CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

Temporal and Spatial Variations in Magmatism and Transpressional Deformation in the
Middle to Lower-Crust of a Cretaceous Arc, Median Batholith, Fiordland, New Zealand

A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Science in Geological Sciences

By

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ABSTRACT

TEMPORAL AND SPATIAL VARIATIONS IN MAGMATISM AND TRANSPRESSIONAL DEFORMATION IN THE MIDDLE TO LOWER-CRUST OF A CRETACEOUS ARC, MEDIAN BATHOLITH, FIORDLAND, NEW ZEALAND

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We investigate the interplay between melt migration and pluton emplacement, as well as the variation in the style of transpression at different crustal levels in a continental arc. We aim to provide further insights into continental arc architecture and the role of deformation and arc magmatism in forming and modifying continental crust. We explore the timing and duration of plutonism and deformational events across the lower and middle crust, in the Cretaceous Median Batholith in Fiordland, New Zealand. We document the temporal and spatial variations in the development of high and low strain zones and pluton emplacement. These structures are part of a lithospheric-scale network of transpressional shear zones formed within the context of an arc flare-up event in the Fiordland sector of the Median Batholith. Fiordland preserves a history of prolonged (>150 m.y.) Mesozoic convergence along the southeast margin of Gondwana, which was followed by high-temperature metamorphism and exhumation leading to continental breakup in the Late Cretaceous.

Here, we present thirty-nine new LASS-ICP-MS and SHRIMP-RG $^{206}\text{Pb}/^{238}\text{U}$ zircon and titanite dates and Zr-in-titanite temperatures to 1) constrain the timing of a Cretaceous flare-up event in the Separation Point Suite, Median Batholith, and 2) document the spatial and temporal correlation of lithospheric-scale transpressional shear zones during widespread Cretaceous arc plutonism. Our zircon and titanite thermochronology results suggest that Separation Point Suite plutonism in central Fiordland lasted from ~129 Ma to ~110 Ma and overlapped with transpressional deformation in both the middle and lower crust of the Median Batholith. Titanite thermochronology reveal that localized, amphibolite-facies mylonitic (fabrics S_2 , L_2) deformation in the Grebe Mylonite Zone in

Lake Manapouri is hosted in Carboniferous rocks and is dated at ca.122-119 Ma. Coeval deformation during the ca.125-116 Ma interval is recorded in a number of diffuse shear zones (fabrics S_2 , L_2) hosted in Jurassic and Carboniferous plutons located in South Fiord, Lake Te Anau. Additionally, based on our titanite thermochronology and structural data from previous studies, we interpret the Indecision Creek Shear Zone as recording upper-amphibolite-facies transpressional deformation at low crustal conditions between ca.119 and 106 Ma.

Interpreting U-Pb ages in titanite can be a challenging task due to the high concentration of common Pb, and the effects of intragrain Pb diffusion in the (re)distribution of radiogenic Pb and isotopic resetting in titanite. We use textural relations, mineral assemblages, REE and trace element geochemistry data from our samples to distinguish between titanite with different origin (e.g. igneous vs metamorphic), and then interpret titanite U-Pb ages and/or P-T paths with a higher degree of certainty.

Our geochronological and structural data suggest that in the case of the Cretaceous Fiordland arc, magmatism preceded transpressional deformation within the arc. Temporal magmatic patterns indicate an inward focusing of magmatism before the onset of extensional orogenic collapse. Furthermore, our data suggest that shear zones did not play a significant role transporting magma throughout the crust in central Fiordland.

1. INTRODUCTION

Cordilleran arcs are locations of continental crust formation and stabilization (Ducea et al., 2015; Cawood et al., 2013; Kelemen et al., 2013; Jagoutz and Kelemen, 2015). An outstanding question in petrology and continental tectonics is how the architecture of the arc is affected by the interaction between deformation and magmatic processes (Brown and Solar, 1998; Matzel et al., 2006; Weinberg et al., 2009; Sen et al., 2014). The apparent existence of a spatial relationship between regional structures and plutons has fueled the debate on how magmatic emplacement processes are influenced by the stress field within the arc. Additionally, there is uncertainty regarding whether magmatism and deformation are coupled, and the timescales over which coupling may occur (Vigneresse, 1995; Blanquat et al., 1998; Paterson and Schmidt, 1999; Schmidt and Paterson, 2000; Vigneresse and Clemens, 2000). Thus, reconstructing the emplacement and deformation history of batholiths is important to our understanding of magmatic arc construction and continental crust growth.

Most modern continental magmatic arcs occur in oblique convergent settings where strike-slip and contractional regimes are common (Harland, 1971; Fossen et al., 1994; Blanquat et al., 1998). Transpression refers to strike-slip deformation that simultaneously accommodates horizontal shortening and vertical extrusion (Harland, 1971; Fossen et al., 1994; Dewey et al., 1998; Sanderson and Marchini, 1984). Harland (1971) and Blanquat et al. (1998) describe transpression as the dominant deformation process in oblique convergent systems where strain is accommodated within the magmatic arc, due mainly to the development of three-dimensional non-coaxial strain, high heat flow and rheological contrasts. Continental arcs are therefore ideal places to study the interaction between transpressional deformation and generation/transport of granitic melts (Fig. 1).

Transpressional deformation during magmatism has been proposed to be an important process in the mobilization of variable volumes of magma through the continental crust (Weinberg et al., 2004; Whitney et al., 2009; Pereira et al., 2013). Other workers, however, have suggested that changes in the thermal gradient of country rocks

contributed to magma transport (Johnson, 2009; Vigneresse, 1995). The interplay between melt migration and pluton emplacement, as well as the variation in the style of transpression, at different crustal levels is still poorly understood (Paterson and Schmidt, 1999; Blanquat et al., 1998; Vigneresse and Clemens, 2000; Pereira et al., 2013; Bitencourt and Nardi, 2000; Sen et al., 2014). Since, there is currently no consensus on a direct link between these two phenomena as a cause-effect relationship, enhanced understanding of 1) how magma is transferred and emplaced within the continental arc, and 2) whether magmatism facilitates the partitioning of strike slip motions within the arc, can provide new insights into the evolution of continental crust and magmatic arc systems.

Figure 1. A. Three-dimensional geometry of oblique subduction in continental arcs. Transpressional kinematics typifies modern and ancient arc settings (Harland, 1971; Blanquat et al., 1998; Fossen et al., 1994). Strike-slip movement occurs within or adjacent to the magmatic arc, while forearc and back-arc regions are dominated by contractional regimes (Blanquat et al., 1998). (Modified from Blanquat et al., 1998). **B.** Models of deformation in ductile transpressional settings. Experimental models suggest that material vertical extrusion from different crustal levels is mainly controlled by rheological boundaries and local pressure gradients (Czeck and Hudleston, 2004). i) Transpression with slip boundaries, ii) transpression with non-slip boundaries, iii) transpression with oblique simple shear component respect to the shear zone boundaries. (Modified from Czeck and Hudleston, 2004).

Here, we explore the timing and duration of plutonism and deformational events across the lower and middle crust, using as a case study the Cretaceous Median Batholith in Fiordland, New Zealand (Fig. 2). We document the temporal and spatial variations in

the development of high and low strain zones and pluton emplacement. These structures are part of a lithospheric-scale network of transpressional shear zones formed within the context of an arc flare-up event in the Fiordland sector of the Median Batholith (Marcotte et al., 2005; Allibone and Tulloch, 2008; Scott et al., 2009). Fiordland preserves a history of prolonged (>150 m.y.) Mesozoic convergence along the southeast margin of Gondwana, which was followed by high-temperature metamorphism and exhumation leading to continental breakup in the Late Cretaceous (Mortimer et al., 1999; Klepeis et al., 2003, 2007; Allibone et al., 2009b). Fiordland also offers excellent exposures of a nearly complete section of a faulted and tilted magmatic arc section from ca. 5-65 km depth (Klepeis et al., 2004, 2003; Scott et al., 2009).

We present thirty-nine new LASS-ICP-MS and SHRIMP-RG $^{206}\text{Pb}/^{238}\text{U}$ zircon and titanite dates and Zr-in-titanite temperatures to 1) constrain the timing of a Cretaceous flare-up event in the Separation Point Suite, Median Batholith, and 2) document the spatial and temporal correlation of lithospheric-scale transpressional shear zones during widespread Cretaceous arc plutonism. This study aims to provide further insights into continental arc architecture and the role of deformation and arc magmatism in forming and modifying continental crust. Our thermochronology results suggest that Separation Point Suite plutonism in central Fiordland lasted from ~129 Ma to ~110 Ma and overlapped with transpressional deformation in both the middle and lower crust of the Median Batholith. Transpression in the lower crust occurring at ca. 119-106 Ma and deformation in the middle crust dated at 129-116 Ma, preceded the initiation of extensional orogenic collapse at ca. 108 Ma. In central and northern Fiordland, the emplacement of plutons is spatially related to a series of transpressional zones that can be traced for several kilometers, deforming various magmatic rocks in both lower and mid-crustal levels (Marcotte et al., 2005).

Figure 2. Cross section of Zealandia Cordillera prior to termination of Cretaceous arc magmatism showing the geology of the Median Batholith. WFO= Western Fiordland Orthogneiss, SPS= Separation Point Suite, DS= Darran Suite, GMZ= Grebe Mylonite Zone, ICSZ= Indecision Creek Shear Zone (Schwartz et al., 2017)

2. GEOLOGIC BACKGROUND

2.1. Tectonic history of Fiordland

New Zealand is part of a submerged continental mass called Zealandia, that broke apart from the supercontinent Gondwana in the Cretaceous (Luyendyk, 1995; Mortimer et al., 2017). New Zealand records a history of Mesozoic subduction-related plutonism, arc thickening and thinning, leading to extensional orogenic collapse in the Late Cretaceous (Mortimer, 2004).

Voluminous magmatism extended across Fiordland during the Late Cambrian to Early Cretaceous in response to consecutive subduction phases of the Phoenix plate beneath the southeastern margin of the ancient continent of Gondwana (Turnbull et al., 2010). Several major intra-batholith shear zones were active before, during and immediately after plutonism (e.g. Grebe shear zone, Scott et al., 2011; George Sound shear zone, Klepeis et al., 2004; the Indecision Creek shear zone, Klepeis et al., 2004, Marcotte et al., 2005; Gutter shear zone, Allibone and Tulloch, 2008). Convergent tectonics dominated Fiordland from the Late Paleozoic until the onset of extensional tectonics in the mid-Cretaceous (Claypool et al., 2002; Klepeis et al., 2007; 2016; Scott et al., 2011; Mortimer, Tulloch, et al., 1999; Laird and Bradshaw, 2004). The rifting caused by the shift from convergence to extensional tectonics led to the breakup of Zealandia from Gondwana and the opening of the Tasman sea at ca. 84 Ma (Hollis et al., 2004; Laird and Bradshaw, 2004; King et al., 2008; Mortimer, 2008).

2.2. Continental arc magmatism and the Median Batholith

Zealandia can be divided into three provinces: Western Province, Eastern Province and the Median Batholith (Fig. 2 and 3A) (Ireland and Gibson, 1998; Mortimer, Gans, et al., 1999; Meert, 2003; Klepeis and Clarke, 2004; Mortimer, 2004). The Pre-Mesozoic framework of the Western Province comprises Early Paleozoic subduction-related, I-type plutons as well as Paleozoic-Mesozoic volcanic and sedimentary rocks. The Eastern Province includes Late Paleozoic-Mesozoic allochthonous terranes (Allibone et al., 2009a;

Schwartz et al., 2017; Scott et al., 2011; Scott, 2013). The boundary between these two provinces is defined by the Median Batholith (Mortimer et al., 1999; Scott, 2013), which has been offset ~480 km by Cenozoic dextral motion along the Alpine Fault (Little et al., 2005).

2.2.1. Western Province

The Western Province consists of Early Paleozoic metasedimentary rocks intruded by Paleozoic and Mesozoic granitoids that are considered to be the metamorphosed paleo-Pacific Gondwana margin (Mortimer, Tulloch, et al., 1999). Upper crustal level exposures of the Western Province can be found in Nelson-Westland area, whereas middle to lower crustal rocks are exposed in Fiordland area (Ireland and Gibson, 1998). In fact, New Zealand is one of the few places where a complete section of the continental crust is preserved (Fig. 3B). The Takaka and Buller terranes are the most prominent Early Paleozoic metasedimentary terranes, while Late Paleozoic and Early Mesozoic metasedimentary units include the Early Devonian Reefton Group, the Triassic Topfer Formation and the Permian Parapara Group (Cawood et al., 1999; Turnbull et al., 2016).

The Median Batholith records a variety of magmatic and metamorphic events from the Devonian to Early Cretaceous as the result of episodic subduction-related magmatism (Mortimer et al., 1999; Scott, 2013; Schwartz et al., 2017; Tulloch and Kimbrough, 2003). It consists of two compositionally distinct plutonic belts: outboard arc (low-Sr/Y <40, Darran Suite magmatism) and inboard arc (high-Sr/Y >40, Separation Point suite and Western Fiordland Orthogneiss magmatism) (Mortimer et al., 1999; Scott, 2013; Decker et al., 2017; Schwartz et al., 2017; Tulloch and Kimbrough, 2003) (Fig. 2). The boundary between the inboard and outboard belt is marked by the Grebe Mylonite zone in central Fiordland (Scott et al., 2011) (Fig. 4).

The Median Batholith is composed of four different suites: 1) The Western Fiordland Orthogneiss (128-116 Ma) which represents the deepest exposed portions of the arc (>40 km) (Mortimer et al., 1999; Allibone et al., 2009b; Allibone et al., 2009a; Schwartz et al.,

2016); 2) Separation Point Suite (ca. 129-105 Ma), mid-crustal calc-alkaline tonalities and granodiorites with high Sr/Y (>40) ratios (Allibone, Jongens, et al., 2009; Decker et al., 2017; this study); 3) Rahu Suite, Early Cretaceous I- and S-type granites (Early Cretaceous; Turnbull et al., 2010); and 4) Darran Suite low Sr/Y ratios Triassic to Early Cretaceous calc-alkaline plutons (ca. 235-136 Ma; Kimbrough et al., 1994; Muir et al., 1998; Allibone et al., 2009b).

2.2.2. Eastern Province

The Eastern Province is composed of accreted exotic Permian to Early Cretaceous plutonic and volcanic-sedimentary rocks of the Brook Street, Maitai Caples and Murihiku terranes, Waipapa and Torlesse composites (Mortimer, 2008). Other terranes in the Eastern Province include the Late Mesozoic-Cenozoic volcanic rocks and quaternary basin sediments. Cawood et al. (1999) and Mortimer (2008), based on detrital zircon geochronology evidence, have suggested that the Median Batholith and Eastern Province forearc-wedge components were amalgamated by the Early Cretaceous. On the other hand, McCoy-West et al. (2014) argues that accretion may have occurred at ca. 288-261 Ma. Green-schist to low-amphibolite facies metamorphism occurred in the Eastern Province during the Late Paleozoic to Early Mesozoic (Cawood et al., 1999; Mortimer et al., 1999).

2.3. Thermal evolution of the continental crust in Fiordland

Previous thermochronologic studies in central Fiordland identified a thermally weakened lower crust (ca. 118-102 Ma) within the Median Batholith, that could have been controlling the transition from crustal thickening to crustal thinning and extensional orogenic collapse (Klepeis et al., 2016; Schwartz et al., 2016). Prolonged heating is also recorded in Northern Fiordland where high temperatures ($>700^{\circ}\text{C}$) persisted in the lower crust from ca. 135 to 94 Ma (Gebauer, 2016). These periods of high heat flow in the crust overlap with a major pulse of arc magmatism, transpression and granulite- to amphibolite-facies metamorphism in central and northern Fiordland (Daczko et al., 2001b; Scott et al.,

2009; Scott, 2013; Marcotte et al., 2005; Stowell et al., 2010; Schwartz et al., 2016; Klepeis et al., 2016; Gebauer, 2016).

In central Fiordland, the Western Province and the Median Batholith boundary is marked by the Early Cretaceous Grebe Mylonite zone along the Lake Manapouri shore. According to Scott et al. (2009), the Grebe Mylonite zone represents a middle-crust amphibolite facies (600 °C, 6 kbar) nearly-vertical fault zone that accommodated oblique motion along the east margin of Gondwana in the Cretaceous (ca. 129-116 Ma). The metamorphic evolution of northern Fiordland involved emplacement of the Western Fiordland Orthogneiss (ca.125-115 Ma; Tulloch and Kimbrough, 2003; Allibone et al., 2009b) at middle to lower crustal conditions (Daczko et al., 2002a). The region exposes the lower crustal root (depth > 45 km) of a Mesozoic magmatic arc that experienced high-P granulite facies metamorphism (14 kbar) during the Early Cretaceous (Daczko et al., 2001b, 2002b). Cretaceous deformation in the Western Fiordland Orthogneiss was dominated by ductile deformation and recrystallization at pressures of 10-13 kbar and temperatures between 750° and 850° C (Hollis et al., 2004; Klepeis et al., 2007, 2016).

Figure 3. A. Geological map of Fiordland, New Zealand. Fiordland preserves a history of prolonged (>150 m.y.) Mesozoic convergence along the southeast margin of Gondwana, which was followed by high-temperature metamorphism and exhumation leading to continental breakup in the Late Cretaceous (Klepeis et al., 2016; Schwartz et al., 2016; Marcotte et al., 2005). Study areas in central (Fig. 4) and northern Fiordland (Fig. 5) are indicated by red squares. **B.** Map showing the current crustal levels exposure. Fiordland offers excellent exposures of a nearly complete section of a faulted and tilted magmatic arc section from ca. 5-65 km depth (Klepeis et al., 2016; Schwartz et al., 2017, 2016). (Modified after Turnbull et al. (2010)).

2.4. Geologic overview

2.4.1. Paleozoic suites

Fiordland is mostly underlain by plutonic rocks that were intruded into Paleozoic metasedimentary basement. Early Paleozoic volcanic and metasedimentary rocks are widespread across the Western Province in Fiordland and are correlatives with the Buller and Takaka terranes of Nelson-Westland. These rocks are among the oldest rocks of New Zealand and were deposited along Gondwana before the formation of Zealandia continent (Turnbull et al., 2010). Early Paleozoic metasedimentary and metavolcanic units include the Cameron, Fanny Bay and Edgumbe groups, Deep Cove Gneiss, Irene Complex (Gibson, 1982; Scott and Cooper, 2006; Turnbull et al., 2010).

Paleozoic magmatism along the east margin of Gondwana spans from 372 to 305 Ma. Devonian-Carboniferous plutonic suites include the Karamea Suite, S-type granites, Ridge Suite, S-type granitoids and related S/A-type plutons; Foulwind Suite, A-type mafic and granitoid plutons, and Tobin Suite I-type plutons (Allibone et al., 2009b; Tulloch et al., 2009; Turnbull et al., 2016).

2.4.2. Arthur River Complex (ARC)

The Arthur River Complex has been subdivided into three units: the Milford Orthogneiss, the Harrison Gneiss and the Pembroke Granulite (Fig. 5) (Allibone et al., 2009b; Turnbull et al., 2010). The Milford Gneiss contains gabbroic-to-dioritic orthogneisses deformed under upper amphibolite and granulite facies. The Pembroke Granulite is a two-pyroxene hornblende granulite facies metadiorite. The Harrison Gneiss consists of banded dioritic and trondhjemitic upper amphibolite facies gneisses (Bradshaw, 1990; Daczko et al., 2001a; Allibone et al., 2009b; Turnbull et al., 2010).

The southern limit of the Arthur River Complex is marked by the intrusive contact with the Worsley Pluton, and to the west, the Anita shear zone. To the east, the Indecision Creek shear zone separates high-pressure orthogneisses of the granulite belt and the Darran Complex (Marcotte et al., 2005; Turnbull et al., 2010).

2.4.3. Darran Suite (DS)

The Darran Suite extends from Stewart Island to the Darran Mountains of northern Fiordland forming a belt ~15 km wide and 300 km long (Allibone et al., 2009b). The Darran Suite consists of Mid-Jurassic–Early Cretaceous (ca. 230 to 130 Ma), calc-alkalic to alkalic-calcic plutonic (gabbros, diorites, and granites) and volcanic rocks (Muir et al., 1998; Tulloch and Kimbrough, 2003; Scott and Palin, 2008; Allibone et al., 2009b). Darran Suite magmatism is characterized by low-Sr/Y (<40), episodic magmatic record, low magma addition rates (MAR) with a magmatic peak recorded at ca. 168–137 Ma (Kimbrough et al., 1994; Muir et al., 1998; Schwartz et al., 2017).

The Darran Suite extends throughout the outboard part of the Median Batholith to the west of Lake Te Anau, reaching the inboard section of the arc. It includes numerous individual plutons: Mistake Diorite, Hut Leucogranite, Mackay Intrusives, Selwyn Creek Gneiss, Supper Cove Orthogneiss, Mid Poteriteri Pluton, Mt Edgar Diorite, Mt Anau Complex, Mt George Gabbro, Lake Hankinson Complex, Indecision Creek Complex, Beehive Diorite, Howitt Peaks, Halfway Peak, West Kepler Gabbro, Luxmore Mafic Complex, Albert Edward Granite, Cleughearn Pluton, Dana Tonalite, Hanging Valley Granitoid Intrusives, Plateau and Flower Pluton, Glade and Nurse plutonic suites, Darran Leucogranite, Hunter and Murchison Intrusives (Turnbull et al., 2010) (Fig. 4).

2.4.4. Separation Point Suite (SPS)

The Separation Point Suite consists of a group of tonalites, diorites, granodiorites, granites and trondhjemites, with a characteristic high-Sr/Y (>40) (Tulloch and Kimbrough, 2003). The Separation Point Suite was emplaced at mid-crustal conditions with the exception of some small plutons in southwestern Fiordland that recorded upper crustal conditions (Muir et al., 1995; Bolhar et al., 2008; Schwartz et al., 2017). Ages of crystallization for the Separation Point Suite range from ca. 129 to 105 Ma (Bolhar et al., 2008; Allibone et al., 2009b; Schwartz et al., 2017) (Fig. 4). The Separation Point Suite is dissected into two sections by the Alpine fault: Fiordland and Nelson-Westland. In

Fiordland, the Separation Point Suite comprises: North Fiord granite (122.0 ± 1.7 Ma; Bolhar et al., 2008), Takahe granodiorite (122.4 ± 2.2 Ma; Bolhar et al., 2008), Titiroa granite (122.5 ± 1.9 Ma; Bolhar et al., 2008), Refrigerator Orthogneiss (120.7 ± 1.71 Ma; Scott and Palin, 2008), Puteketeke pluton (120.8 Ma; Scott and Palin, 2008) and West Arm Leucogranite (116.3 ± 1.2 Ma; Scott and Palin, 2008). In the Nelson-Westland region the Separation Point Suite includes three units: Pearce granodiorite (118.6 ± 1.5 Ma; Bolhar et al., 2008), Separation Point granite (112.7 ± 1.9 Ma; Bolhar et al., 2008) and Rocky granodiorite (115-119 Ma; Bolhar et al., 2008).

Magmatism in the Separation Point suite is recorded by a single, voluminous high-Sr/Y surge at ca. 129-115 Ma (Schwartz et al., 2017). This magmatic transition, from low-Sr/Y Darran Suite to high-Sr/Y SPS magmatism, documented in Fiordland was associated with a regional transpressional event and the flare-up of Separation Point Suite and Western Fiordland Orthogneiss (Kimbrough et al., 1994; Muir et al., 1998; Schwartz et al., 2017).

2.4.5. Western Fiordland Orthogneiss (WFO)

The Western Fiordland Orthogneiss (ca.125-115 Ma; Tulloch and Kimbrough, 2003; Allibone et al., 2009b) represents a Late Cretaceous expression of arc magmatism on the east margin of Gondwana and is the largest intrusion of the Western Province (>3000 km² plutonic belt) (Bradshaw, 1989; Tulloch and Kimbrough, 2003a; Turnbull et al., 2010). The Western Fiordland Orthogneiss was emplaced at mid-crustal levels (<8 kbar) but re-equilibrated to higher pressures (8-12 kbar). Minor components of the WFO recorded very high-P loading at eclogite-granulite facies during emplacement (~ 18 kbar, Breaksea Orthogneiss), this is consistent with crystallization at the base of a thickened continental crust (de Paoli et al., 2009).

The Western Fiordland Orthogneiss plutons have composition dioritic to monzodioritic and are divided into several major intrusives: Worsley pluton, McKerr Intrusives, Omaki Orthogneiss, Lake Wade diorite, and Misty and Malaspina plutons (Tulloch and Kimbrough, 2003; Allibone et al., 2009b).

Figure 4. Detailed geologic map of central Fiordland and major structural features. Grebe Mylonite Zone (GMZ) is the major structural feature in this area. GMZ is a sub-vertical, amphibolite facies Early Cretaceous ductile shear zone in the middle crust. The GMZ forms the boundary between the Outboard Median Batholith and Eastern Province and the Inboard Median Batholith and the Western Province in Fiordland (Modified after Turnbull et al. (2010))

Figure 5. Detailed geologic map of northern Fiordland and major structural features. Early Cretaceous contractional/transpressional structures shown include Indecision Creek shear zone (ICSZ) and the Pembroke thrust. The ICSZ is a high-pressure upper amphibolite facies shear zone that separates the outboard suite of the Median Batholith from the inboard suite at lower crustal levels (Marcotte et al., 2005). Late Cenozoic structural features include the Anita shear zone and the Alpine fault (Modified after Turnbull et al. (2010))

3. METHODS

Zircon (ZrSiO_4) and titanite (CaTiSiO_5) are common accessory minerals in igneous and metamorphic rocks. These minerals are important process indicators and tools for isotopic dating due to their well-known ability to incorporate abundant U, Th, Hf and REE. In this study, we present thirty-nine new zircon and titanite ages and temperatures to constrain the timing and conditions of Cretaceous deformation and magmatism in Fiordland.

3.1. Sample collection

Samples were collected from Lake Manapouri and Lake Te Anau in central Fiordland during the January 2017 field season (Fig. 4 and 5). Twenty-two zircon samples were analyzed by Sensitive High Resolution Mass Spectrometer Reverse Geometry (SHRIMP-RG) at Stanford University, co-operated by the U.S. Geological Survey, and seventeen titanite-bearing samples were analyzed by Laser Ablation Split-Stream Inductively Coupled Plasma Mass Spectrometer (LASS-ICP-MS) at the University of California, Santa Barbara (UCSB). Three additional samples from the Indecision Creek shear zone were obtained from Dr. Klepeis at University of Vermont and dated in this study by LASS at University of California, Santa Barbara. Additional geochronologic data used throughout this study were compiled from Marcotte et al. (2005) Schwartz et al. (2017, 2016) and Gebauer (2016).

Thirty-five samples were analyzed by thin section petrography using a Leica DM EP petrographic microscope at California State University, Northridge. Petrographic analyses were conducted in order to identify mineral assemblages, microstructures, and textures present in all samples examined for geochronology.

Representative whole rock samples from different lithologic units were chosen, giving priority to post- and syn-kinematic dikes, deformed and undeformed host rocks from plutonic units and rocks from shear zones (Fig. 6). In order to evaluate zircon abundance in the field, a short-wave ultraviolet light was used as a preliminary tool. Additionally,

optical microscopic observations of thin sections and grain mounts were necessary to select inclusion-free zircon- and titanite-bearing samples.

3.2. Sample Preparation and Mineral Separation

Zircon was analyzed using mount grains, and titanite was analyzed in-situ using thin sections and grain mounts. Samples were sorted, cut and prepared in Dunedin, New Zealand at the Geological and Nuclear Sciences (GNS Science) rock laboratory facility. Zircon and titanite were separated using the standard mineral separation techniques in the California State University, Northridge rock lab.

Samples were crushed down to gravel-size using a jaw crusher, and then reduced to sand-size particle with a pulverizer Bico disk mill with plates set to 0.016 mm apart. Dense minerals were extracted from the powder using a Wilfley water table. From there, heavy minerals were sieved at 250 μm , and magnetic minerals were preliminary extracted with a hand magnet. Using a L-1S.G. Frantz Co. Inc. Isodynamic Magnetic separator with increasing amperage (0.1, 0.5, 1.0 and 1.5 amps) heavy minerals were further separated based on their magnetic susceptibility. The remaining non-magnetic material was separated based on density using MI-GEE Methylene Iodide with a specific density of 3.32 g/ml. Individual grains of zircon and titanite were picked using a Leica S8APO binocular microscope and were mounted on a 25mm diameter epoxy disc. Grains selected were clear, colorless and inclusion free. In order to prevent a biased selection, variable sizes of grains were analyzed.

Thin sections and grain mounts were polished and imaged to avoid inclusions, cracks and imperfections during the analytical sessions. Zircon samples were imaged using a cathodoluminescence Gatan MiniCL detector on a FEI Quanta 600 variable pressure setting Scanning Electron microscope (SEM), and titanite grains were imaged with the backscattered electron (BSE) detector of the FEI Quanta 600 SEM at California State University, Northridge.

Figure 6. Field images of deformation and magmatism in Central Fiordland. Areas of Lake Te Anau and Manapouri. **A.** Syn-kinematic (respect fabric in the host roc) felsic dike in the Hunter Intrusives mylonites in Lake Te Anau. **B.** Felsic dikes in Lake Manapouri. **C.** Mylonite zone in Hunter Intrusives. **D.** Boudinaged felsic veins in Murchison Intrusives mylonites in Lake Te Anau.

3.3. U-Pb zircon geochronology

3.3.1. SHRIMP-RG U-Pb zircon geochronology

Uranium-lead zircon data in this study were collected by Sensitive High-Resolution Mass Spectrometer Reverse Geometry (SHRIMP-RG) at Stanford University, co-operated by the U.S. Geological Survey. The analytical session took place from May 22th, 2017 to May 26th, 2017. Twenty-two samples in four different epoxy mounts were analyzed for zircon U-Pb isotopes, as well as trace elements. Depending on abundance from mineral separates, between 60 to 100 zircons were picked and mounted per sample. Rims and cores were targeted for analysis in order to determine the timing of magmatism and/or metamorphism for all samples.

The SHRIMP-RG at the USGS-Stanford laboratory uses an O₂ primary ion beam to induce secondary ions from the target material. The analytical pith was set with a diameter of 25µm and ~1-2 µm depth. Prior to each analysis, the sample surface was cleaned by rastering the primary beam 60-120 seconds. The primary and secondary beam were calibrated to reduce interferences. Epoxy mounts were cleaned with 1N HCL solution and rinse in distilled water. Mounts were dried in a vacuum oven and coated with gold. The mounts were stored at 10 torr for several hours before being moved into the source chamber of the SHRIMP-RG to minimize degassing of the epoxy and isobaric hydride interferences. Measurements were performed at mass resolutions of $M/\Delta M = 8200-8800$ (10% peak height), which removes interfering molecular species for the REE.

The typical zircon trace element suite includes the following: Li, Be, B, F, Na, Al, Si, P, K, Ca, Sc, Ti, Fe, Y, Nb, Zr, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Th, Yb, Lu, Hf, Pb, Th, U. The average duration per each analysis was 20 minutes. Zircon age standards were analyzed every eight analyses to bracket unknowns throughout the analytical session. The primary zircon standard used was Temora-2 (417 Ma, Black et al., 2004), and MADDER was used as a trace element standard (Barth and Wooden, 2010).

Data were reduced using the MS Excel add-in SQUID-2 and Isoplot 4.15 software from Ludwig (2012), following methods described by Williams (1998) and Ireland and Williams (2003). The common Pb correction was based on a model Pb composition from Stacey and Kramers (1975). The measured $^{206}\text{Pb}/^{238}\text{U}$ was corrected for common Pb using ^{207}Pb , and the $^{207}\text{Pb}/^{206}\text{Pb}$ measured was corrected using ^{204}Pb , following methods by Tera and Wasserburg (1972) and Stacey and Kramers (1975). No additional error was propagated for the uncertainty in the common Pb composition. All reported $^{206}\text{Pb}/^{238}\text{U}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ model ages and 2σ uncertainties include error summed in quadrature from the external reproducibility of the standard Temora-2 during an individual analytical session (~24 hours). The 1σ standard error of the mean for the reproducibility of the standard was also propagated in the final $^{206}\text{Pb}/^{238}\text{U}$ weighted mean age. Weighted average and Tera Wasserburg Concordia plot age were calculated using the data from the SHRIMP-RG in Isoplot 4.15 add-in for MS Excel (Tera and Wasserburg, 1972).

Data reduction for the trace element concentrations was performed using MS Excel Add-in software SQUID-2. Average count rates of each element of interest were ratio to $^{30}\text{Si}^{16}\text{O}$ to count for any current drift, whereas the derived ratios for the unknowns were compared to the average concentration of the standard MADDER. Individual grain precision varied based on elemental ionization efficiency and concentration.

3.4. LASS U-Pb titanite geochronology

$^{206}\text{Pb}/^{238}\text{U}$ dates for titanite were collected using the Laser Ablation Split-Stream Inductively Coupled Plasma Mass Spectrometer (LASS-ICP-MS) at the University of California, Santa Barbara (UCSB). Depending on abundance, between 30-50 titanite grains per sample were picked and analyzed. Samples were analyzed either in thin section or grain mounts. Rims and cores were targeted for analysis in order to obtain the timing of cooling and/or recrystallization/new growth for all samples.

The analyses were performed with a Photon Machine 193 nm ArF excimer ultraviolet laser with a HelEx ablation cell attached to a Nu Instruments Plasma high-resolution multi-collector inductively coupled plasma mass spectrometer (LA-MC-ICP-MS), following the methods outlined by Spencer et al. (2013) and Kylander-Clark et al. (2013).

Epoxy-mounted titanite grains and thin sections were prepared with the reference materials BHVO (Basalt Hawaiian Volcanic Observatory USGS), MKED-1 (Spandler et al., 2016), BLR-CSUN and P5701G (390.9 ± 1.1 Ma; Kylander-Clark et al., 2008). Grain mounts and thin sections were ablated with a 50-micron preliminary cleaning shot, and 25-micron pre-ablation spot, and a 25-micron ablation spot. Material was ablated at 4 Hz for 20 seconds, resulting in a pit depth of $\sim 8 \mu\text{m}$.

U-Th-Pb was measured on the Nu Plasma where ^{238}U and ^{232}Th were measured on Faraday cups equipped with 1011ohm resistors, and ^{208}Pb , ^{207}Pb , ^{206}Pb and $^{204}\text{Pb} + \text{Hg}$ isotopes were typically measured on four ETP discrete-dynode electron multipliers. U-Th-Pb isotopic ratios, elemental abundances and their uncertainties were calculated based on

the reference materials (BHVO, MKED-1, BLR and P5701G), and then reduced using Iolite 2.5 software (Paton et al., 2010).

Isotopic ratios for each analysis were plotted by Isoplot 4.15 (Ludwig, 2012) using the concordia diagrams from Tera and Wasserburg (1972). Baselines intensity measurements were obtained before each titanite analysis. The mean and standard error of the measured backgrounds and peaks were calculated after rejection of outliers more than 2 standard errors beyond the mean. LASS traverses were performed in single grains to assess the relationship between grain size, spot location (core-rim), Zr-in-titanite temperature and U-Pb dates. LASS traverses can provide further information to understand the role of volume diffusion, conditions of new growth and/or crystallization or recrystallization in our titanite-bearing samples.

3.4.1. Common Pb correction

Titanite can often incorporate variable amounts of Pb into its lattice during crystallization (Frost et al., 2001). Thus, isotopic data require a detailed assessment and correction of the proportion and composition of the initial common Pb in titanite. Titanite data presented in this study were corrected by common Pb (^{204}Pb) using the regression on the Tera-Wasserburg Pb/U isochron, where the y-intercept will yield the $^{207}\text{Pb}/^{206}\text{Pb}$ isotopic ratio of the common Pb for each individual sample (Storey et al., 2006). Titanite ages are presented as lower intercepts calculated from regression of $^{207}\text{Pb}/^{206}\text{Pb}$ and $^{238}\text{U}/^{206}\text{Pb}$ data by Isoplot 4.15 (Ludwig, 2012).

3.5. Titanium-in-zircon thermometry

Zircon temperatures were calculated following the thermometer proposed by Watson et al. (2006):

$$T(^{\circ}\text{C})_{\text{zircon}} = [[5080 \pm 30]/[6.01 \pm 0.03 - \log(\text{ppm Ti, zircon})]] - 273$$

Geochemical data were reduced using the MS Excel add-in software SQUID-2 via the SHRIMP-RG at Stanford University. Measured values of ^{48}Ti [ppm] in each sample were used and $\text{aTiO}_2=0.7$ based on the scarce presence of rutile or ilmenite in analyzed samples.

Watson et al. (2006) thermometer considered a significant range of pressures: ~1-2 GPa obtained from experiments and data from natural zircons that crystallized at ~0.7-1.1 GPa.

The final average temperature value was calculated using:

$$n = \text{number of analyses per sample.}$$

All temperature error values were calculated at 2σ based on the standard deviation of each ^{48}Ti concentration.

3.6. Zirconium-in-titanite thermometry

Titanite metamorphic temperatures were calculated following the methods from Hayden et al. (2008):

$$T(^{\circ}\text{C})_{\text{titanite}} = [7708 + 960P] / [10.52 - \log(a_{\text{TiO}_2}) - \log(a_{\text{SiO}_2}) - \log(\text{ppm Zr, titanite}) - 273]$$

Zirconium (Zr) concentrations in titanite were obtained by LASS-ICP-MS at University of California, Santa Barbara. Temperature uncertainties result from analytical uncertainties of Zr concentration measurements in titanite, which range from 3-12% (2σ). Activity of $\text{TiO}_2=0.7$ based on the scarce presence of rutile or ilmenite in analyzed samples, and activity of SiO_2 was assumed to equal 1 due to the presence of quartz. Pressures, P, were estimated for samples from central Fiordland at 0.6 GPa, while temperature for samples in northern Fiordland were calculated with a pressure of 1.0 GPa (Daczko et al., 2001b; Scott et al., 2009; Scott, 2013; Marcotte et al., 2005; Stowell et al., 2010; Schwartz et al., 2016; Klepeis et al., 2016; Gebauer, 2016).

4. RESULTS

4.1. Field and Structural observations

We used crosscutting relationships, field observations, new structural data and cross sections to reconstruct the geological and structural history of central Fiordland (Fig. 7). The areas of Lake Te Anau and Lake Manapouri reveal 1) magmatic structures (S_0), 2) amphibolite-facies shallow foliations (S_1) and lineations (L_1) in low-strain deformation settings, and 3) amphibolite-facies moderate and foliations (S_2) and lineations (L_2) in high-strain shear zones.

Strain intensity was defined based on grain size reduction (porphyroclast to matrix ratio), fabric intensity and absence/presence of grain-shape alignment. Structural domains described in Table 1 are lithology and strain-intensity dependent.

- ***Magmatic fabric (S_0):*** is defined by weak igneous layering with alignment of biotite, hornblende and minor titanite.
- ***Low-strain fabric (S_1 and L_1)*** is defined by containing more than 50% porphyroclasts, with a fine-grained matrix surrounding larger grains. The rock has a coarse foliation and weak stretching lineations that mold the porphyroclasts. Weak sub-solidus fabric with alignment of minerals such as hornblende, biotite, and minor titanite.
- ***High-strain fabric (S_2 and L_2)*** is characterized by containing 20-40% porphyroclasts, 80 to 60% of fine-grained matrix. Strong mylonitic fabric with alignment of minerals such as hornblende, biotite, titanite, clinozoisite. In some cases, mica fish, strain shadows and augen of plagioclase may be present.

Table 1. Summary of structural and geological features in central Fiordland, Lake Te Anau and Lake Manapouri areas.

Events	Unit	Structures	Orientations
S ₀	Puteketeke Pluton	Magmatic foliations in tonalite and granodiorite	striking 019-085°, dipping 28-54° southeast
S ₁	Refrigerator Orthogneiss	Coarse-medium subsolidus deformation in tonalite. Weak foliation with hbl, bt. Slightly aligned ttn in the fabric.	striking 097-166°, dipping 46-90° southwest
L ₁		Mineral stretching lineations with aligned hbl, bt, ttn	southern trend with shallow south plunging 12- 40°
S ₂	High strain mylonite zones	Moderate to strong mylonitic foliations with hbl, bt, ttn, czo. Aligned ttn in the fabric.	north-striking 65- 86°, west dipping
L ₂		Mineral stretching lineations with aligned hbl, bt, ttn, czo	southern trend with moderate south plunging 45- 65°

Note: Mineral abbreviations after Whitney and Evans (2010): bt- biotite; czo- clinozoisite; hbl-hornblende; ttn- titanite.

We defined the Puteketeke Pluton magmatic fabric (S₀) by weak igneous layering with oriented biotite with minimal alignment of other minerals. Magmatic foliation observed in Puteketeke Pluton is significantly shallower relative to the high strain zones, commonly dipping 20°-50°. Macroscale post-Puteketeke Pluton magmatic fabric z-type folds were measured in South Arm, Lake Manapouri, with limbs oriented 041°, 32°SE and 045°, 68°SE and top-to-the-right vergence towards the SW, and axial surface 040°, 58°SE and hinge line 08°/055°. Minor Chevron-style folding was observed within the Puteketeke Pluton, near the Grebe Mylonite Zone in Lake Manapouri. Folding is characterized by SW-vergent with fold limbs oriented from 041° to 045° and dips 32° to 68° SE.

We characterized subsolidus deformation (S₁) in Refrigerator Orthogneiss by discontinuous lenses of recrystallized biotite around plagioclase and quartz grains. Low-

strain, weak foliation (S_1) is marked by the alignment of biotite, hornblende and titanite. Foliation strikes 097° - 166° with dips of 28° - 54° southwest. Mineral lineation (biotite, hornblende), L_1 , average a southern trend and south plunging 12° - 40° . Subsolidus deformation (S_1) is cut by postkinematic dikes.

High-strain shear zones were identified in the Grebe Mylonite Zone in Lake Manapouri and South Fiord of Lake Te Anau (Fig. 38). These high strain shear zones are nearly vertical, and parallel the overall trend of the Median Batholith. The Grebe Mylonite Zone is a ductile shear zone hosted in Carboniferous plutons that extends northward through Lake Manapouri, North of the Kepler Mountains (Scott, 2013). The northern extension of the Grebe Mylonite Zone is projected to South Fiord, Lake Te Anau as a number of diffuse (~15 km width) shear zones hosted in Jurassic and Carboniferous plutons.

High strain shear zones in Lake Manapouri and Lake Te Anau display north-striking and steeply west-dipping (45° - 84°) S_2 fabrics, with moderate (47° - 64°), south-plunging L_2 mineral lineations. S_2 foliation is defined by penetrative clusters of plagioclase, quartz, biotite, hornblende and minor titanite. S_2 also displays undulose extinction in quartz grains, quartz and plagioclase bands, and elongated mineral assemblages (biotite, hornblende, and minor titanite and clinozoisite). Interpretation of quartz and plagioclase microstructures (Hufford, 2018; McGinn, 2018) and outcrop-scale fabrics in Lake Te Anau and Manapouri indicate an overall regional oblique sinistral west-side-down sense of motion relative to the Median Batholith trend (Grieve, 2015). The high-strain zones show a sinistral component of displacement parallel to the arc and arc-normal shortening, resulting in arc-parallel sinistral oblique slip and strike-slip displacements.

Figure 7. Structural map. Black arrows show lineation data. Steep lineations are characteristic of high-strain shear zones. Data were collected in 2017-field Fiordland season and compiled from Turnbull et al. (2010). Geologic map modified after Turnbull et al. (2010).

4.2. Petrography

Samples in this study were collected from Lake Te Anau and Lake Manapouri in central Fiordland, and South of Milford Sound in northern Fiordland. Geologic maps with sample location are found in Figure 4 and 5. Petrographic descriptions and locations of each individual sample are provided in Table 2.

4.2.1. Separation Point Suite

Refrigerator Orthogneiss

We analyzed seven Refrigerator Orthogneiss samples from Lake Te Anau and Lake Manapouri. Samples 17NZ12, 17NZ11, 17NZ25A and 17NZ25B were collected from South Fiord, Lake Te Anau, and samples 17NZ127, 17NZ124A and 17NZ124B from Lake Manapouri.

The typical mineral assemblage in Refrigerator Orthogneiss consists of plagioclase, quartz, biotite hornblende, titanite, with minor zircon, opaque minerals and apatite (Fig. 8). Samples 17NZ12 (Fig. 8A), 17NZ11 (Fig. 8B) and 17NZ25A (Fig. 8C) are hornblende-biotite tonalites. The Refrigerator Orthogneiss is the only Separation Point Suite pluton that exhibits evidence for sub-solidus deformation. Sub-solidus deformation is defined by discontinuous lenses of elongated biotite and hornblende anastomosing around quartz-plagioclase assemblages. Plagioclase grains are elongate with irregular to well-developed curved boundaries.

Three post-S₁ (Refrigerator Orthogneiss fabric) dikes (17NZ127, 17NZ124B, 17NZ25B) were analyzed to constrain the timing of the sub-solidus deformation (see section 4.2 for further results). Samples 17NZ127 (Fig. 8D), 17NZ124B and 17NZ25B are leucogranite to pegmatite tonalitic dikes consisting mainly of plagioclase, potassium feldspar, quartz, and minor amounts of biotite, titanite and zircon.

Figure 8. Refrigerator Orthogneiss representative petrographic photomicrographs showing textures and mineral assemblages. **A.** Sample 17NZ12, red dashed-lines show deformed layer (S_1) of bt and ttn **B.** Sample 17NZ11, showing in red deformed layer (S_1) of bt, hbl and ttn **C.** Sample 17NZ25A **D.** Sample 17NZ127 felsic post-kinematic dike. Mineral abbreviations after Whitney and Evans (2010). Cross-polarized light, base of photo 2.5 mm.

Takahe Granodiorite

Samples 17NZ81 and 17NZ78B are medium-coarse grained undeformed granodiorite to granite. Albite twins are present in plagioclase grains. Quartz grains are subhedral to anhedral. Samples were collected in South Fiord Lake Te Anau.

Puteketeke Pluton

We collected samples 17NZ98, 17NZ104, 17NZ100 from South Arm of Lake Manapouri. These samples are fine-grained biotite tonalite. Typical mineral assemblage consists of amphibole, biotite, plagioclase, potassium feldspar, quartz, and minor amounts of titanite, apatite, opaque minerals and zircon. Primary igneous textures are preserved throughout the Puteketeke Pluton, but a weak magmatic foliation (S_0) defined by biotite-

hornblende are present in some outcrops. Undulose extinction of quartz grains and albite twins in plagioclase grains are found in some of the samples.

West Arm Leucogranite

Samples 17NZ137, 17NZ134, 17NZ117 and 17NZ114 were collected in West Arm of Lake Manapouri where outcrops of West Arm Leucogranite are found as undeformed leucocratic tonalitic to granitic dikes, hornblende-biotite to biotite tonalite orthogneiss. Samples 17NZ117 (Fig. 9E) and 17NZ137 correspond to biotite tonalite to granodiorite. Figure 9A, B and C show samples from Percy Saddle area (17NZ139, 17NZ140 and 17NZ141) correspond to outcrops of undeformed leucocratic granite to tonalite plutons. Typical mineral assemblages for West Arm Leucogranite consist of potassium feldspar, plagioclase, quartz, biotite, with minimum amounts of opaque minerals, apatite, titanite and zircon. Albite twins in plagioclase grains are found throughout most of samples (Fig. 9). Samples 17NZ114 (hbl-bt tonalite) Fig. 9D) and 17NZ134 (biotite tonalite) (Fig. 9E) show higher proportion hornblende, clinozoisite and biotite relative to samples 17NZ117, 17NZ139, 17NZ140 and 17NZ141.

Figure 9. West Arm Leucogranite representative petrographic photomicrographs showing textures and mineral assemblages. A. Sample 17NZ139 B. Sample 17NZ140 C. Sample 17NZ141 D. Sample 17NZ114 E. Sample 17NZ117 F. Sample 17NZ134 G. Sample 17NZ137. Mineral abbreviations after Whitney and Evans (2010). Cross-polarized light, base of photo 2.5 mm.

4.2.2. Carboniferous and Darran Suites

A deformational area of high-to-medium strain (~8km length, east to west) was identified in South Fiord, Lake Te Anau. Nine samples were analyzed for geochronology. These samples were mapped by Turnbull et al. (2010) in two different units of the Darran Suite: Hunter Intrusives, samples 17NZ72A (Fig. 10A), 17NZ60 (Fig. 10B), 17NZ55A

(Fig. 10C), 17NZ44) and Murchison Intrusives (17NZ40, 17NZ43A, 17NZ43B). According with our geochronology results (see section 4.3) some samples (17NZ44, 17NZ43A and 17NZ43B) yielded Carboniferous dates.

The Darran Suite intrusives (17NZ72A, 17NZ60, 17NZ55A) include foliated diorite, quartz diorite and tonalite. Samples 17NZ55A and 17NZ60 are medium-grained mylonitized hornblende-biotite diorite and tonalite, with deformed bands of plagioclase and subhedral amphibole, biotite, titanite, and occasionally quartz. Sample 17NZ72A, located in South Fiord Lake Te Anau, is a fine-grained hornblende diorite protomylonite. Weak foliation defined by alignment of biotite and hornblende. Post-kinematic granitic dikes were identified in different outcrops.

Carboniferous Suite Intrusives samples, 17NZ44, 17NZ43A (Fig. 10D), and 17NZ43B, are composed of mylonitized diorite to tonalite and pegmatite post-kinematic dike (17NZ43B). Samples 17NZ44 and 17NZ43A show mylonitic foliation (Fig. 10). The development of foliation (S_2) is characterized by lenticular biotite and/or hornblende grains, elongated titanite and polygonal aggregates of plagioclase and/or quartz. Common microscopic textural features of the Carboniferous and Darran Suite intrusives samples comprise variable degrees of sericitization and chloritization and degrees of mylonitization (i.e. protomylonite to mylonite).

Figure 10. Darran and Carboniferous suite representative petrographic photomicrographs showing textures and mineral assemblages. **A.** Sample 17NZ72A **B.** Sample 17NZ60, showing in red deformed layer (S_2) of bt and ttn **C.** Sample 17NZ55A, showing in red deformed layer (S_2) of bt, hbl, czo and ttn **D.** Sample 17NZ43A, showing in red deformed layer (S_2) of bt, hbl and ttn. Mineral abbreviations after Whitney and Evans (2010). Cross-polarized light, base of photo 2.5 mm.

4.2.3. Grebe Mylonite Zone

We collected samples 17NZ96 (Fig. 11A), 17NZ95B (Fig. 11B) and 17NZ94 from the Grebe Mylonite Zone, located in South Arm of Lake Manapouri. Mylonitic foliation (S_2) is characterized by lenticular hornblende and/or biotite grains, alignment of titanite and polygonal aggregates of K-feldspar, plagioclase and quartz. Anastomosing layers rich in titanite are found in sample 17NZ95B. Overall, samples reflect amphibolite facies mineral assemblages (hornblende, biotite, plagioclase, clinozoisite, titanite). Albite twinning is preserved in plagioclase and quartz grains have lobate grain boundaries. Different degrees of chemical alteration (chlorite+sericite) are observed throughout the Grebe Mylonite Zone samples.

Sample 17NZ96 yielded a mylonitic foliation orientation of $170^{\circ}, 87^{\circ}$ SW and a stretching lineation (L_2) (hornblende or biotite) of $64^{\circ}/184^{\circ}$. In the proximities of sample 17NZ95B measurements of $190^{\circ}, 86^{\circ}$ SW foliation and stretching lineation (hornblende or biotite) $61^{\circ}/232^{\circ}$ were observed.

Figure 11. Grebe Mylonite Zone representative petrographic photomicrographs showing textures and mineral assemblages. **A.** Sample 17NZ96 **B.** Sample 17NZ95B. Mineral abbreviations after Whitney and Evans (2010). Cross-polarized light, base of photo 2.5 mm.

4.2.4. Indecision Creek Shear Zone

Samples 0213K1 (Fig. 12A) 0308L1 (Fig. 12B) and 0308F (Fig. 12C) were collected in the northeast of Sutherland Sound by Dr. Klepeis at University of Vermont (see Figure 5).

Samples 0308F and 0213K1 consist of high-strain coarse-grained garnet diorite gneiss and garnet diorite mylonite, respectively. The gneissic layering in sample 0308F (garnet diorite gneiss) is defined by melanosome rich in biotite, hornblende, titanite and clinozoisite, and leucosome rich in quartz and plagioclase. Grains of biotite and minor hornblende are bent, and plagioclase grains display sharp regular grain boundaries. Sample 0308L1 (diorite protomylonite) contains plagioclase, quartz, garnet, biotite, clinozoisite, muscovite, titanite, ilmenite and opaque minerals. Stretching lineations are defined by biotite and/or hornblende.

Figure 12. Petrographic photomicrographs showing textures and mineral assemblages present in Indecision Creek samples. **A.** Sample 0213K1 **B.** Sample 0308L1 **C.** Sample 0308F. Mineral abbreviations after Whitney and Evans (2010). Crossed polars, base of photo 2.5 mm.

Table 2. Sample locations and petrographic descriptions.

Sample	P Collection #	Unit	Rock type	Description	Mineral assemblages	Location	E	N
17NZ4A	89869	Lake Hankinson Complex	bt-hbl diorite mylonite	Moderate to strong mylonitic foliation. Host of a postkinematic felsic dike.	qz, plg, bt, hbl, ttn, zrc, czo	South Fiord, Lake Te Anau	1163910	4968835
17NZ11	89880	Refrigerator Orthogneiss	hbl-bt tonalite	Moderate foliation S ₁ . Low strain. Ttn aligned with S ₁ .	plg, qz, kfs, qz, bt, hbl, ttn, ap, zrn, opq	South Fiord, Lake Te Anau	1167213	4969814
17NZ12	89881	Refrigerator Orthogneiss	hbl-bt tonalite	Moderate foliation S ₁ . Low strain. Ttn aligned with S ₁ .	plg, qz, kfs, qz, bt, hbl, ap, ttn, zrn, opq	South Fiord, Lake Te Anau	1167229	4969851
17NZ25A	89895	Refrigerator Orthogneiss	hbl-bt tonalite	Moderate foliation S ₁ . Low strain. Ttn aligned with S ₁ . Localized anastomosing bands of qtz-plg.	plg, qz, kfs, qz, bt, hbl, ttn, ap, zrn, opq	South Fiord, Lake Te Anau	1166923	4968027
17NZ25B	89896	Refrigerator Orthogneiss	pegmatite dike (post-kinematic)	Postkinematic dike. Cuts fabric in host.	plg, kfs, qz, zrn	South Fiord, Lake Te Anau	1166923	4968027
17NZ40	89906	Murchison Intrusives	diorite mylonite	Moderate to strong foliation S ₂ . high strain fine-grained diorite.	plg, qz, hbl, czo zrn, opq, chl, ser	South Fiord, Lake Te Anau	1170536	4968301
17NZ43A	89913	Murchison Intrusives	diorite mylonite	Moderate to strong foliation S ₂ . High strain. mylonite medium-grained. Ttn aligned in fabric.	plag, qz, hbl, chl, czo, ap, ttn, opq	South Fiord, Lake Te Anau	1170484	4968420

Sample	P Collection #	Unit	Rock type	Description	Mineral assemblages	Location	E	N
17NZ43B	89914	Murchison Intrusives	pegmatite dike (post-kinematic)	Postkinematic dike. Cuts fabric in host.	hbl, bt, ttn, zrn, czo	South Fiord, Lake Te Anau	1170428	4968446
17NZ44	89915	Hunter Intrusives	granite	Moderate foliation S ₂ . moderate to high strain.	plg, qz, hbl, chl, czo zrn, opq	South Fiord, Lake Te Anau	1170909	4967857
17NZ55A	89930	Hunter Intrusives	hbl-bt tonalite mylonite	Strong S ₂ foliation. Medium coarse tonalite high strain mylonite. chl and ser as secondary minerals. Ttn aligned with S ₂ .	qz, plg, hbl, bt, ttn, czo, chl, ser	South Fiord, Lake Te Anau	1173176	4965243
17NZ60	89934	Hunter Intrusives	hbl diorite mylonite	Strong S ₂ foliation. High strain. Medium coarse diorite mylonite. Ttn aligned with S ₂ .	plg, hbl, bt, qz, ttn	South Fiord, Lake Te Anau	1173891	4965315
17NZ72A	89950	Hunter Intrusives	hbl diorite protomylonite	Weak to moderate S ₂ foliation. Fine-grained protomylonite. Ttn aligned with S ₂ .	plg, qz, hbl, bt, ttn, czo	South Fiord, Lake Te Anau	1177474	4964660
17NZ78B	89960	Takahe Granodiorite	bt granodiorite	Undeformed bt granodiorite	plg, kfs, qz, bt, whi mica, ap, zrn, opq	South Fiord, Lake Te Anau	1180744	4965415
17NZ81	89963	Takahe Granodiorite	bt granodiorite	Undeformed bt granodiorite	plg, kfs, qz, bt, whi mica, ap, zrn, opq	South Fiord, Lake Te Anau	1182320	4965639

Sample	P Collection #	Unit	Rock type	Description	Mineral assemblages	Location	E	N
17NZ94	89973	Grebe mylonite zone	bt-hbl diorite mylonite	Moderate foliation S ₂ . High strain. Ttn aligned with S ₂ . Localized anastomosing bands of qtz-plg.	plg, qz, bt, hbl, chl, czo zrn, opq	South Arm, Lake Manapouri	1164229	4940617
17NZ95B	89975	Grebe mylonite zone	hbl-bt diorite mylonite	Strong S ₂ foliation. High strain. Medium-grained diorite mylonite. quartz-rich band. Ttn aligned with S ₂ .	plg, qz, hbl, bt, ttn, opq, zir, czo	South Arm, Lake Manapouri	1164059	4940370
17NZ96	89978	Grebe mylonite zone	bt diorite mylonite	Strong S ₂ foliation. High strain. Fine-grained hbl diorite mylonite. titanite-rich band. Ttn aligned with S ₂ .	plg, qz, bt, hbl, ttn, zir, ap, czo, ser	South Arm, Lake Manapouri	1163941	4940201
17NZ98	89980	Puteketeke Pluton	bt granodiorite	Weak S ₀ foliation. Bt-granodiorite with weak magmatic foliation.	plg, kfs, qz, bt, ap, zrn, opq	South Arm, Lake Manapouri	1162893	4940652
17NZ100	89982	Puteketeke Pluton	bt tonalite	Weak S ₀ foliation. Bt-granodiorite with magmatic foliation (ligment of bt). Moderate alignment of ttn.	plg, kfs, qz, bt, ap, ttn, zrn, opq	South Arm, Lake Manapouri	1162985	4941145
17NZ104	89988	Puteketeke Pluton	bt tonalite	Weak S ₀ foliation. Coarse-grained Bt-tonalite.	plg, kfs, qz, bt, ap, ttn, zrn, opq	South Arm, Lake Manapouri	1163646	4945260
17NZ114	89998	West Arm Leucogranite	hbl-bt tonalite	Weak fabric S ₁ defined by alignment of bt.	plg, kfs, qz, bt, czo, ttn, zrn, ap, opq	West Arm, Lake Manapouri	1158552	4945304

Sample	P Collection #	Unit	Rock type	Description	Mineral assemblages	Location	E	N
17NZ117	90001	West Arm Leucogranite	bt granodiorite	Undeformed bt granodiorite	plg, kfs, qz, bt, zrn, opq, ap	West Arm, Lake Manapouri	1158161	4945072
17NZ124A	90007	Refrigerator Orthogneiss	bt tonalite	Undeformed bt tonalite	plg, qz, bt, hbl, chl, czo zrn, opq	West Arm, Lake Manapouri	1162195	4947036
17NZ124B	90008	Refrigerator Orthogneiss	pegmatite dike (post-kinematic)	Postkinematic dike. Cuts fabric in host.	plg, kfs, qz, bt, zrn, opq, ap	West Arm, Lake Manapouri	1162195	4947036
17NZ127	90010	Refrigerator Orthogneiss	pegmatite dike (post-kinematic)	Undeformed bt granitic dike	plg, kfs, qz, bt, opq, ttn, ap, zrc	West Arm, Lake Manapouri	1161293	4947123
17NZ134	90013	West Arm Leucogranite	bt tonalite	Undeformed bt tonalite	plg, kfs, qz, bt, zrn, opq	North Arm, Lake Manapouri	1160080	4951966
17NZ137	90016	West Arm Leucogranite	bt tonalite	Undeformed bt tonalite	plg, kfs, qz, bt, zrn, opq	North Arm, Lake Manapouri	1158919	4947135
17NZ139	90018	West Arm Leucogranite	bt granite	Undeformed bt granite	plg, kfs, qz, bt, whi mica, zrn, opq, ap	Percy Saddle	1156359	4938844
17NZ140	90019	West Arm Leucogranite	bt granodiorite	Undeformed bt granodiorite	plg, kfs, qz, bt, whi mica, zrn, opq, ap	Percy Saddle	1156257	4939422
17NZ141	90020	West Arm Leucogranite	granodiorite	Undeformed granodiorite	plg, kfs, qz, whi mica, zrn, opq, ap	Percy Saddle	1155735	4941567

Sample	P Collection #	Unit	Rock type	Description	Mineral assemblages	Location	E	N
0213K1	P70481	Indecision Creek shear zone	grt diorite mylonite	High strain grt diorite. Indecision Creek shear zone	grt, plg, qz, cpx, bt, ttn, opq	Steep Hill	1188470	5036126
0308F	P70512	Indecision Creek shear zone	grt diorite gneiss	Well foliated-lineated bt diorite gneiss. High strain mylonite Mt Daniel-Indecision Creek shear zone	plg, qz, hbl, grt, ttn, czo, opq	Mt Daniel	1182211	5029733
0308L1	P70518	Indecision Creek shear zone	diorite protomylonite	Low-to-moderate strain Mt Daniel shear zone	plg, czo, bt, hbl, ttn, opq	Mt Daniel	1182211	5029733

Note: Mineral abbreviations after Whitney and Evans (2010): ap- apatite; bt- biotite; chl- chlorite; cpx-clinopyroxene; czo- clinozoisite; grt- garnet; hbl- hornblende; kfs-k-felspar; opq-opaque mineral; plg- plagioclase; qz- quartz; ser-sericite; ttn- titanite; whi mica- white mica; zrn-zircon.
Unit name following Turnbull et.al., (2010) Fiordland Qmap.

4.3. U-Pb zircon geochronology

Twenty-two new U-Pb zircon ages from central Fiordland are presented in this chapter. Zircon geochronology data were collected by Sensitive High-Resolution Mass Spectrometer Reverse Geometry (SHRIMP-RG) at Stanford University. Rims and cores were targeted for analysis in order to determine the timing of magmatism and/or metamorphism for all samples. Depending on abundance, between 10 to 4 zircons with variable internal textures were analyzed.

Table 3 presents a summary of U-Pb SHRIMP-RG zircon dates and associated Ti-in-zircon temperatures. Complete isotopic data and individual spot dates are found in Appendix A. Concordia diagrams show all analyzed spots including rejected spots (statistically younger and/or older outliers).

4.3.1. Geochronology of the Separation Point Suite

Five different plutons (Refrigerator Orthogneiss, Takahe granodiorite, Puteketeke Pluton, West Arm Leucogranite) were dated in order to constrain the timing of Separation Point Suite magmatism and deformation in central Fiordland (see Figure 2).

Refrigerator Orthogneiss (samples 17NZ12, 17NZ25A, 17NZ25B 17NZ127, 17NZ124A, and 17NZ124B)

Sample 17NZ12 (Fig. 13A), a hornblende-biotite tonalite from South Arm Lake Te Anau, zircon grains display average diameter between 50 and 150 μm and aspect ratios 1:1 to 1:2, with sub- to euhedral crystal habit and a few low U rims. Sample 17NZ12 yielded an error-weighted average date of 128.0 ± 2.9 Ma (MSDW=0.86) from seven individual zircon analyses.

Sample 17NZ25A (Fig. 13B) is located west in South Arm Lake Te Anau. Eight spots were analyzed and yielded an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ date of 129.1 ± 2.0

(MSWD =0.73). This sample represent the oldest date obtained in the Separation Point Suite samples analyzed (Fig. 13).

Zircons from sample 17NZ124A (Fig. 13C), biotite tonalite from Lake Manapouri, are mostly sub- to euhedral and have average diameter between 100 and 250 μm (Fig 18). Ten concordant dates with an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ date of 127.4 ± 2.0 Ma (MSWD = 1.9).

Sample 17NZ127 (Fig. 13D) is a post- S_1 fabric pegmatite dike that was collected in Lake Manapouri. Zircon grains display average diameter between 50 and 150 μm and aspect ratios 1:1 to 1:3, with sub- to euhedral crystal habit, chaotic patchy zoning and low U domains. Eight spots were analyzed and yielded an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ date of 112.7 ± 1.3 (MSWD =1.15).

Sample 17NZ25B (Fig. 13E), post- S_1 fabric pegmatite dike, was collected in South Arm Lake Te Anau. Zircon grains display average diameter between 100 and 250 μm and aspect ratios 1:1 to 1:2, with sub- to euhedral crystal habit, chaotic patchy zoning and low U domains. Six spots were analyzed and yielded an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ date of 124.9 ± 2.7 (MSWD =1.8).

Sample 17NZ124B (Fig. 13F), post- S_1 fabric pegmatite dike, was collected in Lake Manapouri. Zircon grains display average diameter between 50 and 250 μm and aspect ratios 1:1 to 1:3, with sub- to euhedral crystal habit, chaotic patchy zoning and low U domains. Six spots were analyzed and yielded an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ date of 121.8 ± 1.8 (MSWD =1.5).

Sub-solidus deformation in the Refrigerator Orthogneiss is bracketed by post-kinematic dikes between ~129 and ~125 Ma, but is absent in younger plutons (Fig. 13).

Figure 13. Zircon Tera-Wasserburg concordia diagrams and weighted average age plots (wtd-weighted; conf-confidence; rej-rejected). Concordia and weighted average diagrams show all spots (including rejected spots in white). Error ellipses show 2 σ total uncertainty for spot analyses. Green ellipses represent age and uncertainty of concordia age calculation generated by Isoplot 4.15 (Ludwig, 2012). **A.** Sample 17NZ12 **B.** Sample 17NZ25A **C.** Sample 17NZ124A **D.** Sample 17NZ127 (post-kinematic dike) **E.** Sample 17NZ25B (post-kinematic dike) **F.** Sample 17NZ124B (post-kinematic dike).

Takahe granodiorite (samples 17NZ81 and 17NZ78B)

Samples 17NZ81 (Fig. 14A) and 17NZ78B (Fig. 14B) are biotite granodiorites that were collected from South Fiord in the Lake Te Anau. Sample 17NZ78B zircons consistently display a prismatic and sub-to-euhedral crystal shape. Zircon sizes range from 100 to 250 μm and aspect ratios of 1:2 to 1:3. Nine analyses yielded a concordant error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ age of 125.1 ± 1.7 Ma (MSWD = 0.32). Zircon grains from sample 17NZ81 show oscillatory zoned cores with distinct core-rim relationships. Zircon grains have average diameter of 200 μm (aspect ratios= 1:2 to 1:3) (Fig 18). Six analyses are concordant with an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ age of 123.1 ± 3.3 Ma (MSWD = 1.8). These two new crystallization ages for the Takahe granodiorite ages reported here agree with previous geochronologic studies in South Fiord (123.3 ± 1.8 Ma; Muir et al., 1998).

Figure 14. Zircon Tera-Wasserburg concordia diagrams and weighted average age plots (wt-weighted; conf-confidence; rej-rejected). Concordia and weighted average diagrams show all spots (including rejected spots in white). Error ellipses show 2σ total uncertainty for spot analyses. Green ellipses represent age and uncertainty of concordia age calculation generated by Isoplot 4.15 (Ludwig, 2012). **A.** Sample 17NZ81 **B.** Sample 17NZ78B.

Puteketeke Pluton (samples 17NZ98 and 17NZ100)

Sample 17NZ98 (Fig. 15A) zircon grains display prismatic shape and oscillatory zoning with distinct core-rim relationships. Grains have an average diameter between 50 and 100 μm and no inherited cores were observed. Seven zircons from sample 17NZ98 were analyzed and yielded an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ age of 121.8 ± 1.7 Ma (MSWD = 0.39).

Zircons from sample 17NZ100 (Fig. 15B) are patchy and largely euhedral with an average diameter of 200 to 300 μm . Zircon grains are largely prismatic and no discernible inherited cores (Fig 18). Nine spots were analyzed and yielded an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ age 122.8 ± 2.6 Ma (MSWD = 0.75) (Fig. 15). Ramezani and Tulloch (2009) reported a $^{206}\text{Pb}/^{238}\text{U}$ age of ca. 119 Ma and Scott and Palin (2008) a $^{206}\text{Pb}/^{238}\text{U}$ age of ca. 120.8 Ma for Puteketeke Pluton, which agree with our zircon geochronology.

Figure 15. Zircon Tera-Wasserburg concordia diagrams and weighted average age plots (wtd-weighted; conf-confidence; rej-rejected). Concordia and weighted average diagrams show all spots (including rejected spots in white). Error ellipses show 2 σ total uncertainty for spot analyses. Green ellipses represent age and uncertainty of concordia age calculation generated by Isoplot 4.15 (Ludwig, 2012). **A.** Sample 17NZ100 **B.** Sample 17NZ98.

West Arm Leucogranite (samples 17NZ141, 17NZ140, 17NZ139, 17NZ137, 17NZ134, 17NZ117 and 17NZ114)

Zircons from sample 17NZ139 (Fig. 16A) display stubby to elongate prismatic morphologies with fine oscillatory zoning. Four of ten spots analyzed yielded a concordant error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ age of 110.2 ± 4.2 Ma (MSWD = 2.2).

Zircons from sample 17NZ140 (Fig. 16B) display prismatic shape and oscillatory zoning with distinct core-rim relationships. Grains have diameter between 50 and 100 μm and none inherited cores were observed. In six single analyses, sample 17NZ140 yielded an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ age of 116.5 ± 2.9 Ma (MSWD = 1.2).

For samples 17NZ141 (Fig. 16C) and 17NZ137 (Fig. 16D), the most common zircon texture observed in the cathodoluminescence images is chaotic patchy zoning and low U. Zircons show euhedral to subhedral crystal habit with average diameter between 50-250 μm , aspect ratios range from 1:2 to 1:3. Grains from sample 17NZ137 (Fig 18) also display prismatic shape with distinct core-rim relationships. Seven grains from sample 17NZ141 yielded a concordant error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ age of 116.4 ± 1.4 Ma (MSWD = 1.4). Sample 17NZ137 recorded a $^{206}\text{Pb}/^{238}\text{U}$ age of 113.5 ± 3.4 Ma (MSWD = 3.1) in five spots (Fig. 16).

Sample 17NZ117 (Fig. 16E) zircon grains are rounded and stubby in geometry, with an average of diameter 200 μm and aspect ratios ranging from 1:1 to 1:2. Five concordant dates with an error-weighted average age 113.3 ± 2.9 Ma (MSWD = 1.6).

Zircons from sample 17NZ114 (Fig. 17A) display sub- to anhedral rounded geometry. Textures displayed are mostly homogeneous with a minor population of patchy zircons. Average diameter of ~ 200 μm and aspect ratios of 1:1 to 1:2. Ten zircons from sample 17NZ114 yielded an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ date 123.6 ± 2.3 Ma (MSWD = 1.5).

Zircons from samples 17NZ134 (Fig. 17B) exhibit sub-to-anhedral rounded geometry, with 50 μm average diameter and aspect ratios 1:1 to 1:2. Six grains from 17NZ134 (Fig. 17B) yielded a concordant error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ age 122.2 ± 2.6 Ma (MSWD = 1.4).

Figure 16. West Arm Leucogranite zircon Tera-Wasserburg concordia diagrams and weighted average age plots (wtd-weighted; conf-confidence; rej-rejected). Concordia and weighted average diagrams show all spots (including rejected spots in white). Error ellipses show 2 σ total uncertainty for spot analyses. Green ellipses represent age and uncertainty of concordia age calculation generated by Isoplot 4.15 (Ludwig, 2012) **A.** Sample 17NZ139 **B.** Sample 17NZ140 **C.** Sample 17NZ141 **D.** Sample 17NZ137 **E.** Sample 17NZ117.

Figure 17. Zircon Tera-Wasserburg concordia diagrams and weighted average age plots (wtd-weighted; conf-confidence; rej-rejected). Concordia and weighted average diagrams show all spots (including rejected spots in white). Error ellipses show 2σ total uncertainty for spot analyses. Green ellipses represent age and uncertainty of concordia age calculation generated by Isoplot 4.15 (Ludwig, 2012). **A.** Sample 17NZ114 **B.** Sample 17NZ134. These samples were mapped by Turnbull et al. (2010) as West Arm Leucogranite.

Figure 18. Representative cathodoluminescence (CL) images for Separation Point Suite samples: 17NZ124A, 17NZ81, 17NZ100 and 17NZ137. White circles (~30 μm in diameter) show spots targeted during the SHRIMP-RG analyses. Red spots show analyses excluded from error-weighted average age calculation. Scale bars are 100 μm . Age uncertainty 1 σ .

5.1.1. Geochronology of Carboniferous and Darran Suite

Murchison and Hunter Intrusives (Darran Suite)

Eight spots from sample 17NZ40 (Fig. 19) yielded an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ age 170.1 ± 1.6 Ma (MSWD = 1.15). Zircon grains exhibit sub-to-anhedral crystal shape, homogeneous zoning, with occasional subordinate sector and patchy zonation. Zircon sizes range from 100 to 350 μm with aspect ratios of 1:2 to 1:4 (Fig. 22). This sample was mapped in Turnbull et al. (2010) and Allibone et al. (2009a) as Murchison Intrusives.

Samples 17NZ43A and 17NZ43B were mapped in Turnbull et al. (2010) and Allibone et al. (2009a) as Murchison Intrusives. Zircons from sample 17NZ43B (Fig. 20A) are subhedral, long prismatic or stubby grain with sizes ranging from 100 to 350 μm , and aspect ratios of 1:2 and 1:3. Zircons preserve sector to patchy zoning. Five spots yielded an $^{206}\text{Pb}/^{238}\text{U}$ age of 343.1 ± 5.2 Ma (MSWD = 3.8). Ringwood (2018) also reported an LA-SF-ICPMS zircon age of 344.0 ± 7.6 Ma for the host dioritic rock (17NZ43A), which overlaps with our age for the post-kinematic felsic dike 17NZ43B.

Sample 17NZ44 (Fig. 20B) was mapped in Turnbull et al. (2010) and Allibone et al. (2009a) as Hunter Intrusives. Zircons are typically 50-250 μm in length, euhedral, short to long prismatic, with aspect ratios of 1:2 to 1:4 (Fig. 22). Five spots yielded an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ age 341.8 ± 4.8 Ma (MSWD = 1.6).

Figure 19. Zircon Tera-Wasserburg concordia diagrams and weighted average age plot for Sample 17NZ40 (wtd-weighted; conf-confidence; rej-rejected). Concordia and weighted average diagrams show all spots (including rejected spots in white). Error ellipses show 2σ total uncertainty for spot analyses. Green ellipses represent age and uncertainty of concordia age calculation generated by Isoplot 4.15 (Ludwig, 2012).

Figure 20. Zircon Tera-Wasserburg concordia diagrams and weighted average age plots (wtd-weighted; conf-confidence; rej-rejected). Concordia and weighted average diagrams show all spots (including rejected spots in white). Error ellipses show 2σ total uncertainty for spot analyses. Green ellipses represent age and uncertainty of concordia age calculation generated by Isoplot 4.15 (Ludwig, 2012) **A.** Sample 17NZ43B **B.** Sample 17NZ44

4.3.2. Geochronology of Grebe Mylonite Zone host rock

Zircons from 17NZ94 (Fig. 21A) are subhedral to anhedral, elongated or stubby grains with sizes ranging from 50 to 250 μm , and aspect ratios of 1:1 to 1:3. Zircons preserve sector to patchy zoning (Fig. 22). Eight spots from eight grains yielded an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ age 335 ± 10 Ma (MSWD = 0.14).

Zircons from sample 17NZ95B (Fig. 21B) are rounded and stubby in geometry, with an average of 200 μm diameter and aspect ratios of 1:1 to 1:2. Zircons display distinct

core-rim relationships showing outer rims with variable thickness (Fig. 22). Seven spots from ten grains yielded an error-weighted average $^{206}\text{Pb}/^{238}\text{U}$ age 336.2 ± 8.4 Ma (MSWD = 0.14) (Fig 21).

Figure 21. Zircon Tera-Wasserburg concordia diagrams and weighted average age plots (wtd-weighted; conf-confidence; rej-rejected). Concordia and weighted average diagrams show all spots (including rejected spots in white). Error ellipses show 2σ total uncertainty for spot analyses. Green ellipses represent age and uncertainty of concordia age calculation generated by Isoplot 4.15 (Ludwig, 2012) **A.** Sample 17NZ94 **B.** Sample 17NZ95B

4.3.3. Titanium-in zircon thermometer

Zircon temperatures of formation were calculated following the thermometer proposed by Watson et al. (2006) (see chapter 3. Methods). Geochemical data were reduced using

the MS Excel add-in software SQUID-2 via the SHRIMP-RG at Stanford University. Measured values of Ti (ppm) in each sample were used and $a\text{TiO}_2=0.7$ based on the scarce presence of rutile or ilmenite in analyzed samples. A summary of Ti-in-zircon temperatures, their 2σ errors, and their associated dates are presented in Table 3.

Figure 22. Representative cathodoluminescence images for the Carboniferous and Darran Suite samples: 17NZ40, 17NZ44, 17NZ94 and 17NZ95B. White circles ($\sim 30\ \mu\text{m}$ in diameter) show spots targeted during the SHRIMP-RG analyses. Red spots show analyses excluded from error-weighted average age calculation. Scale bars are $100\ \mu\text{m}$. Age uncertainty 1σ .

Table 3. Summary of U-Pb SHRIMP-RG zircon dates and associated temperatures.

Sample	P Collection#	Unit [†]	Rock type	Date (Ma; 2SD)	MSWD	# of zircons [‡]	Temperature* (°C; 2SD)
17NZ12	89881	Refrigerator Orthogneiss	hbl-bt tonalite	128.0±2.9	0.86	7	800±16
17NZ25A	89895	Refrigerator Orthogneiss	hbl-bt tonalite	129.1±1.8	0.73	8	827±15
17NZ25B	89896	Refrigerator Orthogneiss	post-kinematic pegmatite dike	124.9±2.7	1.8	6	801±16
17NZ124A	90007	Refrigerator Orthogneiss	bt tonalite	127.4±2.0	1.9	10	672±13
17NZ124B	90008	Refrigerator Orthogneiss	post-kinematic pegmatite dike	121.8±1.8	1.5	6	653±13
17NZ127	90010	Refrigerator Orthogneiss	post-kinematic pegmatite dike	112.7±1.3	1.15	8	590±11
17NZ78B	89960	Takahe Granodiorite	bt granodiorite	125.1±1.7	0.32	9	609±12
17NZ81	89963	Takahe Granodiorite	bt granodiorite	123.1±3.3	1.8	6	627±12
17NZ98	89980	Puteketeke Pluton	bt granodiorite	121.8±1.7	0.39	7	626±12
17NZ100	89982	Puteketeke Pluton	bt tonalite	122.8±2.6	0.75	9	593±11
17NZ114	89998	West Arm Leucogranite	hbl-bt tonalite	123.6±2.3	1.5	10	828±17
17NZ117	90001	West Arm Leucogranite	bt granodiorite	113.3±2.9	1.6	5	606±12
17NZ134	90013	West Arm Leucogranite	bt tonalite	122.2±2.8	1.4	6	785±15
17NZ137	90016	West Arm Leucogranite	bt tonalite	113.5±3.4	3.1	5	646±12
17NZ139	90018	West Arm Leucogranite	bt granite	110.2±4.2	2.2	4	712±14
17NZ140	90019	West Arm Leucogranite	bt granodiorite	116.5±2.9	1.2	6	699±14
17NZ141	90020	West Arm Leucogranite	bt granodiorite	116.4±1.4	1.4	7	710±14
17NZ40	89906	Murchison Intrusives	diorite mylonite	170.1±1.6	1.15	8	870±17
17NZ43B	89914	Murchison Intrusives	post-kinematic pegmatite dike	343.1±5.2	3.8	5	727±14
17NZ44	89915	Hunter Intrusives	bt-hbl tonalite mylonite	341.8±4.8	1.6	5	649±13
17NZ94	89973	Grebe mylonite zone	bt-hbl diorite mylonite	336.0±10	0.14	8	817±16
17NZ95B	89975	Grebe mylonite zone	hbl-bt diorite mylonite	336.2±8.4	0.14	7	712±14

[†]Unit name following Turnbull et al. (2010) Fiordland Qmap.

[‡]Zircons used in age calculations.

*Zircon temperatures calculated from Ti concentrations following Watson et al. (2006) thermometer
Complete isotopic data and individual spot dates can be found in the Appendix A.

4.4. U-Pb titanite thermochronology

Titanite thermochronology data for seventeen samples were collected by Laser Ablation Split-Stream Inductively Coupled Plasma Mass Spectrometer (LASS-IPC-MS) at the University of California, Santa Barbara (UCSB). Depending on abundance, between 20 to 72 titanite grains with variable internal textures were analyzed. Analyses were plotted on Tera-Wasserburg Concordia diagrams and in most cases, display discordia arrays between common Pb (upper intercepts) and titanite crystallization ages (lower intercepts). All reported $^{206}\text{Pb}/^{238}\text{U}$ ages are lower intercept ages with 2σ error.

Table 4 presents a summary of U-Pb LASS-ICP-MS titanite dates and associated Zr-in-titanite temperatures. Complete isotopic data and individual spot dates may be found in the Appendix B.

4.4.1. High-strain shear zones (fabric S₂): Grebe Mylonite Zone, Lake Te Anau Mylonites and Indecision Creek Shear Zone

Samples 17NZ95B and 17NZ96 were collected in Lake Manapouri where Grebe Mylonite Zone was defined as a structural unit by Allibone et al. (2009a); Turnbull et al. (2010); Scott (2013).

Titanite from sample 17NZ95B (Fig. 23A) show average diameter between 300 and 400 μm and anhedral aggregates that follow the direction of the rock fabric (Fig. 38). Forty-eight titanite grains yielded a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ age 119.9 ± 3.2 Ma (MSWD= 1.06). This sample exhibited an older population that yielded a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ age 306 ± 15 Ma and MSWD= 42. Host rock yielded a zircon $^{206}\text{Pb}/^{238}\text{U}$ age of 336.2 ± 8.4 Ma.

Twenty titanite grains from sample 17NZ96 (Fig. 23B) plot along a discordant array, with a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ age of 122.3 ± 2.9 Ma (MSWD = 2.3). The average diameter for titanites from sample 17NZ96 are approximately 300 μm . Ringwood (2018) reported a $^{206}\text{Pb}/^{238}\text{U}$ age of 322.7 ± 8.6 Ma for the dioritic host rock. Sample 17NZ96 exhibited an older population that yielded a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ age 302 ± 52 Ma and MSWD=73.

Samples 17NZ43A, 17NZ60, 17NZ55A, 17NZ72A, 17NZ31A and 17NZ4A were collected in South Fiord, Lake Te Anau where a series of diffuse high-strain shear zones were identified (Mylonites of Lake Te Anau). Based on our U-Pb data these diffuse shear zones are hosted in Carboniferous and Jurassic dioritic rocks.

Titanite grains from sample 17NZ43A are oriented around plagioclase, quartz and biotite mineral assemblages. Grains have an average diameter between 100 and 200 μm . Sample 17NZ43A (Fig. 24) yielded a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ age of 123.2 ± 9.4 Ma (MSWD = 0.43) in twenty-nine spots. Ringwood (2018) reported a U-Pb age of 344.0 ± 7.6 Ma for the host rock.

Mylonitic to protomylonitic fabrics in samples 17NZ60 (Fig. 25A), 17NZ72A (Fig. 25B), 17NZ55A (Fig. 25C), 17NZ31A (Fig. 25D) and 17NZ4A (Fig. 25E) are hosted in Jurassic Darran Suite rocks. Twenty-eight analyses from sample 17NZ60 form a discordant array, with a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ date of 116.3 ± 1.7 Ma (MSWD = 0.39).

Titanite grains from sample 17NZ31A yielded a titanite $^{206}\text{Pb}/^{238}\text{U}$ date of 125.8 ± 7.3 Ma (MSWD = 0.59) in forty grains.

Forty titanite analyses from sample 17NZ4A plot along a discordant array, with a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ date of 125.3 ± 2.8 Ma (MSWD = 4.3). Sample 17NZ4A is hosted in rocks of Lake Hankinson Complex and Ringwood (2018) reported a zircon $^{206}\text{Pb}/^{238}\text{U}$ emplacement age of 144.2 ± 2.3 Ma.

Titanites from sample 17NZ55A have an average diameter between 150 and 200 μm . Thirty-four analyses plot along a discordant array, with a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ date of 146.8 ± 3.6 Ma (MSWD = 2.4).

Sixty-seven spots in sample 17NZ72A (Fig. 38) yielded a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ age of 130.7 ± 1.8 Ma (MSWD = 1.09). Host rock yielded a zircon U-Pb age of 143.4 ± 4.4 Ma.

Figure 23. Grebe Mylonite Zone titanite Tera-Wasserburg concordia. Concordia diagrams show all spots (including rejected spots in white). Error ellipses show 2σ total uncertainty for spot analyses. **A.** Sample 17NZ95B **B.** Sample 17NZ96.

Figure 24. 17NZ43A (Carboniferous-hosted mylonite) titanite Tera-Wasserburg concordia. Concordia diagrams show all spots (including rejected spots in white). Error ellipses show 2σ total uncertainty for spot analyses.

Figure 25. Darran Suite-hosted mylonites titanite Tera-Wasserburg concordia. Concordia diagrams show all spots (including rejected spots in white). Error ellipses show 2σ total uncertainty for spot analyses. **A.** Sample 17NZ60 **B.** Sample 17NZ72A **C.** Sample 17NZ55A **D.** Sample 17NZ31A **E.** Sample 17NZ4A.

Titanite grains from sample 0231K1 (Fig. 26A), have average diameter are approximately 250-300 μm . Thirty-three spots yielded a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ age of $118.2 \pm 5.9 \text{ Ma}$ (MSWD = 5.4)

Sample 0308F (Fig. 26B) Grains display average diameter between 200 and 300 μm . Forty-two spots plot along a discordant array, with a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ date of $110.1 \pm 2.1 \text{ Ma}$ (MSWD = 3.3)

Titanites from sample 0308L1 (Fig. 26C) have an average diameter between 150 and 250 μm . Forty-four analyses plot along a discordant array, with a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ date of $106.1 \pm 3.5 \text{ Ma}$ (MSWD = 0.96).

Figure 26. Indecision Creek Shear Zone titanite Tera-Wasserburg concordia. Concordia diagrams show all spots (including rejected spots in white). Error ellipses show 2σ total uncertainty for spot analyses. **A.** Sample 0213K1 **B.** Sample 0308F **C.** Sample 038K1.

4.4.2. Refrigerator Orthogneiss (Low-strain fabric S₁)

Titanite grains from Refrigerator Orthogneiss were dated from samples 17NZ12 (Fig. 27A), 17NZ11 (Fig. 27B), 17N124A (Fig. 27C) and 17NZ25A (Fig. 27D).

Seventy-two titanite grains from sample 17NZ12 (Fig. 27A) plot along a discordant array, with a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ age of 123.0 ± 2.2 Ma (MSWD = 6.0). The average diameter of sample 17NZ12 titanites is approximately 250 μm (Fig. 38). Host rock yielded a zircon U-Pb age of 128.0 ± 2.9 Ma.

Titanite grains from sample 17NZ11 display average diameter between 100 and 200 μm . Titanite from sample 17NZ11 (Fig. 27B) yielded a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ age of 121.4 ± 1.5 Ma (MSWD = 1.2) in twenty-eight spots. Grains display average diameter between 100 and 200 μm .

Sample 17NZ124A (Fig. 27C) plot along a discordant array (forty-eight spots), with a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ age of 118.8 ± 1.6 Ma (MSWD = 1.6). The average diameter for titanites is approximately 200 μm (Fig. 38). Sample 17NZ124A is the host rock (127.4 ± 2.0 Ma, U-Pb zircon age) of a postkinematic dike that yielded a $^{206}\text{Pb}/^{238}\text{U}$ age of 121.8 ± 1.8 Ma.

Seventy-two titanite grains from sample 17NZ25A (Fig. 27D) plot along a discordant array, with a lower intercept $^{206}\text{Pb}/^{238}\text{U}$ age of 120.8 ± 1.5 Ma (MSWD = 6.0). The average diameter for titanites is approximately 250 μm (Fig. 38). Sample 17NZ25A is the host rock (129.1 ± 1.8 Ma, zircon age) of a postkinematic dike that yielded a $^{206}\text{Pb}/^{238}\text{U}$ age of 124.9 ± 2.7 Ma.

Figure 27. Refrigerator Orthogneiss titanite Tera-Wasserburg concordia. Concordia diagrams show all spots (including rejected spots in white). Error ellipses show 2σ total uncertainty for spot analyses. **A.** Sample 17NZ12 **B.** Sample 17NZ11 **C.** Sample 17NZ124A **D.** Sample 17NZ25A.

4.4.3. Puteketeke Pluton (magmatic fabric S₀)

Puteketeke Pluton magmatic fabric is defined by weak igneous layering with oriented biotite with no alignment of other minerals. Emplacement of Puteketeke Pluton was dated at 121.8 ± 1.7 to 122.8 ± 2.6 Ma. Titanite grains (Fig. 38) were dated in samples 17NZ104 (Fig. 28A) and 17NZ100 (Fig. 28B) yielded $^{206}\text{Pb}/^{238}\text{U}$ ages of 115.7 ± 1.8 Ma (MSWD = 1.5) and 118.4 ± 1.5 Ma (MSWD = 0.91).

Figure 28. Puteketeke Pluton titanite Tera-Wasserburg concordia. Concordia diagrams show all spots (including rejected spots in white). Error ellipses show 2σ total uncertainty for spot analyses. **A.** Sample 17NZ104 **B.** Sample 17NZ100.

4.4.4. Zirconium-in-titanite thermometer

Zirconium (Zr) concentrations in titanite were obtained by LASS-ICP-MS at University of California, Santa Barbara. Activity of $\text{TiO}_2=0.7$ based on the scarce presence of rutile or ilmenite in analyzed samples, and activity of SiO_2 was assumed to equal 1 due to the felsic composition of all samples. Pressures, P , were estimated for samples from central Fiordland at 0.6 GPa, while temperature for samples in northern Fiordland were calculated with a pressure of 1 GPa. Peak pressure estimates throughout Fiordland for amphibolite to granulite to facies metamorphism range from 0.6-1.6 GPa (Daczko et al., 2001b; Scott et al., 2009; Scott, 2013; Marcotte et al., 2005; Stowell et al., 2010; Schwartz et al., 2016; Klepeis et al., 2016; Gebauer, 2016).

A summary of Zr-in-titanite temperatures, their 2σ errors, and their associated dates are presented in Table 4.

Table 4. Summary of U-Pb LASS-ICP-MS titanite dates and associated temperatures.

Sample	P Collection #	Unit [†]	Rock type	Date (Ma; 2SD)	MSWD	# of titanite grains [‡]	Temperature* (°C; 2SD)
17NZ12	89881	Refrigerator Orthogneiss	hbl-bt tonalite	123.0±2.2	6.0	72	700±14
17NZ11	89880	Refrigerator Orthogneiss	hbl-bt tonalite	121.4±1.5	1.2	28	682±12
17NZ25A	89895	Refrigerator Orthogneiss	bt tonalite	120.8±1.5	0.76	62	674±13
17NZ124A	90007	Refrigerator Orthogneiss	bt tonalite	118.8±3.2	1.6	48	683±14
17NZ100	89982	Puteketeke Pluton	bt tonalite	118.4±1.5	0.91	70	694±8
17NZ104	89988	Puteketeke Pluton	bt tonalite	115.7±1.8	1.5	32	697±7
17NZ4A	89869	Lake Hankinson Complex	bt tonalite mylonite	125.3±2.8	4.2	40	690±10
17NZ31A	89897	Murchison Intrusives	hbl diorite mylonite	125.8±7.3	0.59	40	620±12
17NZ43A	89913	Murchison Intrusives	diorite mylonite	123.2±9.4	0.43	29	608±12
17NZ55A	89930	Hunter Intrusives	hbl-bt tonalite mylonite	146.9±3.7	2.5	34	637±8
17NZ60	89934	Hunter Intrusives	hbl diorite mylonite	116.3±1.7	0.39	28	659±13
17NZ72A	89950	Hunter Intrusives	hbl diorite protomylonite	130.7±1.8	1.09	67	650±13
17NZ95B	89975	Grebe shear zone	hbl-bt diorite mylonite	119.9±3.2	1.06	48	699±14
17NZ96	89978	Grebe shear zone	bt diorite mylonite	122.3±2.9	2.3	20	658±13
0213K1	P70481	Indecision Creek shear zone	grt diorite mylonite	118.2±5.9	5.4	33	665±10
0308F	P70512	Indecision Creek shear zone	grt diorite gneiss	110.1±2.1	3.3	42	631±13
0308L1	P70518	Indecision Creek shear zone	diorite mylonite	106.1±3.5	0.96	44	689±15

[†]Unit name following Turnbull et al. (2010) Fiordland Qmap

[‡]Titanite grains used in age calculations

*Titanite temperatures calculated from Zr concentrations following Hayden et al. (2008) thermometer
Complete isotopic data and individual spot dates can be found in the Appendix B.

4.5. Titanite geochemistry, thermometry and microscopic textures

Trace element geochemistry and petrographic data of titanite were used to further evaluate the diverse environments of formation among titanite-bearing samples analyzed by U-Pb geochronology. Additionally, we used LASS-ICP-MS zirconium (Zr) measurements of titanite and Hayden et al. (2008) thermometer to assess the temperature of crystallization and/or recrystallization of individual grains.

4.5.1. Titanite textural relations

Detailed petrographic analyses were performed in all titanite-bearing samples analyzed by LASS U-Pb geochronology (see section 4.4). Two textural groups of titanite were identified: Titanite Type I (Fig. 29) and Titanite Type II (Fig. 30). These two groups were differentiated based on their morphology, grain size, and textural and mineral relationships within the host rock.

Titanite Type I (aligned in fabrics S_0 and S_1): Euhedral to subhedral grains

Type I titanite is typically represented by euhedral to subhedral morphology (Fig 30). Titanite grains have average length of 400 to 800 μm . Crystals are yellow brown to dark brown. Some samples show titanite grains with minor internal zoning in BSE imaging (Fig. 39). Type I textural group is predominant in samples from Refrigerator Orthogneiss and Puteketeke Pluton.

Figure 29. Representative plane-polarized light images of titanite type I. Samples are from Refrigerator Orthogneiss and Puteketeke Pluton. Mineral abbreviations after Whitney and Evans (2010), ttn- titanite.

Titanite Type II (aligned in fabrics S_2): Anhedral aggregates

Type II titanite is typically represented by layering anhedral aggregates with rounded individual grains (Fig. 30). Titanite grains are on average 100-400 μm long. Crystals are yellow brown to dark brown. Some samples show titanite grains with minor internal zoning in BSE imaging (Fig. 38). Crystals with inclusions of oxides (e.g. magnetite, ilmenite) are common. Titanite grains are oriented parallel to foliation.

Type II titanite textural group is predominant in samples with mylonitic deformation at upper-to-middle amphibolite facies from the Grebe Mylonite Zone, Indecision Creek Shear Zone and Darran Suite (Hunter Intrusives and Murchison Intrusives).

Figure 30. Representative plane-polarized light images of titanite type II. Samples are from Hunter Intrusives, Grebe Mylonite Zone and Indecision Creek Shear Zone. Mineral abbreviations after Whitney and Evans (2010), ttn- titanite.

4.5.2. Trace elements and thermometry in titanite

Isotopic and trace element data from individual titanite grains were simultaneously recovered using the Laser Ablation Split-Stream Inductively Coupled Plasma Mass Spectrometer (LASS-IPC-MS) at the University of California, Santa Barbara (UCSB). Complete trace element analysis results of all individual titanite spots by LASS-ICP-MS can be found in the Appendix C.

Titanite Type I (aligned in fabrics S_0 and S_1): Puteketeke Pluton and Refrigerator Orthogneiss

Titanite-bearing samples from Puteketeke Pluton (Fig. 31A and B) and Refrigerator Orthogneiss (Fig. 32A, B, C and D) exhibit enrichment of LREE (Light Rare Earth

Elements) and Europium anomaly ($\text{Eu}/\text{Eu}^* = \sqrt{\text{Sm} \times \text{Gd}}$) approx. 1 (i.e. no anomaly) or $\text{Eu}/\text{Eu}^* > 1$ (i.e. positive anomaly) is typical in most of these samples.

Temperature vs lanthanum (La) plots show a directly proportional relationship indicating higher intake of La from titanite at higher temperatures. La concentrations range from 0 ppm to 1100 ppm, while temperature values vary from 650°C to 850°C.

Temperature vs lanthanum/samarium (La/Sm) -ratio between LREE (La) and MREE (Sm)- reflect also a directly proportional relationship between temperature and La/Sm, with the exception of samples 17NZ100 (Fig. 31A) and 17NZ12 (Fig. 32A) where outliers obscure the general pattern.

Binary and Chondrite-normalized REE plots of all samples analyzed from Puteketeke Pluton and Refrigerator Orthogneiss reflected similar patterns (Fig. 31 and Fig. 32).

Puteketeke Pluton (Type I)

Figure 31. Puteketeke Pluton REE patterns and binary plots of temperature versus trace element compositional variation (La, La/Sm) in titanite. **A.** Sample 17NZ100 biotite tonalite **B.** Sample 17NZ104 biotite tonalite. The chondrite values for the figures in this study are from Sun and McDonough (1989). Temperature values were obtained using Hayden et al. (2008) zirconium-in-titanite thermometer.

Refrigerator Orthogneiss (Type I)

Figure 32. Refrigerator Orthogneiss REE patterns and binary plots of temperature versus trace element compositional variation (La, La/Sm) in titanite. **A.** Sample 17NZ12 hornblende biotite

tonalite **B.** 17NZ11 hornblende biotite tonalite **C.** 17NZ25A hornblende biotite tonalite **D.** 17NZ124A biotite tonalite. The chondrite values for the figures in this study are from Sun and McDonough (1989). Temperature values were obtained using Hayden et al. (2008) zirconium-in-titanite thermometer.

Titanite Type II (aligned in fabrics S₂): Grebe Mylonite Zone

Figure 33 shows two samples from the Grebe Mylonite Zone: 17NZ95B (Fig. 33A) and 17NZ96 (Fig. 33B). Sample 17NZ96 (bt diorite mylonite) displays depletion in LREE relative to HREE. On the other hand, sample 17NZ95B (hbl-bt diorite mylonite) exhibits both enrichment and depletion in LREE relative to HREE.

Temperature vs lanthanum (La) plots show that a higher intake of La from titanite occurs at relative small intervals of temperature approx. 50°C. This represents a contrasting behavior relative to samples from Puteketeke Pluton and Refrigerator Orthogneiss where the typical temperature range is >100 °C. Temperature vs lanthanum/samarium (La/Sm) - ratio between LREE (La) and MREE (Sm)- and temperature and La/Sm plots show a directly proportional relationship.

Grebe Mylonite Zone (Type II)

Figure 33. Grebe Mylonite Zone REE patterns and binary plots of temperature versus trace element compositional variation (La, La/Sm) in titanite. **A.** Sample 17NZ95B hornblende biotite diorite mylonite **B.** Sample 17NZ196 biotite diorite mylonite. The chondrite values for the figures in this study are from Sun and McDonough (1989). Temperature values were obtained using Hayden et al. (2008) zirconium-in-titanite thermometer.

Titanite Type II (aligned in fabrics S_2): Lake Te Anau Mylonites (Darran Suite)

Darran Suite mylonites from Lake Te Anau are presented in Figure 35: 17NZ55A (Fig. 34A), 17NZ60 (Fig. 34B), 17NZ72A (Fig. 34C), 17NZ31A (Fig. 34D) and 17NZ43A (Fig. 34E).

Samples 17NZ55A, 17NZ60A, 17NZ55A, 17NZ31A and 17NZ43A show a light depletion of LREE relative to HREE, positive anomaly of Eu. Relatively uniform MREE enrichment is observed in samples 17NZ31A, 17NZ43A and 17NZ72A. On the other hand, sample 17NZ72A display a slightly flatten ratio of LREE/HREE, with minor enrichment of LREE relative to HREE.

Generally speaking, temperature vs Lanthanum (La) plots show that a higher intake of La from titanite occurs at relative small intervals of temperature approx. 50°C. Temperature vs Lanthanum/Samarium (La/Sm) -ratio between LREE (La) and MREE (Sm)- and temperature and La/Sm plots show alike patterns.

Darran Suite Mylonites (Type II)

A 17NZ55A hbl-bt tonalite mylonite

B 17NZ60 hbl diorite mylonite

C 17NZ72A hbl diorite protomylonite

D 17NZ31A hbl diorite mylonite

E 17NZ43A diorite mylonite

Figure 34. Darran Suite Mylonite REE patterns and binary plots of temperature versus trace element compositional variation (La, La/Sm) in titanite. **A.** Sample 17NZ55A hornblende biotite tonalite mylonite **B.** 17NZ60 hornblende diorite mylonite **C.** 17NZ72A hornblende diorite mylonite **D.** 17NZ31A hornblende diorite mylonite **E.** 17NZ43A diorite mylonite. The chondrite values for the figures in this study are from Sun and McDonough (1989). Temperature values were obtained using Hayden et al. (2008) zirconium-in-titanite thermometer.

Titanite Type II (aligned in mylonitic fabric): Indecision Creek Shear Zone

Indecision Creek Shear Zone samples 0231K1 (Fig. 35A), 0308F (Fig. 35B) and 0308L1 (Fig. 35B) show chondrite-normalized REE plots characterized by enrichment of HREE relative to LREE and MREE portioning strongly into titanite than LREE and/or HREE.

Temperature vs lanthanum (La) plots show that a higher intake of La from titanite occurs at relative small intervals of temperature approx. 50°C. Temperature vs lanthanum/samarium (La/Sm) -ratio between LREE (La) and MREE (Sm)- and temperature and La/Sm plots show a directly proportional relationship.

Indecision Creek Shear Zone (Type II)

Figure 35. Indecision Creek Shear Zone REE patterns and binary plots of temperature versus trace element compositional variation (La, La/Sm) in titanite. **A.** Sample 0231K1 garnet diorite mylonite **B.** Sample 0308F garnet diorite gneiss **C.** Sample 0308K1 diorite mylonite. The chondrite values for the figures in this study are from Sun and McDonough (1989). Temperature values were obtained using Hayden et al. (2008) zirconium-in-titanite thermometer.

5. DISCUSSION

In the first chapter (Introduction), we discussed the importance of understanding how magmatic emplacement processes are influenced by the stress field within the arc and how magmatism and deformation are coupled and the timescales over which coupling may occur. Nonetheless, some of the most forefront questions in continental tectonics and petrology are how magma is transferred and emplaced within continental crust and is magmatism facilitating the partitioning of strike-slip motions within the arc.

The arguments presented here suggest that in the case of the Cretaceous Fiordland arc, magmatism preceded transpressional deformation within the arc. Temporal magmatic patterns also indicate an inward focusing of magmatism before the onset of extensional orogenic collapse. Moreover, field observations reflect systematic variation in the orientation of lineations across the low and high strain shear zone boundaries in central Fiordland. These low and high strain zones may not have a simultaneous temporal relation. Our data also suggest that shear zones did not play a significant role transporting magma throughout the crust in central Fiordland.

In the sections that follow, we further evaluate our geochronological and structural data in the context of spatial and temporal variations of magmatism and deformation within a continental arc during a magmatic flare-up.

5.1. Origin of titanite

Interpretation of titanite U-Pb ages is further complicated by the uncertainty over titanite's ability to incorporate significant concentrations of common lead (^{204}Pb), formation environment (e.g. magmatic versus metamorphic) and temperature sensitivity of intragrain Pb diffusion (Cherniak, 1993; Parrish, 2001; Frost et al., 2001; Kirkland et al., 2016). Hence, it could be challenging to directly relate the growth of titanite to the development of deformational fabrics, mineral assemblages and/or P-T paths.

Previous workers (Smith et al., 2009; Xie et al., 2010; Che et al., 2013; Ismail et al., 2014; Cao et al., 2015; Tiepolo et al., 2002; Fu et al., 2016) have discussed how the formation environment of titanites could be discriminated by their texture, geochemistry and mineral assemblages. Here, we evaluate whether microscopic textures and trace

element geochemistry could determine the origin of titanite in our samples. Our conclusions presented here are further supported by our petrographic (see section 4.5.1) and titanite geochemistry results (see section 4.5.2).

Two varieties of titanite were identified on the basis of genesis: Magmatic titanite, is 400-800 μm long, euhedral or subhedral wedge-shaped. Compared to metamorphic titanite, magmatic titanite is enriched in LREE. Metamorphic titanite is 100-400 μm long and anhedral aggregates are the predominant morphology.

5.1.1. Titanite textural relations

Based on textural differences, two genetic types of titanite were characterize using petrographic thin section study (see section 4.5.1) for all titanite-bearing samples analyzed by in-situ U-Pb dating and trace element.

- **Magmatic titanite (type I, fabrics S_0 and S_1)** (Fig. 36A) was identified in rocks from Refrigerator Orthogneiss, Puteketeke Pluton and Carboniferous host rocks of the Grebe Mylonite Zone, in fabrics S_0 (magmatic) and S_1 (low strain).
Magmatic titanite is present in tonalite to diorite rocks as euhedral to subhedral wedge-shaped grains about 400-800 μm long. Very weak to non-existent irregular zoning was observed under BSE imaging (Fig. 38).
- **Metamorphic titanite (type II, fabric S_2)** (Fig. 36A) are present in most of the mylonite samples and they are intergrowing with the deformational fabric S_2 (high strain) of the host rock. Titanite grains are about 150 μm in length and habit as anhedral grains. Oxides inclusions (e.g. magnetite, ilmenite) are present throughout the samples.

5.1.2. Trace elements and thermometry in titanite

Titanite can accommodate important amounts of rare earth elements (REEs) and high field strength elements (HFSEs). Titanite with different geologic origins may exhibit characteristic REE patterns (Smith et al., 2009; Xie et al., 2010; Che et al., 2013; Ismail et

al., 2014; Cao et al., 2015; Tiepolo et al., 2002; Fu et al., 2016), thus REE characteristics of titanite could be a good indicator for its formation environment.

In general, LREE/HREE ratios in magmatic titanite are higher than those in titanites with a metamorphic origin. Temperature vs lanthanum (La) binary plots in magmatic titanite reflect higher titanite intake of La at higher temperatures, with lower La concentration at lower temperatures; this pattern is consistent with fractional differentiation/cooling in a typical magmatic system. In contrast, metamorphic titanite temperature vs lanthanum (La) binary plots show a narrow range of temperature ($\Delta 50^{\circ}\text{C}$) under the which La concentration in titanite varies, this behavior is consistent with new growth/ recrystallization of titanite in metamorphic conditions.

- **Magmatic titanite (type I, fabrics S_0 and S_1)** (Fig. 36B and C) chondrite-normalized REE plots display higher ratios of LREE/HREE relative to titanite type II (metamorphic). Some workers (Smith et al., 2009; Kohn and Corrie, 2011; Gao et al., 2012; Cao et al., 2015; Fu et al., 2016; Kohn, 2017) have proposed that light REE enrichment indicates a magmatic origin for titanite which is consistent with field relations for these samples.

Temperature vs Lanthanum (La) plots show a directly proportional relationship indicating a higher titanite intake of La at higher temperatures and lower La concentration at lower temperatures. La concentrations range in average from 0 ppm to 500 ppm, while temperature values vary from 575°C to 800°C .

- **Metamorphic titanite (type II, fabric S_2)** (Fig. 36B and C) chondrite-normalized REE plots display LREE depletion relative to HRE and some samples show a slight positive Eu anomaly. MREE is partitioning more strongly into titanite than LREE and/or HREE, this behavior has been associated to metamorphic reactions in several REE titanite studies (Ventura et al., 1999; Olin and Wolff, 2012; Che et al., 2013; Loader et al., 2017). Titanite temperature vs Lanthanum (La) binary plots show a narrow range of temperature ($\Delta 50^{\circ}\text{C}$), under which intake of La from titanite occurs.

Figure 36. Formation environment (Igneous vs Metamorphic) characterization of titanite based on: **A.** Textural relations. **B.** Chondrite-normalized REE patterns. **C.** Binary plots of temperature versus trace element compositional variation of lanthanum (La).

5.1.3. Testing closure temperature concept

Interpreting U-Pb ages in titanite as reflecting new growth, metamorphic peak conditions, and/or partial or whole reset of ages could be an ambiguous task due to the effects of Pb diffusion in the (re)distribution of radiogenic Pb and isotopic resetting in titanite (Cherniak, 1993; Frost et al., 2001; Parrish, 2001; Stearns et al., 2015; Kirkland et al., 2016).

Kirkland et al. (2016) argues that a process where diffusive Pb loss occurred as a result of a younger metamorphic event in which titanite grew, cannot be completely discriminated from other episodic or prolonged growth event without additional chemical and textural titanite data.

Diffusivity rates and other parameters are necessary when determining closure temperatures of titanite (Cherniak and Watson, 2000). Dodson (1973) defined closure

temperature as the point at which a completely mobile daughter product became completely immobile. Mobility here stands for “a rapid diffusion from the lattice site at which a radiogenic isotope is formed, or very fast annealing of a disturbed crystal lattice” Dodson (1973). Also, some of the latest petrochronologic studies (Kohn and Corrie, 2011; Spencer et al., 2013) show that titanite can preserve peak metamorphic ages at temperatures higher than 800°C, highlighting the importance of titanite as a petrochronologic tool.

In order to interpret titanite ages as the time at which pass through closure temperature occurred, the geochronologic data needs to follow the Dodson’s Criteria. The Dodson’s criteria for interpreting ages as closure temperature states that: 1) new or relict grains were completely purged of radiogenic daughter during the last event (i.e. uniform ages are observed across grains), 2) grains have simple and slow cooling histories, 3) absence of core-rim relations is observed.

In order to evaluate the closure temperature concept and Dodson’s criteria in our data, we completed LASS-ICP-MS split-stream analyses along traverses across titanite grains.

Previous workers (Dodson, 1973; Cherniak, 1993; Frost et al., 2001; Stearns et al., 2015) discussed manners of interpreting ages of titanite based on grain-age covariance with grain size and spot position from core to rim in single grains of titanite. Figure 38, modified after Stearns et al. (2015), using the Dodson’s criteria suggests that U-Pb dates for individual spots in traverse profiles generally show systematic variation from core to rim depending if the U-Pb ages are recording temporal cooling patterns or new growth/recrystallization/volume diffuse loss of Pb. Within individual traverses, effects of Pb diffusion (Fig. 38A) may display age variance with grain size and spot position. On the other hand, titanite grains that experienced new growth/recrystallization (Fig. 37B) may exhibit: different grain sizes with single ages, uniform grain size recording single ages in multiple spots,

Figure 38 shows the intracrystalline variation of age and temperature of some titanite-bearing samples that are recording fabrics S_0 (magmatic), S_1 (low strain) and S_2 (high strain).

In samples (17NZ11, 17NZ12, 17NZ124A, 17NZ25A, 17NZ100 and 17NZ104) that recorded fabrics S_0 (magmatic) and S_1 (low strain), we observed intracrystalline spatial variability in titanite U-Pb ages and temperature without a conclusive pattern that could be useful to test the Dodson's concept of closure temperature. In this case, using the zircon U-Pb crystallization ages obtained previously in this study (see section 4.3), we can conclude that the crystallization of the Refrigerator Orthogneiss took place from ca. 129 to 127 Ma, with postkinematic dikes cutting S_1 fabrics at ca. 125 Ma, and crystallization of the Puteketeke Pluton (containing S_0 fabric) at occurred ca. 122 Ma. As a result, titanite U-Pb ages for samples 17NZ11, 17NZ12, 17NZ124A, 17NZ25A, 17NZ100 and 17NZ104 cannot be explain as reflecting the timing of new growth. Thus, we interpret these titanite dates as recording cooling ages or the timing at which titanite passed through closure temperature.

Samples containing S_2 fabric (high strain) (17NZ95B, 17NZ96, 17NZ31A, 17NZ43A, 17NZ4A, 17NZ60, 17NZ55A and 17NZ72A) and samples from the Indecision Creek shear zone (0213K1, 0308L1 and 0308F), show an over dispersion of U-Pb titanite ages in grains with variable sizes, suggesting that volume diffusion may have not been the main U-Pb resetting mechanism, instead new growth, mylonitic fabric development and/or recrystallization may have been involved (Fig. 38).

Our titanite dataset allowed us to use textural relations and trace element geochemistry to provide stronger supportive evidence to distinguish between titanite with different origin and then interpret with a higher degree of certainty titanite U-Pb ages. Table 5 summarizes the final interpretation of titanite U-Pb ages in the basis of textural relations, REE geochemistry and thermometry, closure temperature concept (Dodson, 1973) also supported by field relations for all samples analyzed.

Figure 37. Titanite intracrystalline U-Pb variability **A.** Intra-grain Pb diffusion. **B.** Partial or incomplete recrystallization, new growth, volume diffusive loss of Pb, multiple crystallization events or prolonged (re)crystallization. Modified after Stearns et al. (2015).

S_0 and S_1
magmatic and low-strain fabric

S_2
high-strain fabric

Figure 38. BSE images of representative titanite grains with individual spots in traverse arrays. Black numbers represent individual U-Pb ages (Ma), red numbers represent individual temperature values (°C) calculated using the pressure-dependent zirconium-in-titanite thermometer of Hayden et al. (2008).

Table 5. Origin-based titanite classification and summary of U-Pb LASS-ICP-MS titanite dates and associated temperatures.

Titanite origin	Sample	Unit [†]	Rock type	Date (Ma; 2SD)	MSWD	# of titanite grains [‡]	Temperature* (°C; 2SD)
Igneous	17NZ12	Refrigerator Orthogneiss	hbl-bt tonalite	123.0±2.2	6.0	72	700±14
	17NZ11	Refrigerator Orthogneiss	hbl-bt tonalite	121.4±1.5	1.2	28	682±12
	17NZ25A	Refrigerator Orthogneiss	bt tonalite	120.8±1.5	0.76	62	674±13
	17NZ124A	Refrigerator Orthogneiss	bt tonalite	118.8±3.2	1.6	48	683±14
	17NZ100	Puteketeke Pluton	bt tonalite	118.4±1.5	0.91	70	694±8
	17NZ104	Puteketeke Pluton	bt tonalite	115.7±1.8	1.5	32	697±7
	17NZ95B	Grebe shear zone	hbl-bt diorite mylonite	119.9±3.2	1.06	48	699±14
Igneous/Metamorphic[¥]	17NZ96	Grebe shear zone	bt diorite mylonite	122.3±2.9	2.3	20	658±13
	17NZ4A	Lake Hankinson Complex	bt tonalite mylonite	125.3±2.8	4.2	40	690±10
Metamorphic	17NZ31A	Murchison Intrusives	hbl diorite mylonite	125.8±7.3	0.59	40	620±12
	17NZ43A	Murchison Intrusives	diorite mylonite	123.2±9.4	0.43	29	608±12
	17NZ55A	Hunter Intrusives	hbl-bt tonalite mylonite	146.9±3.7	2.5	34	637±8
	17NZ60	Hunter Intrusives	hbl diorite mylonite	116.3± 1.7	0.39	28	659±13
	17NZ72A	Hunter Intrusives	hbl diorite protomylonite	130.7±1.8	1.09	67	650±13
	0213K1	Indecision Creek shear zone	grt diorite mylonite	118.2±5.9	5.4	33	665±10
	0308F	Indecision Creek shear zone	grt diorite gneiss	110.1± 2.1	3.3	42	631±13
	0308L1	Indecision Creek shear zone	diorite mylonite	106.1±3.5	0.96	44	689±15

†Unit name following Turnbull et al. (2010) Fiordland Qmap

‡Titanite grains used in age calculations

*Titanite temperatures calculated from Zr concentrations following Hayden et al. (2008) thermometer

¥ For samples with mixed population of titanite-origin the date reported here corresponds to calculated age of recrystallization/new growth
Complete isotopic data and individual spot dates can be found in the Appendix B

5.2. Timing and conditions of transpressional shear zone development

As mentioned in Chapter 4. (Results), the areas of Lake Te Anau and Lake Manapouri reveal 1) magmatic structures (S_0), 2) amphibolite-facies shallow foliations (S_1) and lineations (L_1) in low-strain deformation settings, and 3) amphibolite-facies moderate and foliations (S_2) and lineations (L_2) in high-strain shear zones. Based on our U-Pb titanite geochronology and field relationships, we determine that strain zones (low and high strain) may not be simultaneous with low-strain fabrics (S_1 and L_1) being older than high strain (S_2 and L_2).

The Grebe Mylonite Zone in Lake Manapouri and the diffuse shear zones in South Fiord, Lake Te Anau are characterized by increasing pitch of lineations changing from shallow-plunge ($\sim 20\text{--}40^\circ$) in low-strain zones to moderate to steep-plunge ($60\text{--}90^\circ$) in high-strain zones. Based on our structural observations, variation in the pitch of stretching lineations is correlated with a progressive increase in finite strain in shear zones and moderate to steep-plunge ($60\text{--}90^\circ$) in lineations are characteristic of the high-strain shear zones defined in this study.

The Grebe Mylonite Zone in Lake Manapouri records ductile deformation with components of arc-parallel sinistral strike slip. Interpretation of quartz and plagioclase microstructures (Hufford, 2018; McGinn, 2018) and outcrop-scale fabrics in Lake Te Anau and Manapouri indicate an overall sinistral component of displacement parallel to the Median Batholith trend. Additionally, minor chevron-style folding was observed within the Puteketeke Pluton, near the Grebe Mylonite Zone in Lake Manapouri. Folding is characterized by top-to-the-SW vergence with fold limbs oriented from 041 to 045° and dips from 32 to 68° SE. Folding in the Puteketeke Pluton near the Grebe Mylonite Zone may have played a role accommodating shortening within the arc.

The Grebe Mylonite zone represents a middle crust deformation zone that marks the boundary between the Outboard and Inboard arc in Lake Manapouri area (Scott et al., 2011; Scott, 2013). Structural measurements and variations in finite strain (i.e. fabric intensity, percentage matrix-porphyroclasts) in stretching mineral lineations and mylonitic

fabrics suggest that the boundaries of the shear zone are vertical and parallel the overall trend of the arc. Based on our titanite thermochronology, deformation in amphibolite facies conditions in the Grebe Mylonite Zone took place at ca. 122-119 Ma; and deformation at amphibolite facies conditions in the mylonites of Lake Te Anau (northern extension of the Grebe Mylonite Zone) was dated at ca. 125-116 Ma. On the other hand, two mylonitic samples (17NZ55 and 17NZ72A) from Lake Te Anau recorded old deformation at ca. 146-130 Ma, this may be recording an older deformational event, further research is needed to better constrain this event.

The Indecision Creek Shear Zone was characterized by Marcotte et al. (2005) as lower-crust shear zone that accommodated sinistral oblique-slip and dip-slip displacements. Marcotte et al. (2005) also reported the transfer of small volumes of magma vertically through the Indecision Creek Shear zone until ca. 106 Ma when convergence and arc magmatism waned. Structural patterns that agree with transpression were also observed in the Indecision Creek Shear Zone where changes from 10°-35° to 55°-82° in the plunge of stretching lineations on foliation surfaces is recorded from the margins to the center of the shear zone by Marcotte et al., (2005). Our $^{206}\text{Pb}/^{238}\text{U}$ titanite thermochronology data bracket the deformation in the Indecision Creek shear zone between ca. 119 to 106 Ma at upper amphibolite facies conditions.

In summary, our thermochronology data document a series of temporally related high-grade transpressional shear zones that were active during widespread arc plutonism in the Median Batholith. Titanite thermochronology reveals that localized, amphibolite-facies mylonitic deformation at mid-crustal conditions in the Grebe Mylonite Zone in Lake Manapouri and the Mylonites of Lake Te Anau took place between ca. 125 to 116 Ma. Although, our data suggest that transpression in the middle crust lasted until ca. 116 Ma, deformation at mid-crustal conditions in the South Adams Burn thrust continues until ca. 111 Ma (Blatchford et al., 2017, in press), changes in the deformational regimes in central Fiordland after ca. 116 Ma.

Transpressional deformation in the lower crust was recorded between ca. 119 to 106 Ma in metamorphic titanites from the Indecision Creek shear zone in northern Fiordland. Thus,

deformation in the lower and middle crust in northern and central Fiordland precede extensional orogenic collapse at ca. 108 Ma (Fig 39, 40 and 41).

Grebe Mylonite Zone host rock and Carboniferous-derived dioritic tectonites

The Grebe Mylonite Zone was mapped by Turnbull et al. (2010) in South Arm of Lake Manapouri as a structural dioritic unit dated in the Cretaceous (Turnbull et al., 2010). Two samples (17NZ94 and 17NZ95B) from Lake Manapouri were analyzed using SHRIMP-RG zircon geochronology. Results suggest a Carboniferous age (ca. 336 Ma) for the dioritic host rock of the Grebe Mylonite Zone. The deformation period for the Grebe Mylonite Zone was dated using $^{206}\text{Pb}/^{238}\text{U}$ titanite thermochronology between ca. 122 to 119 Ma at amphibolite facies metamorphic conditions.

Carboniferous-derived dioritic tectonites were also found in Lake Te Anau. These units were previously mapped as Murchison (ca. 137 Ma; Ramezani and Tulloch, 2009) and Hunter Intrusives (ca. 170-130 Ma; Scott and Palin, 2008; Scott et al., 2008; Kimbrough et al., 1994). Our SHRIMP-RG zircon geochronology and LA-SF-ICPMS zircon geochronology from Ringwood (2018) provide evidence for an Unnamed Carboniferous magmatic suite ranging from 354.3 ± 7.8 Ma (Ringwood, 2018) to 341.8 ± 4.8 Ma (this study) in South Fiord, Lake Te Anau. Deformation in amphibolite facies conditions was dated using LASS titanite thermochronology at ca. 125-116 Ma. Two mylonitic samples (17NZ55 and 17NZ72A) recorded oldest ages titanite ages ca. 130-146 Ma that could be providing new insights into older amphibolite facies deformation in the middle crust. In some outcrops in Lake Te Anau the Unnamed Carboniferous suite is found as rafts in the Darran Suite and it may be difficult to identify at outcrop-scale without individual sampling and dating.

Figure 39. Time vs. space diagram summarizing magmatic and metamorphic events in central and northern Fiordland. References: 1- this study, 2-Schwartz et al. (2016), 3- Ramezani and Tulloch (2009), 4-Ringwood (2018), 5- Hollis et al. (2003), 6-Klepeis et al. (2016), 7-Scott et al. (2009), 8-Klepeis et al. (2004) and Marcotte et al. (2005), 9-Stowell et al. (2010), 10- Daczko et al. (2001b)

Figure 40. Lake Te Anau and Lake Manapouri cross sections and geologic map showing location. Black arrows show lineation data. Data were collected in 2017-field Fiordland season and compiled from Turnbull et al. (2010). Geologic map modified after Turnbull et al. (2010).

5.3. Tempo of Cretaceous Arc Magmatism

The Median Batholith recorded three important events of magmatic arc construction: 1) Darran Suite magmatism between ca. 230 and 130 Ma (Allibone et al., 2009b), 2) Separation Point Suite magmatism (including Steward Island rocks) from 129 to 105 Ma (Allibone and Tulloch, 2008; Schwartz et al., 2017; this study), and 3) Western Fiordland Orthogneiss magmatism between 125 to 115 Ma .

Our U-Pb zircon geochronology (see Table 3) data suggest that magma emplacement and crystallization of the Separation Point Suite in central Fiordland occurred from ca. 129 to 110 Ma. Emplacement pressures for the Separation Point Suite range from 4 to 9 kbar, reflecting mid-crustal conditions (Scott et al., 2009; Schwartz et al., 2017).

The Separation Point Suite is dissected into two sections by the Alpine fault: Fiordland-Steward Island, and Nelson-Westland. Each of these regions have slightly different plutonic emplacement ages; emplacement ages for Separation Point Suite in the Westland- Nelson region range from ca. 127 to 117 Ma (Muir et al., 1995; Bolhar et al., 2008; Sagar et al., 2016; Scott and Palin, 2008), Steward Island records the youngest crystallization ages ranging from ca. 128 to 105 Ma (Allibone and Tulloch, 2008), and the Fiordland region records magmatism from ca. 129-110 Ma. In Fiordland, the Separation Point Suite comprises Refrigerator Orthogneiss (ca. 129 Ma; this study), Puteketeke pluton (ca. 122 Ma; this study), West Arm Leucogranite (ca. 116-110 Ma; this study), Takahe granodiorite (ca. 125-123 Ma; this study), North Fiord granite (122.0 ± 1.7 Ma; Bolhar et al., 2008) and Titiroa granite (122.5 ± 1.9 Ma; Bolhar et al., 2008).

The youngest component of the Separation Point Suite in central Fiordland is represented by the West Arm Leucogranite, emplaced between ca. 116 to 110 Ma (this study). This suggests that the Cretaceous arc magmatism in Fiordland had started to wane by ca. 110 Ma, followed by the transition from contractional to extensional regimes around ca. 108 Ma. Thus, the Separation Point Suite reflects the terminal pulse of the Median Batholith magmatism.

The West Arm Leucogranite was identified in two areas: Lake Manapouri as dikes and small plutonic bodies (samples 17NZ117 and 17NZ137), and Percy Saddle as large granitic- to granodioritic plutons (samples 17NZ139, 17NZ140 and 17NZ141). Two additional samples of more tonalitic composition were collected in Lake Manapouri where West Arm Leucogranite was mapped by Turnbull et al. (2010). Sample 17NZ114, a hornblende-biotite orthogneiss, yielded a $^{206}\text{Pb}/^{238}\text{U}$ zircon age 123.6 ± 2.3 Ma and sample 17NZ134, a biotite orthogneiss, yielded $^{206}\text{Pb}/^{238}\text{U}$ zircon ages of 122.2 ± 2.8 Ma. These samples are interpreted as rafts of the Omaki Orthogneiss (124.91 Ma; Ramezani and Tulloch, 2009) based on our geochronology data and petrography. Allibone et al. (2009a) described the contact between the Omaki Orthogneiss and West Arm Leucogranite in Lake Manapouri as a network of dikes of West Arm Leucogranite intruding the Omaki Orthogneiss, and these observations agree with our field relationships. The Omaki Orthogneiss ($\text{High-Sr/Y} > 40$) is part of the Western Fiordland Orthogneiss in central Fiordland, emplaced at the onset of the Western Fiordland Orthogneiss plutonism (Allibone et al., 2009a).

Regional structural mapping of the Refrigerator Orthogneiss shows distinct structural fabrics consisting of shallow foliation and lineation ($28\text{-}54^\circ$) measured in Lake Te Anau and Lake Manapouri. Structural data together with $^{206}\text{Pb}/^{238}\text{U}$ zircon ages for host rocks and post-kinematic dikes suggest that subsolidus deformation in the Refrigerator Orthogneiss occurred between ca 129 to 127 Ma. Our new zircon and titanite geochronology data indicate that magmatic emplacement of the Separation Point Suite plutons in central Fiordland was partially coeval with shear zone deformation at mid-crustal conditions around ca. 129 Ma.

5.4. Spatial and temporal migration of magmatism and deformation

On the basis of our geochronological and structural results, and additional data compiled from previous geochronology studies, we document a series of temporally related high-grade transpressional shear zones and spatio-temporal magmatic patterns that indicate

that deformation and magmatism varied in space and time within the arc in the context of a magmatic flare-up.

5.4.1. Mesozoic arc magmatism and shear zone development

Mesozoic arc magmatism initiated with the Darran Suite in the outboard arc at ca. 230-130 Ma (Allibone et al., 2009b), (Fig. 42A). Transition from a low-Sr/Y to high-Sr/Y magmatism is recorded at 129 Ma with the emplacement at 4-9 kbar of Separation Point Suite (Scott et al., 2009; Schwartz et al., 2017; this study).

Thrusting and regional transpression occurs from 129 to 105 Ma (this study; Daczko et al., 2002a; Klepeis et al., 2004; Marcotte et al., 2005; Allibone and Tulloch, 2008). Shear zone development at mid-crustal condition around ca. 129 Ma, synchronous with the emplacement of Separation Point Suite. The period between ca. 130 to 125 Ma (Fig. 42B) is also marked by the emplacement of Refrigerator Orthogneiss (ca. 129 Ma; this study), East McKerr (ca. 128-120 Ma; Hollis et al., 2004; Schwartz et al., 2017), Mt. Edgar Diorite (ca. 128 Ma; Hollis et al., 2003), Supper Cove Orthogneiss (128±1 Ma; Tulloch and Kimbrough, 2003), Mt Edgar Diorite (ca. 129 Ma; Hollis et al., 2003), and Indecision Creek Complex (ca. 135-124 Ma; Kimbrough unpubl. data in Bradshaw, 1985)

Between 125 to 120 Ma (Fig. 42C), the emplacement of the Separation Point Suite and Western Fiordland Orthogneiss occurred at mid- and low-crustal conditions and it was coeval with regional transpression in the middle crust (i.e. Grebe Mylonite Zone). This period is characterized by the emplacement of the Puteketeke Pluton (ca. 122 Ma; this study), Takahe Granodiorite (ca. 125-123 Ma; this study), Titiroa Granite (ca. 122 Ma; Bolhar et al., 2008), Omaki Orthogneiss (ca. 122-124Ma; this study; Ramezani and Tulloch, 2009), North Fiord Granite (ca. 122 Ma; Bolhar et al., 2008), Worsley Pluton (ca. 124-121 Ma; Tulloch and Kimbrough, 2003; Hollis et al., 2004; Bolhar et al., 2008; Schwartz et al., 2017) and East McKerr (ca. 128-120 Ma; Hollis et al., 2004; Schwartz et al., 2017), Breaksea Orthogneiss (ca. 123 Ma; (Klepeis et al., 2016)) and Indecision Creek Complex (ca. 135-124 Ma; Kimbrough unpubl. data in Bradshaw, 1985).

Around 120 Ma magmatism migrated westwards to the Inboard Arc. Schwartz et al. (2017) describes the inward-focusing arc-parallel magmatism as a result of the Western Fiordland Orthogneiss peak magmatic activity and subsequent crustal thickening within the arc by ca. 128-116 Ma. Between 120-115 Ma (Fig. 42D) magmatism was focused in the Western Fiordland Orthogneiss with minor plutonism still active in the Separation Point Suite. Plutons active during this period include West Arm Leucogranite (ca. 116-110 Ma; this study), Malaspina Pluton (ca. 118-115 Ma; (Tulloch and Kimbrough, 2003; Klepeis et al., 2016; Schwartz et al., 2017), West McKerr (ca. 118 Ma;) Misty Pluton (ca. 116-114 Ma; Allibone et al., 2009b; Schwartz et al., 2017), NW Malaspina (117.5 $\pm$ 1.0 Ma; Schwartz et al., 2017), Resolution Island Orthogneiss (115.1 $\pm$ 1.6 Ma; Klepeis et al., 2016).

Upper-amphibolite facies transpressional deformation was recorded in the Indecision Creek, Mt Daniel and George Sound shear zones in northern Fiordland from 119 to 106 Ma (this study, Marcotte et al., 2005). Regional thrusting is recorded in the Pembroke thrust zone, Caswell Sound fold and thrust belt at granulite facies conditions (Klepeis et al., 2004; Schwartz et al., 2016). Transpressional deformation at mid-crustal conditions was dated by our titanite geochronology and cross-cutting relationships between ca. 129-116 Ma.

After 115 Ma (Fig. 42E) magmatism was waning in the Median Batholith and West Arm Leucogranite (ca. 116-110 Ma; this study), Misty Pluton (ca. 116-114 Ma; Allibone et al., 2009a; Schwartz et al., 2017) and Resolution Island Orthogneiss (115.1 $\pm$ 1.6 Ma; Klepeis et al., 2016) went through late stages of crystallization.

Emplacement of the Separation Point Suite and Western Fiordland Orthogneiss overlap with metamorphism in the middle and lower crust. Previous thermochronologic studies in central Fiordland identified a thermally weakened lower crust (ca. 118-102 Ma) within the Median Batholith, that could have been controlling the transition from crustal thickening to crustal thinning and extensional orogenic collapse (Schwartz et al., 2016).

Prolongated heating is also recorded in Northern Fiordland where high temperatures ($>700^{\circ}\text{C}$) persisted in the lower crust from ca. 135 to 94 Ma (Gebauer, 2016). These periods of high heat flow in the crust overlap with a major pulse of arc magmatism, transpression and granulite- to amphibolite-facies metamorphism in central and northern Fiordland (Daczko et al., 2001a; Scott et al., 2009; Scott, 2013; Marcotte et al., 2005; Stowell et al., 2010; Schwartz et al., 2016; Klepeis et al., 2016; Gebauer, 2016).

By 108 Ma magmatism had stopped in the Median Batholith and extensional deformation was recorded at the Doubtful Sound (Schwartz et al., 2016), Straight River (King et al., 2008) and Mt Irene (Scott and Cooper, 2006) shear zones. These structures are documenting the oldest extensional characteristics in Fiordland, thus preceding the initiation of extensional orogenic collapse (Fig. 42F).

Figure 41. Plot of number of crystallization dates (relative abundance) versus timing of intra-arc magmatic pulses and transpression in Zealandia. Data are not standardized to area. SPS= Separation Point Suite

5.4.2. Causal relationship between magmatism and transpressional deformation

Our zircon and titanite geochronology indicates that magmatic emplacement of the Separation Point Suite plutons in central Fiordland was partially coeval with transpressional shear zone development at mid-crustal conditions. In the case of the Indecision Creek Shear zone in northern Fiordland, Marcotte et al. (2005) described syn-kinematic intrusions and with complex parallel and across shear zones magma transfer during transpression. We did not recognize evidence of magma transport and/or emplacement in central Fiordland shear zones.

Based on our zircon and titanite thermochronology, structural and lithologic mapping, and cross-cutting relationships, we concluded that shear zones did not played a significant role transporting magma throughout the crust in central Fiordland. Our results show that transpression did not help accommodate and move magma through the middle crust during the Separation Point flareup.

Although, the Grebe Mylonite Zone and the Mylonites in Lake Te Anau did not display evidence of magma transport at outcrop scale, our time-magmatism-deformation maps (Fig. 42) show that plutons have elongate shapes parallel to the paleoarc axis. This emplacement pattern may be linked to a focusing of magmatism in a broader zone of transpression across Fiordland. Furthermore, temporal magmatic patterns indicate an inward focusing of magmatism before the onset of extensional orogenic collapse. Cretaceous arc magmatism in Fiordland had started to wane by ca. 110 Ma, followed by the transition from contractional to extensional regimes around ca. 108 Ma.

Figure 42. Time-magmatism-deformation maps of Fiordland from ca.170 Ma to ca.85 Ma. Maps were generated using $^{206}\text{Pb}/^{238}\text{U}$ zircon ages, and titanite chronology and thermometry data from this study and previous geochronologic and structural studies. Maps show the evolution of the Median Batholith magmatic arc, and widespread granulite to amphibolite facies metamorphism affecting both middle and lower crust.

Zealandia palinspastic reconstructions show a Mesozoic orogenic convergent margin active until ca.108 Ma when extensional orogenic collapse initiates, leading to seafloor spreading and final split of Gondwana (Mortimer and Campbell, 2014).

A. Darran Suite active from ca. 220 to 118 Ma; **B.** Separation Suite magmatism initiates at ca.129 Ma being coeval with transpression in the middle crust; **C.** Flare up in Separation Suite takes place at ca.125 Ma, granulite-to-amphibolite facies deformation in the lower crust initiates by ca.120 Ma; **D.** Transpression in the lower and middle crust (granulite and amphibolite facies) is active and coeval during this period, flare up in Separation Point suite continues; **E.** Waning of Separation Point magmatism and end of transpression in the lower crust between ca.115-108 Ma. **F.** Extensional orogenic collapse after ca. 106 Ma.

6. CONCLUSIONS

U-Pb zircon and titanite thermochronology paired with trace element geochemistry, petrology, structural data and field observations, have furthered our understanding of the spatial and temporal correlation of lithospheric-scale transpressional shear zones within the context of an arc flare-up event in the Fiordland sector of the Median Batholith,

Our U-Pb zircon geochronology data document the timing of Separation Point Suite magmatism in central Fiordland. Results from this study suggest that Separation Point Suite plutonism initiated with emplacement of the Refrigerator Orthogneiss at ca.129 Ma and was followed by emplacement of the Takahe granodiorite at 125-123 Ma, the Puteketeke pluton at ca.122 Ma and the West Arm Leucogranite from ca.116-110 Ma. Sub-solidus deformation (fabrics S_1 , L_1) in the Refrigerator Orthogneiss is bracketed by post-kinematic dikes between ca.129 and 125 Ma but absent in younger plutons.

Interpreting U-Pb ages in titanite can be a challenging task as a result of the high concentration of common lead, and the effects of intragrain Pb diffusion in the (re)distribution of radiogenic Pb and isotopic resetting in titanite. Hence, due to titanite ability to incorporate important amounts of rare earth elements (REEs) and previous studies that have suggested that titanite's origin could be discriminated by their texture, geochemistry and mineral assemblages, we used textural relations and trace element geochemistry data from our samples to provide a stronger supportive evidence to distinguish between titanite with different origin (e.g. igneous vs metamorphic), and then interpret titanite U-Pb ages and/or P-T paths with a higher degree of certainty.

Titanite thermochronology reveal that localized, amphibolite-facies mylonitic (fabrics S_2 , L_2) deformation in the Grebe Mylonite Zone in Lake Manapouri is hosted in Carboniferous rocks and is dated at ca.122-119 Ma. Coeval deformation during the ca.125-116 Ma interval is recorded in a number of diffuse shear zones (fabrics S_2 , L_2) in Jurassic and Carboniferous plutons located in South Fiord, Lake Te Anau. Additionally, based on our titanite thermochronology and structural data from Marcotte et al. (2005), we interpret

the Indecision Creek Shear Zone as recording upper-amphibolite-facies transpressional deformation at low crustal conditions between ca. 119 and 106 Ma.

Geochronological and structural data suggest that in the case of the Cretaceous Fiordland arc, magmatism preceded transpressional deformation within the arc. Temporal magmatic patterns indicate an inward focusing of magmatism before the onset of extensional orogenic collapse. Furthermore, our data suggest that shear zones did not play a significant role transporting magma throughout the crust in central Fiordland.

Field observations and structural measurements reflect a systematic variation in the orientation of lineations across the low and high strain shear zone boundaries in central Fiordland. These observations are consistent with transpressional deformation in shear zone development, that was previously identified by Marcotte et al. (2005) in the Indecision Creek Shear Zone in northern Fiordland.

We use structural and geochronological data to document a series of temporally related, high-grade transpressional shear zones that were active during widespread arc plutonism. New geochronology results suggest that Separation Point Suite plutonism in central Fiordland lasted from ca. 129 Ma to 110 Ma and overlapped with transpressional deformation in both the middle and lower crust of the Median Batholith. The data show that mylonitic shear zones exposed at Lake Manapouri and Lake Te Anau were coeval, and that highly-localized strain at Lake Manapouri became more diffuse to the north. Transpressional deformation in the lower crust was recorded between ca. 119 to 106 Ma in the Indecision Creek shear zone in northern Fiordland. Thus, deformation in the lower and middle crust in northern and central Fiordland precede extensional orogenic collapse at ca. 108 Ma

Results from this study will further our understanding of arc construction and the interaction between deformation and magmatic processes. Suggested additional research includes rheological studies that can provide large-scale information regarding changes in deformation mechanisms through time at different levels of the continental crust. Additionally, further work is needed to constrain how high-strain zones connect laterally and vertically within compositionally variable sections of the arc.

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17N214A_99.1	504.21.0.0495	34	505.21.0.0467	8.0127	6.01978	2.1	0.31	127	3	2.7	2.7	662	3.31	450	0.0291	23.6	0.46	1.43	0.88	11.7	39	79	176	8088	0.65	15.0	0.123	38	1.01	9.7	15.6	59	157	497	1091	Probability	0.05	
17N214A_40.1	504.21.0.0496	2.8	501.15.0.0480	4.0132	4.01996	1.5	0.4	128	2	2.4	2.4	653	4.03	430	0.0415	32.1	0.41	1.49	0.73	10.4	41	77	163	8985	0.56	15.6	0.061	52	1.01	10.0	12.9	52	166	479	1011	age error (95% conf., with error in Std)	1.8	
17N214A_40.1	498.15.0.0508	7.8	519.15.0.0489	8.0135	9.02003	1.5	0.2	128	2	3.3	3.1	678	3.96	497	0.0159	36.7	0.71	1.84	0.89	10.3	41	86	176	8118	0.55	13.2	0.067	60	1.55	12.2	15.7	67	188	539	1093	Mean age of coherent group (N=10)	123.6	
17N214A_16.1	497.15.0.0489	2.8	498.15.0.0476	4.0130	4.02004	1.5	0.4	128	2	2.6	2.6	666	2.46	440	0.016	35.6	0.56	1.37	1.17	10.2	41	76	161	8732	0.72	14.2	0.07	56	1.22	10.2	17.3	57	162	472	1007	age error (95% conf., without error in Std)	1.6	
17N214A_16.2	493.15.0.0488	1.8	493.15.0.0485	2.0136	3.020208	1.6	0.4	129	2	3.7	3.5	669	5.93	641	0.0367	67.0	1.46	0.90	12.7	51	112	258	9339	0.64	20.4	0.135	114	1.53	9.9	16.1	64	206	697	1605	MSWD	1.82		
17N214A_16.1	498.15.0.0498	2.7	498.15.0.0489	3.0136	4.020043	1.5	0.4	130	2	2.3	2.3	652	4.08	211	0.0190	25.8	0.19	0.56	0.31	4.8	18	37	88	9694	0.57	18.2	0.063	42	4.01	3.8	5.4	24	71	230	544	Mean age of coherent group (N=10)	123.6	
17N214A_71.2	493.15.0.0509	2.7	493.15.0.0475	0.134	5.020045	1.5	0.3	131	2	2.7	2.5	663	3.31	270	0.0359	37.5	0.62	1.51	0.31	8.3	28	47	93	9493	0.67	10.0	0.151	61	1.35	9.6	14.3	47	114	296	578	age error (95% conf., without error in Std)	1.6	
17N214A_41.1	529.20.0.0674	4.8	531.20.0.0647	7.0167	7.01884	2.0	0.3	116	2	9.5	10.1	774	1.22	518	0.0262	20.0	0.42	1.31	0.36	8.8	33	51	104	9556	0.33	11.9	0.111	33	0.91	8.8	8.4	44	138	320	647	Mean age of coherent group (N=10)	123.6	
17N214A_32.1	515.18.0.0501	10.1	522.20.0.0505	16.0133	16.01916	2.0	0.1	122	2	9.3	9.9	773	1.00	357	0.0159	21.1	0.40	1.38	0.42	8.8	40	60	110	9004	0.35	11.3	0.067	34	0.88	9.3	7.5	49	161	376	684	age error (95% conf., without error in Std)	1.6	
17N214A_17.1	515.21.0.0511	4.6	537.24.0.0229	16.0120	16.01911	1.9	0.1	122	2	8.3	8.4	761	0.95	734	0.0181	21.6	1.17	0.32	0.35	2.8	82	124	208	10059	0.32	8.8	0.076	51	2.55	21.1	16.0	119	333	777	1294	MSWD	1.82	
17N214A_56.1	506.28.0.0502	13.3	514.30.0.0534	46.0099	45.01869	2.4	0.1	123	3	8.7	8.4	776	0.97	641	0.0313	23.1	1.09	2.87	0.94	23.4	75	106	179	9367	0.35	7.6	0.132	38	2.39	19.4	16.7	118	306	661	1112	Mean age of coherent group (N=9)	122.8	
17N214A_18.1	508.20.0.0509	8.4	517.22.0.0508	21.0143	21.01946	2.0	0.1	123	4	17.2	17.2	837	0.71	325	0.0240	18.1	0.49	1.45	0.42	9.5	55	99	8431	0.34	10.4	0.101	30	1.07	9.8	7.4	48	142	345	614	age error (95% conf., with error in Std)	2.0		
17N214A_14.1	508.20.0.0509	8.4	517.22.0.0508	21.0112	21.01946	2.1	0.1	125	3	11.3	11.4	792	1.83	311	0.0166	22.0	1.33	0.41	0.55	33	52	96	8979	0.37	11.3	0.070	37	1.10	9.0	7.2	43	132	323	597	Mean age of coherent group (N=9)	122.8		
17N214A_11.1	509.20.0.0507	3.5	519.21.0.0381	22.0101	22.01928	2.1	0.1	125	3	9.2	9.3	771	1.02	598	0.0255	22.2	0.84	2.52	0.76	20.0	67	109	166	9112	0.32	8.4	0.108	36	1.83	17.7	13.5	101	272	616	1044	Probability	0.82	
17N214A_51.1	508.20.0.0538	4.8	515.21.0.0423	22.0101	21.01941	2.1	0.1	125	2	9.5	9.6	775	0.99	656	0.0149	23.7	1.73	4.32	1.27	26.1	79	105	170	9259	0.37	6.5	0.083	39	3.79	29.2	22.8	131	319	655	1059	age error (95% conf., with error in Std)	2.0	
17N214A_16.1	505.28.0.0570	7.1	523.31.0.0236	32.0078	32.01912	3.1	0.1	125	4	7.9	7.8	756	0.81	335	0.0161	19.6	0.36	1.11	0.27	8.4	32	58	117	10454	0.27	13.9	0.068	32	0.79	7.5	4.9	42	130	362	730	Mean age of coherent group (N=10)	123.6	
17N214A_35.1	490.18.0.0525	2.5	493.15.0.0471	5.0132	6.020027	1.9	0.3	130	2	5.7	5.8	726	2.40	805	0.0071	49.4	0.68	2.68	0.66	20.4	83	140	288	12191	0.31	13.1	0.038	66	1.50	13.9	11.8	102	337	873	1652	age error (95% conf., without error in Std)	1.6	
17N214A_44.1	542.17.0.0576	16.1	557.23.0.0352	43.0087	43.01795	2.3	0.1	117	2	1.1	1.1	597	0.87	108	0.0038	6.3	0.08	0.19	0.12	1.6	9	20	52	10394	0.68	33.1	0.016	10	0.17	1.3	2.1	8	37	126	321	Mean age of coherent group (N=9)	122.8	
17N214A_31.1	539.20.0.0529	10.5	533.21.0.0614	12.0159	12.01875	2.1	0.2	116	3	1.1	1.1	595	1.86	66	0.0259	6.6	0.09	0.21	0.15	1.6	7	18	45	10262	0.78	28.5	0.019	11	0.20	1.4	2.6	8	29	112	279	age error (95% conf., without error in Std)	2.6	
17N214A_26.1	524.18.0.0515	4.6	533.19.0.0436	12.0113	12.01875	1.9	0.2	120	2	0.6	0.6	562	1.13	45	0.0011	1.5	0.02	0.08	0.05	0.4	3	8	30	11010	0.82	73.5	0.005	2	0.04	0.5	0.8	2	12	52	184	MSWD	1.82	
17N214A_14.1	524.17.0.0502	7.2	521.19.0.0508	13.0135	13.01920	1.9	0.1	122	2	0.9	0.9	581	0.52	66	0.0139	2.6	0.03	0.11	0.09	0.9	5	11	37	10423	0.90	41.9	0.059	4	0.06	0.8	1.7	4	19	71	231	Mean age of coherent group (N=9)	122.8	
17N214A_41.1	519.22.0.0508	5.0	519.22.0.0508	5.0134	5.01926	2.2	0.4	123	3	0.7	0.7	564	0.98	52	0.0033	2.2	0.04	0.12	0.07	0.5	3	10	34	10638	0.81	69.5	0.014	4	0.09	0.8	1.2	2	12	61	209	age error (95% conf., with error in Std)	2.8	
17N214A_49.1	503.18.0.0527	8.1	511.15.0.0496	11.0135	11.01959	1.9	0.1	125	2	1.0	0.9	593	1.66	53	0.0038	3.2	0.06	0.08	0.06	3	10	31	11018	1.00	47.4	0.016	5	0.14	0.6	1.3	3	13	60	190	Mean age of coherent group (N=9)	122.8		
17N214A_41.1	510.18.0.0473	5.3	514.17.0.0418	11.0112	11.01947	1.7	0.1	126	2	0.6	0.6	553	1.47	38	0.0144	1.6	0.02	0.07	0.04	0.6	2	7	27	11233	0.59	48.5	0.061	3	0.04	0.5	0.7	3	9	46	169	age error (95% conf., with error in Std)	2.8	
17N214A_32.1	508.15.0.0486	2.4	505.19.0.0468	3.0127	4.01963	1.5	0.4	126	2	5.0	5.1	715	3.84	120	0.0772	12.18	1.93	5.53	2.79	40.9	127	186	302	7977	0.56	7.4	0.326	199	4.23	37.3	49.2	205	518	1160	1875	Probability	0.82	
17N214A_34.1	503.18.0.0507	4.8	505.18.0.0507	9.0138	9.01976	1.8	0.2	126	2	0.8	0.7	575	0.57	39	0.0164	2.2	0.02	0.06	0.05	0.3	3	7	23	10321	1.13	70.9	0.078	4	0.04	0.4	0.9	2	11	44	143	Mean age of coherent group (N=9)	122.8	
17N214A_15.1	570.38.0.0581	7.0	561.37.0.0701	13.0172	14.01781	3.7	0.3	111	4	1.8	1.7	634	0.87	429	0.0459	5.7	0.08	0.47	0.33	6.2	38	83	193	9192	0.59	30.8	0.194	9	0.17	3.2	5.9	31	154	521	1197	age error (95% conf., without error in Std)	11.6	
17N214A_19.1	568.31.0.0509	8.1	548.36.0.0795	18.0200	18.01826	2.6	0.2	112	4	4.2	4.3	698	0.95	777	0.0218	13.3	0.41	1.59	0.99	14.4	69	143	312	7641	0.63	21.6	0.062	22	0.90	10.7	17.5	73	281	894	1938	Mean age of coherent group (N=4)	116.2	
17N214A_20.1	550.18.0.0507	7.8	521.18.0.0511	10.0120	10.01875	1.9	0.2	124	2	1.5	1.4	618	1.23	269	0.0047	26.5	0.17	0.59	0.19	10.4	32	151	264	10233	0.31	13.5	0.104	46	0.82	11.0	10.1	88	334	1638	1445	age error (95% conf., without error in Std)	11.6	
17N214A_22.1	537.18.0.0502	5.4	534.17.0.0621	11.0160	11.01871	1.7	0.2	117	2	3.5	3.7	684	1.79	741	0.0618	11.1	0.31	1.06	0.91	12.0	65	134	288	8203	0.78	24.0	0.261	18	0.69	7.2	16.2	60	265	836	1789	MSWD	1.82	
17N214A_25.1	534.19.0.0526	7.0	544.24.0.0478	24.0121	24.01839	2.4	0.1	118	2	1.2	1.7	619	4.84	308	0.0336	3.7	0.05	0.36	0.23	3.7	25	56	134	9559	0.62	36.4	0.142	6	0.11	2.4	4.1	19	100	250	835	Mean age of coherent group (N=9)	123.6	
17N214A_29.1	524.18.0.0507	11.6	532.20.0.0486	17.0120	17.01875	2.3	0.1	117	2	1.2	1.4	618	1.23	269	0.0047	26.5	0.17	0.59	0.19	10.4	32	151	264	10233	0.31	13.5	0.104	46	0.82	11.0	10.1	88	334	1638	1445	age error (95% conf., without error in Std)	1.7	
17N214A_43.1	190.15.0.0555	3.2	190.15.0.0555	2.0066	3.020577	1.9	0.6	390	6	14	14	615	2.40	600	0.0078	5.9	0.07	0.52	0.21	7.4	51	119	270	11408	0.33	26.7	0.033	10	0.15	3.5	3.7	207	742	1675	1675	Mean age of coherent group (N=9)	123.6	
17N214A_34.1	125.18.0.0571	3.5	125.19.0.0538	6.5922	6.020796	1.9	0.3	140	2	0.7	0.8	331	6.71	0.77	1299	0.103	4.2	0.36	1.73	0.42	23.7	128	255	470	8891	0.20	19.8	0.044	7	0.79	11.7	7.4	119	520	1591	2919	Probability	0.82
17N214A_35.1	513.18.0.0507																																					

Appendix B

	238/206	2 sigma abs err	207/206	2 sigma abs err	FINAL AGES HERE 207-corrected ages for grains <400Ma, 7/6 ages for grains			Common Pb correction (Ma)	Common Pb correction (%)
					Age (Ma)	1-sigma	2-sigma		
0308F-1	28.2087	1.1936	0.4074	0.0078	126.2	4.8	9.3	98.4	77.94%
0308F-10	30.0120	1.1890	0.3769	0.0080	126.6	4.2	8.3	84.7	66.87%
0308F-11	29.7265	0.7423	0.3803	0.0066	126.9	3.8	7.4	86.4	68.03%
0308F-12	26.7237	0.8713	0.4237	0.0088	128.4	4.8	9.5	108.4	84.39%
0308F-13	23.9464	1.0780	0.4377	0.0086	138.6	5.9	11.6	125.1	90.20%
0308F-14	28.7604	0.6783	0.3774	0.0084	132.0	3.9	7.6	88.3	66.94%
0308F-15	29.5858	2.2758	0.3844	0.0168	126.5	6.4	12.5	88.1	69.70%
0308F-16	19.5313	1.1444	0.5025	0.0158	143.9	8.7	17.0	178.2	123.90%
0308F-17	0.7133	0.0305	0.7580	0.0260	1079.3	30.6	60.0	NA	NA
0308F-18	0.1905	0.0145	0.8027	0.0190	2257.0	21.4	42.0	NA	NA
0308F-19	2.9240	0.1881	0.6960	0.0162	434.5	18.4	36.0	4292.5	987.96%
0308F-2	31.7662	1.0495	0.3580	0.0068	124.3	3.6	7.2	75.5	60.70%
0308F-20	34.6741	1.9477	0.3271	0.0198	120.9	4.8	9.3	62.4	51.57%
0308F-21	24.0385	0.7859	0.4526	0.0074	133.3	5.6	10.9	129.4	97.11%
0308F-22	22.1729	1.9666	0.4579	0.0176	142.5	9.0	17.6	141.5	99.24%
0308F-23	22.5225	1.1160	0.4449	0.0100	144.8	6.6	12.9	135.3	93.38%
0308F-24	32.2893	1.3554	0.3388	0.0100	127.0	4.0	7.8	69.6	54.83%
0308F-25	34.2349	0.9845	0.3115	0.0038	126.0	2.9	5.8	59.6	47.25%
0308F-26	28.7109	0.8903	0.3823	0.0086	130.9	4.2	8.2	89.8	68.66%
0308F-27	33.4784	1.2553	0.3420	0.0066	121.7	3.6	7.0	68.0	55.81%
0308F-28	36.2845	0.8163	0.3141	0.0064	118.4	2.6	5.2	56.9	48.05%
0308F-29	40.3551	1.1400	0.2432	0.0038	120.3	2.3	4.4	37.5	31.20%
0308F-3	29.0613	0.6756	0.3920	0.0066	126.7	3.9	7.6	91.4	72.16%
0308F-30	41.8060	1.2933	0.2292	0.0054	118.7	2.3	4.5	33.7	28.34%
0308F-31	22.4517	0.5847	0.4688	0.0094	137.0	6.0	11.8	143.9	105.04%
0308F-32	19.3424	0.8231	0.5164	0.0074	139.6	7.9	15.4	185.2	132.58%
0308F-33	0.7299	0.5648	0.7160	0.0240	1474.4	27.6	54.0	NA	NA
0308F-34	2.8090	0.2525	0.6880	0.0186	473.5	21.4	42.0	4235.5	894.59%
0308F-35	2.9586	0.3151	0.6936	0.0068	435.7	8.0	15.6	4286.2	983.85%
0308F-36	32.2685	1.1662	0.3377	0.0040	127.3	3.6	7.0	69.4	54.49%
0308F-37	30.3767	1.4026	0.3880	0.0078	122.3	4.5	8.8	86.5	70.78%
0308F-38	46.6853	1.5257	0.2311	0.0050	106.1	2.1	4.2	30.5	28.76%
0308F-39	27.2554	1.0846	0.4249	0.0068	125.6	4.9	9.6	106.7	84.97%
0308F-4	30.8452	1.1037	0.3592	0.0060	127.7	3.8	7.5	78.0	61.06%
0308F-40	23.5905	0.6233	0.4814	0.0092	126.3	5.9	11.5	141.3	111.96%
0308F-41	31.9285	1.1825	0.3646	0.0080	122.1	3.8	7.5	76.7	62.83%
0308F-42	31.3578	0.9243	0.3730	0.0102	122.2	3.8	7.4	80.2	65.63%
0308F-43	29.3858	0.8290	0.3833	0.0048	127.6	3.9	7.6	88.1	69.03%
0308F-44	25.6410	0.7627	0.4286	0.0092	132.3	5.0	9.8	114.4	86.45%
0308F-5	27.3075	0.7308	0.3906	0.0080	135.2	4.3	8.4	96.7	71.57%
0308F-6	26.2467	1.0471	0.4141	0.0130	133.6	5.3	10.4	107.4	80.39%
0308F-7	13.5318	0.4395	0.5813	0.0112	161.7	7.6	14.8	297.8	184.13%
0308F-8	14.8148	0.3819	0.5510	0.0118	163.8	5.4	10.6	257.2	157.08%
0308F-9	30.0210	0.7751	0.3907	0.0062	123.0	3.8	7.5	88.2	71.71%
12NZ12-TS-1	43.7063	1.0315	0.1557	0.0040	126.8	1.7	3.4	19.0	15.02%
12NZ12-TS-10	20.7900	1.6425	0.4590	0.0220	151.5	9.4	18.4	151.5	99.95%
12NZ12-TS-11	19.8177	0.6755	0.4770	0.0114	151.8	7.2	14.2	165.6	109.05%
12NZ12-TS-12	22.6244	0.6245	0.4386	0.0096	146.4	5.7	11.2	132.4	90.47%
12NZ12-TS-13	48.7092	1.4710	0.0411	0.0036	132.2	2.0	4.0	1.2	0.92%
12NZ12-TS-14	49.0918	1.2050	0.0387	0.0028	131.6	1.7	3.2	1.6	1.20%
12NZ12-TS-15	48.7329	1.5674	0.0420	0.0022	132.0	2.2	4.2	1.0	0.76%
12NZ12-TS-16	47.2590	1.4294	0.1046	0.0038	125.7	2.0	3.9	9.3	7.36%
12NZ12-TS-17	29.5159	0.9932	0.3362	0.0056	139.5	3.8	7.4	75.3	53.97%
12NZ12-TS-18	49.8256	0.9930	0.0896	0.0022	121.7	1.3	2.5	6.4	5.29%
12NZ12-TS-19	29.1460	0.7815	0.3499	0.0078	137.6	3.7	7.3	79.9	58.07%
12NZ12-TS-2	41.1015	0.8109	0.1827	0.0054	129.6	1.7	3.3	25.4	19.59%
12NZ12-TS-20	43.4028	1.3563	0.1648	0.0046	126.0	2.2	4.3	20.9	16.58%
12NZ12-TS-21	42.8633	0.8084	0.1698	0.0026	126.7	1.5	2.9	22.0	17.39%

12NZ12-TS-22	40.6835	0.9600	0.1933	0.0080	128.9	2.0	4.0	27.6	21.41%
12NZ12-TS-23	41.4766	1.0322	0.1768	0.0068	129.6	2.0	3.9	24.0	18.56%
12NZ12-TS-24	43.2339	0.7851	0.1627	0.0034	126.9	1.4	2.8	20.5	16.18%
12NZ12-TS-25	45.2694	1.2706	0.1409	0.0046	125.0	1.9	3.8	15.9	12.75%
12NZ12-TS-26	44.6429	0.9965	0.1486	0.0042	125.4	1.6	3.2	17.4	13.91%
12NZ12-TS-27	48.6618	1.0419	0.1030	0.0019	122.4	1.4	2.7	8.8	7.19%
12NZ12-TS-28	47.5511	1.4471	0.1157	0.0036	123.2	2.0	3.9	11.0	8.97%
12NZ12-TS-29	49.8504	0.9443	0.0757	0.0018	123.8	1.2	2.4	4.3	3.48%
12NZ12-TS-3	42.2654	1.1433	0.1772	0.0046	127.1	2.0	3.9	23.7	18.66%
12NZ12-TS-30	46.6636	1.8291	0.1182	0.0110	125.1	2.7	5.3	11.6	9.30%
12NZ12-TS-31	34.1647	1.0505	0.2745	0.0090	134.8	3.0	6.0	51.2	38.03%
12NZ12-TS-32	4.6296	0.4715	0.6647	0.0160	328.5	56.1	110.0	933.5	284.21%
12NZ12-TS-4	32.7118	1.7977	0.2900	0.0186	137.0	4.9	9.7	57.1	41.68%
12NZ12-TS-5	44.9236	1.0898	0.1403	0.0030	126.0	1.7	3.3	15.9	12.59%
12NZ12-TS-6	41.9111	0.7377	0.1726	0.0038	129.0	1.5	2.9	23.0	17.82%
12NZ12-TS-7	34.0368	1.0195	0.2680	0.0098	136.8	3.0	6.0	49.9	36.52%
12NZ12-TS-8	40.3388	2.8639	0.2180	0.0440	125.2	6.4	12.5	32.6	26.03%
12NZ12-TS-9	17.6149	0.5647	0.4989	0.0082	161.0	8.2	16.0	194.9	121.09%
17NZ60-TH-1	22.2222	1.4815	0.4350	0.0260	150.3	8.6	16.8	133.7	89.00%
17NZ60-TH-10	34.2818	1.6923	0.2866	0.0086	131.5	4.0	7.8	53.8	40.87%
17NZ60-TH-11	38.4172	1.4759	0.2498	0.0074	125.0	3.0	5.8	40.6	32.52%
17NZ60-TH-12	34.6260	1.7984	0.2961	0.0134	128.1	4.3	8.4	55.4	43.25%
17NZ60-TH-13	29.1545	1.8700	0.3572	0.0188	135.6	6.0	11.7	81.8	60.32%
17NZ60-TH-14	29.6209	0.8072	0.3511	0.0092	135.1	3.7	7.3	78.9	58.41%
17NZ60-TH-15	24.4499	1.1717	0.4030	0.0200	146.9	6.4	12.6	111.5	75.92%
17NZ60-TH-16	31.4268	1.2247	0.3207	0.0158	134.9	4.2	8.2	67.0	49.63%
17NZ60-TH-17	34.7343	0.9410	0.3025	0.0126	126.3	3.1	6.1	56.7	44.93%
17NZ60-TH-18	50.1505	1.0563	0.1134	0.0042	117.2	1.4	2.6	10.1	8.65%
17NZ60-TH-19	53.4474	1.2569	0.0598	0.0012	117.8	1.4	2.8	1.7	1.41%
17NZ60-TH-2	33.1785	1.2769	0.3060	0.0108	131.3	3.7	7.2	60.1	45.75%
17NZ60-TH-20	51.5464	1.8599	0.0864	0.0024	118.1	2.2	4.3	5.8	4.90%
17NZ60-TH-21	23.5849	7.4537	0.4270	0.0920	144.3	28.2	55.3	122.7	85.04%
17NZ60-TH-22	34.0020	1.7111	0.2939	0.0196	130.9	4.6	9.0	55.9	42.66%
17NZ60-TH-23	32.5203	1.4383	0.3051	0.0178	134.2	4.4	8.6	61.0	45.48%
17NZ60-TH-24	28.9017	4.1766	0.3590	0.0400	136.3	11.8	23.2	82.7	60.68%
17NZ60-TH-25	30.5064	0.8934	0.3389	0.0156	134.3	4.0	7.8	73.6	54.78%
17NZ60-TH-26	31.7662	1.0293	0.3218	0.0116	133.2	3.6	7.2	66.6	49.96%
17NZ60-TH-27	25.9067	1.4765	0.4010	0.0184	139.3	6.3	12.4	104.7	75.18%
17NZ60-TH-28	38.1243	1.9476	0.2472	0.0130	126.4	3.9	7.6	40.5	31.99%
17NZ60-TH-3	35.3732	1.2262	0.2853	0.0150	127.8	3.4	6.7	51.9	40.61%
17NZ60-TH-4	32.8084	2.1097	0.3097	0.0196	131.9	5.4	10.7	61.6	46.69%
17NZ60-TH-5	31.6256	1.2602	0.3321	0.0096	131.3	3.9	7.7	69.4	52.88%
17NZ60-TH-6	26.6170	1.3744	0.3900	0.0240	138.8	6.4	12.4	99.0	71.30%
17NZ60-TH-7	24.2718	1.5317	0.4250	0.0200	140.9	7.2	14.1	119.6	84.91%
17NZ60-TH-8	44.3066	2.7876	0.1560	0.0220	125.0	4.5	8.8	18.9	15.11%
17NZ60-TH-9	33.3778	1.6043	0.3050	0.0220	130.8	4.7	9.2	59.5	45.52%
17NZ95B-TH-11	33.6700	1.5645	0.3006	0.0114	130.7	4.0	7.9	58.0	44.41%
17NZ95B-TH-10	29.6736	0.9510	0.3538	0.0132	134.1	4.1	8.1	79.6	59.31%
17NZ95B-TH-25	25.0627	1.6332	0.4154	0.0158	139.5	6.8	13.3	112.6	80.77%
17NZ95B-TH-17	25.2972	0.9343	0.4064	0.0158	140.9	5.5	10.8	109.0	77.30%
17NZ95B-TH-37	26.2467	1.3778	0.3874	0.0184	141.5	6.0	11.8	99.6	70.34%
17NZ95B-TH-35	25.3421	0.8092	0.4028	0.0114	141.8	5.0	9.9	107.7	75.94%
17NZ95B-TH-33	23.8039	0.8953	0.4269	0.0160	143.0	6.0	11.8	122.3	85.52%
17NZ95B-TH-16	22.3214	1.7937	0.4500	0.0320	144.4	9.7	19.1	138.6	96.04%
17NZ95B-TH-7	24.9377	1.7413	0.3990	0.0240	145.3	7.6	14.9	107.9	74.28%
17NZ95B-TH-46	23.5849	1.2237	0.4240	0.0220	145.3	7.1	13.9	122.2	84.12%
17NZ95B-TH-6	27.8552	1.5518	0.3438	0.0172	145.6	5.7	11.2	81.8	56.14%
17NZ95B-TH-3	25.2525	1.2754	0.3857	0.0198	147.6	6.3	12.3	103.0	69.79%
17NZ95B-TH-56	21.5517	1.3005	0.4549	0.0160	147.7	7.7	15.2	144.6	97.90%
17NZ95B-TH-12	21.4592	1.9341	0.4470	0.0200	151.2	9.5	18.7	141.8	93.78%
17NZ95B-TH-44	23.0521	1.0309	0.4147	0.0160	151.8	6.4	12.6	121.9	80.35%
17NZ95B-TH-23	20.2020	2.2855	0.4670	0.0260	152.8	11.8	23.2	158.2	103.50%

17NZ95B-TH-47	21.7391	1.2287	0.4340	0.0240	153.9	8.1	15.9	135.9	88.26%
17NZ95B-TH-38	19.6464	1.7755	0.4750	0.0260	153.9	10.9	21.3	166.1	107.87%
17NZ95B-TH-29	18.7970	0.9893	0.4911	0.0150	154.2	8.6	16.9	179.9	116.72%
17NZ95B-TH-22	17.3913	0.7864	0.5118	0.0142	157.3	9.2	18.0	203.4	129.38%
17NZ95B-TH-30	16.8350	1.5871	0.5100	0.0320	163.2	13.5	26.5	208.8	127.89%
17NZ95B-TH-39	18.4162	1.0175	0.4750	0.0220	164.1	9.5	18.6	176.7	107.63%
17NZ95B-TH-20	15.8983	1.0616	0.5239	0.0152	166.0	11.1	21.7	227.0	136.80%
17NZ95B-TH-27	15.8730	3.2250	0.5100	0.0440	173.0	22.6	44.3	221.0	127.69%
17NZ95B-TH-15	18.8324	0.6951	0.4037	0.0166	190.0	7.4	14.6	143.5	75.55%
17NZ95B-TH-8	17.3310	2.4029	0.3850	0.0400	214.6	18.5	36.2	146.4	68.20%
17NZ95B-TH-26	16.2075	0.5779	0.1973	0.0040	318.5	6.3	12.4	67.5	21.18%
17NZ95B-TH-52	19.2827	0.4834	0.0563	0.0009	324.6	4.1	8.0	1.4	0.44%
17NZ95B-TH-55	19.1975	0.5823	0.0569	0.0006	325.8	5.0	9.7	1.6	0.50%
17NZ95B-TH-54	19.1278	0.4025	0.0595	0.0007	325.9	3.4	6.8	2.6	0.80%
17NZ95B-TH-53	18.7336	0.4352	0.0556	0.0011	334.2	3.9	7.7	1.1	0.32%
17NZ95B-TH-40	15.1057	2.3731	0.5240	0.0320	174.5	31.6	62.0	238.5	136.62%
17NZ95B-TH-1	15.1057	0.5933	0.5291	0.0144	171.9	8.1	15.8	241.2	140.29%
17NZ95B-TH-32	14.9254	0.8911	0.3518	0.0138	265.9	12.2	24.0	152.1	57.18%
17NZ95B-TH-19	14.5773	0.8075	0.4434	0.0190	223.7	12.2	24.0	204.3	91.33%
17NZ95B-TH-28	14.1044	0.7559	0.5400	0.0196	178.0	11.2	22.0	264.0	148.31%
17NZ95B-TH-43	13.3333	0.8533	0.5210	0.0360	199.3	15.3	30.0	266.7	133.87%
17NZ95B-TH-48	12.9366	2.4434	0.5570	0.0360	183.7	43.9	86.0	295.3	160.74%
17NZ95B-TH-13	12.5156	1.1278	0.5640	0.0200	185.5	22.4	44.0	309.5	166.87%
17NZ95B-TH-41	12.4471	0.1890	0.2898	0.0074	356.2	3.8	7.4	142.0	39.86%
17NZ95B-TH-42	12.0192	0.3756	0.3073	0.0132	357.5	7.9	15.4	157.5	44.04%
17NZ95B-TH-18	11.5473	0.4267	0.4305	0.0130	290.2	9.8	19.2	245.1	84.49%
17NZ95B-TH-34	11.4943	0.5813	0.3910	0.0200	317.9	13.3	26.0	220.1	69.25%
17NZ95B-TH-9	11.4811	0.7382	0.4060	0.0240	308.2	17.3	34.0	229.8	74.56%
17NZ95B-TH-24	10.9890	2.4152	0.5800	0.0240	199.7	60.2	118.0	362.3	181.44%
17NZ95B-TH-2	10.3734	0.7102	0.5622	0.0172	224.7	19.4	38.0	368.3	163.92%
17NZ95B-TH-45	10.2881	0.5292	0.4094	0.0184	340.8	14.3	28.0	257.2	75.46%
17NZ95B-TH-36	9.9206	0.5315	0.5034	0.0186	280.5	16.3	32.0	338.5	120.64%
17NZ95B-TH-50	9.9108	1.2376	0.5870	0.0240	215.7	37.8	74.0	403.3	186.98%
17NZ95B-TH-4	9.6061	1.5687	0.6040	0.0300	208.8	51.0	100.0	429.2	205.62%
17NZ95B-TH-49	7.8740	1.9840	0.6210	0.0320	237.4	92.9	182.0	530.6	223.48%
17NZ95B-TH-14	7.5930	0.4728	0.6134	0.0158	253.8	24.5	48.0	544.2	214.40%
17NZ95B-TH-31	7.0822	0.6821	0.6467	0.0122	235.6	38.8	76.0	615.4	261.21%
17NZ95B-TH-21	6.9930	1.6627	0.6330	0.0360	253.7	93.9	184.0	607.3	239.38%
17NZ95B-TH-5	4.5872	0.5892	0.6170	0.0200	410.8	74.5	146.0	860.2	209.38%
17NZ95B-TH-51	2.5510	0.8850	0.6420	0.0280	655.4	33.7	66.0	3949.6	602.63%
17NZ100-1	43.8596	1.9237	0.2090	0.0077	116.8	2.9	5.7	28.5	24.38%
17NZ100-10	36.9549	0.9287	0.2899	0.0070	121.4	2.6	5.1	50.7	41.77%
17NZ100-11	45.2694	0.7787	0.1729	0.0035	119.4	1.4	2.7	21.4	17.88%
17NZ100-12	38.8199	0.7535	0.2755	0.0035	118.5	2.1	4.1	45.5	38.40%
17NZ100-13	31.1526	1.0675	0.3650	0.0063	125.0	3.8	7.4	78.4	62.71%
17NZ100-14	43.4783	0.8318	0.2018	0.0041	119.1	1.6	3.1	27.5	23.05%
17NZ100-15	36.9959	0.7665	0.3053	0.0048	118.0	2.4	4.8	53.9	45.68%
17NZ100-16	39.2465	0.9242	0.2596	0.0054	120.4	2.2	4.3	41.8	34.73%
17NZ100-17	39.3546	0.7124	0.2592	0.0048	120.1	2.0	3.9	41.6	34.60%
17NZ100-18	32.8947	1.2985	0.3726	0.0086	116.6	3.9	7.6	76.3	65.41%
17NZ100-19	28.1690	0.8728	0.4230	0.0120	122.1	4.7	9.2	102.7	84.16%
17NZ100-2	43.6300	0.9328	0.2200	0.0100	115.5	1.9	3.8	30.6	26.54%
17NZ100-20	36.5097	0.7198	0.3089	0.0069	118.8	2.5	5.0	55.4	46.64%
17NZ100-21	43.2900	1.0495	0.1898	0.0034	121.8	1.8	3.5	25.4	20.83%
17NZ100-22	40.4858	1.1802	0.2310	0.0130	122.2	2.6	5.1	35.1	28.67%
17NZ100-23	32.4359	0.8206	0.3680	0.0140	119.4	3.7	7.3	76.3	63.94%
17NZ100-24	33.4336	0.7042	0.3228	0.0053	126.4	2.8	5.6	63.6	50.32%
17NZ100-25	41.4079	0.7887	0.2352	0.0036	118.7	1.8	3.5	35.1	29.52%
17NZ100-26	39.1850	0.9673	0.2486	0.0064	122.8	2.2	4.4	39.7	32.36%
17NZ100-27	43.8982	1.1177	0.1810	0.0110	121.7	2.1	4.0	23.5	19.30%
17NZ100-28	35.7398	1.1496	0.3160	0.0160	119.8	3.4	6.8	58.1	48.52%
17NZ100-29	44.8833	1.2289	0.1828	0.0017	118.7	1.9	3.7	23.3	19.59%

17NZ100-3	37.9075	0.9771	0.2859	0.0033	119.2	2.4	4.8	48.7	40.87%
17NZ100-30	40.0802	0.8996	0.2313	0.0048	123.4	2.0	3.9	35.5	28.75%
17NZ100-31	46.1467	1.3842	0.1590	0.0017	119.5	2.0	3.8	18.7	15.61%
17NZ100-32	44.7027	1.1391	0.1810	0.0034	119.5	1.8	3.5	23.1	19.30%
17NZ100-33	45.8085	1.0492	0.1498	0.0024	122.0	1.6	3.1	17.2	14.11%
17NZ100-34	42.3729	0.7720	0.2092	0.0024	120.9	1.6	3.1	29.5	24.44%
17NZ100-35	31.5358	0.7260	0.3760	0.0056	120.8	3.4	6.8	80.4	66.60%
17NZ100-36	53.5045	1.2882	0.0785	0.0026	115.0	1.4	2.8	4.4	3.85%
17NZ100-37	40.2739	1.2489	0.2208	0.0047	124.9	2.4	4.7	33.2	26.62%
17NZ100-38	46.4253	1.1639	0.1639	0.0029	118.0	1.7	3.3	19.4	16.44%
17NZ100-39	34.9650	2.3229	0.3150	0.0290	122.6	5.7	11.3	59.4	48.40%
17NZ100-4	45.3926	1.0921	0.1769	0.0027	118.4	1.7	3.3	22.1	18.63%
17NZ100-40	40.8998	1.1040	0.2330	0.0049	120.6	2.2	4.3	35.1	29.07%
17NZ100-5	44.8632	0.8655	0.2073	0.0035	114.5	1.6	3.1	27.6	24.08%
17NZ100-6	43.5920	0.8551	0.2099	0.0030	117.4	1.6	3.2	28.8	24.56%
17NZ100-7	43.9947	1.1033	0.1962	0.0029	118.7	1.8	3.6	26.2	22.03%
17NZ100-8	46.6418	0.8049	0.1679	0.0024	116.8	1.3	2.5	19.9	17.05%
17NZ100-9	44.4840	1.6424	0.1728	0.0037	121.6	2.4	4.8	21.7	17.89%
17NZ104-1	50.3778	1.1674	0.1120	0.0029	116.9	1.4	2.8	9.8	8.42%
17NZ104-10	42.3729	3.9500	0.1730	0.0400	127.5	7.2	14.0	22.5	17.61%
17NZ104-11	46.6636	1.3500	0.1690	0.0090	116.6	2.0	4.0	20.1	17.29%
17NZ104-12	51.9481	1.4303	0.1043	0.0024	114.5	1.6	3.2	8.4	7.33%
17NZ104-13	29.0698	1.0986	0.4020	0.0100	124.0	4.5	8.8	93.7	75.62%
17NZ104-14	48.8043	1.2147	0.1349	0.0048	116.9	1.6	3.2	13.9	11.86%
17NZ104-15	34.6021	1.0656	0.3361	0.0053	119.2	3.1	6.2	64.4	54.09%
17NZ104-16	30.0391	0.8482	0.3914	0.0054	122.7	3.9	7.6	88.4	71.99%
17NZ104-17	26.3158	0.8310	0.4493	0.0079	122.8	5.0	9.9	117.8	95.93%
17NZ104-18	41.3052	1.0407	0.2287	0.0044	120.3	2.0	4.0	33.9	28.21%
17NZ104-19	48.8998	1.1717	0.1385	0.0067	116.1	1.6	3.2	14.4	12.37%
17NZ104-2	33.4448	1.1186	0.3056	0.0059	130.4	3.2	6.4	59.3	45.50%
17NZ104-20	51.4403	1.1907	0.1241	0.0015	112.6	1.4	2.7	11.5	10.19%
17NZ104-21	21.8103	0.3568	0.5280	0.0120	119.8	6.9	13.6	169.2	141.25%
17NZ104-22	47.3709	0.6956	0.1909	0.0034	111.2	1.2	2.4	23.5	21.13%
17NZ104-23	18.0180	0.5844	0.5829	0.0090	121.0	9.2	18.0	227.0	187.56%
17NZ104-24	38.9408	0.8037	0.2763	0.0062	118.0	2.2	4.3	45.5	38.59%
17NZ104-25	49.8256	0.7448	0.1210	0.0010	116.7	1.0	1.9	11.4	9.74%
17NZ104-26	45.4545	2.4793	0.1497	0.0063	123.0	3.5	6.9	17.5	14.27%
17NZ104-27	27.4725	1.2076	0.4327	0.0098	122.4	5.1	10.1	107.6	87.94%
17NZ104-28	32.3625	1.2568	0.3505	0.0087	123.9	3.8	7.5	72.3	58.40%
17NZ104-29	50.7099	0.9772	0.1217	0.0012	114.6	1.2	2.4	11.3	9.86%
17NZ104-3	44.9843	0.8297	0.1745	0.0025	119.9	1.4	2.8	21.9	18.25%
17NZ104-30	41.9992	1.6228	0.2336	0.0041	117.4	2.7	5.2	34.3	29.23%
17NZ104-31	52.0833	0.8138	0.1116	0.0012	113.1	1.0	1.9	9.5	8.38%
17NZ104-32	49.2368	1.3576	0.1443	0.0032	114.4	1.7	3.4	15.2	13.27%
17NZ104-4	46.4900	1.2320	0.1759	0.0027	115.8	1.8	3.5	21.4	18.46%
17NZ104-5	41.0172	1.0263	0.2005	0.0032	126.5	2.0	3.9	28.8	22.78%
17NZ104-6	31.2207	0.7700	0.3834	0.0067	120.1	3.6	7.1	83.1	69.15%
17NZ104-7	48.4966	1.1760	0.1262	0.0020	119.1	1.5	3.0	12.5	10.52%
17NZ104-8	45.3515	1.3780	0.1833	0.0072	117.4	2.1	4.1	23.2	19.72%
17NZ104-9	46.2749	1.0493	0.1682	0.0034	117.7	1.6	3.1	20.1	17.12%
17NZ12-1	45.0045	0.9317	0.1772	0.0026	119.4	1.5	3.0	22.3	18.68%
17NZ12-10	46.7946	0.9197	0.1524	0.0085	119.0	1.5	3.0	17.3	14.54%
17NZ12-11	36.4033	0.8614	0.3104	0.0055	118.8	2.6	5.1	55.9	47.03%
17NZ12-12	39.4166	0.8390	0.2806	0.0081	115.7	2.3	4.5	45.8	39.58%
17NZ12-13	48.6145	1.0399	0.1213	0.0013	119.6	1.4	2.7	11.7	9.80%
17NZ12-14	40.8497	0.5840	0.2363	0.0032	120.2	1.6	3.2	35.7	29.75%
17NZ12-15	40.1606	2.4193	0.2650	0.0350	116.6	5.2	10.2	42.1	36.10%
17NZ12-16	43.5161	0.6060	0.1980	0.0044	119.7	1.4	2.7	26.8	22.37%
17NZ12-17	34.3525	0.6609	0.3390	0.0100	119.4	3.0	5.9	65.6	55.00%
17NZ12-18	38.4615	0.8136	0.2670	0.0033	121.3	2.1	4.2	44.2	36.41%
17NZ12-19	45.6413	0.5833	0.1678	0.0020	119.4	1.1	2.2	20.3	17.05%
17NZ12-2	45.3104	0.4311	0.1748	0.0017	119.0	1.0	2.0	21.7	18.23%

17NZ12-20	38.9105	1.8168	0.2560	0.0220	122.1	4.0	7.8	41.2	33.70%
17NZ12-21	34.4828	1.3080	0.3320	0.0190	120.5	4.0	7.9	64.0	53.12%
17NZ12-22	40.4204	1.1927	0.2400	0.0140	120.7	2.7	5.2	36.9	30.57%
17NZ12-23	41.7537	0.6276	0.2135	0.0044	121.8	1.5	3.0	30.8	25.25%
17NZ12-24	40.8831	0.3510	0.2408	0.0038	119.2	1.5	3.0	36.6	30.71%
17NZ12-25	40.0481	0.8821	0.2477	0.0036	120.3	2.0	4.0	38.7	32.15%
17NZ12-26	27.9330	2.7309	0.4300	0.0400	121.1	9.2	18.1	104.9	86.57%
17NZ12-27	33.2226	2.3179	0.3470	0.0320	121.5	6.3	12.4	69.5	57.20%
17NZ12-28	33.0033	2.5052	0.3470	0.0350	122.3	6.9	13.5	69.7	56.98%
17NZ12-29	42.7350	0.5479	0.2052	0.0034	120.6	1.4	2.7	28.5	23.66%
17NZ12-3	45.0045	0.6684	0.1884	0.0029	117.5	1.3	2.5	24.2	20.65%
17NZ12-30	28.7356	1.4863	0.4140	0.0300	122.1	6.5	12.7	97.9	80.14%
17NZ12-31	34.6021	3.4722	0.2980	0.0470	127.8	8.7	17.1	55.2	43.24%
17NZ12-32	42.1763	0.9428	0.2012	0.0020	122.9	1.8	3.5	28.1	22.86%
17NZ12-33	44.9438	1.0100	0.1434	0.0021	125.4	1.6	3.1	16.4	13.05%
17NZ12-34	40.0641	0.5618	0.2365	0.0025	122.5	1.7	3.2	36.5	29.85%
17NZ12-35	36.5764	0.8027	0.2739	0.0039	126.1	2.3	4.6	47.8	37.95%
17NZ12-36	33.0251	0.7307	0.3474	0.0075	122.1	3.1	6.1	70.2	57.45%
17NZ12-37	49.7512	0.8416	0.1213	0.0025	116.9	1.1	2.2	11.4	9.79%
17NZ12-38	39.5101	1.2488	0.2468	0.0033	122.1	2.5	4.9	39.0	31.92%
17NZ12-39	39.7298	0.8997	0.2362	0.0026	123.5	2.0	3.9	36.7	29.68%
17NZ12-4	39.9202	0.4621	0.2772	0.0041	114.9	1.9	3.7	44.6	38.80%
17NZ12-40	39.1389	0.7812	0.2471	0.0036	123.2	2.0	3.9	39.4	31.97%
17NZ12-41	42.0521	0.7427	0.2047	0.0033	122.6	1.6	3.1	28.9	23.56%
17NZ12-42	29.7708	0.5672	0.4080	0.0100	119.5	4.0	7.8	93.5	78.27%
17NZ12-43	34.8068	0.4846	0.3293	0.0034	120.0	2.6	5.0	62.6	52.19%
17NZ12-44	42.1408	0.9234	0.1929	0.0024	124.5	1.7	3.4	26.7	21.40%
17NZ12-45	43.0108	0.5550	0.2118	0.0023	118.6	1.4	2.7	29.6	24.95%
17NZ12-46	31.7864	0.9700	0.3594	0.0087	123.9	3.6	7.1	75.8	61.17%
17NZ12-47	35.1741	0.6928	0.3159	0.0039	121.7	2.6	5.1	59.0	48.46%
17NZ12-48	41.8585	0.7534	0.2136	0.0038	121.5	1.6	3.2	30.7	25.25%
17NZ124A-1	44.7828	1.1632	0.1821	0.0027	119.1	1.8	3.6	23.3	19.54%
17NZ124A-10	44.4444	0.8296	0.1832	0.0031	119.8	1.5	2.9	23.6	19.66%
17NZ124A-11	45.1264	0.9571	0.1760	0.0027	119.3	1.5	3.0	22.0	18.46%
17NZ124A-12	43.7637	1.4747	0.1775	0.0028	122.7	2.3	4.5	23.0	18.74%
17NZ124A-13	44.3656	1.5550	0.1772	0.0024	121.1	2.3	4.6	22.6	18.66%
17NZ124A-14	44.9035	0.9880	0.1813	0.0030	118.9	1.6	3.2	23.1	19.38%
17NZ124A-15	46.4684	1.1228	0.1469	0.0022	120.8	1.6	3.2	16.4	13.62%
17NZ124A-16	48.4496	1.3145	0.1174	0.0015	120.6	1.7	3.4	11.1	9.19%
17NZ124A-17	46.5116	1.2115	0.1454	0.0013	120.9	1.7	3.4	16.2	13.40%
17NZ124A-18	47.5511	0.9497	0.1376	0.0018	119.6	1.3	2.6	14.5	12.17%
17NZ124A-19	45.9770	1.2683	0.1978	0.0029	113.4	1.9	3.7	25.3	22.33%
17NZ124A-2	49.4805	1.4445	0.1589	0.0025	111.6	1.8	3.5	17.4	15.64%
17NZ124A-20	47.5964	1.0874	0.1225	0.0033	121.9	1.5	3.0	12.2	9.99%
17NZ124A-21	44.4444	1.3432	0.1709	0.0020	122.0	2.0	4.0	21.4	17.54%
17NZ124A-22	42.7716	1.3172	0.1942	0.0028	122.5	2.2	4.3	26.4	21.57%
17NZ124A-23	46.8604	0.8784	0.1532	0.0023	118.7	1.3	2.6	17.4	14.66%
17NZ124A-24	36.9959	1.0676	0.2837	0.0039	122.6	2.6	5.2	49.3	40.25%
17NZ124A-25	46.2321	1.5603	0.1160	0.0011	126.6	2.2	4.3	11.3	8.93%
17NZ124A-26	43.6300	1.2754	0.1849	0.0040	121.8	2.1	4.0	24.3	20.00%
17NZ124A-27	43.9367	1.3899	0.1786	0.0043	122.0	2.2	4.3	23.1	18.90%
17NZ124A-28	47.9846	1.6808	0.1626	0.0016	114.4	2.2	4.2	18.5	16.17%
17NZ124A-29	46.0617	1.5488	0.2048	0.0033	112.0	2.2	4.3	26.4	23.59%
17NZ124A-3	42.7899	1.3915	0.2018	0.0026	121.0	2.3	4.5	27.9	23.02%
17NZ124A-30	44.6229	1.3739	0.1689	0.0033	121.9	2.1	4.1	20.9	17.18%
17NZ124A-31	44.3459	1.1209	0.1747	0.0023	121.6	1.8	3.5	22.1	18.18%
17NZ124A-32	44.9843	0.5261	0.1696	0.0025	120.8	1.1	2.1	20.9	17.33%
17NZ124A-33	45.2284	1.3501	0.1904	0.0028	116.5	2.0	3.9	24.5	21.00%
17NZ124A-34	48.5909	0.9444	0.1214	0.0020	119.6	1.3	2.5	11.7	9.76%
17NZ124A-35	39.0625	1.5259	0.2740	0.0110	118.1	3.1	6.1	44.6	37.81%
17NZ124A-36	36.4697	1.1571	0.2789	0.0031	125.4	2.8	5.4	49.0	39.13%
17NZ124A-37	47.7099	1.5023	0.1310	0.0017	120.2	2.0	3.9	13.5	11.19%

17NZ124A-38	41.3736	0.7703	0.2220	0.0030	121.3	1.7	3.4	32.7	26.92%
17NZ124A-39	48.8281	1.2159	0.1252	0.0013	118.4	1.6	3.1	12.3	10.36%
17NZ124A-4	45.4752	0.9099	0.1724	0.0036	119.0	1.5	2.9	21.2	17.82%
17NZ124A-40	45.4959	0.9314	0.1558	0.0026	121.8	1.5	2.9	18.4	15.11%
17NZ124A-41	44.1112	1.0896	0.1753	0.0026	122.1	1.8	3.5	22.4	18.31%
17NZ124A-42	40.2253	1.1974	0.2954	0.0045	110.5	2.5	4.9	47.8	43.25%
17NZ124A-43	51.0725	1.4607	0.1439	0.0013	110.4	1.7	3.3	14.6	13.23%
17NZ124A-44	48.9476	0.9104	0.1561	0.0012	113.2	1.3	2.5	17.2	15.19%
17NZ124A-45	48.6145	1.8907	0.1421	0.0023	116.2	2.4	4.6	15.0	12.88%
17NZ124A-46	49.4560	1.3208	0.1389	0.0016	114.8	1.7	3.2	14.2	12.40%
17NZ124A-47	51.3347	1.2913	0.1612	0.0025	107.2	1.5	3.0	17.2	16.05%
17NZ124A-48	47.6644	1.4995	0.1703	0.0023	113.9	2.0	3.9	19.9	17.47%
17NZ124A-5	43.5730	1.6328	0.1840	0.0025	122.1	2.5	4.9	24.2	19.85%
17NZ124A-6	44.3853	1.0638	0.1895	0.0029	118.9	1.7	3.4	24.7	20.79%
17NZ124A-7	44.1696	1.0535	0.1879	0.0032	119.7	1.7	3.4	24.6	20.51%
17NZ124A-8	44.0335	1.2797	0.1842	0.0025	120.8	2.0	3.9	24.0	19.90%
17NZ124A-9	44.0917	0.8360	0.2029	0.0050	117.3	1.6	3.1	27.3	23.28%
17NZ12-5	29.5858	2.5384	0.4100	0.0470	119.7	9.0	17.6	94.3	78.79%
17NZ12-6	41.3565	0.6157	0.2289	0.0042	120.1	1.6	3.2	33.9	28.24%
17NZ12-7	42.7350	0.8766	0.2029	0.0040	121.0	1.7	3.3	28.1	23.23%
17NZ12-8	44.4642	1.2258	0.2070	0.0150	115.6	2.4	4.6	27.7	23.97%
17NZ12-9	32.8299	0.5066	0.3682	0.0051	117.9	3.1	6.0	75.5	64.04%
17NZ25A-1	46.8604	1.1858	0.1192	0.0012	124.4	1.7	3.3	11.7	9.43%
17NZ25A-10	20.9424	0.4079	0.5249	0.0079	125.9	7.0	13.7	174.8	138.88%
17NZ25A-11	22.7273	0.7748	0.5029	0.0053	123.6	6.3	12.4	154.1	124.63%
17NZ25A-12	35.8423	0.7965	0.2991	0.0034	123.1	2.5	4.9	54.3	44.08%
17NZ25A-13	28.8268	0.7645	0.4112	0.0064	122.5	4.2	8.1	97.3	79.43%
17NZ25A-14	13.4590	0.4529	0.6367	0.0072	462.0	7.7	15.0	0.0	0.00%
17NZ25A-15	14.1443	0.3801	0.6300	0.0120	440.0	6.1	12.0	0.0	0.00%
17NZ25A-16	14.5773	0.3187	0.6285	0.0087	428.0	4.5	8.8	0.0	0.00%
17NZ25A-17	33.1126	0.7346	0.3388	0.0059	123.8	3.0	5.9	68.0	54.88%
17NZ25A-18	17.4216	0.2307	0.5860	0.0120	123.7	9.5	18.7	236.1	190.77%
17NZ25A-19	14.2248	0.4047	0.6330	0.0160	438.0	6.1	12.0	0.0	0.00%
17NZ25A-2	17.4520	0.4569	0.5820	0.0110	125.3	9.5	18.6	233.6	186.39%
17NZ25A-20	32.3625	0.5551	0.3590	0.0063	121.8	3.1	6.1	74.4	61.07%
17NZ25A-21	45.6204	0.9574	0.1595	0.0028	120.8	1.5	2.9	19.0	15.70%
17NZ25A-22	44.3262	0.9824	0.1666	0.0025	123.1	1.6	3.1	20.7	16.83%
17NZ25A-23	20.5761	0.5927	0.5247	0.0088	128.2	7.3	14.3	177.6	138.57%
17NZ25A-24	13.6426	0.5397	0.6600	0.0110	456.0	8.7	17.0	0.0	0.00%
17NZ25A-25	23.2558	1.6225	0.5050	0.0120	120.1	7.5	14.6	151.9	126.43%
17NZ25A-26	27.3075	0.5891	0.4340	0.0100	122.7	4.6	9.0	109.1	88.85%
17NZ25A-27	28.8684	0.7000	0.3999	0.0065	125.4	4.0	7.9	94.1	75.06%
17NZ25A-28	38.6548	0.9413	0.2600	0.0033	122.1	2.2	4.4	42.5	34.77%
17NZ25A-29	34.3053	0.6237	0.3337	0.0048	120.7	2.8	5.4	64.5	53.41%
17NZ25A-3	33.3444	0.8228	0.3433	0.0065	121.9	3.1	6.1	68.6	56.24%
17NZ25A-30	50.0250	0.7758	0.1034	0.0008	119.0	1.0	1.9	8.6	7.20%
17NZ25A-31	49.5295	0.9567	0.1035	0.0012	120.2	1.2	2.4	8.6	7.16%
17NZ25A-32	48.7805	1.2612	0.1140	0.0018	120.3	1.6	3.2	10.5	8.69%
17NZ25A-4	27.9330	1.0924	0.4240	0.0063	122.8	4.7	9.3	104.0	84.67%
17NZ25A-5	24.5640	0.4043	0.4801	0.0093	121.7	5.5	10.8	135.5	111.35%
17NZ25A-6	34.6260	0.7434	0.3249	0.0058	121.6	2.8	5.5	61.9	50.90%
17NZ25A-7	20.9644	0.2769	0.5280	0.0120	124.6	7.2	14.1	175.8	141.11%
17NZ25A-8	21.8818	0.5746	0.5256	0.0096	120.3	6.9	13.4	168.0	139.73%
17NZ25A-9	22.8833	1.6233	0.4940	0.0150	125.8	7.8	15.2	150.2	119.35%
17NZ72A-1	25.1256	1.2626	0.4530	0.0110	127.4	6.0	11.8	124.6	97.77%
17NZ72A-10	41.6146	1.2296	0.1458	0.0020	135.0	2.1	4.2	18.1	13.45%
17NZ72A-11	24.1546	0.6418	0.4890	0.0110	120.9	5.9	11.6	140.6	116.36%
17NZ72A-12	23.9234	0.7440	0.4498	0.0084	134.8	5.6	10.9	129.4	95.96%
17NZ72A-13	40.7664	1.5788	0.1567	0.0083	135.7	2.9	5.7	20.5	15.15%
17NZ72A-14	43.2713	0.7677	0.1422	0.0024	130.5	1.4	2.7	16.8	12.90%
17NZ72A-15	25.7732	0.9300	0.4187	0.0074	134.6	5.0	9.8	110.7	82.19%
17NZ72A-16	23.9234	1.2019	0.4781	0.0058	125.6	6.3	12.3	138.4	110.22%

17NZ72A-17	27.7008	0.9208	0.3812	0.0069	135.9	4.3	8.5	93.0	68.42%
17NZ72A-18	36.7782	1.2850	0.2454	0.0061	131.4	2.9	5.7	45.2	34.37%
17NZ72A-19	18.6916	0.7686	0.5600	0.0110	126.3	8.8	17.3	209.7	166.11%
17NZ72A-2	25.8398	0.9348	0.4139	0.0090	135.7	5.0	9.9	108.9	80.19%
17NZ72A-20	13.7174	0.4516	0.6410	0.0150	454.0	7.1	14.0	0.0	0.00%
17NZ72A-21	23.0734	0.4525	0.5070	0.0120	120.4	6.3	12.4	153.1	127.18%
17NZ72A-22	32.1234	0.9287	0.3157	0.0045	133.2	3.2	6.2	64.4	48.30%
17NZ72A-23	14.2857	0.7755	0.6080	0.0130	436.0	11.7	23.0	0.0	0.00%
17NZ72A-24	17.6678	0.5931	0.5680	0.0110	130.0	9.3	18.2	225.0	173.10%
17NZ72A-25	36.0881	0.7033	0.2634	0.0042	130.0	2.2	4.4	46.2	35.51%
17NZ72A-26	23.4192	0.6582	0.4606	0.0073	134.1	5.7	11.1	135.2	100.81%
17NZ72A-27	29.9401	1.3446	0.3792	0.0080	126.3	4.5	8.8	85.5	67.66%
17NZ72A-28	37.8931	0.8759	0.2393	0.0043	128.8	2.2	4.2	39.1	30.31%
17NZ72A-29	33.8524	0.7105	0.3032	0.0057	129.4	2.7	5.3	58.3	45.09%
17NZ72A-3	15.9744	1.0718	0.6040	0.0140	126.1	11.6	22.8	264.9	210.14%
17NZ72A-30	35.7526	0.8948	0.2580	0.0047	132.4	2.5	4.8	45.4	34.27%
17NZ72A-31	21.5054	0.4625	0.5087	0.0092	128.5	6.7	13.1	164.2	127.80%
17NZ72A-32	13.5870	0.4431	0.6240	0.0110	458.0	7.1	14.0	0.0	0.00%
17NZ72A-4	22.6757	0.8227	0.4870	0.0150	129.4	6.7	13.2	148.6	114.87%
17NZ72A-5	24.6609	0.5473	0.4556	0.0096	129.0	5.3	10.4	127.2	98.63%
17NZ72A-6	20.5339	0.6325	0.5165	0.0078	131.6	7.2	14.1	174.7	132.82%
17NZ72A-7	12.5000	1.8750	0.6210	0.0250	493.0	36.7	72.0	0.0	0.00%
17NZ72A-8	8.1967	0.9406	0.7120	0.0200	741.0	40.3	79.0	0.0	0.00%
17NZ72A-9	22.4215	0.4374	0.4631	0.0096	139.2	5.9	11.5	142.1	102.14%
17NZ95B-1	13.3333	0.4267	0.3411	0.0062	466.0	7.7	15.0	0.0	0.00%
17NZ95B-10	22.2222	0.6914	0.0865	0.0018	271.8	4.3	8.4	11.8	4.35%
17NZ95B-11	21.5054	1.2025	0.1180	0.0230	269.4	8.7	17.1	23.6	8.74%
17NZ95B-12	23.3155	0.3262	0.1146	0.0015	249.9	1.9	3.8	20.8	8.32%
17NZ95B-13	23.7361	0.4226	0.1240	0.0023	242.5	2.4	4.7	23.5	9.70%
17NZ95B-14	8.4104	0.2829	0.5690	0.0053	724.0	11.7	23.0	0.0	0.00%
17NZ95B-15	16.9779	0.6342	0.2853	0.0096	264.4	6.8	13.3	104.6	39.56%
17NZ95B-16	13.5685	0.4419	0.3430	0.0110	458.0	7.7	15.0	0.0	0.00%
17NZ95B-17	14.0252	0.4328	0.2723	0.0059	444.0	6.6	13.0	0.0	0.00%
17NZ95B-18	20.7426	0.3141	0.1826	0.0053	255.2	2.9	5.6	48.3	18.92%
17NZ95B-19	9.1324	0.3836	0.4930	0.0100	670.0	13.8	27.0	0.0	0.00%
17NZ95B-2	13.9860	0.8216	0.6030	0.0250	445.0	12.8	25.0	0.0	0.00%
17NZ95B-20	18.2149	0.3318	0.1196	0.0014	316.7	3.1	6.1	27.5	8.69%
17NZ95B-21	3.1546	0.4677	0.7590	0.0230	4870.0	27.0	53.0	NA	NA
17NZ95B-22	27.7008	1.1510	0.4220	0.0061	124.4	4.8	9.5	103.9	83.52%
17NZ95B-23	4.8544	0.3299	0.7090	0.0130	1203.0	39.3	77.0	NA	NA
17NZ95B-24	25.3165	0.8973	0.1010	0.0037	234.5	4.3	8.4	15.2	6.47%
17NZ95B-25	19.3386	0.3515	0.0736	0.0005	316.8	2.9	5.7	8.2	2.59%
17NZ95B-26	31.7864	0.5759	0.1092	0.0022	185.2	1.8	3.5	14.5	7.80%
17NZ95B-27	14.9790	0.1952	0.2790	0.0041	416.6	2.7	5.2	0.0	0.00%
17NZ95B-28	8.4317	0.3768	0.6034	0.0067	722.0	15.8	31.0	0.0	0.00%
17NZ95B-29	6.5359	0.4272	0.6420	0.0150	919.0	29.1	57.0	0.0	0.00%
17NZ95B-3	19.7239	0.5446	0.0942	0.0013	302.7	4.3	8.3	15.9	5.25%
17NZ95B-30	21.2766	0.5432	0.1562	0.0019	258.5	3.6	7.1	37.6	14.56%
17NZ95B-31	13.1062	0.6871	0.4240	0.0180	474.0	12.2	24.0	0.0	0.00%
17NZ95B-32	13.2979	0.9195	0.4530	0.0230	467.0	15.8	31.0	0.0	0.00%
17NZ95B-33	15.4083	0.3561	0.2920	0.0063	405.3	4.7	9.3	0.0	0.00%
17NZ95B-34	19.6232	0.3812	0.1279	0.0036	291.0	3.1	6.2	29.4	10.09%
17NZ95B-35	9.3458	0.4367	0.5080	0.0170	655.0	14.8	29.0	0.0	0.00%
17NZ95B-36	8.8339	0.6165	0.6940	0.0150	691.0	23.5	46.0	0.0	0.00%
17NZ95B-37	19.1939	0.4421	0.1918	0.0031	271.8	3.9	7.6	55.8	20.52%
17NZ95B-38	12.7551	0.5043	0.5280	0.0220	486.0	9.2	18.0	0.0	0.00%
17NZ95B-39	9.8328	0.4061	0.6500	0.0150	624.0	12.8	25.0	0.0	0.00%
17NZ95B-4	3.3898	0.3677	0.7280	0.0180	4799.0	20.9	41.0	NA	NA
17NZ95B-40	11.0742	0.9320	0.6020	0.0150	557.0	23.0	45.0	0.0	0.00%
17NZ95B-41	15.6986	0.8379	0.5380	0.0120	161.1	10.6	20.7	236.9	147.10%
17NZ95B-42	10.3842	0.6901	0.5930	0.0200	592.0	18.9	37.0	0.0	0.00%
17NZ95B-43	11.6686	1.3479	0.5280	0.0450	529.0	30.1	59.0	0.0	0.00%

17NZ95B-44	9.8232	0.4921	0.4720	0.0110	625.0	15.3	30.0	0.0	0.00%
17NZ95B-45	24.2718	0.7069	0.4905	0.0083	119.8	5.8	11.4	140.5	117.28%
17NZ95B-46	15.2439	0.4648	0.2446	0.0043	409.0	6.1	12.0	0.0	0.00%
17NZ95B-47	35.8038	1.1665	0.3274	0.0068	117.1	3.1	6.1	60.4	51.61%
17NZ95B-48	18.7266	0.7014	0.3440	0.0100	215.8	6.5	12.7	119.2	55.26%
17NZ95B-5	2.8986	0.3613	0.7810	0.0240	4920.0	28.1	55.0	NA	NA
17NZ95B-6	6.4935	0.4638	0.7320	0.0160	925.0	31.6	62.0	0.0	0.00%
17NZ95B-7	5.4645	0.5375	0.6610	0.0210	1079.0	48.5	95.0	NA	NA
17NZ95B-8	2.5773	0.3188	0.7640	0.0170	4881.0	19.9	39.0	NA	NA
17NZ95B-9	1.9417	0.2526	0.7980	0.0150	4958.0	17.3	34.0	NA	NA
0213K1-10	1.5385	0.5207	0.7230	0.0440	682.2	50.0	98.0	4105.8	601.87%
0213K1-12	1.5674	0.3292	0.7226	0.0140	671.8	16.3	32.0	4115.2	612.53%
0213K1-16	1.6129	0.6764	0.7170	0.0540	679.3	63.3	124.0	4095.7	602.96%
0213K1-34	1.6667	0.3833	0.8303	0.0196	140.1	22.4	44.0	4889.9	3490.68%
0213K1-44	3.1546	0.3582	0.8180	0.0200	104.9	23.5	46.0	4898.1	4671.29%
0213K1-40	3.2895	0.6276	0.8220	0.0182	91.0	21.4	42.0	4921.0	5404.92%
0213K1-25	3.4483	0.5707	0.7620	0.0118	222.5	13.3	26.0	4653.5	2091.81%
0213K1-31	3.5486	0.2367	0.7837	0.0188	168.8	21.4	42.0	4756.2	2818.13%
0213K1-5	3.5971	0.5435	0.7150	0.0200	314.1	23.5	46.0	4455.9	1418.69%
0213K1-17	3.9526	0.3437	0.7057	0.0164	304.3	18.4	36.0	4444.7	1460.51%
0213K1-13	4.9020	0.9131	0.6760	0.0340	292.8	112.2	220.0	897.2	306.44%
0213K1-3	5.3191	0.9620	0.6926	0.0126	246.1	90.8	178.0	860.9	349.90%
0213K1-11	7.6687	0.6116	0.6480	0.0220	216.5	30.6	60.0	573.5	264.96%
0213K1-2	10.5042	0.8165	0.6283	0.0152	173.1	22.4	44.0	412.9	238.53%
0213K1-33	10.9170	0.7866	0.7001	0.0162	115.3	19.4	38.0	449.7	390.07%
0213K1-1	12.1065	0.7915	0.6402	0.0146	142.7	16.3	32.0	368.3	258.09%
0213K1-41	12.2100	0.6858	0.6787	0.0172	116.9	14.3	28.0	390.1	333.83%
0213K1-32	12.7226	1.0683	0.6640	0.0220	121.2	20.4	40.0	366.8	302.56%
0213K1-30	15.1286	1.2359	0.6160	0.0200	126.9	17.3	34.0	285.1	224.73%
0213K1-4	15.6740	0.5405	0.5710	0.0118	144.9	10.6	20.7	253.8	175.14%
0213K1-7	15.8228	0.7010	0.5711	0.0120	143.5	10.7	20.9	251.8	175.46%
0213K1-36	17.4825	0.9169	0.6047	0.0186	114.9	10.8	21.1	243.4	211.71%
0213K1-8	17.8253	1.2074	0.5421	0.0126	140.2	9.9	19.4	211.8	151.08%
0213K1-28	18.0180	0.7792	0.5745	0.0178	124.7	9.9	19.3	223.5	179.32%
0213K1-29	20.9644	1.0548	0.5540	0.0200	114.9	8.6	16.8	185.6	161.55%
0213K1-42	21.6450	1.1244	0.5340	0.0136	118.5	7.7	15.2	172.8	145.76%
0213K1-19	21.6920	0.9411	0.4935	0.0140	132.9	7.2	14.1	157.3	118.41%
0213K1-27	23.1481	0.9859	0.4978	0.0130	123.1	6.7	13.1	149.5	121.42%
0213K1-6	23.6016	0.8913	0.4733	0.0112	128.9	6.1	12.0	138.6	107.56%
0213K1-37	23.9234	1.6025	0.4969	0.0116	119.4	7.1	14.0	144.8	121.20%
0213K1-21	25.1889	1.5228	0.4434	0.0150	130.1	6.5	12.8	120.7	92.80%
0213K1-43	25.3421	1.2202	0.5008	0.0140	111.6	6.3	12.4	137.8	123.50%
0213K1-22	25.5493	1.1097	0.4443	0.0148	128.0	5.8	11.4	119.5	93.38%
0213K1-35	26.4971	1.3480	0.4725	0.0138	115.1	6.0	11.7	123.7	107.45%
0213K1-14	27.9564	1.1098	0.4034	0.0116	128.5	4.8	9.5	98.1	76.38%
0213K1-9	31.0752	0.7146	0.3669	0.0084	124.8	3.5	6.9	79.4	63.57%
0213K1-15	32.2269	0.9347	0.3696	0.0078	119.8	3.6	7.0	77.2	64.51%
0213K1-24	32.2789	1.5629	0.3701	0.0100	119.4	4.3	8.5	77.3	64.69%
0213K1-23	33.2116	0.7942	0.3761	0.0078	114.7	3.4	6.6	76.6	66.80%
0213K1-18	#VALUE!	#VALUE!	no value	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0213K1-20	#VALUE!	#VALUE!	no value	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0213K1-39	#VALUE!	#VALUE!	no value	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0308L1-5	1.1161	0.1868	0.8450	0.0200	105.8	23.5	46.0	4958.2	4684.44%
0308L1-29	1.1534	0.2262	0.8350	0.0200	170.1	24.5	48.0	4870.9	2863.14%
0308L1-2	1.2987	0.4385	0.8420	0.0300	109.1	34.7	68.0	4946.9	4532.93%
0308L1-25	1.5221	0.3290	0.8390	0.0360	108.6	41.8	82.0	4940.4	4547.52%
0308L1-27	1.5385	0.5207	0.8250	0.0900	178.5	102.0	200.0	4841.5	2712.58%
0308L1-9	1.6949	1.0342	0.8420	0.1160	83.7	132.7	260.0	4976.3	5943.04%
0308L1-18	1.7065	0.3786	0.8400	0.0260	92.4	30.6	60.0	4960.6	5370.78%
0308L1-20	1.7182	0.3956	0.8480	0.0260	55.1	30.6	60.0	5014.9	9093.33%
0308L1-13	1.7391	0.2601	0.8370	0.0240	104.2	27.6	54.0	4940.8	4743.55%
0308L1-6	1.7606	0.3100	0.8330	0.0200	120.7	23.5	46.0	4916.3	4073.83%

0308L1-14	1.9048	0.3918	0.8312	0.0140	119.0	16.3	32.0	4914.0	4129.72%
0308L1-42	2.0000	0.8000	0.8170	0.0360	168.8	42.9	84.0	4831.2	2862.75%
0308L1-17	2.0661	0.3757	0.8477	0.0192	47.0	22.4	44.0	5023.0	10680.48%
0308L1-39	2.1097	0.5964	0.8500	0.0280	37.5	31.6	62.0	5036.5	13443.48%
0308L1-1	2.2173	0.4130	0.8170	0.0170	152.4	19.4	38.0	4847.6	3181.85%
0308L1-34	2.3148	0.6323	0.8290	0.0640	105.5	73.5	144.0	4922.5	4667.36%
0308L1-11	2.5063	0.2387	0.8510	0.0240	28.4	27.6	54.0	5047.6	17775.29%
0308L1-33	2.7027	0.3068	0.8270	0.0220	96.2	26.5	52.0	4926.8	5121.12%
0308L1-21	2.7322	0.3285	0.8240	0.0220	103.8	25.5	50.0	4913.2	4734.48%
0308L1-28	2.7548	0.2428	0.8281	0.0116	91.3	13.3	26.0	4933.7	5406.06%
0308L1-38	2.7548	0.3491	0.8300	0.0240	85.9	28.6	56.0	4944.1	5758.93%
0308L1-40	3.1153	0.3106	0.8253	0.0144	87.8	16.3	32.0	4931.2	5616.17%
0308L1-24	3.1847	0.3854	0.8153	0.0172	110.5	19.4	38.0	4886.5	4421.84%
0308L1-35	3.4247	0.2346	0.8411	0.0132	43.6	15.3	30.0	5011.4	11492.51%
0308L1-37	3.4722	0.4340	0.8250	0.0240	79.5	27.6	54.0	4939.5	6213.76%
0308L1-8	3.9526	0.4062	0.8062	0.0124	107.2	14.3	28.0	4868.8	4542.42%
0308L1-36	3.9635	0.2639	0.8167	0.0126	86.1	14.3	28.0	4913.9	5705.63%
0308L1-23	4.1841	0.4902	0.8005	0.0156	112.0	74.5	146.0	1267.0	1131.76%
0308L1-22	5.2329	0.3998	0.8000	0.0260	90.4	40.8	80.0	1036.6	1147.08%
0308L1-31	6.2305	0.6832	0.7790	0.0220	102.4	50.0	98.0	856.6	836.52%
0308L1-10	16.5289	0.6557	0.6358	0.0154	106.8	11.3	22.2	271.9	254.54%
0308L1-43	17.3913	0.6654	0.6155	0.0144	110.7	10.4	20.4	249.6	225.51%
0308L1-12	30.5904	0.7299	0.4595	0.0122	103.1	4.5	8.7	104.3	101.12%
0308L1-30	49.0436	1.0583	0.0493	0.0007	130.0	1.4	2.8	0.1	0.06%
0308L1-15	#VALUE!	#VALUE!	no value	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0308L1-16	#VALUE!	#VALUE!	no value	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0308L1-19	#VALUE!	#VALUE!	no value	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0308L1-26	#VALUE!	#VALUE!	no value	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0308L1-3	#VALUE!	#VALUE!	no value	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0308L1-32	#VALUE!	#VALUE!	no value	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0308L1-4	#VALUE!	#VALUE!	no value	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0308L1-41	#VALUE!	#VALUE!	no value	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0308L1-44	#VALUE!	#VALUE!	no value	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0308L1-7	#VALUE!	#VALUE!	no value	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
17NZ4A-1	36.5631	1.8716	0.3024	0.0140	120.0	4.0	7.9	53.9	44.90%
17NZ4A-10	24.9377	1.2438	0.4750	0.0188	121.5	6.6	13.0	132.1	108.76%
17NZ4A-11	25.3678	1.2098	0.4511	0.0130	126.8	6.0	11.7	122.4	96.53%
17NZ4A-12	20.0401	0.9639	0.5703	0.0142	113.8	8.6	17.0	199.8	175.58%
17NZ4A-13	47.8698	1.3291	0.1225	0.0072	121.2	1.9	3.7	12.1	9.96%
17NZ4A-14	19.1939	1.1789	0.5710	0.0220	118.5	10.0	19.5	208.5	175.95%
17NZ4A-15	43.5540	2.0108	0.1811	0.0180	122.6	3.4	6.7	23.8	19.37%
17NZ4A-16	36.1402	1.5673	0.2890	0.0200	124.3	4.0	7.9	51.7	41.59%
17NZ4A-17	39.7456	1.6113	0.2280	0.0280	125.1	4.0	7.9	35.1	28.06%
17NZ4A-18	39.1850	0.9213	0.2226	0.0162	128.0	2.6	5.1	34.4	26.92%
17NZ4A-19	44.4840	1.4643	0.1377	0.0050	127.7	2.3	4.4	15.6	12.19%
17NZ4A-2	22.3214	1.0961	0.5359	0.0196	114.3	7.9	15.4	168.0	146.99%
17NZ4A-20	34.9284	0.9516	0.2902	0.0118	128.3	3.0	5.9	53.7	41.83%
17NZ4A-21	23.6967	1.4600	0.4870	0.0260	123.8	8.0	15.7	142.3	114.87%
17NZ4A-22	24.8756	1.4851	0.4650	0.0300	124.9	7.9	15.4	129.1	103.32%
17NZ4A-23	8.1169	1.1596	0.7430	0.0200	113.5	52.0	102.0	634.5	559.20%
17NZ4A-24	10.7181	0.8960	0.7114	0.0172	109.2	23.5	46.0	465.8	426.72%
17NZ4A-25	19.3798	1.4272	0.5608	0.0138	121.5	9.5	18.5	202.5	166.70%
17NZ4A-26	40.4040	1.4692	0.2195	0.0052	124.7	2.7	5.2	32.9	26.37%
17NZ4A-27	21.7675	0.7486	0.4973	0.0106	131.0	6.8	13.3	158.6	120.99%
17NZ4A-28	15.8983	0.7583	0.5888	0.0170	134.1	11.4	22.2	259.1	193.13%
17NZ4A-29	15.1976	0.9239	0.6010	0.0260	134.0	12.2	24.0	276.0	205.94%
17NZ4A-3	31.2402	1.0150	0.4045	0.0198	114.8	4.6	9.0	88.3	76.96%
17NZ4A-30	42.1053	3.1202	0.1902	0.0074	125.2	4.9	9.5	26.1	20.89%
17NZ4A-31	45.8926	1.7270	0.1216	0.0042	126.6	2.5	4.9	12.4	9.82%
17NZ4A-32	12.6103	0.5089	0.6438	0.0112	134.8	10.0	19.6	357.3	265.02%
17NZ4A-33	25.2525	1.2754	0.4620	0.0320	124.0	7.7	15.0	126.3	101.85%
17NZ4A-34	20.5339	1.0119	0.5010	0.0240	137.5	8.7	17.0	169.3	123.20%

17NZ4A-35	22.0264	2.6199	0.4860	0.0420	133.5	12.5	24.5	152.5	114.19%
17NZ4A-36	20.1207	0.9716	0.4885	0.0196	145.1	8.3	16.3	167.3	115.29%
17NZ4A-37	46.2963	1.5432	0.0984	0.0030	129.4	2.2	4.4	8.4	6.50%
17NZ4A-38	41.6146	1.2815	0.1555	0.0134	133.1	2.6	5.0	20.0	15.00%
17NZ4A-39	20.7469	1.5496	0.4741	0.0174	146.2	8.8	17.3	157.8	107.97%
17NZ4A-4	14.3062	0.7777	0.6467	0.0174	117.3	11.2	22.0	317.7	270.70%
17NZ4A-40	14.0845	1.3886	0.5865	0.0154	152.6	21.4	42.0	289.4	189.74%
17NZ4A-5	38.0662	2.2895	0.2729	0.0126	121.4	4.3	8.4	45.8	37.77%
17NZ4A-6	46.5766	1.8223	0.1909	0.0090	113.1	2.5	5.0	23.9	21.14%
17NZ4A-7	24.7525	0.9558	0.4915	0.0150	117.2	6.2	12.2	138.1	117.88%
17NZ4A-8	45.9137	1.4756	0.1337	0.0054	124.5	2.2	4.2	14.4	11.61%
17NZ4A-9	16.0256	0.6677	0.6202	0.0134	117.8	11.3	22.2	272.5	231.42%
17NZ96-32	17.2354	0.3921	0.1088	0.0026	339.2	4.0	7.9	24.3	7.17%
17NZ96-33	17.2891	0.5500	0.1133	0.0038	336.2	5.5	10.8	26.3	7.84%
17NZ96-9	17.5131	0.6134	0.0969	0.0030	339.1	6.0	11.8	18.8	5.55%
17NZ96-31	18.3655	0.4857	0.0943	0.0032	324.7	4.4	8.7	17.1	5.27%
17NZ96-35	19.9601	0.8765	0.1183	0.0072	289.9	6.6	13.0	25.1	8.66%
17NZ96-34	20.0682	0.4511	0.1190	0.0054	288.1	3.6	7.0	25.3	8.79%
17NZ96-29	20.4082	0.9996	0.1667	0.0032	265.3	6.8	13.3	43.1	16.23%
17NZ96-39	20.4248	0.6758	0.0709	0.0020	301.2	5.0	9.9	6.9	2.28%
17NZ96-30	20.9512	0.7989	0.1654	0.0056	259.0	5.3	10.4	41.6	16.05%
17NZ96-1	21.3675	1.0958	0.5267	0.0174	122.7	8.0	15.7	172.1	140.20%
17NZ96-28	21.6029	0.5787	0.1446	0.0050	258.7	3.8	7.5	33.0	12.74%
17NZ96-10	21.8245	0.4763	0.0896	0.0028	275.6	3.1	6.1	13.2	4.80%
17NZ96-40	22.1239	1.0768	0.5186	0.0148	121.4	7.4	14.6	163.4	134.55%
17NZ96-21	22.1729	0.9833	0.0756	0.0038	276.2	6.2	12.2	8.0	2.91%
17NZ96-20	22.5530	0.7731	0.0885	0.0040	267.2	4.7	9.2	12.5	4.69%
17NZ96-14	23.3372	0.8932	0.0798	0.0017	261.2	5.1	9.9	9.3	3.56%
17NZ96-8	23.3645	1.2010	0.0859	0.0030	258.9	6.7	13.2	11.1	4.30%
17NZ96-17	26.2123	0.6596	0.1091	0.0024	224.2	2.9	5.8	17.1	7.62%
17NZ96-11	26.4410	1.1466	0.0921	0.0015	227.3	5.0	9.8	12.0	5.29%
17NZ96-7	27.6243	2.2893	0.1124	0.0068	212.0	8.9	17.5	17.3	8.18%
17NZ96-38	33.7496	1.6858	0.3047	0.0174	129.4	4.5	8.8	58.8	45.42%
17NZ96-23	33.7838	2.7392	0.1763	0.0098	158.9	6.7	13.2	29.1	18.29%
17NZ96-36	34.2466	2.8148	0.3210	0.0360	123.8	7.0	13.8	61.7	49.80%
17NZ96-22	35.2609	1.4423	0.2190	0.0240	142.9	4.3	8.3	37.3	26.12%
17NZ96-13	35.6125	1.5980	0.1296	0.0052	161.1	3.8	7.4	17.4	10.83%
17NZ96-15	41.7885	1.9558	0.1323	0.0040	136.9	3.3	6.5	15.5	11.31%
17NZ96-27	42.0168	6.0024	0.2040	0.0760	122.8	11.5	22.6	28.2	22.92%
17NZ96-3	42.3908	1.1141	0.2080	0.0082	121.0	2.1	4.1	29.3	24.18%
17NZ96-6	42.7168	2.1167	0.2020	0.0320	121.2	4.4	8.6	28.0	23.09%
17NZ96-5	43.1593	1.6392	0.2131	0.0076	118.0	2.6	5.2	29.7	25.21%
17NZ96-16	43.4972	2.0055	0.2062	0.0042	118.3	3.0	5.9	28.2	23.84%
17NZ96-18	43.7254	1.5295	0.1435	0.0060	128.9	2.4	4.8	16.9	13.12%
17NZ96-4	44.8833	1.8131	0.1844	0.0080	118.5	2.7	5.3	23.5	19.87%
17NZ96-12	44.9236	1.4934	0.1794	0.0122	119.2	2.4	4.8	22.7	19.02%
17NZ96-19	44.9843	1.6593	0.1204	0.0054	129.3	2.5	4.9	12.4	9.57%
17NZ96-2	45.0450	2.8813	0.2050	0.0300	114.5	4.7	9.2	27.0	23.62%
17NZ96-24	45.8295	1.7643	0.1667	0.0188	119.1	2.9	5.8	20.1	16.92%
17NZ96-26	46.2963	1.8861	0.1427	0.0160	121.9	2.9	5.7	15.9	13.03%
17NZ96-37	47.5059	2.3020	0.1290	0.0068	121.1	3.1	6.0	13.2	10.92%
17NZ96-25	48.0769	2.1727	0.1135	0.0032	122.2	2.8	5.6	10.5	8.61%
17NZ31A-1	14.9925	0.8991	0.6220	0.0270	124.9	12.2	24.0	291.1	233.09%
17NZ31A-10	3.6900	0.5447	0.7870	0.0200	155.4	22.4	44.0	4777.6	3074.55%
17NZ31A-11	18.5874	1.1747	0.5660	0.0180	124.4	9.9	19.4	213.6	171.61%
17NZ31A-12	22.4215	1.4579	0.5270	0.0110	116.9	7.6	15.0	164.1	140.39%
17NZ31A-13	22.4719	1.0100	0.4690	0.0120	136.8	6.7	13.1	143.2	104.67%
17NZ31A-14	18.9036	1.8939	0.5390	0.0230	133.5	11.3	22.2	198.5	148.63%
17NZ31A-15	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ31A-16	10.9051	1.1179	0.6570	0.0210	146.3	28.1	55.0	418.7	286.22%
17NZ31A-17	9.1743	1.0100	0.6790	0.0290	155.0	34.7	68.0	512.0	330.40%
17NZ31A-18	9.3633	0.5874	0.6990	0.0190	135.2	19.9	39.0	518.8	383.71%

17NZ31A-19	20.0401	1.0040	0.5540	0.0230	120.2	9.3	18.1	193.8	161.32%
17NZ31A-2	9.3721	0.8344	0.7190	0.0210	118.4	28.1	55.0	534.6	451.51%
17NZ31A-20	8.1967	0.9406	0.7190	0.0160	135.3	39.3	77.0	603.7	446.35%
17NZ31A-21	4.4248	0.4699	0.7910	0.0170	122.7	66.3	130.0	1187.3	967.67%
17NZ31A-22	14.9254	0.5569	0.6350	0.0130	118.6	7.7	15.0	299.4	252.33%
17NZ31A-23	13.8504	1.0551	0.6140	0.0200	139.6	16.8	33.0	309.4	221.57%
17NZ31A-24	19.8020	0.8627	0.5560	0.0200	120.8	9.0	17.6	197.2	163.23%
17NZ31A-25	18.4502	0.7149	0.5600	0.0210	127.9	9.7	19.0	212.1	165.83%
17NZ31A-26	19.7628	1.0155	0.5350	0.0120	129.3	8.4	16.4	188.7	145.85%
17NZ31A-27	16.8634	0.6541	0.5940	0.0130	124.1	10.3	20.2	246.9	198.94%
17NZ31A-28	14.6199	0.9405	0.6150	0.0200	131.8	13.8	27.0	294.2	223.23%
17NZ31A-29	12.0482	2.1774	0.6380	0.0340	144.8	46.4	91.0	365.2	252.18%
17NZ31A-3	8.3333	1.1806	0.7230	0.0160	129.3	49.5	97.0	600.7	464.54%
17NZ31A-30	0.7143	1.3265	0.8000	0.1000	644.5	122.4	240.0	4315.5	669.56%
17NZ31A-31	17.1821	0.8266	0.5760	0.0130	130.0	10.0	19.7	235.0	180.76%
17NZ31A-32	24.3309	1.1248	0.4740	0.0140	124.8	6.4	12.5	134.2	107.51%
17NZ31A-33	16.1812	0.7855	0.5545	0.0088	148.4	10.1	19.8	237.6	160.19%
17NZ31A-34	22.3714	1.0510	0.4860	0.0170	131.5	7.2	14.2	150.5	114.48%
17NZ31A-35	9.0909	0.9091	0.7020	0.0250	136.7	32.1	63.0	533.3	390.30%
17NZ31A-36	8.7719	3.1548	0.6430	0.0400	193.9	117.3	230.0	486.1	250.65%
17NZ31A-37	5.2910	0.5879	0.7640	0.0150	142.6	56.1	110.0	967.4	678.33%
17NZ31A-38	20.3252	1.4459	0.5370	0.0150	125.0	8.9	17.4	185.0	147.95%
17NZ31A-39	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ31A-4	6.0976	0.5577	0.7490	0.0180	143.1	40.8	80.0	834.9	583.53%
17NZ31A-40	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ31A-5	15.3139	1.0319	0.6050	0.0200	131.0	13.8	27.0	276.0	210.78%
17NZ31A-6	15.2207	0.6255	0.6270	0.0220	120.5	8.2	16.0	289.5	240.36%
17NZ31A-7	12.3457	0.7011	0.6550	0.0150	130.6	13.8	27.0	371.4	284.38%
17NZ31A-8	9.4877	0.6481	0.7140	0.0250	121.1	21.4	42.0	524.9	433.49%
17NZ31A-9	5.8140	0.4056	0.7400	0.0140	162.1	32.7	64.0	861.9	531.83%
17NZ43A-1	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ43A-10	8.3333	1.2500	0.7580	0.0260	96.4	51.0	100.0	633.6	656.94%
17NZ43A-11	19.8020	0.9803	0.5451	0.0098	125.1	8.3	16.2	192.9	154.18%
17NZ43A-12	16.1551	1.6181	0.5900	0.0220	131.4	13.1	25.7	255.6	194.43%
17NZ43A-13	17.6056	0.8679	0.5760	0.0130	126.9	9.8	19.3	229.1	180.54%
17NZ43A-14	18.2815	0.8355	0.5780	0.0170	121.4	9.7	19.1	221.6	182.58%
17NZ43A-15	0.3135	0.0580	0.8420	0.0270	444.6	31.1	61.0	4611.4	1037.23%
17NZ43A-16	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ43A-17	12.3916	0.7678	0.6810	0.0190	113.7	15.3	30.0	386.3	339.70%
17NZ43A-18	7.0423	0.6943	0.7600	0.0240	111.8	39.3	77.0	744.2	665.70%
17NZ43A-19	4.1667	1.7361	0.7500	0.1300	206.8	280.6	550.0	1173.2	567.25%
17NZ43A-2	6.3694	0.8520	0.7790	0.0190	100.2	61.2	120.0	839.8	838.32%
17NZ43A-20	6.4516	0.5827	0.7620	0.0160	119.5	38.8	76.0	805.5	673.81%
17NZ43A-21	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ43A-22	8.9286	1.0364	0.7280	0.0220	116.4	38.3	75.0	565.6	486.10%
17NZ43A-23	9.5147	0.7242	0.7070	0.0210	126.5	23.5	46.0	516.5	408.31%
17NZ43A-24	5.5556	0.7407	0.7390	0.0220	170.9	66.3	130.0	889.1	520.10%
17NZ43A-25	5.5249	0.6410	0.7680	0.0390	131.0	56.1	110.0	939.0	717.01%
17NZ43A-26	4.9505	0.6862	0.8000	0.0250	95.5	76.5	150.0	1094.5	1146.07%
17NZ43A-27	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ43A-28	6.5359	1.6660	0.7830	0.0320	92.8	107.1	210.0	817.2	880.16%
17NZ43A-3	7.8125	1.2817	0.7210	0.0180	139.9	61.2	120.0	630.1	450.53%
17NZ43A-30	3.5336	0.5494	0.7800	0.0290	177.6	33.2	65.0	4739.4	2668.13%
17NZ43A-4	0.9174	0.1263	0.8426	0.0069	149.0	8.2	16.0	4909.0	3294.08%
17NZ43A-5	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ43A-6	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ43A-7	6.6225	1.4912	0.7100	0.0300	177.7	96.9	190.0	722.3	406.45%
17NZ43A-8	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ43A-9	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ55A-1	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ55A-10	15.1745	1.6349	0.6050	0.0230	132.2	21.9	43.0	278.8	210.99%
17NZ55A-11	37.0370	0.9053	0.1294	0.0082	154.9	2.2	4.3	16.8	10.81%

17NZ55A-12	38.0228	1.5903	0.1344	0.0043	149.9	3.3	6.4	17.1	11.38%
17NZ55A-13	40.7498	1.5443	0.0758	0.0009	151.2	2.9	5.7	5.1	3.38%
17NZ55A-14	37.0233	0.6991	0.1431	0.0043	152.1	1.7	3.3	19.7	12.94%
17NZ55A-15	33.4448	1.5660	0.1980	0.0130	155.5	4.2	8.2	34.5	22.21%
17NZ55A-16	37.2856	1.3207	0.1446	0.0037	150.7	2.8	5.6	19.9	13.17%
17NZ55A-17	0.2326	0.0330	0.8580	0.0130	67.9	15.3	30.0	5025.1	7404.79%
17NZ55A-18	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ55A-19	0.1266	0.0160	0.8490	0.0140	666.2	16.3	32.0	4406.8	661.53%
17NZ55A-2	39.3856	0.9773	0.1477	0.0035	142.2	2.0	3.9	19.4	13.68%
17NZ55A-20	30.0300	1.2625	0.3580	0.0120	131.5	4.4	8.7	79.9	60.80%
17NZ55A-21	17.6991	1.1591	0.5710	0.0120	128.4	10.1	19.7	225.6	175.62%
17NZ55A-22	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ55A-23	0.2101	0.0199	0.8357	0.0060	879.1	7.1	14.0	4163.9	473.64%
17NZ55A-24	16.4474	0.9198	0.5810	0.0140	133.4	10.8	21.2	246.6	184.87%
17NZ55A-25	38.0084	1.0546	0.1088	0.0017	155.2	2.2	4.4	12.2	7.83%
17NZ55A-26	36.1664	1.2688	0.2180	0.0150	139.5	3.3	6.4	36.3	25.98%
17NZ55A-27	32.2165	0.8303	0.2370	0.0180	151.9	3.4	6.7	45.1	29.67%
17NZ55A-28	23.3645	1.5831	0.4370	0.0310	142.3	8.7	17.0	127.7	89.73%
17NZ55A-29	7.8125	1.0376	0.7120	0.0220	148.9	49.0	96.0	623.1	418.63%
17NZ55A-3	40.9500	1.0900	0.1094	0.0021	144.1	2.0	3.9	11.5	8.01%
17NZ55A-30	3.5714	0.1403	0.8075	0.0035	115.7	4.1	8.0	4863.3	4203.15%
17NZ55A-31	15.2207	0.4865	0.6150	0.0180	126.6	6.6	13.0	283.4	223.79%
17NZ55A-32	14.9701	1.0981	0.6040	0.0220	134.5	14.8	29.0	281.5	209.36%
17NZ55A-33	30.7692	1.6095	0.2640	0.0160	152.2	5.0	9.7	53.8	35.37%
17NZ55A-34	24.8756	0.7426	0.4625	0.0083	125.7	5.4	10.6	128.1	101.89%
17NZ55A-35	11.0254	0.4984	0.6780	0.0180	129.8	12.2	24.0	430.2	331.31%
17NZ55A-36	21.2314	1.1269	0.5310	0.0200	121.9	8.4	16.4	175.1	143.58%
17NZ55A-37	14.4509	1.9630	0.5900	0.0270	146.8	28.6	56.0	283.2	192.87%
17NZ55A-38	25.7069	1.1895	0.4616	0.0084	121.9	5.7	11.1	124.1	101.73%
17NZ55A-39	20.7469	0.8609	0.5040	0.0110	134.9	7.4	14.4	168.1	124.57%
17NZ55A-4	38.9712	1.1239	0.1205	0.0040	149.1	2.3	4.5	14.2	9.52%
17NZ55A-40	13.8889	2.5077	0.6020	0.0270	146.0	39.3	77.0	301.0	206.20%
17NZ55A-5	31.8471	2.0285	0.3200	0.0150	133.3	5.3	10.4	65.7	49.24%
17NZ55A-6	22.6244	0.8702	0.5300	0.0130	114.8	7.1	13.8	164.2	143.00%
17NZ55A-7	4.4248	0.3916	0.7690	0.0200	161.5	51.0	100.0	1148.5	711.19%
17NZ55A-8	13.9470	1.3616	0.6310	0.0160	129.1	21.4	42.0	316.9	245.34%
17NZ55A-9	40.1284	1.4976	0.1236	0.0021	144.2	2.8	5.5	14.5	10.03%
17NZ100-1	36.7918	0.7310	0.2941	0.0047	121.0	2.4	4.6	51.9	42.85%
17NZ100-10	26.7380	2.0733	0.4450	0.0270	122.1	7.6	15.0	113.9	93.24%
17NZ100-11	41.3052	1.4843	0.2204	0.0054	121.8	2.6	5.1	32.4	26.56%
17NZ100-12	42.4268	1.2780	0.2203	0.0042	118.7	2.2	4.3	31.4	26.50%
17NZ100-13	33.1016	0.9533	0.3700	0.0120	116.5	3.6	7.1	75.4	64.71%
17NZ100-14	29.3255	1.0320	0.4100	0.0150	120.8	4.7	9.2	95.5	79.13%
17NZ100-15	40.4858	0.9343	0.2379	0.0052	120.9	2.0	4.0	36.4	30.09%
17NZ100-16	40.3551	0.7980	0.2524	0.0051	118.5	2.0	3.9	39.3	33.17%
17NZ100-17	46.1042	0.6802	0.1634	0.0045	118.9	1.2	2.4	19.4	16.31%
17NZ100-18	33.2668	0.6197	0.3547	0.0066	119.5	3.0	6.0	71.4	59.70%
17NZ100-19	43.8982	0.6167	0.2405	0.0062	111.1	1.6	3.2	34.1	30.69%
17NZ100-2	42.1053	0.8155	0.2036	0.0049	122.7	1.7	3.3	28.6	23.35%
17NZ100-20	46.1467	0.8305	0.1794	0.0020	116.1	1.4	2.7	22.1	19.05%
17NZ100-21	42.9553	1.0148	0.2416	0.0039	113.3	1.9	3.8	35.0	30.86%
17NZ100-22	32.2581	1.4568	0.3700	0.0210	119.5	4.8	9.4	77.4	64.72%
17NZ100-23	29.9940	0.6567	0.4110	0.0130	117.8	4.2	8.2	93.6	79.43%
17NZ100-24	36.8868	0.7483	0.3106	0.0038	117.2	2.5	4.8	55.2	47.07%
17NZ100-25	44.9843	0.7690	0.1651	0.0026	121.6	1.3	2.6	20.1	16.57%
17NZ100-26	45.6830	0.8556	0.1630	0.0044	120.1	1.4	2.8	19.5	16.27%
17NZ100-27	41.8235	0.6822	0.2319	0.0039	118.2	1.7	3.3	34.1	28.86%
17NZ100-28	34.7222	0.7354	0.3440	0.0120	117.0	3.1	6.1	66.0	56.46%
17NZ100-29	55.5556	9.5679	0.1671	0.0087	98.3	8.6	16.9	16.7	17.04%
17NZ100-3	40.8163	0.6331	0.2313	0.0039	121.2	1.7	3.3	34.8	28.71%
17NZ100-30	38.6847	1.0775	0.2610	0.0140	121.8	2.8	5.4	42.7	35.01%
17NZ100-4	39.0016	1.2169	0.2732	0.0089	118.4	2.7	5.3	44.8	37.83%

17NZ100-5	44.7628	0.8816	0.1823	0.0024	119.1	1.5	2.9	23.3	19.52%
17NZ100-6	44.4050	0.7098	0.1853	0.0041	119.6	1.4	2.7	24.0	20.10%
17NZ100-7	47.2144	1.1146	0.1311	0.0037	121.5	1.6	3.1	13.6	11.21%
17NZ100-8	44.0723	1.0100	0.2045	0.0039	117.1	1.8	3.4	27.5	23.52%
17NZ100-9	38.0662	1.0143	0.2720	0.0057	121.5	2.5	4.8	45.7	37.56%
17NZ11-1	42.9369	0.6637	0.2190	0.0048	117.5	1.6	3.1	30.9	26.30%
17NZ11-10	45.7247	0.7527	0.1451	0.0022	123.0	1.2	2.4	16.5	13.40%
17NZ11-11	43.1593	0.7451	0.1817	0.0040	123.7	1.5	2.9	24.0	19.45%
17NZ11-12	37.2856	0.7785	0.2770	0.0066	123.0	2.3	4.6	47.6	38.67%
17NZ11-13	18.0180	0.8766	0.5930	0.0140	116.6	9.9	19.3	231.4	198.37%
17NZ11-14	12.4224	0.4629	0.6972	0.0096	103.2	9.2	18.0	395.8	383.42%
17NZ11-15	35.8809	0.9527	0.3137	0.0052	119.8	2.8	5.4	57.4	47.89%
17NZ11-16	40.4531	0.8510	0.2290	0.0110	122.7	2.1	4.2	34.7	28.25%
17NZ11-17	29.2912	0.5405	0.4339	0.0073	114.5	4.2	8.1	101.9	88.98%
17NZ11-18	32.3102	0.4489	0.3937	0.0060	113.6	3.3	6.5	82.9	72.96%
17NZ11-2	43.6110	1.1982	0.1973	0.0049	119.6	2.0	3.9	26.5	22.17%
17NZ11-20	35.2361	0.8070	0.3205	0.0063	120.5	2.8	5.4	59.9	49.73%
17NZ11-21	33.5909	0.6432	0.3515	0.0077	119.1	3.0	6.0	70.0	58.73%
17NZ11-22	23.3155	0.3805	0.5219	0.0072	114.1	6.2	12.1	156.6	137.14%
17NZ11-23	34.2700	1.1392	0.3511	0.0057	116.9	3.3	6.5	68.5	58.63%
17NZ11-24	34.7222	0.8801	0.3138	0.0089	123.8	2.9	5.8	59.2	47.86%
17NZ11-25	32.3834	0.8389	0.3455	0.0055	125.0	3.2	6.3	71.1	56.89%
17NZ11-26	19.1939	0.8473	0.5728	0.0094	117.8	8.7	17.1	209.2	177.67%
17NZ11-27	39.3856	0.8221	0.2380	0.0051	124.3	2.0	3.9	37.3	30.06%
17NZ11-28	31.0559	1.0609	0.3700	0.0180	124.1	4.4	8.6	80.2	64.58%
17NZ11-3	34.4828	1.1891	0.3480	0.0095	116.9	3.5	6.8	67.3	57.62%
17NZ11-4	22.9885	1.0569	0.5210	0.0120	116.1	7.0	13.6	157.9	136.07%
17NZ11-5	45.6830	0.5843	0.1631	0.0022	120.0	1.1	2.1	19.6	16.29%
17NZ11-6	14.5349	0.5915	0.6495	0.0082	114.0	8.7	17.0	315.0	276.30%
17NZ11-7	49.3583	0.7796	0.1271	0.0075	116.9	1.2	2.4	12.4	10.64%
17NZ11-8	9.6154	0.3051	0.7228	0.0057	112.3	9.7	19.0	525.7	467.96%
17NZ11-9	38.9257	0.9849	0.2421	0.0045	124.9	2.2	4.4	38.6	30.92%
17NZ25A-1	28.8767	0.8088	0.4207	0.0086	119.7	4.3	8.5	99.7	83.26%
17NZ25A-10	16.8067	1.1581	0.6070	0.0250	118.5	12.2	23.9	254.5	214.84%
17NZ25A-11	31.7561	0.6353	0.3923	0.0073	115.9	3.5	6.9	84.0	72.44%
17NZ25A-12	28.9855	1.1762	0.4260	0.0150	117.8	5.0	9.8	100.8	85.50%
17NZ25A-13	22.9358	0.7365	0.5320	0.0120	112.6	6.8	13.4	162.3	144.18%
17NZ25A-14	33.1126	1.0635	0.3586	0.0090	119.2	3.5	7.0	72.6	60.95%
17NZ25A-15	40.0320	1.1859	0.2280	0.0130	124.2	2.6	5.2	34.9	28.09%
17NZ25A-16	24.6914	0.6706	0.4890	0.0130	118.3	5.9	11.6	137.8	116.57%
17NZ25A-17	36.4166	0.8222	0.2920	0.0130	122.7	2.8	5.5	52.0	42.35%
17NZ25A-18	28.9855	0.7141	0.4230	0.0089	118.7	4.3	8.4	99.9	84.24%
17NZ25A-19	30.8261	0.6082	0.3965	0.0075	118.3	3.7	7.2	87.5	73.91%
17NZ25A-2	29.9133	0.6800	0.3965	0.0074	121.9	3.8	7.5	90.1	73.88%
17NZ25A-21	16.3132	1.0379	0.5990	0.0170	125.9	11.5	22.6	258.1	205.09%
17NZ25A-22	26.3089	0.6160	0.4647	0.0077	118.3	5.0	9.8	122.2	103.38%
17NZ25A-23	18.4162	0.4748	0.5910	0.0099	115.0	9.1	17.8	226.1	196.67%
17NZ25A-24	15.7233	0.5686	0.6410	0.0100	109.7	11.6	22.7	287.3	262.00%
17NZ25A-25	10.7991	0.6997	0.7100	0.0120	109.4	17.9	35.0	460.6	421.18%
17NZ25A-26	28.6369	0.5494	0.4360	0.0076	116.5	4.3	8.4	104.8	89.90%
17NZ25A-27	27.0563	0.5930	0.4591	0.0093	116.6	4.9	9.5	117.4	100.65%
17NZ25A-28	26.2123	0.4329	0.4729	0.0072	116.2	5.0	9.8	125.1	107.59%
17NZ25A-29	26.8097	0.8625	0.4623	0.0098	116.8	5.1	10.1	119.5	102.39%
17NZ25A-3	14.4300	0.4165	0.6360	0.0110	122.1	6.1	12.0	309.9	253.68%
17NZ25A-30	21.2314	0.7212	0.5260	0.0097	123.8	7.2	14.1	172.6	139.47%
17NZ25A-4	13.9276	0.4655	0.6570	0.0150	114.7	7.1	14.0	332.3	289.61%
17NZ25A-5	17.3010	0.5987	0.5970	0.0160	119.6	10.3	20.1	242.4	202.61%
17NZ25A-6	10.0705	0.3550	0.7090	0.0140	118.0	10.2	20.0	492.0	416.91%
17NZ25A-7	16.1551	0.5220	0.6120	0.0110	120.8	10.8	21.2	266.2	220.37%
17NZ25A-8	28.9771	0.6382	0.4240	0.0100	118.4	4.3	8.4	100.3	84.69%
17NZ25A-9	21.2766	0.5432	0.5595	0.0095	111.2	7.5	14.6	184.7	166.11%
17NZ72A-1	19.4932	1.1400	0.5500	0.0180	125.1	9.2	18.1	196.9	157.37%

17NZ72A-10	#VALUE!	#VALUE!	no value	NAN	#VALUE!	#VALUE!	NAN	#VALUE!	#VALUE!
17NZ72A-11	0.0592	0.0217	0.8879	0.0020	-5243.5	2.2	4.4	10404.1	-198.42%
17NZ72A-12	14.5773	0.5525	0.6410	0.0130	118.2	8.2	16.0	309.8	261.99%
17NZ72A-13	2.1552	0.2137	0.8180	0.0110	153.1	12.8	25.0	4850.9	3168.59%
17NZ72A-14	14.0647	0.8902	0.6370	0.0140	124.7	13.8	27.0	318.3	255.14%
17NZ72A-15	23.2558	0.7572	0.4990	0.0110	122.1	6.3	12.4	149.3	122.20%
17NZ72A-16	15.5039	0.9855	0.6190	0.0190	122.3	12.8	25.0	280.7	229.49%
17NZ72A-17	5.2083	0.4069	0.7800	0.0180	120.9	41.8	82.0	1008.1	834.08%
17NZ72A-18	19.7628	1.0155	0.5840	0.0140	110.0	9.0	17.6	208.0	189.20%
17NZ72A-19	20.7039	0.9430	0.5440	0.0160	120.1	8.2	16.0	183.9	153.11%
17NZ72A-2	5.4348	0.3249	0.7900	0.0140	101.5	30.6	60.0	986.5	972.38%
17NZ72A-20	22.6757	0.6684	0.5010	0.0110	124.6	6.5	12.7	153.4	123.19%
17NZ72A-21	20.0803	0.4435	0.5640	0.0110	116.0	8.0	15.7	197.3	170.03%
17NZ72A-22	16.8919	0.5136	0.6000	0.0120	121.1	10.2	20.0	249.9	206.31%
17NZ72A-23	39.2927	0.7102	0.0536	0.0009	161.1	1.5	2.9	0.9	0.53%
17NZ72A-24	32.7654	0.9447	0.3130	0.0100	131.3	3.3	6.4	62.5	47.60%
17NZ72A-25	6.3980	0.3070	0.7520	0.0160	132.7	21.4	42.0	803.3	605.09%
17NZ72A-26	39.6983	0.7092	0.2230	0.0043	126.2	1.8	3.5	34.2	27.07%
17NZ72A-27	15.7233	0.4203	0.6250	0.0180	117.6	11.9	23.2	280.4	238.35%
17NZ72A-28	9.5238	1.9048	0.7090	0.0210	124.7	61.2	120.0	515.3	413.08%
17NZ72A-29	14.6413	0.3644	0.6480	0.0100	114.0	5.1	10.0	312.0	273.75%
17NZ72A-3	29.0698	1.0986	0.3848	0.0074	128.6	4.3	8.5	89.5	69.62%
17NZ72A-31	14.1044	0.3382	0.6540	0.0120	115.0	5.1	10.0	327.0	284.46%
17NZ72A-32	14.0845	0.4364	0.6450	0.0100	120.1	6.6	13.0	321.9	267.95%
17NZ72A-33	21.8341	0.6197	0.5380	0.0110	116.1	7.1	13.9	172.8	148.88%
17NZ72A-34	5.9809	0.2611	0.7800	0.0130	105.3	20.4	40.0	890.7	845.49%
17NZ72A-35	6.7751	0.3672	0.7610	0.0120	115.0	22.4	44.0	772.0	671.17%
17NZ72A-36	6.0976	0.4090	0.7510	0.0100	140.5	29.6	58.0	839.5	597.40%
17NZ72A-37	12.5786	0.3323	0.6600	0.0110	125.1	6.6	13.0	367.9	294.12%
17NZ72A-38	18.2482	0.6327	0.5820	0.0110	119.9	9.2	18.0	224.1	186.94%
17NZ72A-39	21.7865	0.6645	0.5060	0.0120	127.8	6.9	13.4	161.5	126.34%
17NZ72A-4	0.0091	0.0140	0.8760	0.0100	0.0	11.7	23.0	5134.0	#DIV/0!
17NZ72A-40	19.3050	0.8572	0.5720	0.0091	117.4	8.6	16.9	208.6	177.65%
17NZ72A-5	0.0154	0.0154	0.8700	0.8700	-9314.9	2602.0	5100.0	14414.9	-154.75%
17NZ72A-6	13.0548	0.4261	0.6570	0.0100	122.4	7.7	15.0	353.6	289.04%
17NZ72A-7	16.6945	0.3623	0.6031	0.0090	121.1	10.1	19.8	253.9	209.69%
17NZ72A-8	2.9070	0.2282	0.8310	0.0160	78.7	18.4	36.0	4953.3	6295.83%
17NZ72A-9	0.0227	0.0062	0.8718	0.0074	-6105.4	8.7	17.0	11229.4	-183.93%

Appendix C

THE

REPORT

OF THE

COMMISSIONERS OF THE LAND OFFICE

FOR THE YEAR 1867.

LONDON:

H.M.S. PRINTING OFFICE,

1868.