Concentrated in
Charters
Towers region



Macrossan Province: Outcrop



Modified from Bain & Haipola (1997) digital data

Concentrated in
Charters Towers
region

Also:

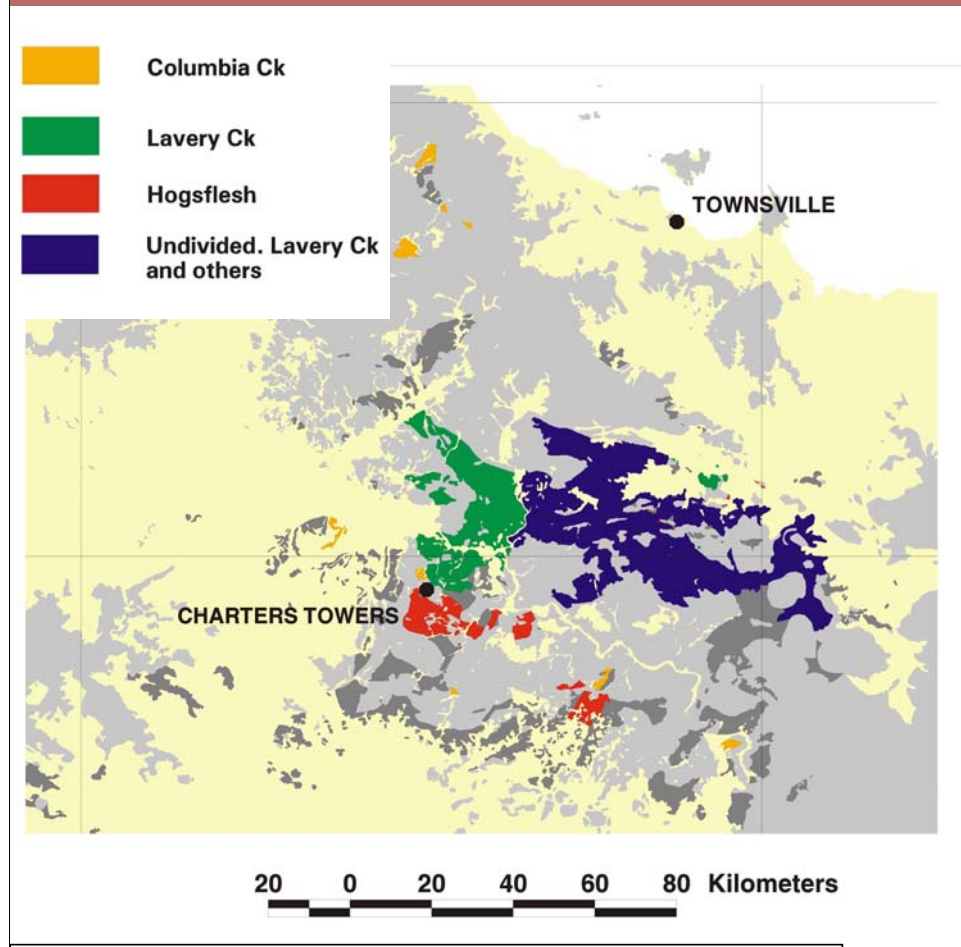
- Barnard Province
- east Georgetown

Late Cambrian to Early
Ordovician (blue)

Early to Mid Ordovician
(red)



Macrossan Province: Charters Towers region

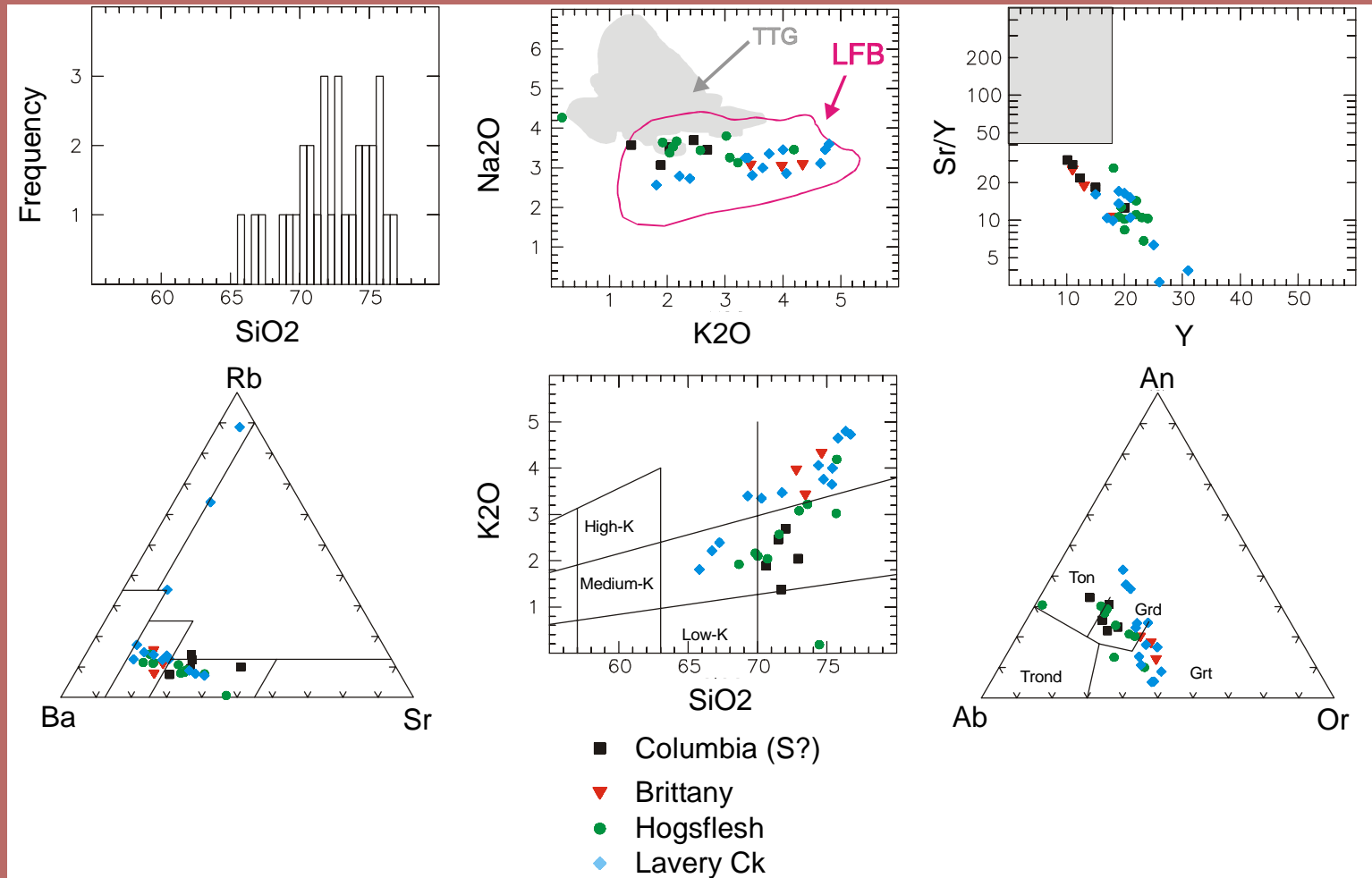


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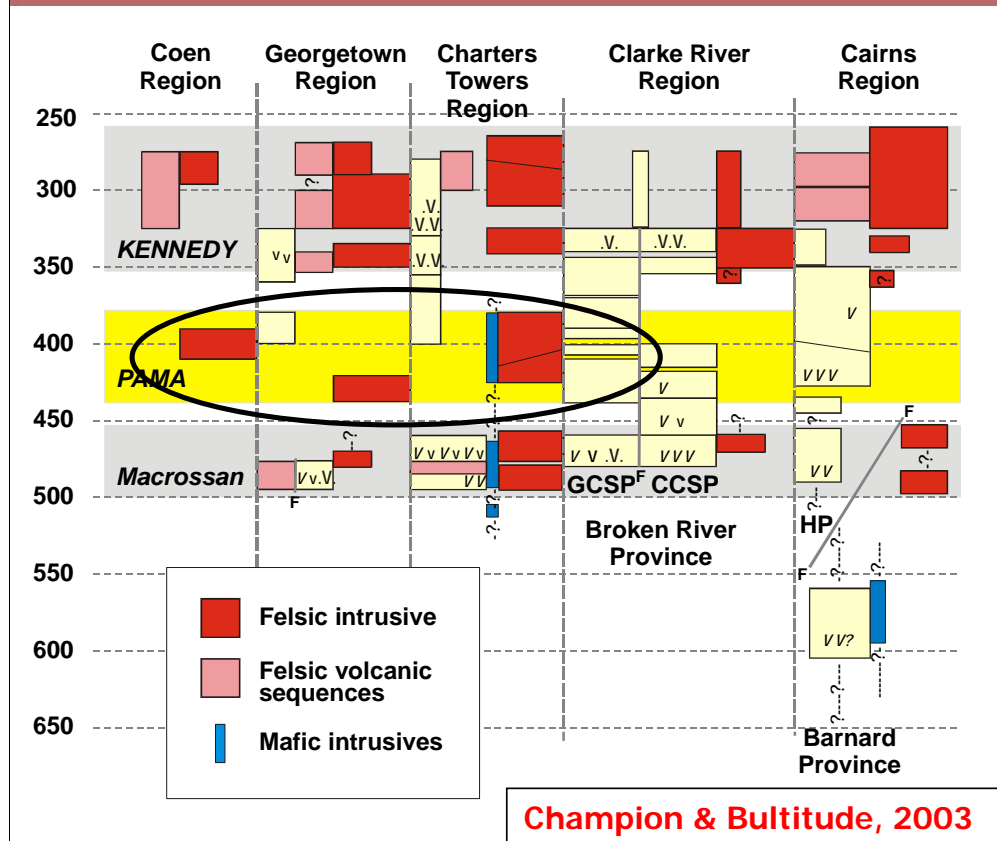
- dominantly granodioritic to granitic I-types
- some interpreted S-types granites (Columbia Ck), spatially associated with high grade metamorphism & migmatites



Macrossan Province: Charters Towers region



Pama Province: Silurian-Devonian Magmatism



2 age subgroups

- Silurian to Early Devonian (green)
- Devonian (red)

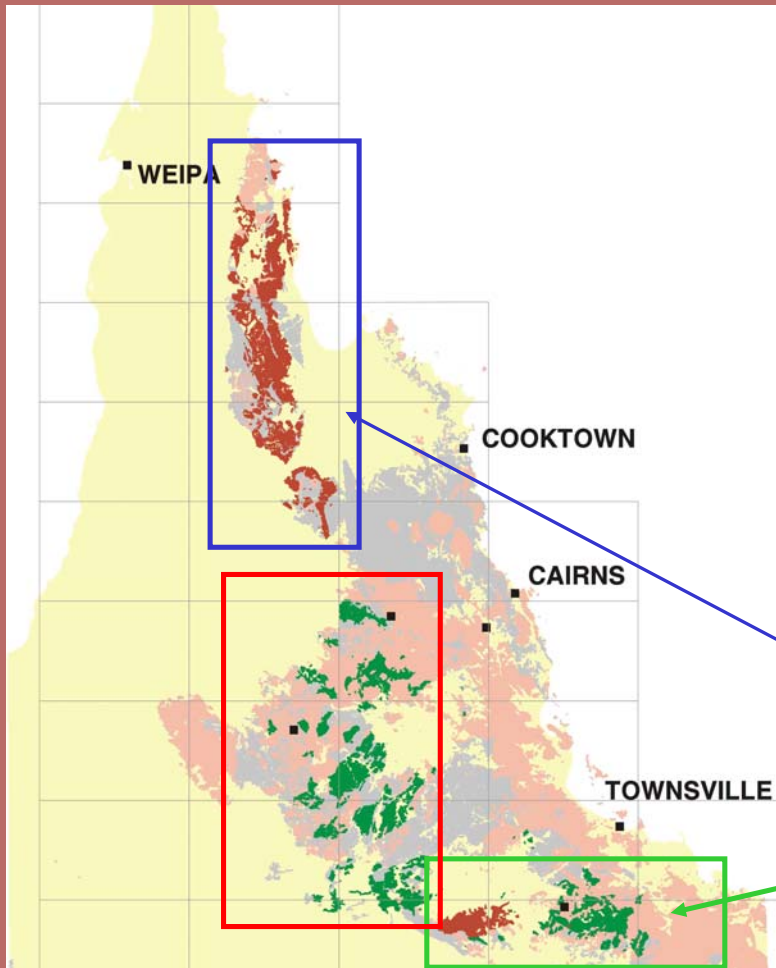
Occurs in

- Cape York
- Georgetown
- Charters Towers

Voluminous



Pama Province: outcrop



Modified from Bain & Haipola (1997) digital data

2 age subgroups

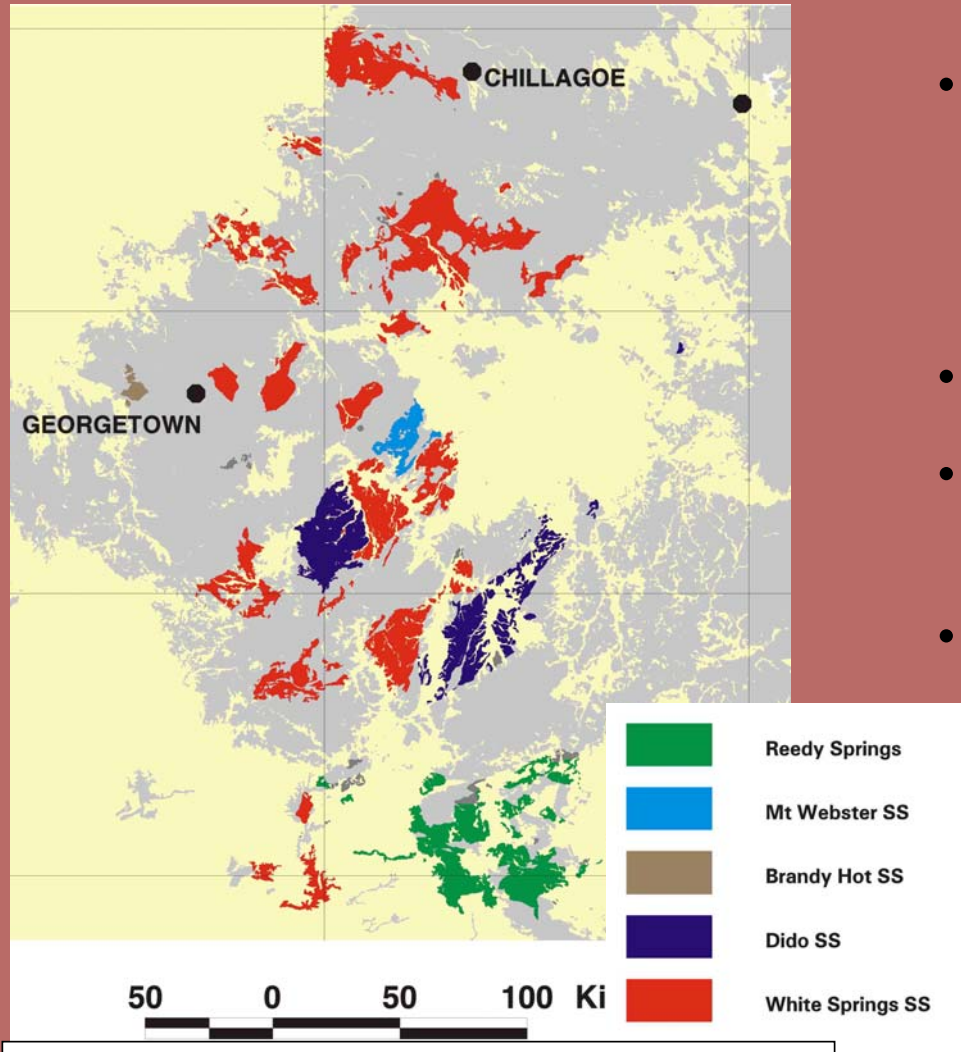
- Silurian to Early Devonian (green)
- Devonian (red)

Pronounced regionality

- Cape York
- Georgetown
- Charters Towers



Pama Province: Georgetown region

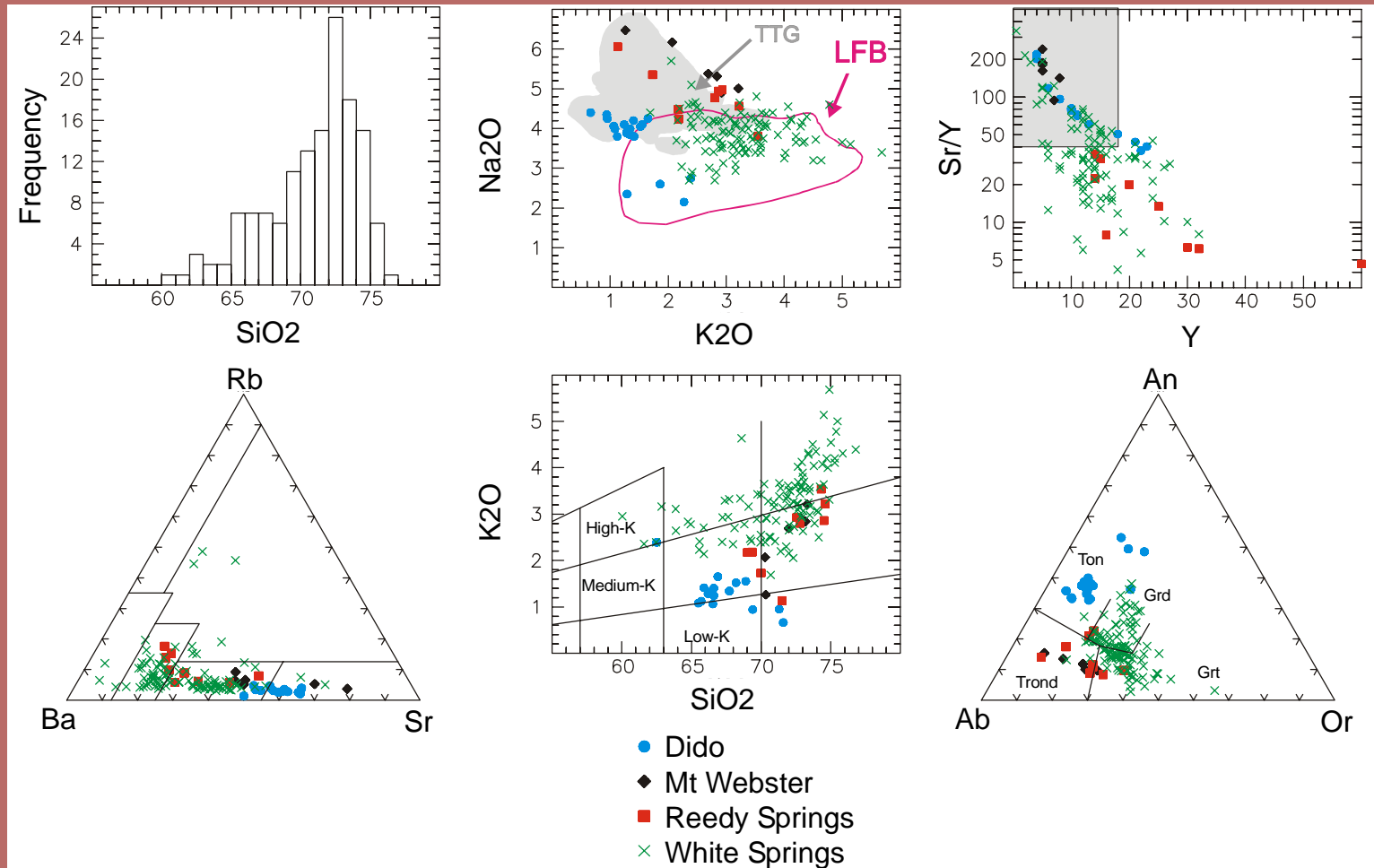


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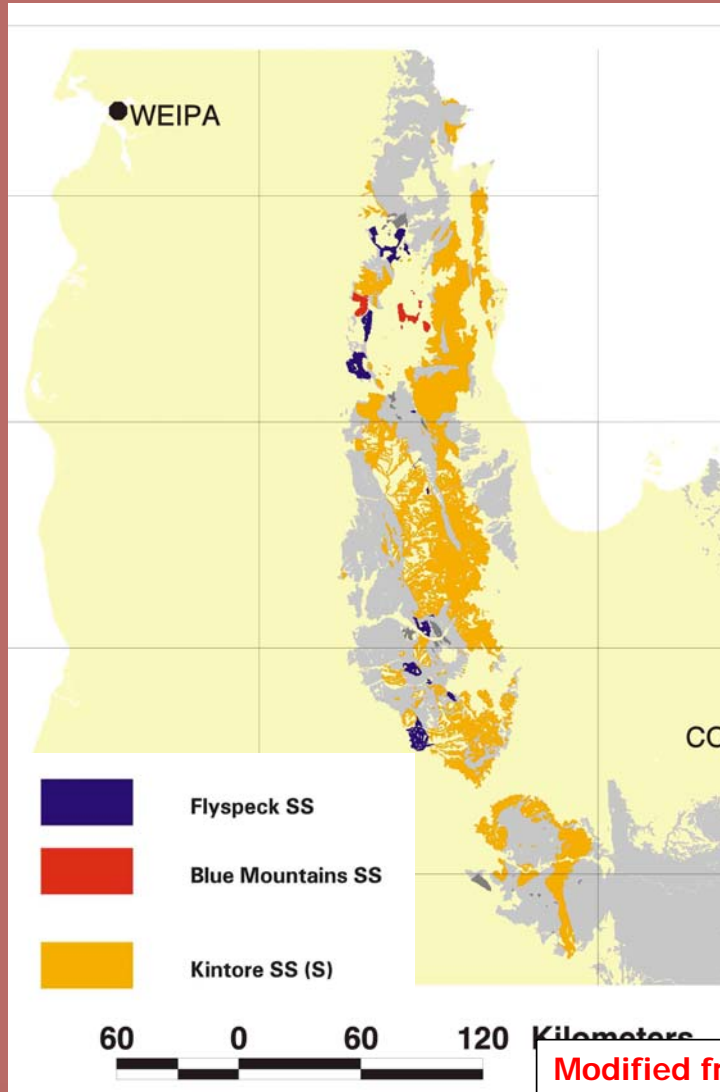
- All I-types: tonalite, trondhjemite & granodiorite, lesser granite
- ca 430 Ma
- White Springs SS main group
- Reedy Springs actually Charters Towers region but chemically more akin to Georgetown



Pama Province: Georgetown region



Pama Province: Coen region



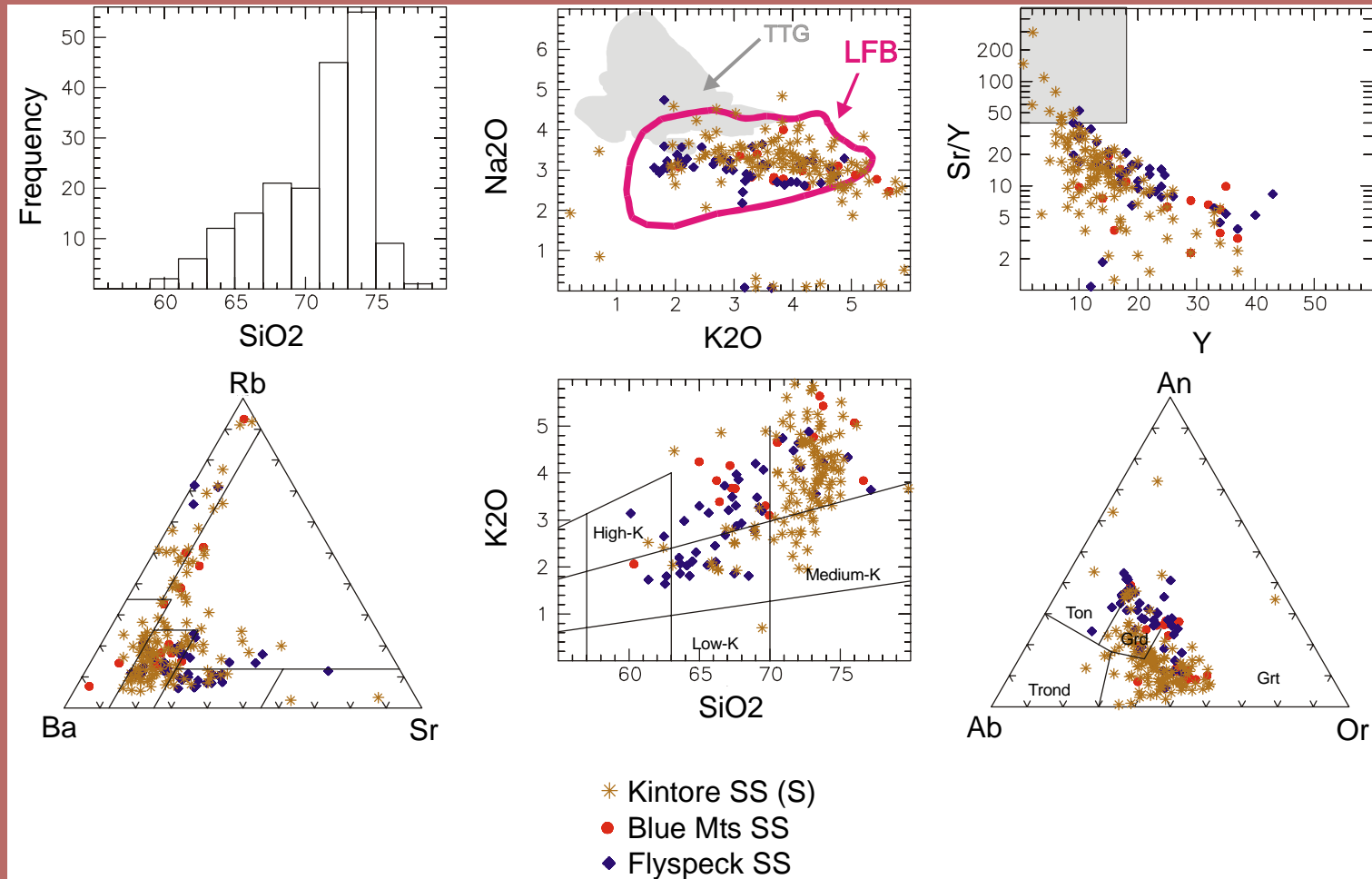
- Dominated by LFB-like S-types (Kintore SS)
- minor I-types (<15%)
- ca 410-390 Ma

- Dominance of S-types, potassic chemistry and younger ages all contrast with Georgetown region

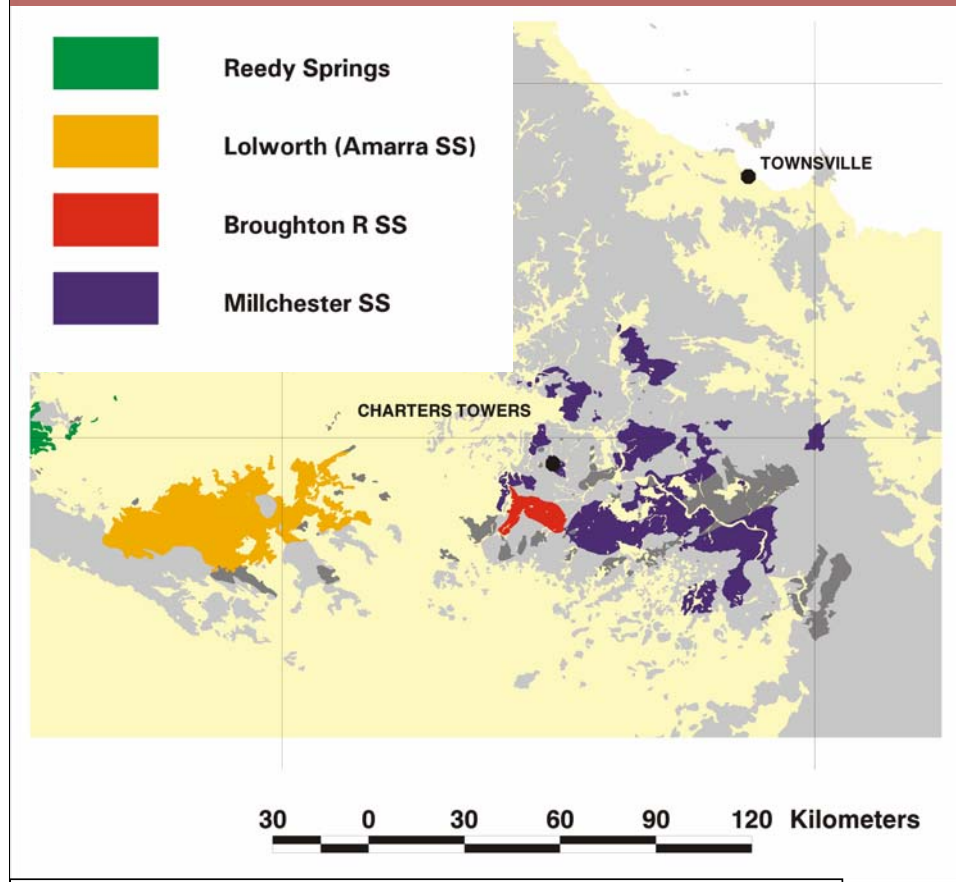
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Pama Province: Coen region



Pama Province: Charters Towers region

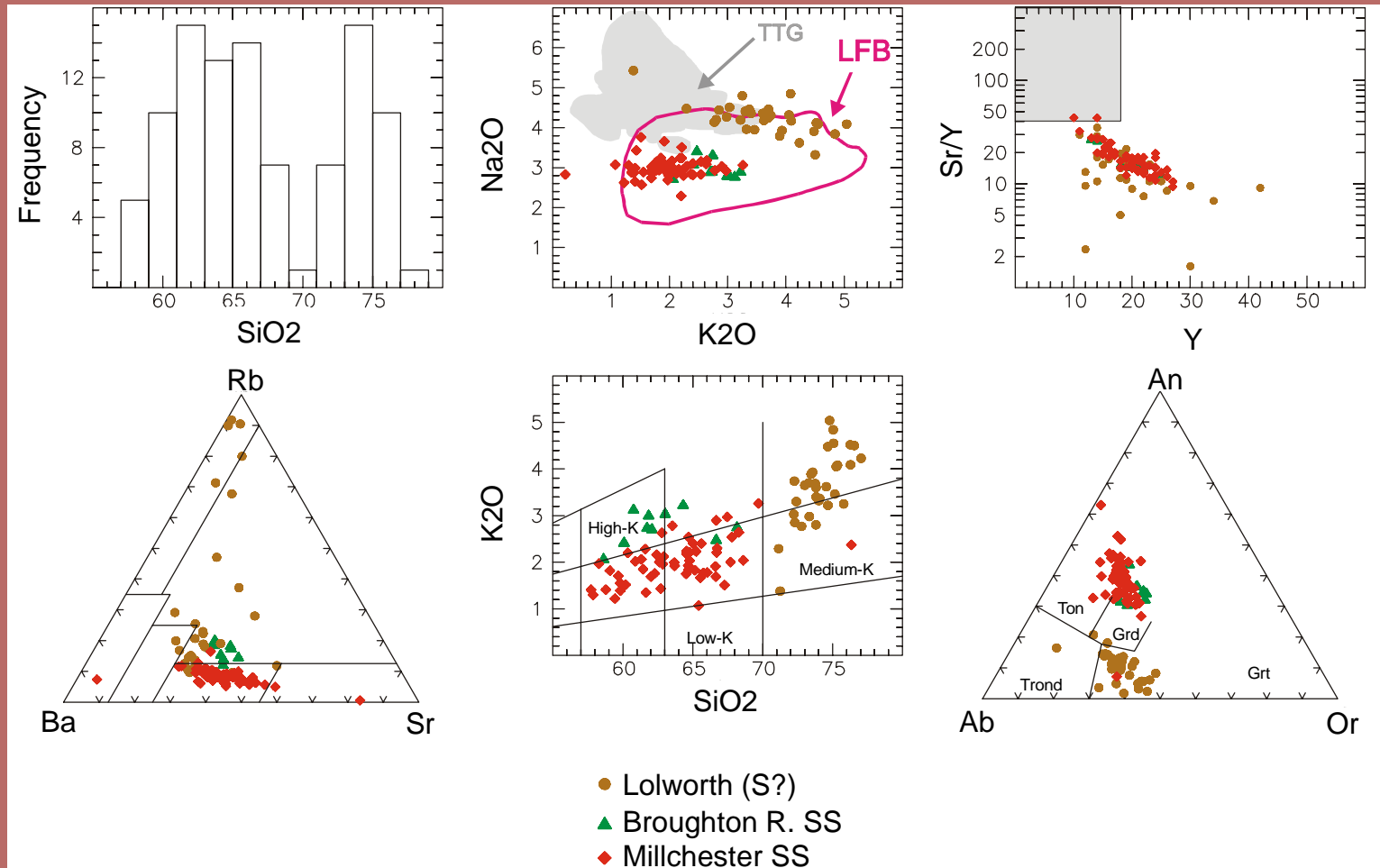


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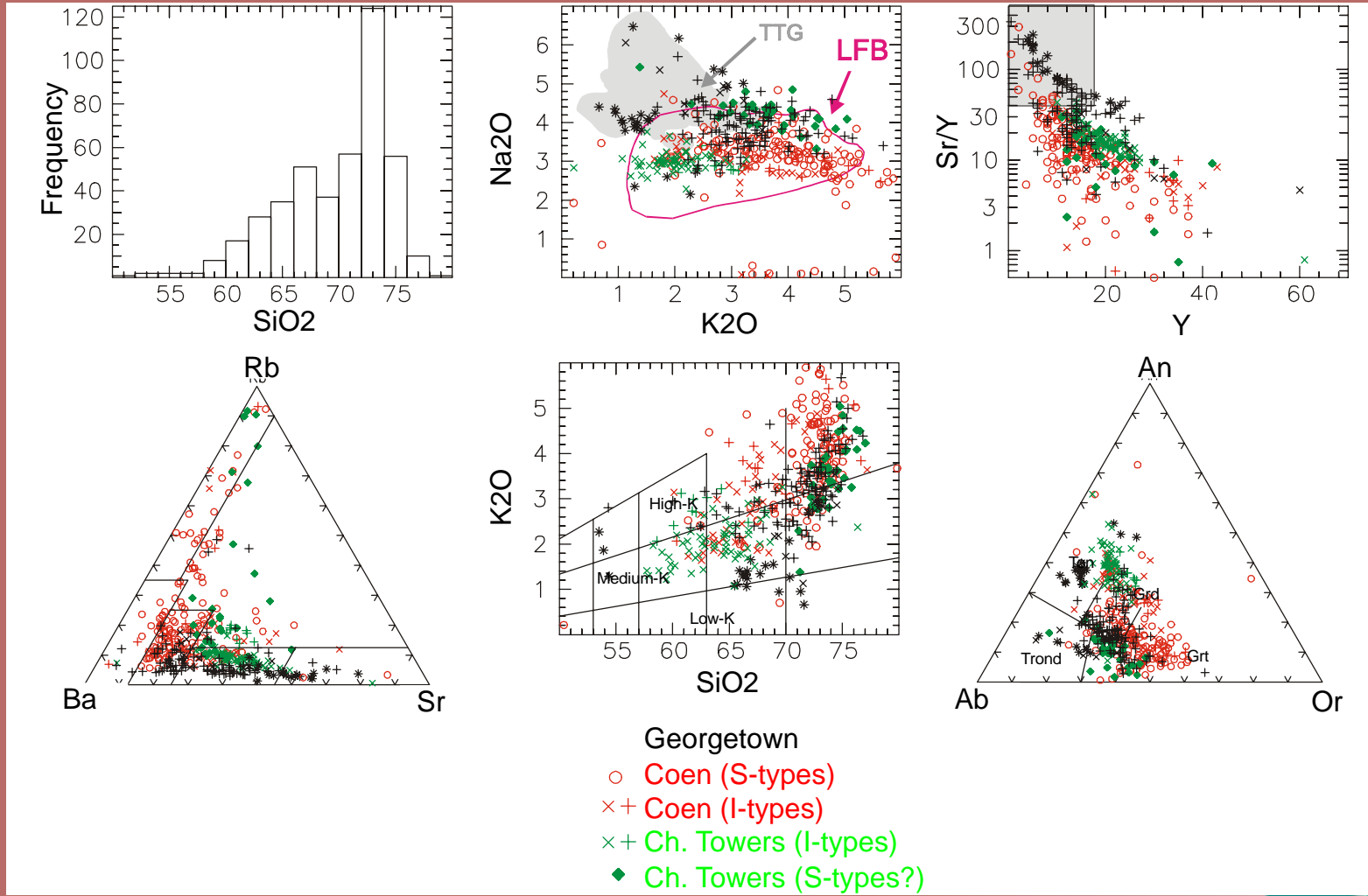
- dominated by granodioritic I-types
- Interpreted (granitic) S-types, confined to Lolworth batholith
- ca 425 to 385 Ma
- overlaps age range of Georgetown and Coen



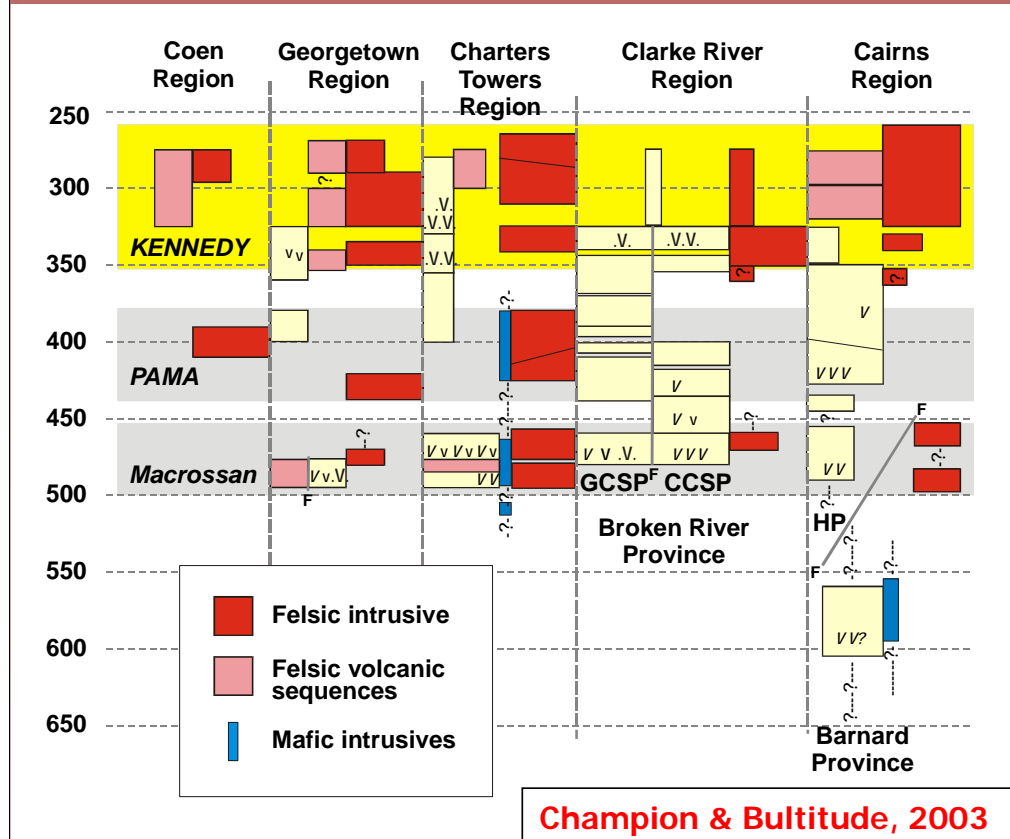
Pama Province: Charters Towers region



Pama Province: All regions



Kennedy Province: Carboniferous-Permian



- Most voluminous magmatism
- most mineralised
- best studied

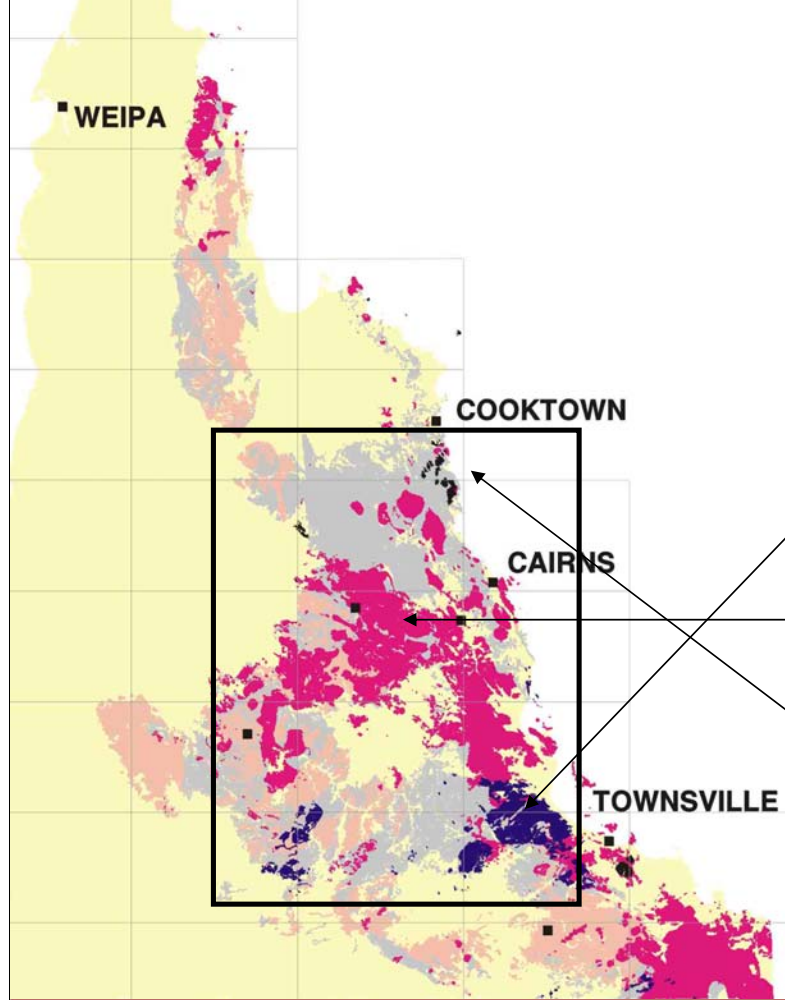
3 age subgroups

- Late Devonian to Early Carboniferous
- Mid-Carboniferous to Permian
- Late Permian



Kennedy Province: Carboniferous-Permian

Modified from Bain & Haipola (1997) digital data

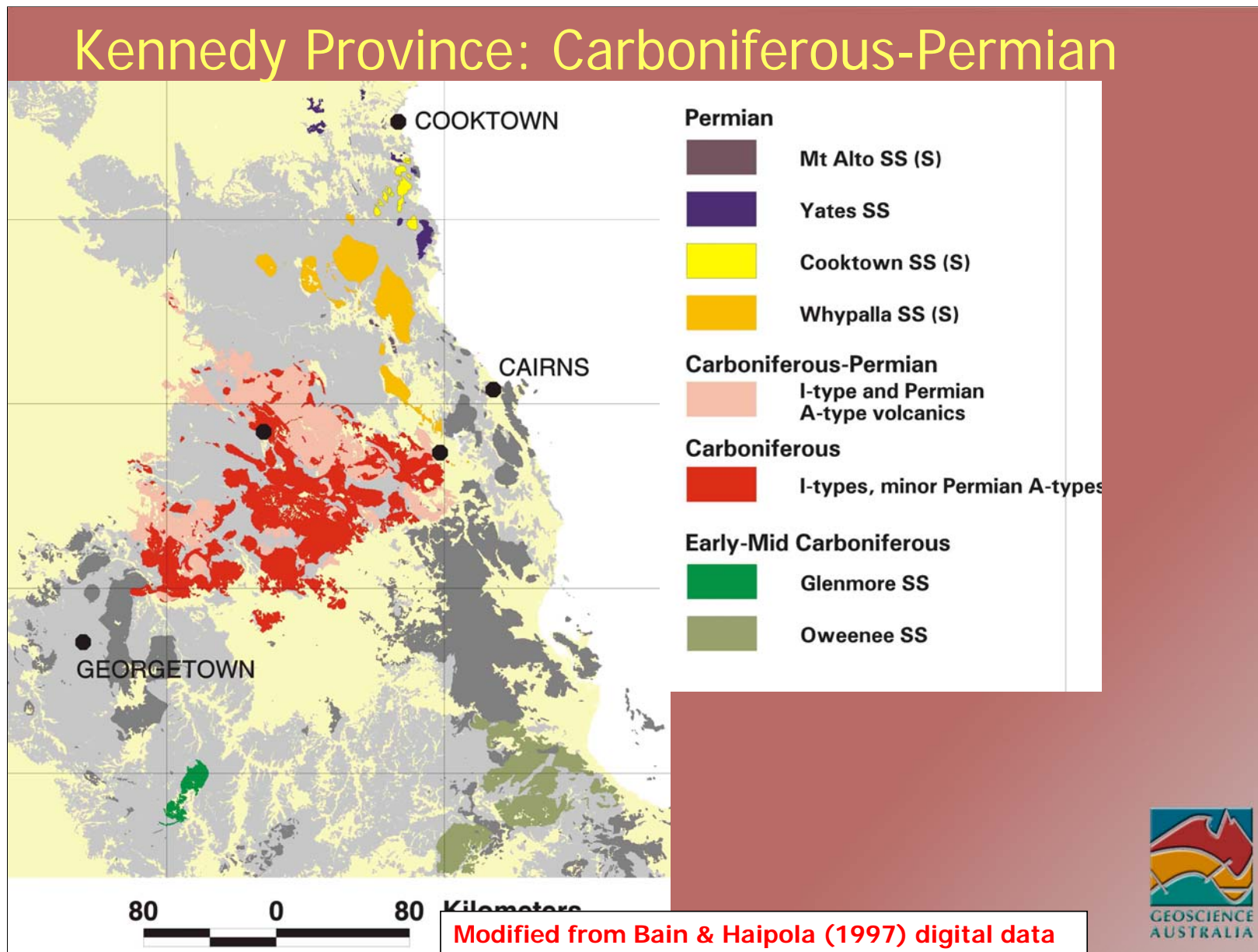


Dominantly siliceous I-types
but includes significant S-
types and lesser A-types

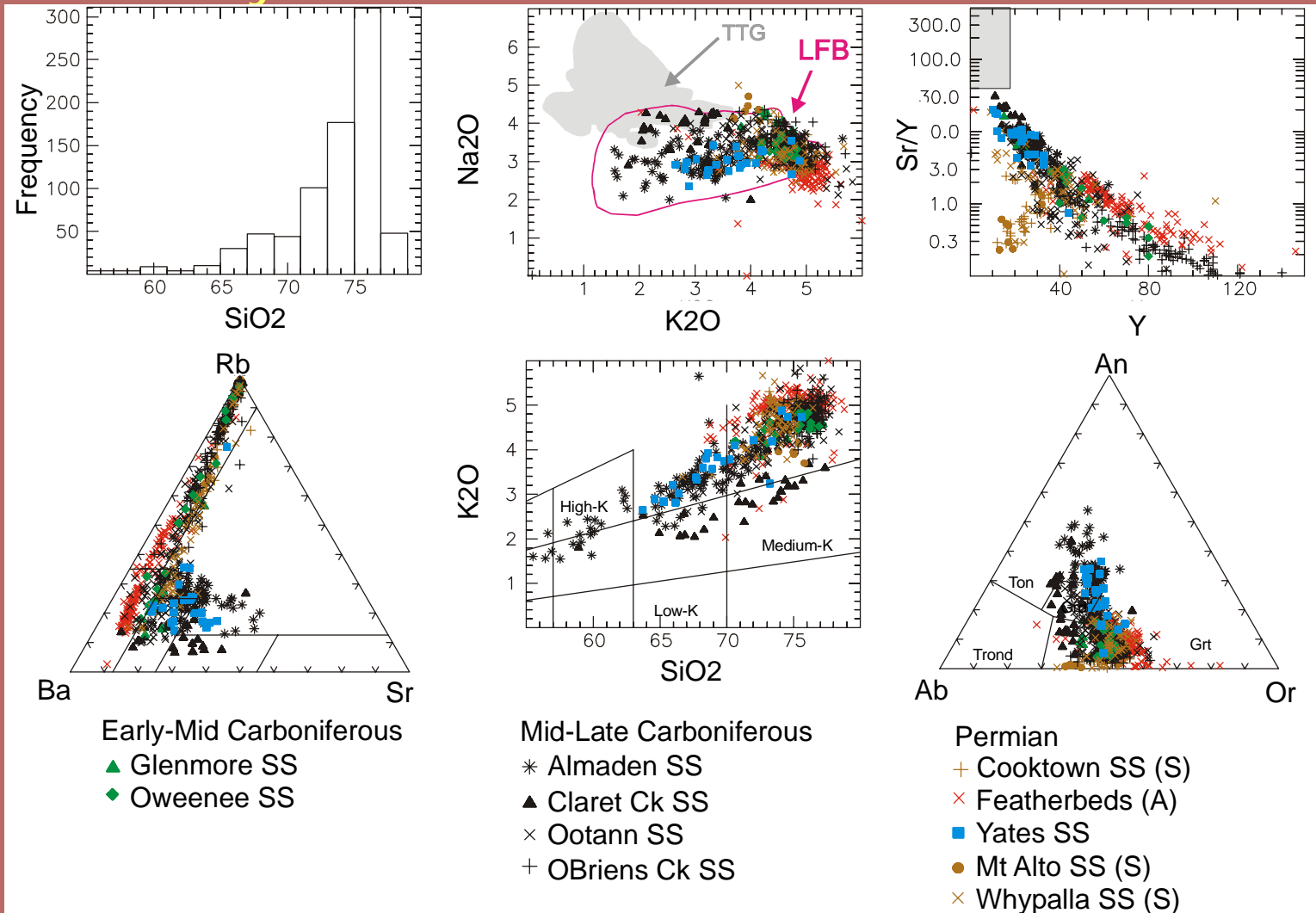
3 age subgroups

- Late Devonian to Early Carboniferous
- Mid-Carboniferous to Permian
- Late Permian





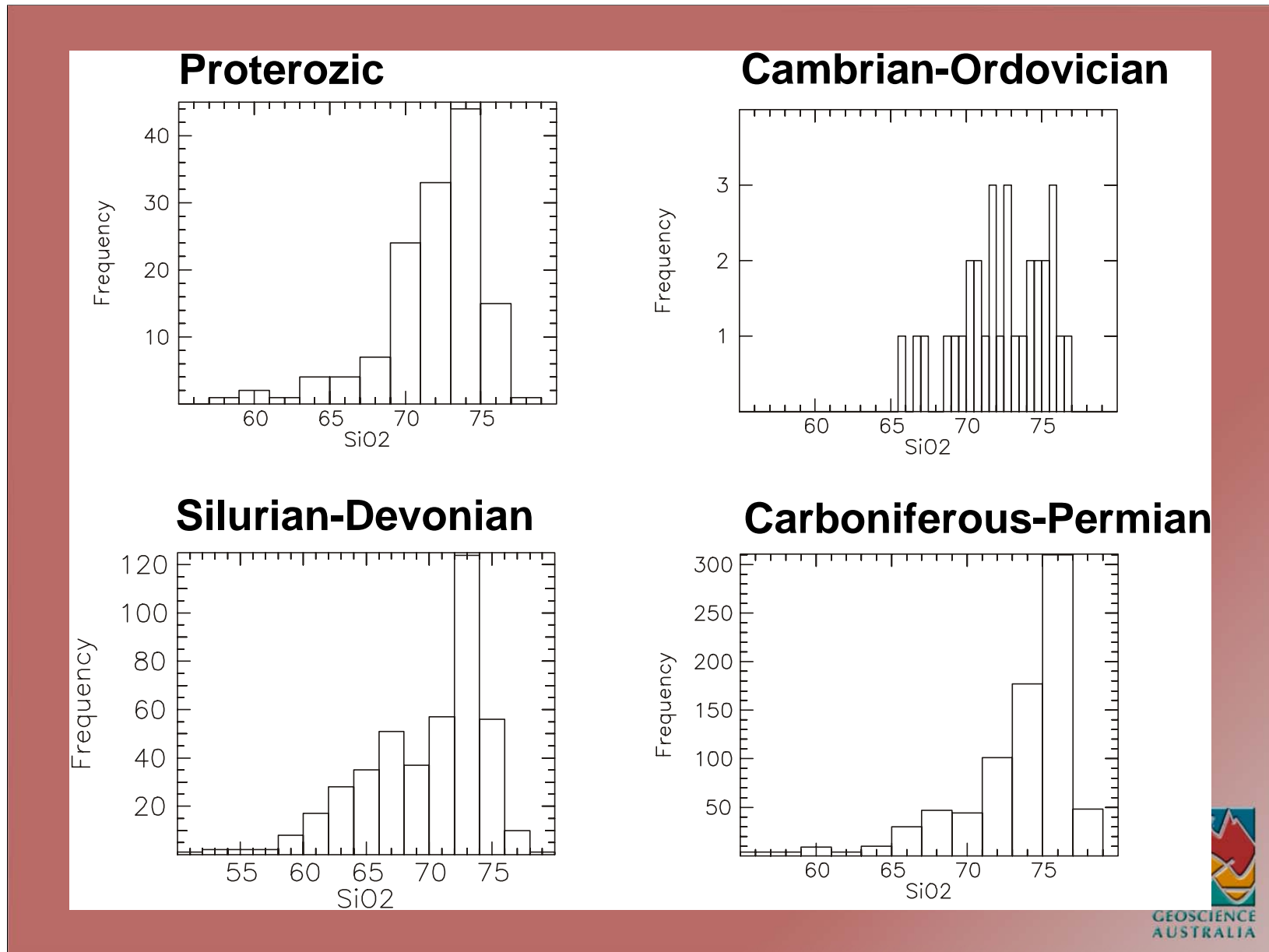
Kennedy Province: Carboniferous-Permian



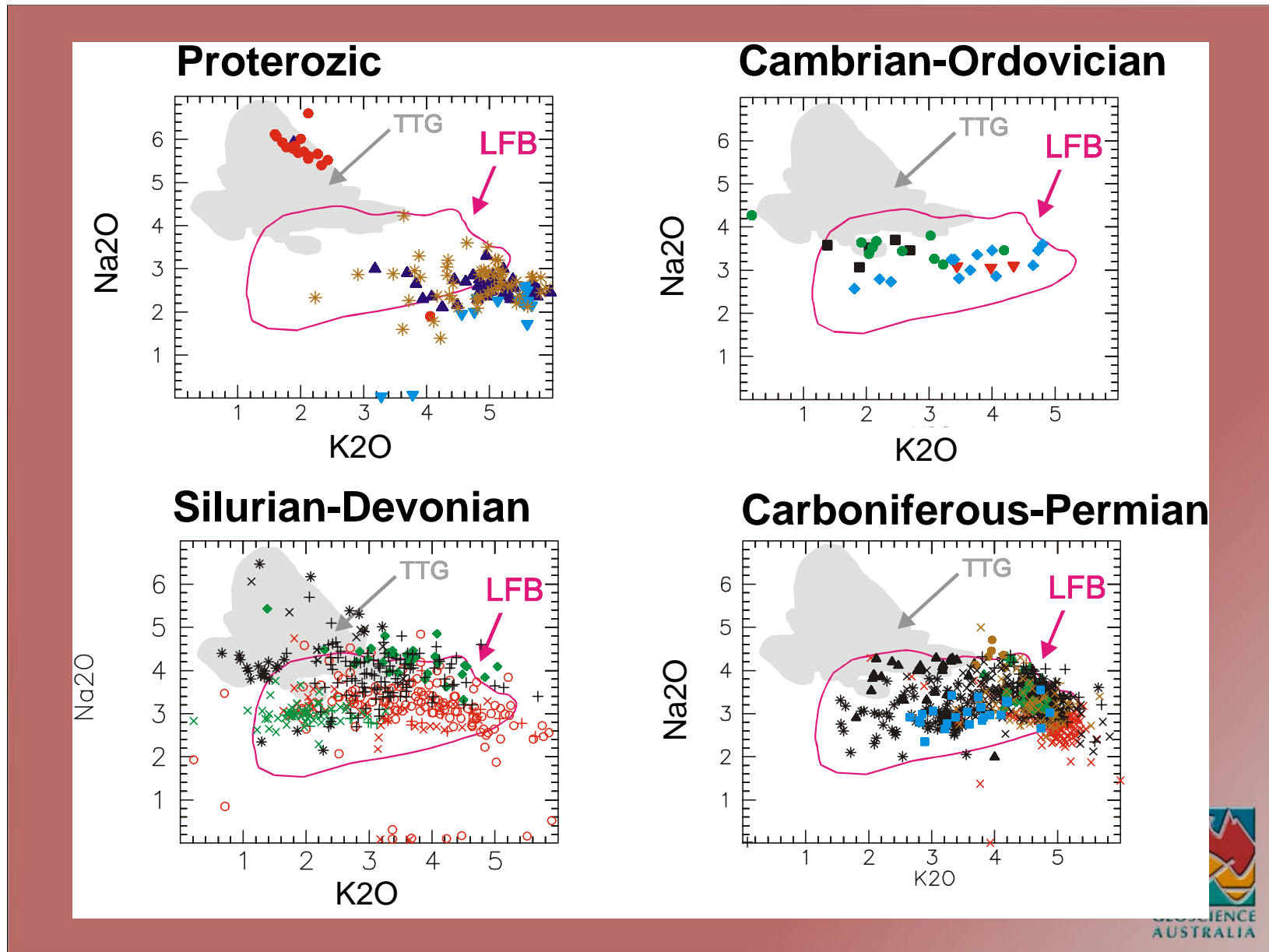
North Old Magmatism

- long lived from Mesoproterozoic to Permian
- 4 episodes spanning some 1200 Ma
- dominantly felsic: monzogranite, granodiorite and syenogranite
- sodic granites largely Proterozoic & Silurian-Early Devonian
- largely I-type, S-types locally dominant, lesser A-types





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Age	Coen region	Georgetown region	Charters Towers	Hodgkinson region	Clarke River region
Permian	Ig If (M)	If Ig A (M)	If Ig (M)	S Ig If A	
Mid Carboniferous - Early Permian	If (Ig)	If Ig (It M)	Ig If (M)	If Ig (M)	(I?) ((S))
Early Carboniferous		If	If (M)	(If, A??)	(If M)
Early – mid Devonian	S Ig (M)		If S? Ig (M)	?(S)	
Silurian – Early Devonian		It Ig (If)	Ig If It (M)		((It))
Late Cambrian – Ordovician		(It)	Ig If S (It M)	S (I)	
Mesoproterozoic	(Ig S)	S It			

Table 1. Granite types for geographic regions of north Queensland. It = dominantly tonalitic I-types, Ig = dominantly granodioritic I-types, If = dominantly granitic (monzogranitic & syenogranitic) I-types, S = S-types, A = A-types, M = mafic rocks (largely gabbros to diorites). Items in bold indicate dominant granite type for that age period and region; items in single or double parentheses indicate only minor or uncommon component, respectively. Data compiled from information in Bain & Draper (1997).

Champion & Bultitude, 2003

