1 **Mesoarchean and Paleoproterozoic history of the Nimrod Complex,**
2 **Central Transantarctic Mountains, Antarctica:**
3 **Stratigraphic revisions and relation to the Mawson Continent in East Gondwana**
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13 **ABSTRACT**

14 High-grade metamorphic and igneous rocks originally mapped as the Nimrod Group
15 represent the only known crystalline basement of the East Antarctic shield exposed in the
16 Transantarctic Mountains. SHRIMP U-Pb age data from zircon show that this assemblage
17 preserves multiple geologic events spanning 2.5 b.y. of Archean to early Paleozoic history,
18 culminating in thermomechanical reworking and active-margin magmatism during the Ross
19 Orogeny. New age data from igneous and metamorphic rocks, as well as from detrital zircons in
20 metasedimentary quartzites, refine the Mesoarchean to Paleoproterozoic history and indicate the
21 need to abandon the stratigraphic term Nimrod Group and its five formations. In its place, we
22 redefine only the igneous and high-grade gneissic parts of the assemblage as the Nimrod
23 Complex, and all other metasedimentary rocks exposed in the Miller and Geologists ranges are
24 included in a newly defined Argosy Schist. Within the Nimrod Complex, the oldest layered

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gneisses represent magmatic Mesoarchean crust formed between about 3150-3050 Ma. Correspondence of U-Pb zircon crystallization ages with whole-rock Sm-Nd model ages indicates formation from juvenile mantle melts. Magmatism at ca. 3100 Ma was followed closely by high-temperature metamorphism, recorded by zircon crystallization at 2955-2900 Ma, likely due to high advective heat transfer and/or thermal insulation of newly stabilized crust. Metagneous units with ages of ca. 2500 Ma indicate a late Neoarchean period of anatexis and/or magmatism, although the geologic context for these events is uncertain. Gneissic, eclogitic and metagneous rocks record an important period of deep-crustal metamorphism, thickening and magmatism between 1730-1700 Ma, referred to as the Nimrod Orogeny, that may have played an early role in assembly of East Gondwana cratons. A new lithodemic unit, Argosy Schist, consists of interlayered mica schist, quartzite, amphibolite, and calc-silicate schist. Quartzites from the schist unit have two distinctive detrital-zircon provenance characteristics; one type has populations that correlate with dated gneissic and metagneous units of the Nimrod Complex, indicating a proximal provenance, whereas a second type has detrital zircon ages resembling those from Neoproterozoic Beardmore Group sandstones, indicating a common broader East Antarctic shield provenance. Their maximum depositional ages range widely from about 2000 to 900 Ma, leaving unresolved their age and geologic relationship to either the Nimrod Complex or Beardmore Group, yet they comprise a metasedimentary assemblage that is distinctive from the Nimrod Complex. Recent findings of Mesoarchean gneisses in the Gawler Craton, geochronology from Terre Adélie, and our new age data from the Nimrod Complex thus highlight the importance of ca. 3.1, 2.5 and 1.7 Ga events in formation of the composite East Antarctic shield adjacent to the modern Transantarctic Mountains. Correlative crustal units may extend to the southern Prince Charles Mountains and Shackleton Range. Collectively, this

extensive crustal province, referred to as the Mawson Continent, represents an elongate belt of primary Mesoarchean crust that experienced major reworking at ca. 2.5 and 1.7 Ga. The latter period includes both high- and low- P/T petrologic signatures, providing evidence of crustal thickening and magmatism that may signify collisional processes related to Paleoproterozoic cratonal amalgamation during formation of the Nuna supercontinent.

Keywords: Antarctica, craton, Nimrod Complex, zircon, geochronology

1. Introduction

East Antarctica comprises a composite Precambrian shield containing some of Earth's oldest crustal rocks that have a long-lived tectonic association with other East Gondwana cratons in Australia, India, and southern Africa (Fig. 1; Tingey, 1991; Fitzsimons, 2003; Harley and Kelly, 2007; Boger, 2011; Harley et al., 2013). In addition to its early ancestry dating to 3.8-3.0 Ga, the East Antarctic shield shares orogenic ties with other now-distant continental pieces thought to reflect Paleoproterozoic (~1.7-1.6 Ga), Late Mesoproterozoic-Early Neoproterozoic (or 'Grenvillian', ~1.2-0.9 Ga), and Late Neoproterozoic-early Paleozoic (or Pan-African, ~0.6-0.5 Ga) crustal assembly related to formation of the Nuna, Rodinia, and Gondwana supercontinents, respectively. East Antarctica played a critical role in the assembly and dispersal of each of these supercontinents, and recent advances in our understanding of the ages, kinematics and continuity of orogenic belts within and adjacent to East Antarctica (e.g., Fitzsimons, 2000a, 2000b, 2003; Boger et al., 2001, 2006; Jacobs et al., 2003; Goodge et al., 2001, 2008, 2010; Boger, 2011) help to clarify these stages in their assembly. Unfortunately, because of the polar ice cap and remote access in East Antarctica, it is difficult to extrapolate isolated outcrop data across the continental

71 scale necessary for tectonic reconstruction.

72 As a basis for establishing supercontinent assembly relations, cratonic growth in East
73 Antarctica can be correlated with crustal evolution in geologic provinces of other continents.
74 Comparison of age relationships in South Australia and East Antarctica led to the idea of an
75 extensive Paleo- to Mesoproterozoic crustal province – defined originally as the Mawson
76 Continent or 'Block' (Fanning et al., 1995, 1996) – that forms the nucleus of the East Antarctic
77 and South Australian shield areas. As originally envisioned, this province principally included
78 the Gawler Craton in South Australia, formerly adjacent areas of Terre Adélie and George V
79 Land (Terre Adélie Craton) in Antarctica, and the Miller Range in the central Transantarctic
80 Mountains, which share a distinctive geologic history involving correlated basement ages of
81 about 2.55-2.45 Ga, a common ca. 1.7-1.6 Ga magmatic record, superimposed high-grade
82 metamorphism, and similar detrital zircon provenance ages within low-grade Paleoproterozoic
83 metasedimentary rocks (summarized by Oliver and Fanning, 1997; Fanning et al., 2007).
84 Fanning et al. (1996) further speculated that the Mawson Continent may extend to the
85 Shackleton Range. Although many elements of the Mawson Continent are covered by sediment
86 and ice, seismic, magnetic and gravity signatures mark a well-defined region of old, thick crust
87 overlying low-density subcontinental lithospheric mantle that extends from the Terre Adélie
88 coast to interior Wilkes Land in Antarctica (Finn et al., 2006; Goodge and Finn, 2010; An et al.,
89 2015).

90 Key crust-forming igneous and metamorphic events between ca. 2.5-1.7 Ga are now well
91 recognized in the central Transantarctic Mountains (Bennett and Fanning, 1993; Goodge and
92 Fanning, 1999; Goodge et al., 2001), southern Prince Charles Mountains (e.g., Boger et al., 2006,
93 2008; Mikhalsky et al., 2006, 2010), and the Shackleton Range (e.g., Pankhurst et al., 1983;

Helper et al., 2000; Will et al., 2009) of Antarctica, further enhancing their inclusion in an extensive Mawson province. Gneisses from the Miller Range with ages of 3150-3050 Ma (Bennett and Fanning, 1993) were thought to record the earliest events in the Mawson Continent, but at the time were not recognized in Terre Adélie or the Gawler Craton. When first proposed (Fanning et al., 1996), the presence of similar-age Mesoarchean basement in the Gawler Craton was inferred from inherited and detrital zircon components together with initial Nd isotopic ratios (e.g., Creaser & Fanning, 1993). However, recent age data from basement outcrops provide critical direct evidence of Mesoarchean events in the Gawler Craton at ca. 3.2-3.1 Ga (Fraser et al., 2010), strengthening the age correlations. The Mawson Continent, therefore, represents a fundamental crustal province of Mesoarchean and Paleoproterozoic age within present-day East Antarctica and Australia (e.g., Goodge et al., 2001; Payne et al., 2009; Goodge and Fanning, 2010; Harley et al., 2013; Halpin and Reid, 2016). As considered here, at a minimum it includes the Gawler Craton, Adélie Craton, and basement rocks in the central Transantarctic Mountains (Nimrod Group), which have characteristic ages of ca. 3.1, 2.5, and 1.7 Ga. The presence together of all three age components is not recognized in other Australian cratons and makes the Mawson Continent unique. Crust with similar ages may extend to the Shackleton Range and southern Prince Charles Mountains, although due to extensive sedimentary and ice cover these correlations are less certain. Further, a common connection among the various tracts by ca. 1.7 Ga provides evidence of a single coherent 'continent' in the late Paleoproterozoic. As part of this association, Archean to Proterozoic igneous and metamorphic rocks in the central Transantarctic Mountains of Antarctica help to refine the Mawson Continent evolution.

Like other areas covered by the polar ice cap, the East Antarctic shield has only limited

exposure along the Transantarctic Mountains. This orogenic belt circumscribes about one third of the East Antarctic shield margin. It is marked chiefly by deformed Neoproterozoic and lower Paleozoic sedimentary sequences associated with the Ross Orogen, in turn covered by Gondwanide sediments of early Paleozoic to Mesozoic age. Exposed within a small geographic area of the central Transantarctic Mountains are crystalline basement rocks of the shield itself (Nimrod Group), juxtaposed against Neoproterozoic and lower Paleozoic marginal-basin sedimentary assemblages (Beardmore and Byrd groups). Nimrod Group exposures in the Miller Range (Fig. 1) therefore provide a rare window into the East Antarctic shield along the hinterland side of the Ross orogenic belt, and refinement of their Mesoarchean to Paleoproterozoic history can improve our understanding of early crustal evolution in the Transantarctic Mountains part of the East Antarctic shield.

Early efforts to constrain the Precambrian evolution of the Nimrod Group relied on K-Ar and Rb-Sr dating (McDougall and Grindley, 1965; Grindley and McDougall, 1969; Gunner, 1976; Adams et al., 1982). Consistently varying and progressively older K-Ar ages suggested that the Nimrod Group was deformed during a late Precambrian (~1100 Ma) high-grade metamorphic event (Grindley and Laird, 1969) that did not affect younger outboard sedimentary units. Although this provided an indication of Late Mesoproterozoic to Neoproterozoic activity, it was not possible to define meaningful, unambiguous ages of geologic events prior to the widespread Cambro-Ordovician Ross Orogeny. Subsequent $^{40}\text{Ar}/^{39}\text{Ar}$ mineral cooling ages of 525-485 Ma showed, however, that the previously reported K-Ar ages were the result of excess radiogenic ^{39}Ar , partial resetting, and isotopic mixture, and that they therefore reflect Ross Orogen thermal reactivation of much older rocks rather than a definable Meso- to Neoproterozoic tectonic event (Goodge and Dallmeyer, 1992, 1996).

Because the Nimrod Group bears a strong metamorphic and structural overprint of Ross orogenesis evident between about 540-515 Ma (Goodge et al., 1991, 1992, 1993a, 1993b; Goodge and Dallmeyer, 1992, 1996), its pre-Ross history has remained obscure. Deciphering the geologic history of ancient crustal rocks such as the Nimrod Group is often problematical in an absolute time sense because of isotopic re-equilibration and/or mixing during multiple geologic events (e.g., Goodge and Fanning, 1999). These processes make it difficult to obtain meaningful geologic ages, particularly in multi-cycle igneous and metamorphic rocks. For example, previous Rb-Sr, Sm-Nd, and multi-grain U-Pb zircon studies identified Precambrian age components (Gunner and Mattinson, 1975; Gunner, 1976, 1983; Borg et al., 1990; Walker and Goodge, 1991), but it was not possible to distinguish individual geologic events with certainty because these studies relied on whole-rock isotopic approaches or sampling sizes that compounded the effects of disequilibrium mineral growth as a result of overprinting. In cases where zircon retains an internal structure reflecting multiple growth events, including igneous or metamorphic crystallization, resorption, and one or more stages of overgrowth, U-Pb analysis of zircon by ion microprobe (SIMS) has allowed the spatial and isotopic resolution necessary in multi-domain zircons to identify distinct geologic events at ca. 3.1, 2.5 and 1.7 Ga (Bennett and Fanning, 1993; Goodge and Fanning, 1999; Goodge et al., 2001).

Here we report new sensitive high-resolution ion microprobe (SHRIMP) U-Pb zircon age results from Nimrod Group metaigneous and metasedimentary rocks, including layered gneisses, orthogneisses, igneous units, and metasedimentary quartzites (Table 1). Because of the high-*T*, high-strain effects of Ross orogenic events (Goodge et al., 1992, 1993a, 1993b; Goodge and Dallmeyer, 1992, 1996), U-Pb zircon geochronology is the best method for resolving the pre-Ross history, and the oldest parts of this relict history can best be resolved by small-scale,

SHRIMP analysis of intracrystalline zircon domains. Data from these samples, when integrated with earlier results, reveal previously unrecognized igneous events, establish sedimentary provenance, refine the overall geologic history of the Nimrod Group, and correlate its Archean and Paleoproterozoic petrotectonic evolution with other crystalline terrains in Antarctica, Australia and North America, which appears to culminate in crustal assembly at about 1.7 Ga.

These new data also lead us to recommend revision of the basement stratigraphy. New geochronologic data presented in this paper demonstrate that the previously defined stratigraphic terminology for the Nimrod Group and its five formations is no longer valid, and we recommend abandonment of the group term. Herein we recognize three broadly defined basement lithodemic units in the Miller and Geologists ranges: (1) high-grade, deformed gneissic, schistose and metaigneous rocks, defined here collectively as the Nimrod Complex, which have ages of ca. 3.1-1.7 Ga; (2) a high-grade metasedimentary assemblage defined here as the Argosy Schist, with depositional ages mostly <1050 Ma and mixed provenance signatures, and likely juxtaposed with older rocks of the Nimrod Complex during the Ross Orogeny; and (3) syn- to post-kinematic granitoids of Granite Harbour Intrusives affinity (540-480 Ma), including large plutons and stocks, as well as smaller sheets, dikes and anatectic leucosomes. Following presentation of new geochronologic data, definitions of the Nimrod Complex and Argosy Schist are provided in section 4 (Stratigraphic Revisions). In the remainder of this paper, the term Nimrod Complex supercedes previous use of Nimrod Group.

2. Geologic setting

2.1. Nimrod Complex

The central Transantarctic Mountains is the only section of the Ross Orogen where pre-orogenic crystalline basement rocks of the East Antarctic shield are exposed. In the Miller and Geologists ranges at the edge of the polar ice cap (Fig. 1), crystalline rocks of the Nimrod Complex correlate with cratonic crust imaged by magnetic and gravity signatures (Goodge and Finn, 2010). Although the boundary with outboard supracrustal rocks is traditionally thought to be hidden beneath Marsh Glacier (Fig. 2), geophysical data indicate that the Nimrod Complex represents the edge of coherent cratonic basement of the East Antarctic shield where it is juxtaposed with rift-margin and orogenic strata. The high-grade, penetratively-deformed metamorphic and igneous rocks of the Nimrod Complex provide clear isotopic and geochronologic evidence of their Mesoarchean and Paleoproterozoic ancestry (Borg et al., 1990; Goodge and Fanning, 1999; Goodge et al., 2001). The Nimrod assemblage also shows a strong thermomechanical imprint by the Ross Orogeny (Goodge et al., 1991, 1993a, b; Goodge and Dallmeyer, 1992, 1996; Goodge, 2007), providing the opportunity to assess the role of basement reactivation during Ross events.

Stratigraphically, the Nimrod Group was originally divided into the Argo, Argosy, Aurora, Miller, and Worsley formations (Grindley et al., 1964; Grindley and Laird, 1969). Subsequent detailed geologic mapping revealed more numerous and lithologically heterogeneous mappable rock units (Goodge et al., 1990, 1993a), and these workers avoided using the previously defined formation names. In general terms, however, lithologic descriptions of the dominantly metasedimentary Argosy schists, Miller gneisses, and Worsley calc-silicate schists are valid. As depicted in Figure 2, metasedimentary and metaigneous lithologies of this crystalline assemblage include upper-amphibolite to lower-granulite facies, interlayered pelitic schist, micaceous quartzite, amphibolite, banded quartzofeldspathic to mafic gneiss, homogeneous (garnet-)biotite-

hornblende gneiss, granitic to gabbroic orthogneiss, calc-silicate gneiss and marble, migmatite, and relict eclogite (Grindley et al., 1964; Grindley, 1972; Goodge et al., 1990, 1991, 1993a; Peacock and Goodge, 1995). Gneisses, amphibolites, orthogneisses, and eclogites of this assemblage are herein considered as part of the Nimrod Complex, whereas metasedimentary schists, quartzites, and calc-silicate rocks are included in the Argosy Schist (lithodemic unit definitions provided in section 4). Medium- to high- P/T kyanite-zone mineral assemblages are widespread in all units, reflecting exposure of relatively deep crustal levels in this part of the Transantarctic Mountains (Grindley, 1972; Goodge et al., 1992; Goodge, 2007). Within the Nimrod Complex, first-order geological events recognized as pre-dating the Ross Orogeny include Archean and Paleoproterozoic magmagenesis and deep-crustal granulite- to eclogite-facies metamorphism (Goodge and Fanning, 1999, 2002; Goodge et al., 2001). Eclogites occur as detached blocks within layered gneisses and have mineralogical characteristics of lower-crustal eclogites (Grindley, 1972; Goodge et al., 1992; Peacock and Goodge, 1995). Zircon ages of ca. 1.7 Ga from gneisses, eclogites and orthogneiss units define a period of Paleoproterozoic activity ascribed to the Nimrod Orogeny (Goodge et al., 2001). The outermost thin overgrowths on zircons from Nimrod Complex gneisses typically yield ages of ~530 Ma (Goodge and Fanning, 1999), corresponding with U-Pb ages obtained for metamorphic monazite and igneous zircon growth related to Ross orogenic activity in the region (Goodge et al., 1993b, 2004a, 2012).

A compositionally diverse suite of igneous rocks characterized by variable development of solid-state deformation fabrics occurs throughout the Miller and Geologists ranges (Goodge et al., 1993a, 1993b). They include diorite, tonalite, granodiorite, granite, aplite and pegmatite lithologies, emplaced as plutons, wide sheets, sills and dikes. Many of these bodies, including

large post-kinematic plutons and smaller syn-kinematic dikes and sheets, are linked to the Ross Orogeny and have yielded U-Pb zircon ages ranging from about 545-490 Ma (Granite Harbour Intrusives; Goodge et al., 1993b, 2004a; 2012). The variations in fabric development relative to the Nimrod Complex tectonites they intrude indicate progressively weakening Ross tectonism during this interval in the Early Cambrian. However, other rocks with petrographically-similar compositions and deformation fabrics yield much older, pre-Ross ages between about 2500-1700 Ma (Goodge et al., 2001) and are discussed further in this paper.

Sr-Nd isotopic methods applied to the Ross-age granitic intrusions have been used to constrain granite petrogenesis and define average crustal residence times along the Ross Orogen (Borg et al., 1990; Borg and DePaolo, 1994; Goodge et al., 2012). Sr-Nd isotopic compositions of the granitoids intruding Nimrod Complex basement vary widely ($^{87}\text{Sr}/^{86}\text{Sr}_i = 0.705\text{-}0.752$; $\epsilon\text{Nd}_i = -1.3$ to -15.0), indicating a complex petrologic and structural mixture of rock types with highly variable depleted-mantle Nd-model ages of 3.14-1.23 Ga. With one exception, Nd-isotope data taken directly from gneissic and schistose samples (Miller and Argosy formations of the original Nimrod Group, respectively) yielded depleted-mantle model ages ranging from ca. 3.54 to 2.75 Ga, reflecting Archean average mantle-separation ages for the Nimrod basement (Borg et al., 1990; Borg and DePaolo, 1994); one other sample of schist yielded a model age of about 1.87 Ga, suggesting it represents derivation from a younger primary source.

2.2. *Outboard supracrustal rocks*

Outboard of the Miller and Geologists ranges, the Ross Orogen is underlain by two principal sedimentary successions, the late Neoproterozoic Beardmore Group, associated with development of a passive rift margin along East Antarctica (Goodge et al., 2002), and Early

Cambrian to Ordovician carbonate and siliciclastic strata of the lower and upper Byrd Group, respectively (Myrow et al., 2002; Goodge et al., 2004b). The Beardmore Group is a thick assemblage of unfossiliferous sandstone, shale, carbonate, diamictite, and minor volcanic rocks (Gunn and Walcott, 1962; Laird et al., 1971; Goodge et al., 2004b). Although the Beardmore Group was previously thought to underlie a large region of the Transantarctic Mountains between the Byrd and Beardmore glaciers, detrital zircon geochronology and ages of intercalated volcanic units show that the Beardmore Group is restricted to the Nimrod Glacier area and was deposited between 1100-660 Ma (Goodge et al., 2002, 2004b). Despite low-grade metamorphism, calcareous schist, impure marble, and quartzite in the lower Beardmore Group (Cobham Formation) bear a lithologic resemblance to higher-grade metasedimentary units of the Argosy Formation, suggesting a possible stratigraphic correlation overprinted by metamorphic and deformational effects of the Ross Orogeny (Stump et al., 1991). As discussed below, such a correlation can be tested with new detrital mineral age data.

2.3. Ross reactivation

Ductile L-S tectonite fabrics and folds of Ross Orogen age are pervasive in all crystalline units of the Miller and Geologists ranges, and kinematic features at all scales record top-to-the-SE (local coordinates, as in Fig. 2) displacement through a minimum structural thickness of 12-15 km (Goodge et al., 1993a). Shear fabrics in the basement rocks are oblique in their orientation relative to coeval contractional structures observed within outboard supracrustal units (Goodge, 1997), suggesting a sinistral-oblique transpressional plate margin during Ross time. Concurrent with the formation of ductile shear fabrics, the main phase of Ross metamorphism in the Nimrod Complex and Argosy Schist occurred under moderate- P , high- T metamorphic conditions ($P = 8$ -

12 kbar; $T = 650\text{--}750\text{ }^{\circ}\text{C}$) in the upper-amphibolite to lower-granulite facies (Goodge, 2007).

Phase relations and thermobarometry indicate Ross metamorphism followed a clockwise P - T path along a moderately-steep geotherm, reflecting significant crustal thickening.

As summarized below, a host of mineral chronometers constrain the age of peak igneous activity, deformation, metamorphism, and cooling within the crystalline rocks through the Ross orogenic cycle between about 540–485 Ma. Existing age data show that the dominant structural and petrologic features of the Nimrod Complex and associated Argosy Schist are primarily a manifestation of deep-seated Ross orogenic events, permitting differentiation of Ross from older events and an assessment of basement reactivation during plate-margin orogenesis. These ages overlap with detrital mineral and metamorphic ages obtained from deformed rocks of the Beardmore and Byrd successions, providing a coherent temporal framework of Ross activity in the central Transantarctic Mountains region (Goodge et al., 2004a).

High-grade metamorphism and deformation in the Argosy Schist is constrained to about 525 Ma, based on U-Pb dating of syn-kinematic monazite (Goodge et al., 1993b). The effects of Ross-age dynamothermal activity on Nimrod Complex gneisses is also shown by zircon crystals with texturally distinct overgrowths on older cores, as well as newly crystallized metamorphic zircon grains. Zircon overgrowths in these gneisses have ages of ca. 545–520 Ma (Goodge and Fanning, 1999; Goodge et al., 2001). A compositionally diverse suite of igneous rocks that show variable development of solid-state deformation fabrics intrudes Nimrod Complex metamorphic tectonites; these include tonalite, diorite and granodiorite with U-Pb zircon ages that range from ca. 545–515 Ma (Walker and Goodge, 1991; Goodge et al., 1993b, 2012). Variations in fabric development with age indicate progressively weakening Ross tectonism during the Early Cambrian. The U-Pb data described above all point to pronounced reactivation of crystalline

basement during Ross time, followed by progressive post-orogenic cooling between about 525-485 Ma (Goodge and Dallmeyer, 1992, 1996).

Mineral chronometers applied to the tectonites indicate late- to post-orogenic cooling rates of about 10 °C/m.y. (Goodge, 2007). Combined with an inferred geotherm, these cooling ages suggest a denudation rate of about 0.4 mm/year. Thus, the Nimrod Complex gneisses and associated Argosy Schist were strongly reconstituted during the Ross orogenic process, taking a clockwise *P-T* path to moderate pressures indicative of crustal thickening, followed by relatively rapid exhumation.

3. SHRIMP U-Pb results

3.1. Analytical methods

Here we present new zircon age results from nine samples of Nimrod Complex igneous and metamorphic units, and detrital zircon ages from three samples of quartzite from the Argosy Schist (Table 1). Briefly, zircons were separated from whole rock samples using standard protocols of washing, heavy liquid (Sp. Gr. 2.96 and 3.3), and paramagnetic procedures. For the igneous and metamorphic samples, grains were hand-picked from the heavy mineral concentrates and cast into epoxy disks with appropriate reference zircons (AS3, FC1 and Temora; c.f., Paces and Miller, 1993, Black et al., 2003). For the provenance samples, zircon-rich heavy mineral concentrates were poured onto double-sided tape, mounted in epoxy together with chips of reference zircon, sectioned approximately in half, and polished. The U-Th-Pb analyses were made using SHRIMP at the Research School of Earth Sciences, The Australian National University, Canberra, Australia following procedures given in Williams (1998, and references therein). Data have been processed using the SQUID Excel macro (Ludwig, 2001). Uncertainties

given for individual analyses (ratios and ages) are at the one sigma level (see tables in Supplementary files). Concordia plots, probability density plots, weighted mean age calculations and concordia intercept ages have been made using ISOPLOT (Ludwig, 2003) and those ages are given at the 95% confidence level.

3.2. *Nimrod Complex metamorphic and igneous units*

We analyzed nine samples of layered gneiss, orthogneiss, granite and metavolcanic units from the Nimrod Complex that yield Archean and Paleoproterozoic ages (Table 1; Fig. 3). All samples show L-S tectonite fabrics obtained during amphibolite- to granulite-facies ductile shear associated with mid-crustal displacements during the Ross Orogeny; however, importantly, the zircons retain evidence of their pre-Ross ancestry. Layered gneisses are heterogeneous at the decimeter scale, but the sampled portions are more uniformly quartzofeldspathic to intermediate composition gneisses containing abundant hornblende and biotite; their origin is unclear based on textural characteristics but consistent with deformed and metamorphosed igneous parents. Units described as orthogneisses differ primarily by being homogeneous at the outcrop scale, and they vary from Hbl-rich metadiorites to leucocratic metagranites. An igneous origin for these units is interpreted on the basis of composition and uniform texture. One granite (99-303B) occurs as a thick sill-like concordant sheet within layered gneiss (Fig. 3C), but it also contains well-developed L-S tectonite fabrics.

3.2.1. *Hbl-Bt gneiss, Gerard Bluffs (90-121B)*

One of the main geologic units in the southern Miller Range is a heterogeneous layered gneiss enclosing round to subangular bodies of mafic eclogite (Fig. 2). At Gerard Bluffs, the gneissic assemblage includes quartzofeldspathic gneiss, Hbl-Bt gneiss and Grt amphibolite that

enclose eclogitic pods and larger blocks dated by U-Pb zircon to 1720 Ma (Goodge et al., 2001). These units show tight, disharmonic folding with axes parallel to regional elongation lineation formed within the Ross-age L-S tectonites. Sample 90-121B, a quartzofeldspathic layered Hbl-Bt gneiss, is typical of this geologic unit. The sample contains Qtz + Pl + Ksp + Bt + Hbl, with accessory chlorite, apatite, titanite, magnetite and zircon. Folded thin layers in the gneiss are marked by an axial-planar alignment of biotite, indicating the folds formed during syn-metamorphic ductile shear. Zircons in this sample are mostly faceted, euhedral, clear prisms with a 2:1 to 4:1 aspect ratio; their euhedral shape suggests they are igneous in origin. Internally, cathodoluminescence (CL) imaging shows that they are composite grains, typically showing banded or sector-zoned cores that are overgrown along curved discontinuities by thinly banded to homogeneous rims (Fig. 4A). Most of the cores show length-parallel growth zoning that indicates a volcanic origin, whereas a few show oscillatory zoning that is consistent with a plutonic origin. Twenty areas were analyzed on 11 grains (Table 2). There is a wide range of ages recorded, from ~3100 Ma to ~565 Ma, and many of these analyses are significantly discordant (Fig. 4B). Seventeen of the oldest analyses do not form a coherent concordant grouping, but appear to project to an upper intercept at ~3100 Ma. Eight analyses of grain interiors have $^{207}\text{Pb}/^{206}\text{Pb}$ ages between 3061 and 3114 Ma, with a weighted-mean age of 3087 ± 14 Ma (MSWD = 3.1; Fig. 4C). One grain core has an older age of 3152 Ma. Eight rim analyses yielded ages between 2876 and 3080 Ma, with a distinct older group of five grains giving a weighted-mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 3060 ± 12 Ma (MSWD = 2.5).

Several grains have younger ages, including one tip (5.2) with a $^{206}\text{Pb}/^{238}\text{U}$ age of 550 ± 7 Ma. The Th/U ratio from this analysis is < 0.001 and probably reflects new high-*T* metamorphic growth during the Ross Orogeny. Two other tips from grain 7 yielded variably discordant ages

with $^{207}\text{Pb}/^{206}\text{Pb}$ ages of ~1620 Ma and ~1200 Ma that may be a result of multi-stage radiogenic Pb-loss at both ~1700 and ~500 Ma. The discordant rim with a $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2876 Ma (grain 3.1) is consistent with radiogenic Pb-loss at ~500 Ma. These younger but discordant ages reflect thermal effects of Nimrod and Ross orogenies that are well documented in the Nimrod basement complex (Goodge and Dallmeyer, 1996; Goodge and Fanning, 1999; Goodge et al., 2001).

We interpret the U-Pb age data from this sample as indicating that the gneiss protolith was derived from an igneous parent that initially crystallized at ca. 3090 Ma. This parent was probably volcanic or volcano-plutonic in origin, and the spread in ages obtained from the zircon cores may reflect a combination of diachronous magmatism and incorporation of older magmatic components and/or xenocrystic inheritance. A younger overprinting event is evident in the overgrowth and rim analyses; these may be the result of late magmatic resorption or post-magmatic recrystallization (they show somewhat lower Th/U ratios compared to the grain cores). Rim areas record ages of around 3000 Ma and 3060 Ma. This Archean orthogneiss was subsequently affected by metamorphic recrystallization events at ~1700 Ma (Nimrod overprint) and ~565 Ma (Ross overprint), but due to radiogenic Pb-loss neither of these are well-constrained in this sample.

3.2.2. *Hbl-Bt layered orthogneiss, Gerard Bluffs (99-300)*

Similar in outcrop appearance to sample 90-121B, sample 99-300 is a layered Hbl-Bt gneiss containing Qtz + Pl + Hbl + Bt + Ksp with accessory epidote, titanite, and zircon (Fig. 3A). As in several areas of the Nimrod Complex, this layered gneiss encloses round to subangular pods of mafic eclogite. It contains coarse, fragmented zircons with blocky sector-zoned interiors and some mottling (Fig. 5A). In CL, many have a very thin bright rim, but most of these are too narrow to be analyzed ($<<10\text{ }\mu\text{m}$). A set of 24 analyses from 18 grains gave near-concordant

ages in two age groups connected by a discordia line with upper and lower intercepts at about 1740 and 510 Ma, respectively (Table 3; Fig. 5B, C). Analyses of the zircon cores consistently yielded ages of about 1700-1740 Ma with a weighted-mean age of 1733 ± 5 Ma (13 analyses; MSWD = 0.85; Fig. 5D). These grains have an average Th/U ratio of ~ 0.7 , which together with their CL structures indicate a likely igneous origin. One low-U grain (13.2) yielded a highly-discordant older $^{207}\text{Pb}/^{206}\text{Pb}$ age of ~ 2130 Ma, but this anomalous analysis probably indicates radiogenic Pb-loss and is unlikely to reflect the presence of an older inherited component. Bright (low U), homogeneous CL overgrowths cut across the older growth banding, and together with the very low Th/U ratios (< 0.01 ; with one at 0.03) suggest metamorphic growth on older resorption surfaces (Table 3); near-concordant $^{206}\text{Pb}/^{238}\text{U}$ ages for these overgrowths of ca. 510-540 Ma indicate metamorphic recrystallization in this rock during high-grade Ross Orogen reactivation.

We interpret this sample as having an igneous protolith of intermediate composition with a primary magmatic age of ca. 1740 Ma. This age is similar to other igneous units in the Nimrod Complex (Goodge et al., 2001; this paper), but in this case its layered gneissic fabric and enclosed relict eclogite pods, which elsewhere yielded metamorphic ages of ~ 1720 Ma (Goodge et al., 2001), indicate that this rock was itself deformed and metamorphosed during the Paleoproterozoic Nimrod Orogeny. It was further deformed and metamorphosed during the Ross Orogeny, as shown by the younger zircon overgrowths.

3.2.3. *Quartzofeldspathic gneiss, Gerard Bluffs (99-301)*

Sample 99-301 is a quartzofeldspathic Bt-Ms gneiss from the Gerard Bluffs area that is cross-cut by a distinctive homogeneous aplitic pink gneiss (99-302). It is weakly banded, relatively homogeneous and medium-grey in color (Fig. 3B). This fine-grained grey gneiss

contains Qtz + Pl + Ksp + Bt + Ms, with minor epidote, calcite, titanite, and zircon. Zircons from this sample are fine-grained and clear, with prismatic and euhedral shape, well-formed external facets, and colorless to pale golden color. The zircons show distinct cores and rims in CL imaging (Fig. 6A). Cores are typically elliptical to slender prisms with round terminations, and they show thin, length-parallel growth banding. They are commonly overgrown by wide (25-50 μm) rims that are uniformly bright in CL and show weak internal growth zoning. We analyzed 34 areas on 30 zircon grains from sample 99-301 (Table 4). A concordia plot of all data shows a broad scatter of concordant and near-concordant analyses (Fig. 6B), with ages ranging from 3122 to 2995 Ma. A regression line fitted to the oldest subset of these has an upper-intercept at 3114 ± 4 Ma. On a probability density plot with stacked histogram (Fig. 6C) there are distinct groupings of older cores overgrown by CL-bright younger rims and likely metamorphic overgrowths based on low Th/U ratios. Sixteen of the older cores have a poorly-fitted weighted-mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 3108 ± 6 Ma (MSWD = 19), and a subset of eight cores showing distinct internal growth zonation indicative of igneous crystallization give a weighted-mean age of 3113 ± 2 Ma (MSWD = 3.7). Ten analyses from wide overgrowth areas have a weighted-mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 3050 ± 5 Ma (MSWD = 1.6). Two metamorphic overgrowths with Th/U < 0.03 have $^{207}\text{Pb}/^{206}\text{Pb}$ ages of ~2985 and ~2955 Ma.

Field relations suggest this unit could be a paragneiss or have a felsic igneous parent, although the effects of Ross Orogen metamorphism and deformation make it difficult to interpret any clear origin. If the older cores are interpreted as having crystallized comagmatically, their average age of ~3115 Ma likely represents the time of this primary igneous event. It is not possible to distinguish on the basis of field relationships and the distribution of zircon ages whether this rock represents a primary igneous protolith or was perhaps reworked in a

volcaniclastic setting. Significant growth of new zircon overgrowths occurred at ~3050 Ma; their high Th/U ratios and faceted appearance suggest these zircon domains reflect either a new *in situ* melting event or high-*T* metamorphism. Alternatively, the ~3050 Ma rims may represent the main magmatic crystallization of this rock and contain older xenocrystic cores. There is no evidence for recrystallization of zircon in this sample at the time of either the Nimrod or Ross orogenies.

3.2.4. *Ms-Bt leucogneiss, Gerard Bluffs (99-302)*

Sample 99-302 is a fine-grained, K-feldspar-rich, pink-colored Ms-Bt leucogneiss that cuts the grey gneiss (99-301) along a bifurcating, tabular seam with sharp contacts that are concordant to local foliation (Fig. 3B). It has a leucocratic, aplitic appearance and contains Qtz + Ksp + Pl + Ms + Bt, with accessory calcite, apatite, zircon, and an opaque phase. Like other gneisses of the Nimrod Complex, it is well foliated and it has a texture of coarse, round crystals of K-feldspar and plagioclase set in a mosaic of finer, anhedral quartz and microcline. Based on its composition, texture and cross-cutting relation with the grey gneiss, we interpret this rock as a felsic meta-igneous unit. Zircons in this sample are heterogeneous, with shapes ranging from coarse broken fragments to euhedral stubby prisms, and mostly milky pale brown color. The zircons are very weakly luminescent, possibly because of irradiation damage due to their high-U content (White and Ireland, 2012), and show a mottled, sievy texture with no evident growth zoning. We analyzed only 6 zircons from this sample, all of which are extremely U-rich (1755-5525 ppm) and significantly discordant (Table 5; Fig. 6D). A discordia regression fitted to all six analyses has excess scatter (MSWD = 44); if the analysis of grain 2 is excluded, there is still excess scatter (MSWD = 9) and the concordia intercepts are at 2868 ± 23 and 459 ± 94 Ma. We interpret the upper-intercept age of ~2870 Ma as providing an estimate for the crystallization age

of this igneous unit, whereas the lower intercept reflects the effects of significant radiogenic Pb loss during Ross metamorphism.

3.2.5. *Bt granite, Gerard Bluffs (99-303B)*

Layered gneisses in the Gerard Bluffs area host a thick, tabular body of megacrystic Bt granite (Fig. 3C). It is a coarse-grained, foliated and lineated grey rock with prominent pink K-feldspar megacrysts (≤ 4 cm) showing elongate tails parallel to foliation. The contacts of the granite are sharp and concordant with respect to layering in the host gneisses. We interpret this body to be a sill-like sheet that has intruded the gneisses. The granite contains Qtz + Ksp + Pl + Bt + Ep, with accessory apatite, titanite, and zircon. Epidote forms a thin rim of crystals surrounding coarse allanite cores. Zircon in this sample are clear, slender, faceted prisms that typically show thin, high-contrast banding under transmitted light; some grains have optically dark cores. The CL images reveal that many grains contain very bright elliptical to round cores, surrounded by thinly-banded prismatic shells (Fig. 7A). In other cases, planar zoned cores are overgrown by oscillatory zoned rims. Many grains show thin, CL-bright overgrowths on tips or cracked edges; we were unable to analyze any of these zones, but they probably result from new metamorphic zircon growth during the Ross Orogeny.

We analyzed twenty-eight areas on 21 zircon grains from sample 99-303B (Table 6). In general, two age groupings are apparent (Fig. 7B): an older, mostly discordant and scattered group of nine analyses with some near-concordant analyses around 3100-2900 Ma, and a younger, more coherent grouping of near-concordant analyses at ca. 1750-1700 Ma. The 3100-2900 Ma group consistently comprises analyses of the CL-bright cores, whereas the analyses with ~1750-1700 Ma ages are of banded cores or overgrowths. The older group has $^{207}\text{Pb}/^{206}\text{Pb}$ ages ranging from about 2790 to 3140 Ma, which overlap ages of grains in gneissic samples 90-

121B and 99-301, indicating that these zircon ages reflect inherited components incorporated into the granite melt. Their round outline in cross-section indicates that they were partly resorbed by the melt prior to growth of new zircon during final emplacement and crystallization. All analyses that form the younger age grouping show some scatter about a discordia regression line with an upper intercept at 1739 ± 12 Ma (Fig. 7C; MSWD = 2.4, 19 analyses). We interpret this as the crystallization age of the granitic body.

3.2.6. *Hbl-Bt amphibolite gneiss, Orr Peak (99-304)*

Heterogeneous schist and gneiss units are exposed southwest of Orr Peak along the western margin of Marsh Glacier, including Hbl-Bt layered gneiss and dark-grey to black amphibolitic gneiss. Both units are cut by thin felsic veins, possibly associated with the Orr Peak granite that crops out to the east. Sample 99-304 is a grey, intermediate-composition Hbl-Bt amphibolite gneiss sampled from an outcrop containing small (≤ 10 cm) clots of amphibolite and concordant thin layers of respectively more felsic and mafic composition (Fig. 3D). The gneiss shows mainly straight foliation with a well-developed elongation lineation. It contains Qtz + Pl + Ksp + Hbl + Bt (~40% mafics), with accessory titanite, allanite, apatite, and zircon. This sample contains two types of zircon: (a) coarse, resinous grains ranging from euhedral prisms to broken fragments with cloudy orange-brown color; and (b) fine-grained, clear euhedra with elliptical faceted shape. Both types contain numerous fractures. In CL the dark-colored grains appear uniformly dark and pitted, indicating a high degree of metamict structure. The relatively clear grains show weak internal structure (Fig. 8A), mostly consisting of faint parallel growth bands and sector zonation, and most are marked by very thin CL-bright rims.

We analyzed 12 of the clear, internally structured grains in sample 99-304 (Table 7). All analyses were taken from clear, crack-free areas showing growth zonation in CL. These grains

have uniformly high Th/U ratios (≥ 0.70), suggesting an igneous origin. Grain 9 is significantly discordant ($\sim 21\%$) so it is not considered in the following age calculations and not plotted in Fig. 8B. Ten of the remaining 11 analyses define a discordia trend with an upper intercept at 2513 ± 6 Ma (MSWD = 0.56; Fig. 8B). Given the lack of obvious inheritance, the internal growth zonation, high Th/U and uniform $^{207}\text{Pb}/^{206}\text{Pb}$ ages, we interpret the zircons to reflect crystallization from a melt during formation of a pre-Ross igneous parent. We regard the intercept age of about 2515 Ma to indicate the crystallization age of this protolith. Although the mineral assemblage in this sample indicates high-temperature metamorphism, which is compatible with nearby samples giving metamorphic mineral cooling ages (monazite, hornblende and muscovite) of 524-496 Ma (Goodge and Dallmeyer, 1992; Goodge et al., 1993b), we cannot be certain whether reconstitution as a layered gneiss occurred during Ross or an earlier metamorphism.

3.2.7. *Hbl-Bt orthogneiss, Mt. Albright (03-403A)*

Sample 03-403A is a homogeneous dark-grey Hbl-Bt gneiss from the southern Geologists Range near Mt. Albright (Fig. 2). It represents a distinctive mappable body of dioritic orthogneiss, but shares fabric and metamorphic features with heterogeneous schist and gneiss units in the area. It lacks internal layering and is characterized by strong L-S tectonite fabrics, dark clots of Hbl (2-4 mm), a streaky mineral elongation lineation made of plagioclase and quartz, and contains sparse felsic veins (Fig. 3E). The sample contains Qtz + Pl + Ksp (microcline) + Hbl + Bt, with accessory titanite, apatite, monazite, and zircon. Zircons in this sample are mostly stubby, prismatic to sub-round grains ranging from colorless to dark pink appearance; they contain numerous inclusions and in many cases they show optically distinctive

tips that correspond to CL-bright overgrowths in section (Fig. 9A). Under CL, the central areas show strong sector and oscillatory growth zonation indicative of an igneous origin.

We analyzed 23 areas on 21 zircon grains from sample 03-403A (Table 8). Of these, 12 analyses are from grain interiors and eleven are from the bright CL overgrowth areas. The analyses are variably discordant, and a discordia line fitted to all analyses has upper- and lower-intercept ages of 1727 ± 14 and 457 ± 32 Ma, respectively (Fig. 9B). Most of the U-Pb discordance occurs in those analyses located in grain tips and may be a result of partial spot overlap with older age domains. Twelve analyses from grain interiors were $\leq 6\%$ discordant and yielded a weighted-mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1721 ± 9 Ma (MSWD = 0.85; Fig. 9C, D). No older grain components were found. Excluding grains showing marked discordance, the analyses taken from tips yielded near-concordant $^{206}\text{Pb}/^{238}\text{U}$ ages between ~ 420 Ma and ~ 495 Ma, which are similar to the lower-intercept age for the group of 457 Ma. Compared to the older zircons, these grains have lower Th/U ratios (0.05-0.22) that likely reflect metamorphic growth. Based on their internal growth zonation and age coherence, we interpret the mean age of 1721 ± 9 Ma to represent the best estimate for crystallization of the dioritic igneous parent to this gneiss. Overgrowth of new metamorphic zircon during Ross orogenesis is indicated by the young near-concordant ages of the discrete tips.

3.2.8. *Grt metafelsite, Mt. Albright (03-404)*

Sample 03-404 comes from a unit in the Geologists Range mapped as Grt-Bt schistose quartzite. It is a grey- to tan-colored, massive quartz-rich rock with a strong L-S tectonite fabric expressed as thin platy partings (Fig. 3F). This unit is interlayered in the field with fine-grained Bt schist, Ms-Bt schist, Grt calc-silicate and amphibolite, together representing a metasedimentary or metavolcanic assemblage. Based on the zircon characteristics and age data,

described below, we now interpret this unit to be a felsic metaigneous rock, identified here as a Grt metafelsite. The sample contains Qtz + Pl + Grt + Bt, with accessory opaque, zircon, and secondary chlorite, forming a fine-grained granoblastic texture. Garnet consists of ≤ 5 mm sievy porphyroblasts. Zircons from this sample consist of short terminated prisms (typical aspect ratio of 2:1), some showing external twin forms, and crystal fragments; they are mostly clear, colorless to brown, and many are cross-hatched with thin cracks. In CL, they show angular, fragmented and blocky cores, often offset along fractures, that are overgrown by wide, CL-dark (U rich) rims which show symmetrical pyramidal terminations (Fig. 10A). The zircon interiors show concentric and angular growth zonation, commonly truncated along fractures. Their blocky nature with broad homogenous internal domains may be indicative of a volcanic paragenesis.

We analyzed 20 areas on 19 zircon grains from sample 03-404 (Table 9). Analyses of the broad to weakly zoned central components range from concordant at about 1730 Ma, to discordant, but lying along a radiogenic Pb-loss discordia with a lower Ross-age intercept at 524 ± 19 Ma (Fig. 10B). The upper concordia intercept is at 1730 ± 9 Ma (Fig. 10C; MSWD = 1.4) and this constrains the time of igneous crystallization. The CL structure of these 1730 Ma zircon components indicates a likely volcanic origin for this magmatic event. Five concordant analyses from CL-dark, high-U rims (1000-1500 ppm) with low Th/U (≤ 0.01) yielded a weighted mean $^{206}\text{Pb}/^{238}\text{U}$ age of 524 ± 5 Ma (MSWD = 0.94), which we interpret as the age of a Ross metamorphic overprint.

3.2.9. *Hbl-Bt orthogneiss, Camp Ridge (10MR-11)*

Sample 10MR-11 is a coarse-grained, strongly foliated orthogneiss collected from Camp Ridge in the western Miller Range (Fig. 2). It is petrographically similar to sample M28 described by Goodge et al. (2001), and 99-303B (described above), and it is considered to be

from a similar deformed meta-igneous unit. This unit displays prominent K-feldspar megacrysts having a high aspect ratio within a well-developed L-S tectonite fabric. It contains Qtz + Mc + Pl + Bt + Hbl, and accessory epidote, apatite, titanite, zircon and Fe-oxide. Zircons in 10MR-11 are texturally similar to those in M28, consisting of coarse, well-formed prisms with simple oscillatory growth zonation indicating a magmatic origin (Fig. 11A). Many grains show wide, CL-dark oscillatory outer domains surrounding dark regions with commonly mottled texture.

We analyzed 16 areas on 15 zircon grains from sample 10MR-11 (Table 10). The zircons have moderate U and Th contents, and relatively uniform Th/U ratios averaging 0.46. Most of the grains are strongly discordant but lie along a well-defined radiogenic Pb-loss discordia with an upper intercept age of 1709 ± 15 Ma and a lower Ross-age intercept (Fig. 11B). Seven analyses that are <15% discordant have an upper intercept age of 1697 ± 17 Ma (Fig. 11C). Because the regression based on all analyses has a lower intercept corresponding to known Ross-age overprinting, we consider the most likely time of igneous crystallization to be about 1710 Ma.

3.3. Detrital zircons from Argosy Schist quartzites

We analyzed three samples of quartzite collected from metasedimentary units in the Miller Range (Argosy Formation as originally defined by Grindley et al., 1964; herein defined as Argosy Schist) in order to determine their detrital zircon age distributions (Table 1). Two of the samples are representative of micaceous quartzites commonly interlayered with pelitic schists and calc-silicate rocks typical of the Argosy metasedimentary assemblage, and one sample comes from a distinctive marker unit of fuchsite-bearing quartzite (sample 03-422).

3.3.1. Bt quartzite, Gerard Bluffs (99-298)

A diverse metasedimentary assemblage is associated with layered gneisses and metaigneous rocks in the southern Miller Range. In the Gerard Bluffs area, the former include quartzites interlayered with pelitic schist, amphibolite, and calc-silicate gneiss. The quartzites are tabular, platy units with a strong foliation and lineation (Fig. 12A). For detrital zircon analysis we sampled an ~2 m-thick, medium-grained Bt quartzite adjacent to amphibolite and mica schist that contains $\geq 95\%$ Qtz. Sample 99-298 contains Qtz + Pl + Bt + Ged, with accessory titanite, calcite, apatite, and zircon. Zircons are generally coarse, with textures ranging from clear terminated prisms, faceted equant grains, and round grains, indicating a detrital origin of mixed grains. Many grains have faceted tip overgrowths suggesting metamorphic overgrowth. In CL, the grains show a variety of igneous textures (including prominent banding and sector zonation) overgrown by medium-grey homogeneous tips (Fig. 13).

The detrital components of this sample (62 grains) include abundant Grenvillian ages (~1250-1050 Ma), with smaller populations between 1900-1300 and 3200-2400 Ma (Table 11; Figs. 14A, C). The Proterozoic group can be divided into three populations (Figs. 14B, D): (a) a group with a mean age of ~1200 Ma (29% of the overall detrital population); (b) a group with an age of ~1400 Ma (23%); and (c) a small group of grains with an age of ~1790 Ma. The youngest concordant grain age is 1055 Ma. This and the abundance of Grenville-age grains indicate that the sedimentary precursor represented by this sample has a Neoproterozoic deposition age.

Many grains in this sample show well-rounded grain cores overgrown by angular or pyramidal tips that appear with medium to dark CL response and oscillatory growth zonation (Fig. 13). The tips have uniformly low Th/U ratios (≤ 0.10) implying a metamorphic origin that is distinctly younger than the detrital populations (Fig. 14C). Five analyses of these distinct grain overgrowths gave young $^{206}\text{Pb}/^{238}\text{U}$ ages between 490-550 Ma. To refine this age, we ran 6-scan

analyses on seven additional tip overgrowths (grains 60.1, 65.1, 66.1, 67.1, 37.2, 40.2, and 68.1). These zircon tips gave $^{206}\text{Pb}/^{238}\text{U}$ ages of 534-511 Ma (excluding grain 40.2, which probably includes more than one growth domain), and a weighted-mean $^{206}\text{Pb}/^{238}\text{U}$ age of 534 ± 10 Ma (MSWD = 1.8; 8 analyses), constraining the age of metamorphism in these metasedimentary rocks with a high-temperature chronometer that is consistent with U-Pb monazite ages (Goodge et al., 1993b).

3.3.2. *Bt-Ms quartzite, Lookout Dome (03-415)*

Sample 03-415 is a Bt-Ms quartzite collected from a metasedimentary assemblage in the Lookout Dome area of the northern Miller Range (Fig. 2). We sampled a tabular, platy quartzite from ledges above a buff-colored metacarbonate (Fig. 12B). This rock is a compositionally homogeneous micaceous quartzite, with well-developed foliation and mineral-elongation lineation, divided by sheaves of Ms-rich schist or phyllite. It contains Qtz + Ksp + Pl + Bt + Ms, with accessory apatite, Fe-Ti-oxide, and zircon. Zircons in this sample are heterogeneous, ranging from sub-angular prismatic grains, to sub-rounded elliptical grains and well-rounded small spheres, together indicating a detrital origin. Most grains have smooth or frosted surfaces, but some have very small pointed tips that may be a result of metamorphic overgrowth.

We analyzed 60 detrital zircon grains in this sample (Table 12). They are generally concordant or nearly concordant, with some radiogenic Pb loss (Fig. 15A). Both a Wetherill plot and probability distribution show that the sample contains three main age groups at ca. 2000, 2500 and 3100 Ma (Fig. 15A, B). The oldest group, along with scattered grains between ca. 3000-2800 Ma, are similar in their age distribution to dated meta-igneous gneisses showing primary igneous and slightly younger metamorphic ages (Goodge and Fanning, 1999; this study). A large intermediate group of grains (~43% of the sample population) comprise a well-defined

peak at ~2500 Ma; a subset of 21 analyses yields a weighted-mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2499 ± 5 Ma (MSWD = 1.4). This age is virtually equivalent to the age of the Orr Peak orthogneiss (sample 99-304; this study). The youngest group of 13 grains (~22%) yields a weighted-mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2007 ± 5 Ma (MSWD = 0.53). To date, no similar ages have been reported from direct exposure of the Nimrod Complex. Both the ~2500 and ~2000 Ma detrital zircons have Th/U ratios consistent with an igneous origin.

The distribution of detrital zircon ages in this quartzite shows that it has a relatively simple provenance comprising early Archean and Paleoproterozoic sources. Because at least two of the major age populations correspond to known zircon ages in Nimrod Complex gneisses, it is likely that the sedimentary parent to this quartzite was derived from a basement terrain not unlike that represented by the Nimrod Complex lithologies. We cannot determine if there is a direct sedimentary link or the sedimentary transport distance. The youngest distinct age population in this sample indicates a Paleoproterozoic or younger deposition age (after ~2000 Ma). Notably, this date correlates with gneissic rocks in the Gawler Craton (e.g., Miltalie Gneiss; Fanning et al., 2007).

3.3.3. *Fuchsite quartzite, Camp Ridge (03-422)*

Metasedimentary rocks in the Miller Range include distinctive green fuchsite-bearing quartzites. Several occurrences of these fuchsitic quartzites are mapped in the vicinity of Argosy Glacier, notably near Greene Ridge, Camp Ridge, and Aurora Heights (Goodge et al., 1993a). Because of stratigraphic ambiguity due to metamorphism and deformation, it is not clear if these mapped quartzites should be regarded as correlative horizons, although they represent distinctive marker units. We sampled one of the fuchsite quartzite horizons at a locality east of Camp Ridge where it is interlayered with biotite schist, biotite quartzite, garnet-mica schist, amphibolite and

vein quartzite (Fig. 2). Sample 03-422 comes from an interval of variably schistose to massive quartzite containing emerald-green platy fuchsite (Fig. 12C). The sampled layer consists of relatively massive, vitreous, translucent greenish light-grey quartzite with thin (<1 cm) micaceous partings spaced several centimeters apart. The sample contains Qtz + Cr-Ms (fuchsite) with accessory tourmaline, Fe-Ti-oxide, and zircon.

Detrital zircons in this sample are heterogeneous, ranging from dark-brown densely fractured fragments, to round equant and elliptical grains with brown to rosy color, to relatively clear, football-shaped euhedral grains with pyramidal tips. The grains are mostly sub-angular to angular, and euhedral prisms are common. We analyzed 60 grains in sample 03-422 (Table 13). Many of the areas yielded near to concordant analyses, scattering along concordia up to ~3000 Ma (Fig. 16A). Thirty-eight near to concordant analyses (63%) form a dominant population with ages between about 1760-1680 Ma (Fig. 16A, B). A regression line fitted to these analyses has an upper concordia intercept at 1739 ± 10 Ma and lower intercept at 490 ± 210 Ma (MSWD = 1.6). The remaining analyses span 3100-900 Ma, with no distinctive groups other than a few grains each of ~2500 and ~3100 Ma. Although this sample is dominated by a single age population, the textural character of the grains, heterogeneous appearance, and wide distribution of ages both younger and older than the main population indicate that the sample has a detrital origin. If this is the case, the main population at ~1740 Ma indicates a single major source of igneous detritus in the sedimentary precursor. Ages of ~1740 Ma are represented in the associated metamorphic basement rocks of the Nimrod Complex (Goodge and Fanning, 1999; Goodge et al., 2001; this study), as are older Archean units, indicating the source may have been very local. Seven grains in this sample with high Th/U ratios have near-concordant ages ≤ 1600 Ma and the youngest of these single grains has a $^{207}\text{Pb}/^{206}\text{Pb}$ age of ~900 Ma, indicating a

maximum depositional age for this fuchsitic quartzite of about 900 Ma. Like the quartzite from Gerard Bluffs (sample 99-298), this unit probably has a Neoproterozoic depositional age.

Fuchsitic quartzites are also known from the Pioneers Group at the Pioneers Escarpment in the northern Shackleton Range (Clarkson, 1995; Roland et al., 1995), where they are interlayered with a heterogeneous assemblage of metasedimentary and metavolcanic rocks. The depositional age of the Pioneers Group strata is not known, in part due to pervasive Barrovian-type metamorphism and deformation during the Ross Orogeny (Brommer and Henjes-Kunst, 1999; Brommer et al., 1999; Zeh et al., 1999, 2004). Other units in the northern Shackleton Range give thermochronologic evidence of dynamic metamorphism between about 1740-1570 Ma (Pankhurst et al., 1983; Zeh et al., 1999, 2004), indicating a Paleoproterozoic depositional age, but their relationship to the fuchsite-bearing parts of the Pioneers Group is unclear. Although direct correlation of such distinctive fuchsitic metasedimentary rocks is not possible, these Cr-rich sedimentary units may share a common provenance in cratonic East Antarctica.

3.3.4. Provenance of Argosy Schist and Beardmore Group detrital precursors

As shown in Figure 17, compared to a composite detrital signature in the Beardmore Group rift-margin succession (Goodge et al., 2002, 2004b), the Argosy Schist quartzites have dissimilar age distributions. Beardmore sediments are notable for their large but variable proportions of Proterozoic detritus, chiefly spanning 1800-1100 Ma. A composite of 398 individual grain ages from six samples yields main groupings at ca. 1170, 1540, 1800 and 2510 Ma (Goodge et al., 2002, 2004b). Compared to the Beardmore Group, one Argosy sample has a major age group of ~1200 Ma, two of the three samples have a grouping of ~1700-1800 Ma, one has a major population of ~2500 Ma (the other two have minor populations of this age), two have minor

groups of ~3100 Ma, and there are no matches for the dominant Beardmore Group population of ~1540 Ma (itself a mixture). Notably, the Argosy quartzites share mixed age overlap with the characteristic igneous and metamorphic ages summarized above from Nimrod Complex crystalline units; the sample from Gerard Bluffs has groups at ~1700 and ~2500 Ma, the Lookout Dome quartzite shows overlap at ~2500 and ~3000 Ma, and the Camp Ridge quartzite shows all three ages. Only the sample from Gerard Bluffs shows a diverse Proterozoic age distribution that resembles that of the Beardmore Group, whereas quartzites from Lookout Dome and Camp Ridge show restricted age groups with only one or two dominant age populations. These two samples each have major input from a source with similar ages to the Nimrod Complex, and virtually none of the younger Proterozoic ages (<1600 Ma) characteristic of the Beardmore Group, indicating a relatively proximal source like that of the Nimrod Complex.

In detail, the sample from Gerard Bluffs (99-298) shows some similarity to Beardmore Group detrital zircon patterns. Compared to the Beardmore Group composite, it contains similar grain groupings with ages of about 1800 and 2500 Ma, but it contains a greater proportion of Grenville-age grains. The youngest major population is about 1200 Ma (compared to 1170 Ma in the Beardmore composite), and it contains a second major Mesoproterozoic grouping of about 1400 Ma (compared to 1540 Ma in the Beardmore). Based on its overall similarity to the Beardmore Group, the detrital zircon signature in this sample indicates a more general East Antarctic craton provenance. There is no question that this sample has a Neoproterozoic depositional age. Because the associated metasedimentary rocks at Gerard Bluffs are separated structurally from high-grade crystalline gneisses and metaigneous units below by mapped high-strain shear zones (Goodge et al., 1993a), the boundary between metasedimentary (cover) and

crystalline units (basement) may represent a primary depositional boundary reactivated as a zone of displacement at mid-crustal levels during the Ross Orogeny.

4. Stratigraphic revisions

Based on the new geochronologic data presented here, we recommend revision of the stratigraphic terms used to describe crystalline rocks in the Miller and Geologists ranges. As noted previously, five formations of metamorphic rocks with both igneous and sedimentary precursors were designated by Grindley et al. (1964) as comprising the Nimrod Group. Although appropriately defined as mappable rock units, more recent geochronologic data demonstrate that petrographically similar igneous units have widely different crystallization ages, some units were formed and metamorphosed long before deposition of others, and some units may have provenance and/or stratigraphic affinities with outboard, lower-grade supracrustal assemblages. We therefore recommend abandoning the stratigraphic term Nimrod Group and its subdivisions, and here introduce two new lithodemic units, the Nimrod Complex and Argosy Schist. We also compare the latter with the Beardmore Group.

4.1. Nimrod Complex

The **Nimrod Complex** is here defined as comprising all igneous and high-grade gneissic rocks exposed in the Miller and Geologists ranges with Archean or Paleoproterozoic ages; to date, these rocks have yielded U-Pb zircon ages between about 3.1 and 1.7 Ga, and they entirely pre-date the Ross Orogeny. This assemblage includes quartzofeldspathic to intermediate layered gneiss, granodioritic to dioritic orthogneiss, mafic gneiss and amphibolite, and eclogitic and other mafic and ultramafic blocks in gneiss. These rocks represent the crystalline basement

formed prior to late Neoproterozoic rifting and initiation of the Ross Orogeny. As defined here, rocks of the Nimrod Complex are primarily exposed in the southernmost Geologists Range, in the western Miller Range near Camp Ridge, Milan Ridge and Ascent Glacier, and in the southern Miller Range at Orr Peak and Gerard Bluffs (Fig. 2). Although many of these rocks were formerly included in the Argo, Aurora and Miller formations, we likewise advocate abandoning these terms. The Nimrod Complex does not include a number of deformed igneous rocks underlying this area that have ages ≤ 545 Ma (Granite Harbour Intrusives; Fig. 2). Because of the petrographic similarity of many rocks assigned to the Nimrod Complex with those of Granite Harbour affinity, and due to the pervasive effects of the Ross Orogeny which has intimately interleaved all rock types, it is essentially impossible to distinguish geologic age from field relationships alone. Therefore, the assignment of any given rock type to a particular lithodemic unit as suggested above can only be defined on the basis of individual sample geochronology.

4.2. *Argosy Schist*

The **Argosy Schist** is a newly defined lithodemic unit consisting of all pre-Ross Orogen metasedimentary rocks exposed in the Miller and Geologists ranges not included in the Nimrod Complex and that have a likely sedimentary, volcanic or volcanoclastic origin. The Argosy Schist includes a heterogeneous assemblage of interlayered mica schist, garnet-staurolite-Al-silicate pelitic schist, quartzite, micaceous quartzite, amphibolite, calc-silicate schist, and marble. These rocks were formerly included in the Argosy and Worsley formations of the Nimrod Group, but because they are intimately interlayered at all scales we recommend the former terms be abandoned in favor of the more general lithodemic unit. The term Argosy Schist is adopted here to reflect the typical petrographic appearance of rocks in the Argosy Glacier area of the central

Miller Range, and also to retain historical reference to the previously recognized Argosy Formation. Detrital zircon age components constrain the maximum depositional ages to between 2000-900 Ma, and they show two distinguishable provenance patterns; therefore, although these metasedimentary rocks may not share the same origin, no further division is warranted without more detailed geochronology.

4.3. Beardmore Group correlations

As noted above, the detrital zircon age patterns from the Argosy Schist quartzites can be used to address whether metasedimentary units in the Miller Range are correlative with lithologically similar rocks of the Neoproterozoic Beardmore Group, which are exposed to the east but are of lower metamorphic grade. Although the differences in metamorphic grade have long been thought to distinguish the age of these units (e.g., Grindley et al., 1964; Grindley and Laird, 1969), they share some lithological similarity in siliciclastic and calcareous compositions that suggest possible correlation (Stump et al., 1991). Our detrital-zircon results indicate that metasedimentary units mapped as Argosy Schist in the Miller and Geologists ranges could indeed have Neoproterozoic depositional ages; two of the samples clearly were deposited after about 1050-900 Ma, and the protolith of the third (03-415) was deposited since ca. 2.0 Ga. Further, Nd isotopic compositions of these schists ($\epsilon_{\text{Nd}} = -22$ to -10 ; Argosy Formation; Borg et al., 1990; Borg and DePaolo, 1994) are similar to those of Neoproterozoic and Lower Cambrian siliciclastic rocks from the Beardmore Group and basal Byrd Group ($\epsilon_{\text{Nd}} = -21$ to -16 ; Goodge et al., 2008), indicating similar source compositions. A depleted-mantle model age from the Argosy Formation at Kreiling Mesa in the Miller Range ($T_{\text{DM}} = 1.87$ Ga; Borg and DePaolo,

1994) may indicate a dominance of Paleoproterozoic material like that observed in the Beardmore Group detrital zircon populations.

On the basis of the data summarized here, correlation between the Argosy Schist and Beardmore Group is attractive, yet at this time we consider the Argosy Schist metasedimentary units to be a distinct lithotectonic assemblage relative to the Beardmore Group. They share some individual source characteristics, but this is not unexpected given the likelihood that similar types of crust were exposed during Neoproterozoic erosion of the East Antarctic craton and subsequent sediment transport across the passive rift margin. In fact, a basement source provided overall similar detrital age input for some considerable time, even extending further up-sequence to Permian sandstones (Elliot et al., 2015). Both the Argosy and Beardmore sedimentary precursors have cratonic, Archean and Paleoproterozoic sources, although neither is restricted to or solely derived from the Nimrod Complex crystalline units, but rather they are distinct in detrital character and probably represent different stages of Neoproterozoic deposition along the cratonic rift margin of East Antarctica.

5. Discussion

5.1. Craton-forming events in the Ross sector of East Antarctica

The new zircon geochronology presented here (Table 1), coupled with previously reported age results from the Nimrod Complex and related plutonic rocks (Borg et al., 1990; Goodge and Dallmeyer, 1992, 1996; Goodge et al., 1993b, 2001, 2004a; Borg and DePaolo, 1994; Goodge and Fanning, 1999), document a rich history of punctuated geologic events that shaped cratonic basement in this sector of East Antarctica. Figure 18 shows cumulative age results from individual samples based on available $^{40}\text{Ar}/^{39}\text{Ar}$, U-Pb zircon, and Sm-Nd chronometers.

Although this diagram as plotted mixes different types of thermochronometric data, the ages show distinct periods of magmatic crustal growth and modification due to metamorphism and orogenesis. The combined plot in Figure 18B highlights the prominence of orogenic activity during the Ross (~0.5 Ga) and Nimrod orogenies (~1.7 Ga), overprinted on crust-forming events at ~2.5 and ~3.1 Ga. Each of these four major time periods were marked by significant magmatism that contributed to crust formation in this part of the East Antarctic craton. Further, it shows that whole-rock Sm-Nd model ages, mostly of about 2.7 Ga, represent composite protolith ancestry by mixing of earlier-formed materials and do not directly correspond to recognizable geologic events. Thus far, few Lu-Hf analyses on specific zircon components have been undertaken but clearly are needed (in conjunction O isotope analyses) to examine in further detail the isotopic evolution of the various, specific magmatic age components.

5.2. Nimrod Complex history

A geologic history for the Nimrod Complex and associated units, shown in Figure 19 and summarized in Table 14, is discussed below. Although new geologic events may be recognized with additional geochronology, the events illustrated here appear to bracket a complete chronology based on replicate age results from diverse lithologies. Remarkably, some samples of layered gneiss preserve much of this history within complexly zoned composite zircons (Goodge and Fanning, 1999).

5.2.1. Juvenile crustal magmatism

Layered gneisses containing composite zircons with visible cores reveal the oldest part of the Nimrod Complex history from about 3150-3050 Ma. Zircons in gneisses from Camp Ridge and Gerard Bluffs show distinct inner cores, typically as equant or prismatic domains with faceted to

round shape, having internal oscillatory growth banding and sector zoning, which are common in igneous zircons (Vavra, 1990). Many cores are bounded by discontinuity surfaces and/or embayments, reflecting incomplete zircon dissolution or melting after initial crystallization. The cores are therefore interpreted as having crystallized from an igneous melt, followed by metamorphic recrystallization or grain-boundary resorption during partial melting.

As recognized from the age distributions in individual samples, SHRIMP analyses of zircons from these gneisses yield two main magmatic age populations: one with $^{207}\text{Pb}/^{206}\text{Pb}$ ages between about 3155-3095 Ma and a second between about 3060-3050 Ma (Bennett and Fanning, 1993; Goodge and Fanning, 1999; Goodge et al., 2001; this study). The entire distribution of individual Mesoarchean grain ages shows that those analyzed from innermost cores range from about 3150-3050 Ma, whereas ages from magmatic rims range more widely from about 3120-2875 Ma (Fig. 20). It is clear from the plot of individual grain ages, however, that more than half of all magmatic crystallization occurred between about 3150-3050 Ma. Most zircons yielded ages that are >95% concordant, consistent with primary crystallization from an igneous melt, and little isotopic dispersion. Slightly discordant analyses project towards ~1720 and ~530 Ma, reflecting radiogenic Pb loss during younger orogenic events. The two Archean age populations are interpreted to indicate episodic magmatic crystallization with peaks at about 3125 and 3055 Ma. The morphology, element ratios, and age patterns of zircon cores with planar or oscillatory growth banding and prismatic terminations suggest primary magmatic growth. In particular, the prismatic character of the cores and the lack of ages much older than ~3125 Ma suggest an igneous precursor. Although it is possible that these zircon cores are detrital in origin, an igneous and metamorphic origin best explains their external grain morphology, internal structure, and discrete age populations. General correspondence of the zircon crystallization ages with whole-

rock Sm-Nd model ages, ranging from 3.48-2.72 Ga (Borg et al., 1990; Borg and DePaolo, 1994), indicates these rocks formed initially as juvenile mantle melts. Their ages thus reflect formation of Mesoarchean to Neoarchean igneous parents that experienced subsequent Paleoproterozoic and late Neoproterozoic dynamothermal effects (Fig. 19).

As a complement to previously studied samples showing multi-stage histories (Goodge and Fanning, 1999), the new samples presented here combine detailed chronometry with observed geologic field relations. Two layered gneiss units from Gerard Bluffs (samples 90-121B and 99-301) show evidence for multiple crystallization and metamorphic stages at ~3100, 3050, and 3000 Ma (Figs. 4, 6), but one of them is cross-cut by a leucocratic metaigneous unit (sample 99-302) having an age of ~2870 Ma. Together, these samples document a reproducible pattern of initial magmatic growth, secondary melt crystallization, late-stage metamorphic overgrowth, and finally cross-cutting intrusion over a 200 m.y. timespan.

5.2.2. Archean modifications

Magmatism at ~3150-3050 Ma was followed closely by high-temperature metamorphism, as recorded in slightly younger (2955-2900 Ma), mottled zircon overgrowths on Archean igneous cores in the gneisses discussed above (Goodge and Fanning, 1999; this study). These correspond generally to the low-Th/U grains shown in Fig. 20, with ages mostly <3000 Ma. This Mesoarchean metamorphism may be a consequence of high advective heat transfer associated with magmatism and/or a regionally elevated geotherm. Alternatively, the younger domains may represent late-stage magmatic (non-metamorphic) recrystallization, but this is less likely because the mottled zircon areas give consistently younger and less uniform ages than igneous growth zones.

5.2.3. Late Neoarchean anatexis and magmatism

Bennett and Fanning (1993) studied a leucocratic layer within gneisses and schists on the north side of Argosy Glacier that shows intricate margins against the host rocks, suggesting an origin by either metamorphic differentiation or anatexis. Zircons from this layer are anhedral and yielded a SHRIMP U-Pb age of ~2505 Ma. Based on the zircon morphology and isotopic composition, the age of this leucosome was interpreted to reflect a period of ultrametamorphism related to orogenic activity at the end of the Archean. Until the present study, this was the only evidence from the Nimrod Complex for magmatic activity of this age. As described here, the orthogneiss unit at Orr Peak represents a discrete igneous body with an age of ~2515 Ma (Figs. 8, 19). To date, these are the only known examples of late Neoarchean anatexis and magmatism in the Nimrod Complex, although detrital zircon signatures in craton-margin sediments indicate this is a significant age component in crust of central East Antarctica and it is an important age component in the Mawson Continent.

5.2.4. *Paleoproterozoic Nimrod Orogeny*

Evidence for a significant period of Paleoproterozoic orogenesis affecting the Nimrod Complex comes from zircon U-Pb ages in layered gneisses, orthogneisses, and discrete mafic bodies with relict eclogitic mineral assemblages. Although petrologic evidence for this event was mostly obliterated by younger activity, it is manifested by widespread zircon ages in the Miller and Geologists ranges, in partially preserved eclogite relics, and in mappable igneous units. Due to its importance in overall evolution of the Nimrod Complex, Goodge et al. (2001) referred to the event linking these geologic features as the Nimrod Orogeny (Fig. 19; Table 14).

Zircons from Nimrod Complex layered gneisses show homogeneous, CL-dark domains that occur both as cores to prismatic grains and as wide overgrowths on Archean cores (Goodge and Fanning, 1999; this study). Overgrowths cover cores showing rational crystal faces or slightly

round external shapes, suggesting topotactic growth on an unmodified or weakly modified core. Under CL, they show an absence of oscillatory zoning, interpreted as evidence of metamorphic crystallization. These domains yield ages of ~1720 Ma, with some discordance toward ~530 Ma. We interpret these ~1720 Ma overgrowths to represent new metamorphic zircon growth because: (1) oscillatory growth zoning is absent; (2) Th/U ratios are low; (3) the domains occur texturally as both cores and rims, indicating the formation of both new grains and overgrowths; and (4) concordant ages reflect zircon growth in disequilibrium with older cores. The ~1720 Ma domains therefore likely reflect high-temperature heating during crustal orogenesis and magmatism.

In addition to metamorphic crystallization in layered gneisses, a granodioritic orthogneiss with an igneous crystallization age of ~1735 Ma crosscuts layered gneisses near Camp Ridge (Bennett and Fanning, 1993; Goodge et al., 2001). Zircons from this orthogneiss show no evidence of inheritance, yet a depleted-mantle Nd model age of 2.74 Ga (Borg and DePaolo, 1994) indicates melting of pre-existing Archean crust. In this paper, we provide data for five newly recognized Paleoproterozoic metaigneous units with ages of 1740-1710 Ma, including a layered orthogneiss, deformed granite or granodiorite, an intermediate composition orthogneiss, and a Grt-bearing metafelsite (Fig. 2; Tables 1, 14). Despite patterns of younger zircon overgrowth at ~500 Ma, these units show relatively simple magmatic histories. Together with the evidence of zircon crystallization in pre-existing gneisses, these units indicate a significant component of compositionally diverse magmatism in the developing Nimrod crystalline complex. The Nimrod Orogeny is therefore associated with both high-temperature metamorphism and melting.

Numerous mafic and ultramafic tectonic blocks occur within the Nimrod Complex, particularly along the boundaries of pelitic schist and quartzofeldspathic gneiss (Goodge et al.,

1993a). The cores of the mafic tectonic blocks commonly show relict eclogitic mineral assemblages, whereas the rims have been retrogressed to amphibolite-facies mineralogy compatible with the host gneisses (Peacock and Goodge, 1995; Goodge et al., 2001). An omphacite-bearing eclogitic pod enclosed by layered gneisses near Gerard Bluffs in the southern Miller Range (Fig. 2) contains distinctly small, equant zircons with internal sector zoning, low U contents, and low Th/U ratios, suggesting a metamorphic origin (Goodge et al., 2001); concordant U-Pb SHRIMP analyses yielded a weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of ca. 1720 Ma.

Together, these data from gneissic, igneous and eclogitic rocks reveal an important period of orogenic activity between 1740-1700 Ma. Although the present metamorphic and structural character of the Nimrod Complex is primarily a manifestation of younger Ross orogenic activity, the zircon age data from these petrologically diverse samples indicate that the Nimrod Orogeny commenced with magmatism between ~1740-1710 Ma, followed by metamorphism at ~1720-1700 Ma. The high pressures and high temperatures together attending deep-crustal metamorphism, eclogite formation, and magmatism suggest that the Nimrod Orogeny involved crustal thickening brought about by plate convergence and/or collision. The Nimrod eclogite-gneiss association is representative of the E-HPG (eclogite and high-pressure granulite) thermal gradient that is the characteristic signature of continental subduction in collisional orogens during the Paleoproterozoic (Brown, 2006, 2007).

5.2.5. *Siliciclastic sedimentation*

Metasedimentary units of diverse composition were originally mapped as a major component of the Nimrod Group, yet until now their age and provenance have been largely unconstrained. Gunner (1983) previously suggested a Late Archean source for these rocks based on multi-grain zircon analyses, and a few single-grain ages required additional input from Paleoproterozoic

sources (Walker and Goodge, 1991). Whole-rock Nd model ages of 3.6-1.9 Ga from the Miller and Argosy formations indicated ancient sources (Borg et al., 1990), but they are not useful as age constraints. Detrital zircon ages from three samples of quartzite reported here demonstrate that some, if not all, of these metasedimentary units have Neoproterozoic depositional ages (≤ 1050 -800 Ma). One sample from Lookout Dome is dominated by Archean detritus and could be considerably older in depositional age, whereas the other two samples are dominated by Paleoproterozoic and Mesoproterozoic sources. In some cases, the detrital zircon age peaks correspond to known igneous and metamorphic events in Nimrod Complex gneissic units (1.7, 2.5 and 3.1 Ga), suggesting proximal sources. These detrital age patterns show that at least some Nimrod sediment was derived from a terrestrial provenance composed of Archean and Proterozoic crust, and the similarity between detrital grain ages and those obtained from other Nimrod Complex metamorphic and igneous units suggests a component of locally derived sediment. Although each of the samples shows a provenance compatible with sources in the East Antarctic craton, they reflect erosion of distinctive Archean, Paleoproterozoic (Nimrod Orogen) and Mesoproterozoic (Grenvillian) crustal provinces within the interior of East Antarctica.

5.3. Comparison of Nimrod Complex ages with other parts of the East Antarctic shield

In the broader context of cratonic evolution, available U-Pb zircon age data firmly establish the Nimrod Complex as the only known Archean crust exposed along the Transantarctic Mountains margin of East Antarctica between Terre Adélie and perhaps the Shackleton Range (Figs. 1, 21). To build a more complete picture of Archean and Proterozoic development of the East Antarctic shield, we first summarize results obtained from analysis of glacial igneous clasts

that have a source in central East Antarctica, and then compare the combined Nimrod Complex, detrital zircon and glacial clast ages with those documented from other areas (Fig. 22).

5.3.1. Glacial clast provenance

Because outcrop of crystalline basement in the Ross Sea sector is limited to the Miller and Geologists ranges, the pre-Ross basement history represented there might well differ from the deeper interior of East Antarctica. In order to expand our knowledge of cratonic East Antarctica, general indications of its age and composition are provided by study of glacial clasts transported through the Byrd Glacier and related ice-stream drainages, catchment areas of which cover a large area inboard of the Transantarctic Mountains (Goodge et al., 2008, 2010). Published and preliminary age results on glacially-transported clasts show igneous and metamorphic zircon age groupings of ca. 2010, 1880-1850, 1795, 1575, 1505-1410, and 1220-1060 Ma (Fig. 22; Goodge et al., 2008, 2010, 2012, 2013; Nissen et al., 2013). With the exception of 1488-1425 Ma ages in Enderby Land (Black et al., 1987) and 1900-1850 Ma in the northern Prince Charles Mountains (Kinny et al., 1997), none of these ages are recognized in other exposed areas of East Antarctica and none are known from the exposures of Nimrod Complex studied to date, although ages of about 2.0, 1.8, 1.4 and 1.2 Ga are present in Argosy-type detrital populations, as noted above. The glacial clast ages nonetheless provide helpful clues to the age and composition of the craton interior and strengthen the case for episodic magmatic growth of East Antarctic crust, providing impetus for further study.

5.3.2. East Antarctic shield correlatives

Signatures of 3.1, 2.5 and 1.7 Ga crustal events are well known from elsewhere in East Antarctica (Fig. 22). U-Pb geochronology has demonstrated ~3.1 Ga magmatism in other areas of Antarctica, including the Denman Glacier area of the Bunger Hills (Black et al., 1992;

1009 Sheraton et al., 1993), the Ruker Complex in the southern Prince Charles Mountains (Boger et
1010 al., 2006, 2008; Mikhalsky et al., 2006, 2010), the Napier Complex in Enderby Land (Sheraton et
1011 al., 1987), and along the Mawson Coast (Grew et al., 1988). Among these, the Denman Glacier
1012 area has a notably similar history to the Nimrod Complex. There, tonalitic orthogneiss with a
1013 3003 Ma zircon crystallization age also yielded ages indicating granulite facies metamorphism at
1014 ~2990 Ma and a younger disturbance at ~600 Ma (Black et al., 1992). These events reflect a
1015 period of Archean magmatism coupled with slightly younger high-grade metamorphism,
1016 followed by still younger Pan-African thermal effects (see below). Although reliable
1017 geochronological evidence for mid-Archean events is sparsely scattered across East Antarctica,
1018 3.1-3.0 Ga appears to be a time of major magmatism, deformation, deep-crustal metamorphism,
1019 and anatexis within early-formed crustal elements that later amalgamate as the East Antarctic
1020 shield. The Archean zircon ages obtained from the Nimrod Complex correspond to early crustal
1021 growth associated with this vibrant period of activity. Furthermore, the zircon data show that
1022 magmatic Archean crust initially formed in this region by ~3.1 Ga is roughly contemporaneous
1023 with other parts of the East Antarctic shield found near Denman Glacier and in the southern
1024 Prince Charles Mountains. Unfortunately, the older basement units in these areas are preserved
1025 mainly as relics within younger Proterozoic metamorphic terrains and are separated by both
1026 Grenvillian and Pan-African-age suture belts, it is difficult to compare their Archean ancestry.
1027 However, several areas have histories marked by similar ~2.5 and ~1.7 Ga crustal events as
1028 occur in the Nimrod Complex, including Terre Adélie, the Bunger Hills of the Wilkes Land
1029 coast, the southern Prince Charles Mountains, and the Shackleton Range (Figs. 21, 22), discussed
1030 in turn below.

1031 In Terre Adélie and the George V Coast, outcrops of Neoarchean and Paleoproterozoic high-
1032 grade gneisses and metaigneous rocks form the Terre Adélie Craton (Oliver and Fanning, 1997,
1033 2002; Peucat et al., 1999; Ménot et al., 2005; Gapais et al., 2008; Carson, 2011). At Cape
1034 Denison and adjacent areas, heterogeneous orthogneisses and paragneisses with U-Pb zircon
1035 ages of about 2445-2420 Ma date emplacement and metamorphism under conditions of about 9
1036 kbar and 800 °C (Ménot et al., 1999; Carson, 2011). The presence of Neoarchean basement is
1037 also reflected in low-grade phyllitic metamorphic rocks from Cape Hunter that contain detrital
1038 zircons with ages between 2500–1700 Ma (Oliver and Fanning, 1997). To the west, high-
1039 temperature, low-pressure (750 °C; 4-6 kbar) siliciclastic metasedimentary rocks have zircon U-
1040 Pb metamorphic ages of ~1690 Ma overprinted on ≥ 1720 Ma cores (Oliver and Fanning, 1997;
1041 Peucat et al., 1999), suggesting sedimentary deposition of migmatite precursors between 1720
1042 and 1690 Ma, followed by high-*T*/low-*P* metamorphism. Peucat et al. (1999) interpreted the
1043 metamorphic assemblages and cooling patterns to reflect crustal melting and slow cooling as a
1044 result of mafic magmatic underplating associated with lithospheric thinning. Other isolated
1045 outcrops contain ~1650 Ma migmatites and ~1600 Ma granitoids (Duclaux et al., 2007). Shear
1046 zones that juxtapose the Archean and Paleoproterozoic blocks are thought to be ~1700 Ma (Di
1047 Vincenzo et al., 2007).

1048 Archean and Proterozoic relicts are preserved at several localities within Grenville-age
1049 terrains of the Wilkes province (Fig. 1). Despite a strong Mesoproterozoic overprint, these areas
1050 retain age signatures resembling parts of the Mawson Continent. In the Obruchev-Bunger hills
1051 area, tonalitic orthogneiss with a 2641 Ma crystallization age represents Archean basement that
1052 was intruded by felsic orthogneisses with U–Pb zircon ages of about 1700–1500 Ma, including a
1053 1699 Ma granodiorite (Sheraton et al., 1992, 1993). These rocks were strongly metamorphosed

and intruded by mantle-derived melts between 1170-1150 Ma (Sheraton et al., 1992). Likewise, granulite-facies rocks in the Windmill Islands show isotopic evidence of a Late Archean to Paleoproterozoic ancestry (depleted-mantle Nd-model ages of 3.2-1.9 Ga), overprinted by Albany-Fraser belt metamorphism between 1340-1180 Ma (Post et al., 1997; Möller et al., 2002). In the Denman Glacier area, 3050-2990 Ma granitic and tonalitic orthogneisses underwent granulite-facies metamorphism at ~2890 Ma (Black et al., 1992). These rocks give 3.6-1.6 Ga depleted-mantle Nd model ages, suggesting multiple blocks with different histories or partial melting of discrete Archean and Paleoproterozoic crustal components at 1700–1600 Ma to yield a range of model ages by isotopic mixing (Black et al., 1992). Although these non-contiguous areas may represent different crustal blocks, together these age data suggest that Archean crustal remnants in the Wilkes province were modified by ca. 1700 Ma metamorphism and intracrustal melting.

High-grade metamorphic and igneous rocks of the southern Prince Charles Mountains are significant because of their prominent position toward the interior of East Antarctica. A wide range of ages have been reported from igneous, metamorphic and sedimentary rocks, but most relevant to this study are igneous rocks and orthogneisses with ages between about 3180-1740 Ma (Boger et al., 2006, 2008; Mikhalsky et al., 2006, 2010). A suite of variably metamorphosed tonalite, gabbro and charnockite yielded ages of about 3180-3150 Ma, representing initial juvenile magmatism. Formation of younger crustal melts of largely granitic composition followed at about 2800 and 1740 Ma, with minor igneous events at 2500 and 2200 Ma. Similarities to the Nimrod Complex thus include ~3100 Ma juvenile magmatism, followed by about 2800 Ma crustal metamorphism and magmatism, with subsequent metamorphic and igneous events at about 2500 and 1740 Ma.

Granulite-facies ortho- and paragneisses in the Shackleton Range show a polygenetic history of Archean and Paleoproterozoic crustal growth overprinted by both Grenvillian and Ross Orogen activity (Pankhurst et al., 1983; Talarico and Kroner, 1999; Zeh et al., 1999, 2004; Will et al., 2009). Primary crust formation of early Paleoproterozoic age is indicated by granitic orthogneiss units from the Read and Stratton groups that have U-Pb zircon ages of ~2460 Ma and ~2330 Ma, respectively (Brommer et al., 1999; Helper et al., 2000). Will et al. (2009, 2010) identified orthogneisses in the Southern Terrane formed by magmatism at 1850-1810 Ma and paragneisses that experienced high-*T* granulite-facies metamorphism at 1710-1680 Ma; they distinguished these Paleoproterozoic rocks from a temporally distinct Eastern Terrane that records only a Mesoproterozoic history of Grenvillian magmatism at about 1060 Ma. Age and isotopic data from the Southern Terrane together indicate a crustal history that includes important events between about 2.5 and 1.7 Ga, overlapping temporally with key elements in other areas.

Multiple indications of a Paleoproterozoic magmatic and metamorphic crustal history between about 2.4 and 1.7 Ga (Pankhurst et al., 1983; Zeh et al., 1999; Brommer et al., 1999; Will et al., 2009) thus provide evidence that the Mawson crustal province may extend across East Antarctica into the Shackleton Range as shown in Figure 21 (see also Boger, 2011). However, the craton is unlikely to be contiguous but rather may be interrupted by a Grenville-age belt that appears to underlie the southern Transantarctic Mountains and may extend into the interior of East Antarctica (Goodge et al., 2010). Evidence of Grenvillian basement comes from ~1060 Ma rocks exposed in the eastern Shackleton Range, isotopic evidence of Mesoproterozoic crust in the southern Transantarctic Mountains (Borg et al., 1990; Borg and DePaolo, 1994), and glacial clasts with ages of ~1100-1060 Ma sourced from the Byrd Glacier catchment (Fig. 21).

Collectively, these age and isotopic data point to the presence of Mesoproterozoic crust between the central Transantarctic Mountains and Shackleton Range (shown hypothetically in Fig. 21 as a belt extending from the Grenville Province in Laurentia). Therefore, at a minimum, the Mawson Continent as a single crustal entity should include the basement terrains of the Gawler Craton, Terre Adélie, and Nimrod Complex. The basement geological histories of the Shackleton Range and southern Prince Charles Mountains provide compelling evidence for inclusion in the Mawson Continent, but perhaps disrupted by younger Grenvillian events.

5.4. Paleoproterozoic Crustal Assembly of the Mawson Continent

5.4.1. Gawler Craton

The Gawler Craton underlies much of central and south-central South Australia and comprises Archean to Mesoproterozoic rocks that have remained substantially undeformed since about 1450 Ma (Parker, 1993; Fanning et al., 2007; Hand et al., 2007). As recently summarized by Fraser et al. (2010), the eastern Gawler craton contains Mesoarchean igneous rocks with crystallization ages of ~3150, ~2530 and ~1740 Ma that are consistent with magmatic ages in the Nimrod Complex. The ~3150 Ma Cooyenderoo Granite has a U-Pb zircon age of ~3150 Ma and is interpreted as evidence of I-type, high-K magmatism (Fraser et al., 2010). Other gneissic rocks in the region have significant inheritance of ~3150 Ma zircon components. This Mesoarchean basement may be more extensive than known from outcrop but is buried by younger sediments and volcanics. For example, it is clearly the source for the ~1590 Ma Charleston Granite (Creaser and Fanning, 1993) and confirms the presence of Mesoarchean basement upon which younger volcanic-sedimentary successions were formed; this was the initial evidence that led to the Mawson Continent concept (Fanning et al., 1996).

1123 Subsequent history of the Gawler assemblage is marked by basin sedimentation and felsic
1124 and mafic-ultramafic volcanism between about 2560-2500 Ma to form the Mulgathing and
1125 Sleaford complexes (Daly and Fanning, 1993; Swain et al., 2005; Hand et al., 2007). These
1126 volcanic-sedimentary successions were intruded by felsic to intermediate magmas between about
1127 2520 and 2500 Ma, including the Dutton Suite (Daly and Fanning, 1993; Fanning et al., 2007),
1128 and were inferred to have been deposited on the older Mesoarchaen basement (Daly and
1129 Fanning, 1993; Creaser and Fanning, 1993). Sleafordian collisional deformation, magmatism,
1130 and medium-*P* granulite-facies metamorphism occurred between about 2480 and 2420 Ma (Daly
1131 et al., 1998; Dutch et al., 2010), and was followed by about 400 m.y. of tectonic inactivity. The
1132 Sleafordian events may be correlative with cryptic Neoproterozoic magmatism in the Terre Adélie
1133 and Nimrod segments of East Antarctica.

1134 Paleoproterozoic events are represented in the Gawler Craton by the ~2000 Ma Miltalie
1135 Gneiss, ~1870 Ma Hutchison Group, and ~1850 Ma Donington Suite granites (Parker and
1136 Fanning, 1998; Fanning et al., 2007). Cryptic evidence of an ~1850 Ma orogenic event is known
1137 in the southern Gawler Craton from deformation fabrics and metamorphic assemblages recorded
1138 in the Donington granitoids and associated paragneisses, and in the southern Yorke Peninsula
1139 (Zang and Fanning, 2001) where it has been termed the Cornian Orogeny (Reid et al., 2008). To
1140 date, there are no known correlatives with age signatures of 2000-1850 Ma in Terre Adélie or
1141 basement to the Transantarctic Mountains, however igneous rocks of this age are represented in
1142 subglacially-derived clasts sampled in the Byrd Glacier drainage (Figs. 21, 22).

1143 A hallmark of the Gawler Craton are Paleoproterozoic metamorphic and igneous events of
1144 ~1730-1700 Ma age (Daly et al., 1998; Fanning et al., 2007), including: (a) eruption of bimodal
1145 volcanics at ~1740 Ma (McGregor Volcanics and Moonta porphyry); (b) intrusion of the

1146 Middlecamp granite at ~1730 Ma; (c) intrusion of Moody Suite granites and other unnamed
1147 aplitic intrusions of the Lincoln Complex at ~1710 Ma; (d) emplacement of the slightly younger
1148 Engenina Granite at ~1690 Ma; and (e) granulite-facies metamorphism at ~1735 Ma. These
1149 magmatic and metamorphic events are recognized primarily in the Eyre Peninsula, but extend
1150 northward to the Mount Woods inlier (Daly et al., 1998; Fanning et al., 2007). They are
1151 associated in several areas with multi-phase deformation attributed generally to the 1730-1700
1152 Ma Kimban Orogeny, including isoclinal folding and mylonitic shear zone displacement under
1153 upper amphibolite- to granulite-facies conditions (Hoek and Schaefer, 1998; Vassallo and
1154 Wilson, 2002; Ferris et al., 2002; Schwarz, 2003; Hand et al., 2007; Fanning et al., 2007; Dutch
1155 et al., 2010). South of the Yilgarn craton in Western Australia, orthogneisses in the Biranup
1156 Complex of the Albany–Fraser Orogen yield ages of 1634 Ma to 1695 Ma (Nelson et al., 1995),
1157 indicating a somewhat younger period of granitic magmatism that was later overprinted by 1345-
1158 1140 Ma events (Kirkland et al., 2015).

1159 5.4.2. *Mawson Continent*

1160 Fanning et al. (1995, 1996) introduced the concept of a cratonic nucleus, the so-called
1161 Mawson Continent, or ‘Block’, on the basis of the broad similarity of Archean to
1162 Paleoproterozoic histories in the Gawler Craton, Terre Adélie, and the central Transantarctic
1163 Mountains regions of East Antarctica (Fig. 21). Age correlations across this now extended
1164 province indicate that these magmatic and deep-crustal metamorphic events may reflect an
1165 important period of Paleoproterozoic crustal orogenesis, affecting older (~2.5 and ~1.85 Ga)
1166 crustal materials, preceding magmatism at ~1.6 Ga, and prior to stabilization of the Rodinia
1167 supercontinent.

Building on this concept, the distinctive Mawson-type age patterns are now known from several areas in East Antarctica (Fig. 21A). As noted above, these include: (a) 2445-2420 Ma igneous and metamorphic rocks in Terre Adélie, overprinted by ~1690 Ma magmatism and metamorphism, followed by Gawler-type ~1600 Ma volcanism; (b) ~3100 and ~2500 Ma juvenile metaigneous basement of the Nimrod Complex in the central Transantarctic Mountains, overprinted by ~1720 metamorphic and magmatic events of the Nimrod Orogeny; (c) magmatic events in the southern Prince Charles Mountains at ca. 3160, 2500, 2200, and 1740 Ma; and (d) 2460-2330 Ma and ~1850 Ma basement in the Shackleton Range overprinted by ~1700 and ~1570 Ma events. In addition, igneous glacial clasts recovered from the Byrd Glacier drainage covering central East Antarctica yield ages of ~2010, ~1860, and ~1580 Ma, among others (Goodge et al., 2010, 2012), informally referred to as the Nimrod igneous province (NIP). These clast ages represent the first direct indication of Paleoproterozoic magmatism in ice-covered areas of central East Antarctica, in addition to Mesoproterozoic magmatism of ~1450 and ~1060 Ma. Together, the unique age patterns define a wide crustal province extending from the Gawler Craton in present-day Australia to the Shackleton Range and southern Prince Charles Mountains of East Antarctica that, despite Grenvillian interruption, likely represents a coherent craton constructed between about 2500 Ma and about 1570 Ma, and that probably was extant as a stable tract until about 1060 Ma (Fig. 21A; see also Will et al., 2009; Boger, 2011). Documented metamorphic signatures of ~1700 Ma age indicate that some parts of the Mawson assemblage have characteristics of low- P/T metamorphic belts accompanied by magmatism (Fig. 21B; Gawler proper, Terre Adélie and Shackleton Range), including high- T granulites, whereas other areas are marked by eclogite/high- P granulite (high- P/T) signatures indicative of orogenesis and/or collision affecting older basement (Nimrod Complex). Although the rock assemblages are

discontinuous and the evidence is fragmentary, the correlated events at ~1.7 Ga indicate that the Mawson Continent may best be regarded as an assemblage of Mesoarchean and younger crustal rocks that were amalgamated during a key period of Paleoproterozoic crustal assembly (locally exemplified by the Kimban and Nimrod orogenies). The relatively outboard location of high- P/T metamorphic rocks in the Nimrod Complex may indicate that the present-day Ross margin of East Antarctica formed the tectonically-active, orogenic boundary associated with formation of, or accretion to, the Mawson Continent.

5.5. Implications for supercontinent assembly and breakup

It is possible that the widespread period of Paleoproterozoic activity defined above for the Mawson Continent was related to late-stage amalgamation of the Nuna supercontinent (generally considered to have formed between 2.0-1.9 Ga). As noted by Payne et al. (2009), a proto-SWEAT reconstruction based on paleomagnetic data also appears attractive for the pre-Rodinian (i.e., post-Nuna-Columbia) interval of 1740–1590 Ma. Critical ages from glacial clasts of 2010, 1880-1850, 1795 Ma (Goodge et al., 2008, 2010, 2012, 2013; Nissen et al., 2013), which pre-date ~1.7 Ga and younger ages associated with the Mawson Continent, provide intriguing evidence of Paleoproterozoic assembly events in the deep interior of East Antarctica that could be related to episodic crustal growth related to the formation of Nuna and Rodinia. As such, the SWEAT geometry for Rodinia might be inherited from 1.9-1.7 Ga assembly events, punctuated by 1.6-1.4 Ga magmatism. Younger magmatic events at ~1.6 and ~1.4 Ga provide petrologically distinctive points of correlation stretching across Australia, East Antarctica and Laurentia prior to Grenvillian tectonism, linking these cratons at the time of Rodinia. The continuity of 1.4 Ga granites from Laurentia into East Antarctica (Goodge et al., 2008) indicates that the Nuna

assembly was stitched together by this time and led to protracted stability of Austral-Antarctica with respect to Laurentia at least to the time of Rodinia (Fig. 22).

It may be possible to explain the ca. 1.7 Ga events intrinsic to development of the Mawson Continent as related to crustal convergence that brought it together with Laurentia during formation of supercontinent Nuna-Columbia. Alignment of the Nimrod Complex with the Mojave province, as suggested previously by Goodge et al. (2001), age correspondence of glacial clasts in East Antarctica to western Laurentia (Goodge et al., 2008, 2010), and provenance correlation of the Mount Isa region with strata in Yukon, Canada (Medig et al., 2014), might provide key Paleoproterozoic tie points related to supercontinent amalgamation. In this model, the Nimrod Complex represents an outboard part of the Mawson Continent that was positioned at the collisional front of this assembly, and which experienced high-*P/T* metamorphism indicative of crustal thickening, whereas the other areas were involved mainly in thermal-orogenic reworking in a relatively hinterland position within the Mawson assembly. New age findings continue to expand the extent of a likely contiguous Mawson Continent, as linked by ~1.7 Ga events; in many cases the only record of these events is provided by relict zircon geochronology, but preserved evidence of metamorphic regime and spatial distribution allows us to characterize the kinds of petrotectonic events that occurred within the elongate Mawson crustal province. It therefore appears possible to begin to evaluate not only when but how the Mawson Continent was assembled.

5.6. Provenance correlations with Mojave Province

Zircon ages from the Nimrod Complex reflecting Paleoproterozoic orogenesis and magmatism at ~1.7 Ga correlate not only with similar ages of basement in Terre Adélie but also

1237 with the ~1790-1730 Ma Mojave Province of southwestern Laurentia (Figs. 21, 22; Wooden and
1238 Miller, 1990). These ages and other geologic and isotopic tracers indicate a linkage between
1239 central East Antarctica and southwestern Laurentia (Goodge et al., 2001, 2008). Detrital-zircon
1240 provenance data from metasedimentary rocks in the western Mojave Province indicate a mixture
1241 of local and non-local sources dominated by ca. 1200, 1400 and 1800 Ma age components (Fig.
1242 23; Barth et al., 2009). Local sources explain the presence of ubiquitous 1400 Ma detrital
1243 components, but the major recognized Mojave basement igneous and metamorphic age of about
1244 1700 Ma (Wooden and Miller, 1990; Strickland et al., 2013) is not evident as a major source in
1245 the Mojave metasedimentary signatures. Preserved sedimentary structures in these rocks indicate
1246 sources to the west or northwest (in present-day coordinates), across the adjacent Neoproterozoic
1247 rift margin. Comparison of the Mojave detrital signatures with those from Antarctica reveals
1248 strong similarities (Fig. 23C). The Argosy detrital signatures are themselves explained by known
1249 age sources in Nimrod Complex igneous and metamorphic basement (this paper), in addition to
1250 some provenance signatures in common with the Beardmore Group rift-margin succession (Fig.
1251 23A; particularly those of about 1200, 1700-1800 and 2500 Ma; Goodge et al., 2004b). The
1252 Mojave Province metasedimentary rocks share some provenance characteristics with signatures
1253 in both the Beardmore Group (overlaps at about 1200 and 1800 Ma) and Nimrod Complex (1700
1254 Ma), as well as with 1200, 1400 and 1850 Ma basement ages inferred from glacial clasts
1255 (Goodge et al., 2008, 2013). Because a local source in southwest Laurentia does not account for
1256 all of the Mojave Province detrital signatures (missing populations at about 1200 and 1800 Ma),
1257 it is possible that the Mojave metasedimentary rocks had a source to the west in basement of East
1258 Antarctica. This is consistent with the transport directions inferred from paleocurrent indicators
1259 and confirmation of the juxtaposition of the Austral-Antarctic and Laurentian cratons provided

by a variety of geochronologic and isotopic correlations (Goodge et al., 2008). It is possible, therefore, that the problematic Mojave Province sedimentary provenance is explained by an East Antarctic source.

Primary igneous events in the Nimrod Complex at about 2500 and 3100 Ma, also reflected in the age distribution of detrital zircons in some of our samples (Fig. 23A), are also similar in age to two principal Archean detrital zircon age peaks found in metasedimentary samples of the Vishnu Schist from the Grand Canyon (Shufeldt et al., 2010). These workers noted particular similarity between their detrital zircon age populations and ages of Precambrian basement in the Gawler Craton and East Antarctica. Although they suggested an as yet unidentified, buried source within southwestern Laurentia for Vishnu Schist provenance, the similarity of detrital signatures to known basement in southern Australia and East Antarctica, including a newly recognized East Antarctic igneous province of ~1850 Ma age (Goodge et al., 2013), suggests that the Vishnu Schist sedimentary precursor might have had a western provenance in Austral-Antarctica.

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Figure captions

Fig. 1. Tectonic reconstruction of East Antarctica in a Gondwana supercontinent fit with

Australia, India and eastern Africa (major crustal elements after Fitzsimons, 2003; Veevers et al., 2006; Harley and Kelly, 2007). This map shows diagrammatically the important ages recognized within crustal provinces, many of which have a polygenetic metamorphic history (e.g., Paleoproterozoic relics within a Mesoproterozoic orogen); as such, the figure is not intended to show single age signatures in any given area. Route of the Kuunga suture generally follows that proposed by Meert (2003), Boger et al. (2001), and Boger and Miller (2004). From bathymetry, East Antarctic crust extends out to shelf edge (grey). Location of Nimrod Complex basement in the Miller (MR) and Geologists ranges of the central Transantarctic Mountains shown by box (see Fig. 2). Main basement divisions of East Antarctica include the Adélie, Wilkes, Rauer, Rayner, Maud and Ross provinces. General region of rocks having age affinities with the Mawson Continent shown by purple shading. Major suture zones are thought to accommodate Gondwana (blue, Pan-African) and Rodinia (green, Grenville) assembly; their continuation beneath the East Antarctic ice sheet is highly speculative. Geographic localities and geologic features: AB, Adelaide basin; AF, Albany-Fraser Belt; BH, Bunger Hills; cDML, central Dronning Maud Land; CP, Curnamona Province; DG, Denman Glacier; DHR, Dharwar Craton; DO, Delamerian Orogen; EG, Eastern Ghats belt; GSM, Gamburtsev Subglacial Mountains; GC, Gawler Craton; GR, Grunehogna province; KAL, Kalahari Craton; LB, Lachlan Fold Belt; LC, Leeuwin Complex; LHB, Lutzow-Holm Bay; LV, Lake Vostok; MB/EAO, Mozambique Belt/East African Orogen; MR, Miller Range; MU, Musgrave Ranges; NAP, Napier Complex; nPCM, northern Prince Charles Mountains; PB, Pinjarra Belt; PZ, Prydz Bay; RBT, Robertson Bay terrane; ShR, Shackleton Range; SL, Sri Lanka; sPCM, southern Prince Charles Mountains;

1682 SR, Sor Rondane; T, Tasmania; TA, Terre Adélie; VH, Vestfold Hills; wDML, western
1683 Dronning Maud Land; WB, Wilkes Subglacial Basin; WI, Windmill Islands; YIL, Yilgarn
1684 Craton.

1685
1686 **Fig. 2.** General geology of Nimrod Complex and associated units in the Miller and Geologists
1687 ranges (after Goodge et al., 1993a). Both Archean and Proterozoic metaigneous and
1688 metasedimentary units are intruded by numerous plutons and stocks of Granite Harbour Intrusive
1689 series, including syn- and post-tectonic phases (see Goodge et al., 2012). Grey boxes indicate
1690 ages reported in this paper; white boxes give approximate U-Pb SHRIMP ages from previous
1691 studies (Goodge and Fanning, 1999; Goodge et al., 2001).

1692
1693 **Fig. 3.** Field occurrence of metamorphic and igneous units sampled for zircon geochronology.
1694 (A) Hbl-Bt gneiss sample 99-300, from Gerard Bluffs in southern Miller Range. Dark-colored
1695 mafic blocks within gneiss are eclogite or retrogressed eclogite (Goodge et al., 2001). (B) Cross-
1696 cutting gneissic units in Gerard Bluffs area of southern Miller Range. Aplitic “pink” leucogneiss
1697 (p, 99-302) infolded and sheared with “grey” Bt-Ms gneiss (g, 99-301), showing that pink gneiss
1698 intrudes grey quartzofeldspathic gneiss. (C) Granite sample 99-303B, from Gerard Bluffs in
1699 southern Miller Range. Contacts of granite sheet with surrounding layered gneisses shown by
1700 dashed lines. (D) Amphibolite gneiss sample 99-304 from Orr Peak in southern Miller Range.
1701 (E) Dioritic Hbl-Bt orthogneiss sample 03-403A, from Mt. Albright area of southern Geologists
1702 Range. (F) Garnet metafelsite unit 03-404, from Mt. Albright area of southern Geologists Range.

Fig. 4. U-Pb results for Hbl-Bt gneiss sample 90-121B. **(A)** Cathodoluminescence (CL) images of representative zircons (grain number in bold type; spot ages in Ma). Spot size typically 10-20 microns. **(B)** Concordia plot of near-concordant analyses clustered near 3000-3150 Ma, including cores (grey) and rims (white), showing no coherent concordia group. **(C)** Histogram showing individual ages for old grain cores (black), an older set of rims (grey), and a set of younger rims (white).

Fig. 5. U-Pb results for Hbl-Bt gneiss sample 99-300. **(A)** CL images of representative zircons (grain number in bold; spot ages in Ma). **(B)** Concordia plot of 22 analyses, showing upper and lower intercepts of two near-concordant groups. **(C)** Close-up of concordia plot showing analyses near upper intercept of 1735 Ma. **(D)** Ages and errors of 13 individual spot analyses, giving a weighted-mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1733 ± 5 Ma.

Fig. 6. U-Pb results for cross-cutting gneiss samples 99-301 and 99-302. **(A)** CL images of representative zircons in grey gneiss sample 99-301 (grain number in bold; spot ages in Ma), showing older igneous cores overgrown by CL-bright rims. **(B)** Concordia plot of all data in grey Bt-Ms gneiss 99-301, showing a poorly-defined group with an upper-intercept of about 3120 Ma. Individual ages range from about 3120-2995 Ma. **(C)** Histogram and relative probability curve of all 34 analyses in sample 99-301, separated by textural type with individual ages for old grain cores (black), an older set of CL-bright rims (grey), and a set of younger metamorphic overgrowths (white). **(D)** Concordia plot of all data in pink leucogneiss sample 99-302, showing a poorly-defined upper intercept at ~2870 Ma.

1727 **Fig. 7.** U-Pb results for Bt granite sample 99-303B. **(A)** CL images of representative zircons
 1728 (grain number in bold; spot ages in Ma). **(B)** Concordia plot of all data. **(C)** Concordia plot of
 1729 analyses giving ages of about 1700 Ma. Analyses in grey yield an upper-intercept age of $1739 \pm$
 1730 12 Ma, similar to a weighted-mean age for the group.

1731
 1732 **Fig. 8.** U-Pb results for Hbl-Bt amphibolite gneiss sample 99-304. **(A)** CL images of
 1733 representative zircons (grain number in bold; spot ages in Ma). **(B)** Concordia plot of data from
 1734 11 grains with an upper-intercept age of 2513 ± 6 Ma. Ages and errors of 10 individual spot
 1735 analyses give a weighted-mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2506 ± 3 Ma (analysis in white excluded from
 1736 age calculations).

1737
 1738 **Fig. 9.** U-Pb results for Hbl-Bt orthogneiss sample 03-403A. **(A)** CL images of representative
 1739 zircons (grain number in bold; spot ages in Ma). **(B)** Concordia plot of all data with best-fit chord
 1740 giving intercept ages of 457 ± 32 and 1727 ± 14 Ma. **(C)** Concordia plot of analyses giving ages
 1741 of about 1700 Ma. Analysis in white excluded from age calculations. **(D)** Ages and errors of 12
 1742 individual spot analyses, giving a weighted-mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1721 ± 9 Ma.

1743
 1744 **Fig. 10.** U-Pb results for Grt metafelsite sample 03-404. **(A)** CL images of representative zircons
 1745 (grain number in bold; spot ages in Ma). **(B)** Concordia plot of all data with best-fit chord giving
 1746 intercept ages of 524 ± 19 and 1730 ± 9 Ma. **(C)** Concordia plot of analyses giving an upper
 1747 intercept age of about 1730 Ma.

1748

Fig. 11. U-Pb results for foliated Hbl-Bt orthogneiss sample 10MR-11. **(A)** CL images of representative zircons (grain number in bold; spot ages in Ma). **(B)** Concordia plot of all data with best-fit discordia giving intercept ages of 423 ± 51 and 1709 ± 15 Ma. **(C)** Concordia plot of analyses giving ages of about 1700 Ma with best-fit discordia giving intercept ages of 283 ± 180 and 1697 ± 17 Ma.

Fig. 12. Field occurrence of metasedimentary units sampled for detrital zircons. **(A)** Biotite quartzite sample 99-298, from Gerard Bluffs in southern Miller Range. **(B)** Biotite quartzite sample 03-415, from Lookout Dome area of northern Miller Range. **(C)** Fuchsite quartzite sample 03-422, from Camp Ridge area of central Miller Range.

Fig. 13. CL images of representative detrital zircons in sample 99-298, showing variety of internal textural zones, round outline of detrital grain surface, and banded tip overgrowths (grain number in bold; spot ages in Ma).

Fig. 14. U-Pb detrital-zircon results for Bt quartzite sample 99-298. **(A)** Concordia plot of all data. **(B)** Enlargement showing concordia plot of grains giving Proterozoic ages. **(C)** Histogram and relative probability curve of all grain ages ($n = 74$). The younger group of 12 analyses are from metamorphic overgrowths. **(D)** Histogram and relative probability curve of 62 Proterozoic grain ages.

1770 **Fig. 15.** U-Pb detrital-zircon results for Bt-Ms quartzite sample 03-415. **(A)** Concordia plot of all
1771 data. General fit of intercepts at ~2000, ~2500 and ~3100 Ma shown by dashed lines for
1772 reference only. **(B)** Histogram and relative probability curve of all grain ages (n = 60).

1773
1774 **Fig. 16.** U-Pb detrital-zircon results for fuchsite quartzite sample 03-422. **(A)** Concordia plot of
1775 all data and inset to show Proterozoic grain ages. **(B)** Histogram and relative probability curve of
1776 all grain ages (n = 60).

1777
1778 **Fig. 17.** Summary age probability distributions for detrital zircon samples from the Argosy
1779 Schist (this study) compared to a composite of detrital-zircon grain ages from sandstones in the
1780 Beardmore Group (lower panel). Beardmore data compiled from 398 individual ages in six
1781 samples (Goodge et al., 2002, 2004b). Beardmore sandstones show abundant Proterozoic grains
1782 with significant populations at about 1170, 1540, 1800 and 2510 Ma, highlighted by vertical
1783 green bars for reference. Proterozoic and Archean ages from orthogneiss units of the Nimrod
1784 Complex shown by purple bars.

1785
1786 **Fig. 18.** Plots of thermochronologic and isotopic age data from individual samples in the Nimrod
1787 Complex and Argosy Schist. **(A)** Plot of different chronometers, with grey bars highlighting
1788 interpretation of important igneous, metamorphic and orogenic events. Dashed grey line
1789 indicates time period represented by whole-rock Nd-isotope model ages and reflects mixing of
1790 age components within samples. Sources: (a) $^{40}\text{Ar}/^{39}\text{Ar}$ cooling ages for hornblende and
1791 muscovite (Goodge and Dallmeyer, 1992, 1996); (b) U-Pb igneous zircon crystallization ages
1792 (Goodge et al., 1993, 2001; Goodge and Fanning, 1999; this study); (c) U-Pb metamorphic ages

1793 from zircon and monazite (Goodge et al., 1993, 2001; Goodge and Fanning, 1999; this study);
1794 (d) Sm-Nd whole-rock model ages (Borg et al., 1990; Borg and DePaolo, 1994). **(B)** Plot of all
1795 data, showing major crustal events.

1796
1797 **Fig. 19.** Schematic geologic history of the Nimrod Complex and associated units in the central
1798 Transantarctic Mountains. Note that the time span shown by geologic patterns in the graphic log
1799 is greater than the actual duration of these events, as indicated by age brackets in the right-hand
1800 legend. Notable detrital zircon ages in Beardmore Group and Argosy-type metasedimentary
1801 rocks correlate with dated basement events, and they also indicate other geologic provenance
1802 sources unknown in the Nimrod Complex.

1803
1804 **Fig. 20.** Plot of all individual SHRIMP zircon $^{207}\text{Pb}/^{206}\text{Pb}$ analyses from Nimrod Complex
1805 samples with Archean ages. Sources: Bennett and Fanning (1993); Goodge and Fanning (1999);
1806 Goodge et al. (2001); this study. Individual ages designated as cores range from about 3150-3050
1807 Ma, whereas ages from magmatic rims range from 3120-2875 Ma. Grains with $\text{Th}/\text{U} \leq 0.1$
1808 (white circles) are interpreted as of metamorphic origin.

1809
1810 **Fig. 21.** Tectonic correlation of ~1.7 Ga elements of the Mawson Continent, and basement ties
1811 and sedimentary links between East Antarctica and the Mojave Province of Laurentia. **(A)**
1812 Geologic linkages between basement provinces in East Antarctica, Australia, and Laurentia
1813 (modified from Goodge et al. 2008, 2010). Map in (A) shows the spatial relationships between
1814 cratonic East Antarctica and former neighbors in order to illustrate geotectonic correlations only,
1815 rather than a representation of paleogeography at a given time period. Hence, the Gondwana

1816 elements of Australia-Antarctica are in a 500 Ma fit, whereas the Australia-Antarctica-Laurentia
1817 fit is much older. Australia and East Antarctica are positioned relative to western Laurentia based
1818 on correlation of Precambrian Nimrod and Mojave provinces, stratigraphic and isotopic
1819 correlation of Neoproterozoic rift-margin successions in Beardmore and Death Valley-Uinta
1820 areas, Pandurra-Belt sediment sources in the Gawler Craton, correlation of ~1.4 Ga A-type
1821 granite occurrences, and continuation of ~1.1 Ga metaigneous rocks based on correlation of
1822 glacial clasts in East Antarctica and Laurentian basement (Borg and DePaolo, 1994; Goodge et
1823 al. 2004b, 2008, 2010; Fanning et al., 2009). Possible extension of the Grenville Orogen belt into
1824 East Antarctica from Goodge et al. (2010). Byrd Glacier catchment area shown by diagonal
1825 dotted-line pattern, which is the source region of the Nimrod Igneous Province (NIP). Age
1826 sources for Proterozoic provinces cited in text (GC, Gawler Craton; MP, Mojave Province; NC,
1827 Nimrod Complex; sPC, southern Prince Charles Mountains; SR, Shackleton Range; TA, Terre
1828 Adélie). Geologic features: AF, Albany-Fraser Orogen; B, Beardmore Group; DML, Dronning
1829 Maud Land; DV, Death Valley Group; G, Gawler craton; GSM, Gamburtsev Subglacial
1830 Mountains; M, Musgrave Ranges; Mo, Mojave province; N, Nimrod Complex; Pa, Pandurra
1831 Formation; Pj, Pinjarra Orogen; PM, Pensacola Mountains; Pr, Pritchard Formation; R, Ross
1832 Orogen; SR, Shackleton Range; T, Tasmania; TA, Terre Adélie; TH, Trans-Hudson Orogen; U,
1833 Uinta Mountains; W, Wyoming craton. Asterisks indicate age signatures correlative with Gawler
1834 Craton and suggestive of a coherent Mawson Continent. (B) Summary of *P-T* conditions
1835 represented by ~1.7 Ga events in the Nimrod Complex, Gawler Craton, Shackleton Range, Terre
1836 Adélie, and the Mojave Province.
1837

Fig. 22. Timeline with geochronologic links between Precambrian units in East Antarctica, southeast Australia, and western Laurentia. Vertical bars indicate dated igneous and metamorphic events (black, samples from outcrop; grey, detrital mineral or glacial clast ages). Time periods of major supercontinent existence shown on right side, and orogenic activity noted by colored horizontal bars. Sources: (a) Goodge and Fanning (1999), Goodge et al. (2001, this paper); (b) Goodge et al. (2002, 2004, 2008, this paper); Wysoczanski and Allibone (2004); (c) Goodge et al. (2008, 2010, 2012, 2013); Nissen et al. (2013); (d) Oliver and Fanning (1997); Peucat et al. (1999, 2002); Menot et al. (1999); Duclaux et al. (2007, 2008); Carson (2011); (e) Black et al. (1992); Sheraton et al. (1992, 1993, 1995); (f) Brommer et al. (1999); Zeh et al. (1999, 2004); Will et al. (2009, 2010); (g) Boger et al. (2006, 2008); Mikhalsky et al. (2006, 2010); (h) Daly et al. (1998); Fairclough et al. (2003); Swain et al. (2005); Fraser and Lyons (2006); Fanning et al. (2007); Hand et al. (2007); Payne et al. (2009); (i) Bennett and DePaolo (1987); Wooden and Miller (1990); Gleason et al. (1994); Barth et al. (2000, 2009); Ramo et al. (2003); Schufeldt et al. (2010); Strickland et al. (2013); Wooden et al. (2013); (j) Doughty and Chamberlain (2008); Zirakparvar et al. (2010); Nesheim et al. (2011); Fisher et al. (2013); (k) Barth et al. (2009); Gehrels et al. (2011).

Fig. 23. Comparison of detrital zircon signatures and basement crustal ages in TAM area of Antarctica and Mojave Province of Laurentia. (A) Argosy-type quartzites (this study; Fig. 17) superimposed on known basement ages of 1.1, 1.4, 1.7, 2.5 and 3.1 Ga in the Nimrod Complex and clasts from glacial deposits (solid and dashed purple bars, respectively; Goodge and Fanning, 1999; Goodge et al., 2001, 2008, 2010). (B) Composite Beardmore Group sandstones with inferred Proterozoic basement sources of 1.2, 1.4-1.5, 1.7-1.8, and 2.5 Ga shown by orange

Figure 1

Figure 2
Geology of the Miller and Geologist ranges,
central Transantarctic Mountains

(after Goodge et al., 1993a)

Legend

Glacial moraine (Quaternary)

Beacon Supergroup (Devonian-Jurassic);
includes Ferrar Dolerite

Granite Harbour Intrusives (Cambrian-Ordovician)

muscovite-biotite granite and biotite-hornblende
granite (post-tectonic); 499-494 Ma

K-feldspar megacrystic biotite-hornblende
granodiorite (foliated); 540 Ma

biotite-hornblende tonalite (foliated); 541 Ma

biotite leucogranite (foliated); 545 Ma

biotite-hornblende diorite (foliated); 547 Ma

gabbro

Argosy Schist (Proterozoic or age uncertain)

schist, with quartzite, amphibolite, calc-silicate

calc-silicate gneiss and marble (cs)

quartzite

Nimrod Complex (Archean and Paleoproterozoic)

hornblende-biotite granodiorite gneiss
and hornblende dioritic gneiss

quartzofeldspathic gneiss, with amphibolite

garnet-hornblende-biotite mafic gneiss

★ mafic and ultramafic tectonic blocks

trend of foliation in schistose units

U-Pb zircon sample location

● new U-Pb zircon age (in Ma; dz = detrital zircons)

○ existing U-Pb zircon age (in Ma),
from Goodge & Fanning (1999),
Goodge et al. (2001)

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

Figure 11

Figure 12

Figure 13

99-298

Figure 14

Figure 6570

Figure 16

Figure 17

Figure 18

Figure 19

Nimrod Complex

Figure 20

Figure 21

A

Figure 22

Figure 23

Table 1. Samples of Nimrod Complex and associated rocks dated by SHRIMP U-Pb zircon method.

Sample No.	Unit	Location	Latitude (S)	Longitude (E)	Rock type	Zircon type	Age(s) (Ma)
<i>Nimrod Complex metamorphic and igneous units</i>							
90-121B	layered gneiss	Gerard Bluffs	83°32.4'	157°27.4'	Hbl-Bt gneiss	igneous + overgrowth	~3090
99-300	orthogneiss	Gerard Bluffs	83°36.9'	157°17.7'	Hbl-Bt gneiss	igneous + overgrowth	~1735 & ~510
99-301	layered gneiss	Gerard Bluffs	83°36.2'	157°21.2'	grey Bt-Ms gneiss	igneous + overgrowth	~3115
99-302	orthogneiss	Gerard Bluffs	83°36.2'	157°21.2'	pink Ms-Bt leucogneiss	igneous	~2870
99-303B	granite	Gerard Bluffs	83°36.9'	157°19.3'	Bt granite sheet	igneous	~1740
99-304	orthogneiss	Orr Peak	83°29.1'	157°52.7'	Hbl-Bt amphibolite gneiss	igneous	~2515
03-403A	orthogneiss	Geologists Range	82°49.6'	154°57.5'	Hbl-Bt gneiss	igneous	~1720
03-404	metaigneous	Geologists Range	82°49.6'	155°00.3'	Grt metafelsite	igneous + overgrowth	~1730 & ~525
10MR-11	orthogneiss	Camp Ridge	83°10.0'	156°03.0'	Hbl-Bt gneiss	igneous	~1710
<i>Argosy Schist metasedimentary units</i>							
99-298	quartzite	Gerard Bluffs	83°36.9'	157°16.2'	Bt quartzite	detrital + metamorphic	1200, 1400, 1790
03-415	quartzite	Lookout Dome	83°06.0'	156°09.0'	Bt-Ms quartzite	detrital	2000, 2500, 3100
03-422	quartzite	Camp Ridge	83°09.0'	156°08.8'	fuchsite quartzite	detrital	1740, 2500, 3100

Table 2. Summary of SHRIMP U-Pb zircon results for sample 90-121B, Hbl-Bt gneiss, Gerard Bluffs, Miller Range.

Grain. spot	U (ppm)	Th (ppm)	Th/U	²⁰⁶ Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total Ratios				Radiogenic Ratios						Age (Ma)				% Disc	
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	r	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb		±
1.1C	54	15	0.27	26	0.000003	<0.01	1.777	0.025	0.2345	0.0013	0.5627	0.0079	18.192	0.274	0.2345	0.0013	0.931	2878	32	3083	9	7
1.2R	77	29	0.38	38	0.000080	0.11	1.743	0.023	0.2323	0.0011	0.5731	0.0075	18.280	0.254	0.2313	0.0011	0.938	2921	31	3061	8	5
2.1C	105	40	0.38	51	0.000018	0.02	1.757	0.022	0.2369	0.0009	0.5691	0.0070	18.573	0.240	0.2367	0.0010	0.949	2904	29	3098	6	6
2.2R	131	21	0.16	58	0.000023	0.03	1.940	0.023	0.2291	0.0009	0.5152	0.0060	16.258	0.201	0.2289	0.0009	0.948	2679	26	3044	6	12
3.1R	273	94	0.34	84	-	<0.01	2.786	0.031	0.2061	0.0007	0.3589	0.0040	10.202	0.117	0.2062	0.0007	0.958	1977	19	2876	5	31
3.2C	45	9	0.20	24	-	<0.01	1.619	0.024	0.2387	0.0014	0.6181	0.0092	20.376	0.328	0.2391	0.0015	0.926	3102	37	3114	10	0
4.1C	105	46	0.43	52	0.000146	0.19	1.751	0.022	0.2362	0.0010	0.5699	0.0071	18.426	0.249	0.2345	0.0013	0.917	2907	29	3083	9	6
4.2R	41	11	0.26	20	0.000046	0.06	1.772	0.028	0.2346	0.0015	0.5641	0.0089	18.203	0.313	0.2340	0.0016	0.916	2883	37	3080	11	6
4.3R	49	11	0.23	25	0.000003	<0.01	1.730	0.025	0.2230	0.0014	0.5781	0.0084	17.773	0.282	0.2230	0.0014	0.914	2941	34	3002	10	2
5.1C	141	66	0.46	68	0.000034	0.04	1.781	0.021	0.2333	0.0011	0.5611	0.0067	18.019	0.231	0.2329	0.0011	0.924	2871	27	3072	8	7
5.2R	145	0.2	0.001	11	0.000286	0.14	11.216	0.153	0.0597	0.0016	0.0890	0.0012						550	7			
6.1R	252	34	0.13	115	0.000003	<0.01	1.885	0.021	0.2317	0.0008	0.5304	0.0059	16.940	0.198	0.2316	0.0008	0.950	2743	25	3063	6	10
7.1C	54	33	0.62	26	0.000157	0.21	1.758	0.025	0.2466	0.0018	0.5675	0.0080	19.161	0.309	0.2449	0.0019	0.876	2898	33	3152	12	8
7.2R	255	69	0.27	58	0.000066	0.11	3.782	0.064	0.1007	0.0008	0.2641	0.0045	3.632	0.069	0.0997	0.0009	0.891	1511	23	1619	16	7
7.3R	360	26	0.07	44	0.000208	0.36	7.067	0.079	0.0831	0.0007	0.1410	0.0016	1.558	0.030	0.0801	0.0012	0.586	850	9	1200	31	29
8.1C	49	13	0.27	26	0.000043	0.06	1.632	0.025	0.2349	0.0015	0.6122	0.0092	19.788	0.324	0.2344	0.0015	0.921	3079	37	3082	10	0
9.1R	194	24	0.12	95	-	<0.01	1.748	0.020	0.2313	0.0007	0.5722	0.0065	18.252	0.213	0.2313	0.0007	0.967	2917	26	3061	5	5
10.1C	122	42	0.34	59	0.000024	0.03	1.771	0.021	0.2316	0.0018	0.5643	0.0068	18.000	0.259	0.2313	0.0018	0.833	2884	28	3061	13	6
10.2R	221	39	0.18	103	0.000015	0.02	1.842	0.021	0.2233	0.0007	0.5428	0.0062	16.697	0.197	0.2231	0.0007	0.965	2795	26	3003	5	7
11.1R	87	20	0.23	42	0.000056	0.07	1.764	0.022	0.2256	0.0012	0.5665	0.0071	17.568	0.240	0.2249	0.0012	0.920	2893	29	3016	9	4

Notes :

1. C = core; R = rim. Uncertainties given at the one σ level.
2. Error in AS3 reference zircon calibration was 0.31% for the analytical session.
(not included in above errors but required when comparing ²⁰⁶Pb/²³⁸U data from different mounts).
3. f₂₀₆ % denotes the percentage of ²⁰⁶Pb that is common Pb.
4. For areas older than ~800 Ma correction for common Pb made using the measured ²⁰⁴Pb/²⁰⁶Pb ratio.
5. For areas younger than ~800 Ma correction for common Pb made using the measured ²³⁸U/²⁰⁶Pb and ²⁰⁷Pb/²⁰⁶Pb ratios following Tera and Wasserburg (1972) as outlined in Williams (1998).
6. For % Disc, 0% denotes a concordant analysis.

Table 3. Summary of SHRIMP U-Pb zircon results for sample 99-300, Hbl-Bt gneiss, Gerard Bluffs, Miller Range.

Grain. spot	U (ppm)	Th (ppm)	Th/U	²⁰⁶ Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Radiogenic Ratios						ρ	Age (Ma)				% Disc
							²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U		±	²⁰⁷ Pb/ ²⁰⁶ Pb	±		
1.1	166	100	0.603	44	0.000037	0.06	0.3098	0.0043	4.541	0.074	0.1063	0.0009	0.846	1740	21	1737	16	0
2.1	340	242	0.711	90	-	<0.01	0.3093	0.0037	4.549	0.062	0.1067	0.0006	0.894	1737	18	1743	11	0
3.1	193	147	0.763	50	0.000148	0.23	0.2982	0.0043	4.292	0.075	0.1044	0.0010	0.819	1683	21	1703	18	1
4.1	243	183	0.755	65	0.000037	0.06	0.3101	0.0040	4.593	0.069	0.1074	0.0008	0.852	1741	20	1756	14	1
5.1	155	129	0.832	39	-	<0.01	0.2909	0.0035	4.313	0.059	0.1075	0.0007	0.870	1646	17	1758	12	6
6.1	153	115	0.753	41	-	<0.01	0.3130	0.0037	4.594	0.059	0.1064	0.0005	0.921	1755	18	1739	9	-1
7.1	188	139	0.742	50	0.000031	0.05	0.3091	0.0035	4.509	0.057	0.1058	0.0006	0.898	1736	17	1728	10	0
8.1	219	142	0.645	57	-	<0.01	0.3023	0.0034	4.399	0.053	0.1055	0.0005	0.928	1703	17	1724	8	1
9.1	333	230	0.692	88	0.000016	0.03	0.3063	0.0033	4.470	0.054	0.1058	0.0006	0.890	1723	16	1729	10	0
9.2	274	1	0.005	20	0.000022	0.04	0.0855	0.0010	0.694	0.011	0.0589	0.0006	0.734	529	6	563	23	6
10.1	174	157	0.902	32	0.000008	0.01	0.2105	0.0025	2.879	0.038	0.0992	0.0006	0.887	1232	13	1609	11	23
11.1	274	221	0.806	72	0.000037	0.06	0.3070	0.0034	4.483	0.053	0.1059	0.0005	0.927	1726	17	1730	8	0
12.1	237	255	1.077	59	0.000031	0.05	0.2892	0.0032	4.177	0.051	0.1048	0.0005	0.912	1637	16	1710	9	4
12.2	97	1	0.006	7	0.000110	0.19	0.0825	0.0011	0.680	0.020	0.0598	0.0016	0.458	511	7	597	57	14
13.1	1041	440	0.423	272	-	<0.01	0.3038	0.0032	4.439	0.049	0.1060	0.0003	0.963	1710	16	1731	5	1
13.2	23	3	0.144	3	-	<0.01	0.1463	0.0050	2.669	0.199	0.1323	0.0088	0.454	880	28	2129	116	59
14.1	147	128	0.870	38	0.000075	0.12	0.3040	0.0035	4.428	0.059	0.1057	0.0007	0.868	1711	17	1726	12	1
14.2	93	1	0.007	7	0.000214	0.38	0.0833	0.0011	0.658	0.036	0.0573	0.0031	0.250	516	7	505	117	-2
15.1	130	102	0.788	33	0.000057	0.09	0.2988	0.0036	4.358	0.059	0.1058	0.0007	0.879	1686	18	1728	12	2
15.2	237	1	0.006	17	0.000047	0.08	0.0834	0.0010	0.684	0.012	0.0595	0.0008	0.647	516	6	584	30	12
16.1	517	129	0.249	132	-	<0.01	0.2964	0.0031	4.293	0.047	0.1050	0.0004	0.952	1674	16	1715	6	2
16.2	11	0	0.029	1	-	<0.01	0.0854	0.0023	1.055	0.049	0.0896	0.0034	0.570	529	13	1416	73	63
17.1	200	135	0.675	54	-	<0.01	0.3127	0.0035	4.579	0.062	0.1062	0.0008	0.827	1754	17	1735	14	-1
18.1	441	3	0.006	33	0.000042	0.07	0.0877	0.0009	0.737	0.010	0.0609	0.0005	0.788	542	6	635	18	15

Notes :

1. Uncertainties given at the one σ level.
2. f₂₀₆ % denotes the percentage of ²⁰⁶Pb that is common Pb.
3. Correction for common Pb made using the measured ²⁰⁴Pb/²⁰⁶Pb ratio.
4. For % Disc., 0% denotes a concordant analysis.

Table 4. Summary of SHRIMP U-Pb zircon results for sample 99-301, gray Bt-Ms gneiss, Gerard Bluffs, Miller Range.

Grain. spot	U (ppm)	Th (ppm)	Th/U	²⁰⁶ Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Radiogenic Ratios						ρ	Age (Ma)				% Disc
							²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U		±	²⁰⁷ Pb/ ²⁰⁶ Pb	±		
1.1c	954	704	0.74	405	0.000076	0.10	0.4936	0.0051	15.62	0.17	0.2295	0.0007	0.963	2586	22	3049	5	15
1.2r	43	25	0.58	22	0.000273	0.35	0.5929	0.0084	18.64	0.31	0.2280	0.0019	0.864	3001	34	3038	13	1
2.1r	89	77	0.86	46	0.000187	0.24	0.5965	0.0085	18.91	0.28	0.2299	0.0011	0.950	3016	34	3051	8	1
3.1r	58	31	0.54	30	0.000232	0.30	0.6092	0.0080	19.56	0.28	0.2328	0.0012	0.926	3067	32	3072	9	0
4.1c	512	171	0.33	261	0.000038	0.05	0.5946	0.0063	19.38	0.21	0.2364	0.0004	0.988	3008	26	3096	3	3
5.1c	483	166	0.34	242	0.000040	0.05	0.5831	0.0062	18.48	0.20	0.2299	0.0004	0.987	2961	25	3051	3	3
6.1c	913	261	0.29	459	0.000032	0.04	0.5847	0.0061	19.17	0.20	0.2378	0.0004	0.988	2968	25	3105	3	4
6.2r	50	23	0.45	25	0.000401	0.51	0.5687	0.0077	18.02	0.27	0.2298	0.0015	0.896	2902	32	3051	11	5
7.1r	867	566	0.65	443	0.000054	0.07	0.5944	0.0061	19.64	0.21	0.2396	0.0004	0.989	3007	25	3117	3	4
8.1r	67	32	0.48	34	0.000418	0.54	0.5904	0.0076	18.50	0.27	0.2272	0.0014	0.896	2991	31	3032	10	1
9.1c	462	185	0.40	236	0.000054	0.07	0.5941	0.0063	19.21	0.21	0.2345	0.0004	0.987	3006	25	3083	3	2
10.1c	665	336	0.51	366	0.000043	0.05	0.6397	0.0095	21.14	0.32	0.2396	0.0007	0.981	3188	37	3117	5	-2
11.1c	1274	1301	1.02	632	0.000028	0.03	0.5768	0.0059	18.79	0.20	0.2362	0.0003	0.992	2936	24	3095	2	5
12.1c	206	18	0.09	102	0.000186	0.24	0.5746	0.0064	18.41	0.21	0.2324	0.0008	0.958	2927	26	3068	5	5
13.1	559	303	0.54	297	0.000067	0.08	0.6182	0.0065	20.37	0.22	0.2390	0.0004	0.986	3103	26	3113	3	0
14.1c	602	107	0.18	310	0.000062	0.08	0.5988	0.0063	19.52	0.21	0.2364	0.0006	0.971	3025	25	3096	4	2
14.2r	871	640	0.73	456	0.000060	0.08	0.6086	0.0063	20.04	0.21	0.2388	0.0003	0.992	3064	25	3112	2	2
15.1r	18	19	1.06	9	0.002073	2.65	0.5677	0.0102	18.15	0.50	0.2319	0.0048	0.656	2898	42	3065	33	5
16.1	200	52	0.26	96	0.000208	0.27	0.5557	0.0062	17.01	0.20	0.2220	0.0008	0.956	2849	26	2995	5	5
17.1	114	19	0.16	63	0.000487	0.63	0.6392	0.0076	20.02	0.26	0.2272	0.0013	0.898	3186	30	3032	9	-5
18.1r	54	1	0.03	28	0.000817	1.06	0.5932	0.0080	18.03	0.28	0.2204	0.0016	0.883	3003	32	2983	12	-1
18.2c	510	240	0.47	270	0.000136	0.17	0.6148	0.0074	20.22	0.25	0.2385	0.0004	0.990	3089	30	3110	3	1
19.1c	1070	801	0.75	575	0.000057	0.07	0.6248	0.0065	20.68	0.22	0.2400	0.0003	0.994	3129	26	3120	2	0
20.1c	738	457	0.62	384	0.000123	0.16	0.6053	0.0063	19.79	0.21	0.2372	0.0005	0.980	3051	25	3101	3	2
21.1r	75	42	0.57	39	0.000543	0.70	0.6083	0.0076	19.09	0.26	0.2277	0.0012	0.920	3063	31	3036	9	-1
22.1c	677	497	0.73	361	0.000087	0.11	0.6190	0.0097	20.36	0.32	0.2386	0.0005	0.992	3106	39	3110	3	0
23.1r	83	38	0.46	47	0.001248	1.59	0.6471	0.0086	20.90	0.33	0.2342	0.0019	0.847	3217	34	3081	13	-4
24.1r	54	1	0.02	28	0.001138	1.48	0.6012	0.0081	17.96	0.28	0.2167	0.0018	0.855	3035	33	2956	13	-3
25.1c	616	308	0.50	306	0.000086	0.11	0.5778	0.0061	18.82	0.20	0.2362	0.0006	0.973	2940	25	3095	4	5
26.1c	951	742	0.78	411	0.000089	0.11	0.5021	0.0052	15.95	0.17	0.2304	0.0004	0.986	2623	22	3055	3	14
27.1r	71	38	0.53	35	0.000836	1.07	0.5664	0.0072	17.85	0.26	0.2285	0.0017	0.868	2893	30	3042	12	5
28.1c	282	103	0.37	158	0.000168	0.21	0.6496	0.0070	21.44	0.24	0.2394	0.0005	0.980	3227	28	3116	4	-4
29.1c	413	202	0.49	218	0.000156	0.20	0.6139	0.0065	20.23	0.22	0.2389	0.0005	0.980	3086	26	3113	3	1
30.1c	645	313	0.49	353	0.000097	0.12	0.6359	0.0067	21.07	0.22	0.2403	0.0004	0.990	3173	26	3122	2	-2

Notes :

1. Uncertainties given at the one σ level.
2. f₂₀₆ % denotes the percentage of ²⁰⁶Pb that is common Pb.
3. Correction for common Pb made using the measured ²⁰⁴Pb/²⁰⁶Pb ratio.
4. For % Disc., 0% denotes a concordant analysis.

Table 5. Summary of SHRIMP U-Pb zircon results for sample 99-302, pink Bt-Ms leucogneiss, Gerard Bluffs, Miller Range.

Grain. spot	U (ppm)	Th (ppm)	Th/U	²⁰⁶ Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Radiogenic Ratios						ρ	Age (Ma)				% Disc
							²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U		±	²⁰⁷ Pb/ ²⁰⁶ Pb	±		
1.1	2369	171	0.07	911	0.000248	0.33	0.4463	0.0072	12.35	0.20	0.2007	0.0003	0.995	2379	32	2832	3	16
2.1	5525	529	0.10	661	0.000173	0.24	0.1389	0.0021	3.48	0.08	0.1815	0.0030	0.668	838	12	2667	27	69
3.1	2619	136	0.05	927	0.000014	0.02	0.4120	0.0042	11.11	0.11	0.1956	0.0002	0.995	2224	19	2790	2	20
4.1	1755	42	0.02	554	0.000030	0.04	0.3671	0.0041	9.85	0.11	0.1946	0.0004	0.980	2016	19	2782	4	28
5.1	3802	160	0.04	1769	0.000020	0.03	0.5414	0.0063	15.23	0.18	0.2040	0.0003	0.990	2789	26	2858	3	2
6.1	5143	216	0.04	881	0.000049	0.07	0.1993	0.0043	4.49	0.10	0.1635	0.0010	0.961	1171	23	2492	10	53

Notes :

1. Uncertainties given at the one σ level.
2. f₂₀₆ % denotes the percentage of ²⁰⁶Pb that is common Pb.
3. Correction for common Pb made using the measured ²⁰⁴Pb/²⁰⁶Pb ratio.
4. For % Disc., 0% denotes a concordant analysis.

Table 6. Summary of SHRIMP U-Pb zircon results for sample 99-303B, Bt granite, Gerard Bluffs, Miller Range.

Grain. spot	U (ppm)	Th (ppm)	Th/U	²⁰⁶ Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Radiogenic Ratios				ρ	²⁰⁷ Pb/ ²⁰⁶ Pb		Age (Ma)				% Disc
							²⁰⁷ Pb/ ²³⁵ U	²⁰⁶ Pb/ ²³⁸ U	±	±		²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	
1.1	497	57	0.12	218	0.000039	0.05	13.773	0.158	0.5103	0.0057	0.968	0.1958	0.0006	2658	24	2791	5	5
1.2	228	115	0.50	88	0.000050	0.07	12.359	0.165	0.4513	0.0055	0.912	0.1986	0.0011	2401	24	2815	9	15
2.1	543	98	0.18	144	-	<0.01	4.538	0.054	0.3083	0.0034	0.934	0.1067	0.0005	1732	17	1745	8	1
3.1	199	46	0.23	51	0.000110	0.17	4.277	0.069	0.2969	0.0038	0.793	0.1045	0.0010	1676	19	1705	18	2
3.2	720	248	0.34	179	0.000020	0.03	4.167	0.048	0.2899	0.0031	0.944	0.1042	0.0004	1641	16	1701	7	4
4.1	45	50	1.10	22	0.000366	0.48	16.735	0.374	0.5799	0.0110	0.850	0.2093	0.0025	2948	45	2900	19	-2
4.2	994	275	0.28	260	-	<0.01	4.483	0.049	0.3046	0.0032	0.962	0.1067	0.0003	1714	16	1745	5	2
5.1	365	72	0.20	95	-	<0.01	4.449	0.057	0.3018	0.0035	0.911	0.1069	0.0006	1700	17	1748	10	3
6.1	398	60	0.15	99	0.000026	0.04	4.153	0.052	0.2891	0.0033	0.909	0.1042	0.0005	1637	17	1700	10	4
7.1	337	144	0.43	88	-	<0.01	4.502	0.063	0.3052	0.0036	0.841	0.1070	0.0008	1717	18	1748	14	2
7.2	1124	314	0.28	283	0.000280	0.44	4.265	0.048	0.2918	0.0031	0.929	0.1060	0.0004	1651	15	1732	8	5
8.1	53	14	0.26	27	0.000072	0.09	19.111	0.409	0.5888	0.0104	0.829	0.2354	0.0028	2984	42	3089	19	3
8.2	660	140	0.21	176	-	<0.01	4.584	0.052	0.3114	0.0034	0.952	0.1068	0.0004	1747	17	1745	6	0
9.1	494	70	0.14	134	0.000014	0.02	4.589	0.055	0.3161	0.0035	0.934	0.1053	0.0005	1771	17	1719	8	-3
10.1	361	58	0.16	94	-	<0.01	4.453	0.057	0.3032	0.0035	0.908	0.1065	0.0006	1707	17	1741	10	2
11.1	85	82	0.97	41	0.000014	0.02	15.954	0.257	0.5549	0.0083	0.934	0.2085	0.0012	2846	35	2894	9	2
11.2	782	136	0.17	203	-	<0.01	4.400	0.049	0.3017	0.0032	0.960	0.1058	0.0003	1700	16	1727	6	2
12.1	149	38	0.25	72	0.000061	0.08	17.952	0.276	0.5604	0.0074	0.859	0.2323	0.0018	2868	31	3068	13	7
13.1	429	122	0.29	107	0.000010	0.02	4.184	0.055	0.2906	0.0033	0.866	0.1044	0.0007	1645	17	1704	12	4
14.1	652	309	0.47	177	0.000014	0.02	4.646	0.054	0.3167	0.0035	0.947	0.1064	0.0004	1774	17	1739	7	-2
15.1	68	23	0.34	38	-	<0.01	21.366	0.384	0.6385	0.0105	0.917	0.2427	0.0017	3183	41	3138	11	-1
16.1	221	36	0.17	56	0.000034	0.05	4.391	0.062	0.2978	0.0037	0.881	0.1069	0.0007	1680	19	1748	12	4
17.1	641	631	0.99	163	0.000011	0.02	4.332	0.051	0.2957	0.0033	0.946	0.1063	0.0004	1670	16	1736	7	4
18.1	750	241	0.32	184	0.000136	0.21	4.170	0.050	0.2851	0.0031	0.901	0.1061	0.0005	1617	15	1733	10	7
19.1	395	56	0.14	94	0.000238	0.37	3.988	0.054	0.2766	0.0031	0.840	0.1046	0.0008	1574	16	1707	14	8
20.1	102	57	0.56	51	0.000093	0.12	18.152	0.314	0.5878	0.0086	0.842	0.2240	0.0021	2981	35	3009	15	1
21.1	51	47	0.92	22	0.000449	0.60	13.917	0.303	0.4938	0.0091	0.846	0.2044	0.0024	2587	39	2862	19	10
21.2	767	163	0.21	204	0.000041	0.06	4.498	0.052	0.3087	0.0033	0.936	0.1057	0.0004	1734	16	1726	7	0

Notes :

1. Uncertainties given at the one σ level.
2. f₂₀₆ % denotes the percentage of ²⁰⁶Pb that is common Pb.
3. Correction for common Pb made using the measured ²⁰⁴Pb/²⁰⁶Pb ratio.
4. For % Disc., 0% denotes a concordant analysis.

Table 7. Summary of SHRIMP U-Pb zircon results for sample 99-304, Hbl-Bt amphibolite gneiss, Orr Peak, Miller Range.

Grain. spot	U (ppm)	Th (ppm)	Th/U	²⁰⁶ Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Radiogenic Ratios						ρ	Age (Ma)				% Disc
							²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U		±	²⁰⁷ Pb/ ²⁰⁶ Pb	±		
1.1	896	858	0.96	348	0.000030	0.04	0.4522	0.0047	10.29	0.11	0.1651	0.0003	0.988	2405	21	2508	3	4
2.1	663	714	1.08	261	0.000032	0.05	0.4590	0.0048	10.46	0.11	0.1653	0.0003	0.985	2435	21	2510	3	3
3.1	234	164	0.70	91	0.000122	0.17	0.4498	0.0050	10.25	0.12	0.1653	0.0006	0.943	2394	22	2510	7	5
4.1	918	1082	1.18	353	0.000033	0.05	0.4469	0.0047	10.14	0.11	0.1645	0.0003	0.988	2382	21	2503	3	5
5.1	499	454	0.91	184	0.000098	0.14	0.4274	0.0085	9.69	0.19	0.1644	0.0004	0.991	2294	38	2502	4	8
6.1	998	926	0.93	371	0.000036	0.05	0.4326	0.0045	9.81	0.10	0.1644	0.0003	0.988	2317	20	2502	3	7
7.1	387	282	0.73	148	0.000083	0.12	0.4451	0.0048	10.07	0.11	0.1641	0.0004	0.972	2373	21	2498	4	5
8.1	473	440	0.93	195	0.000085	0.12	0.4799	0.0054	10.95	0.13	0.1655	0.0004	0.980	2527	23	2513	4	-1
9.1	335	327	0.98	99	0.000162	0.23	0.3445	0.0038	7.43	0.09	0.1564	0.0008	0.909	1908	18	2417	9	21
10.1	445	417	0.94	174	0.000135	0.19	0.4547	0.0048	10.33	0.11	0.1647	0.0004	0.973	2416	21	2505	4	4
11.1	537	376	0.70	200	0.000092	0.13	0.4331	0.0046	9.71	0.11	0.1626	0.0004	0.979	2320	21	2483	4	7
12.1	174	146	0.84	71	0.000294	0.41	0.4733	0.0054	10.80	0.13	0.1655	0.0007	0.930	2498	24	2512	8	1

Notes :

1. Uncertainties given at the one σ level.
2. f₂₀₆ % denotes the percentage of ²⁰⁶Pb that is common Pb.
3. Correction for common Pb made using the measured ²⁰⁴Pb/²⁰⁶Pb ratio.
4. For % Disc., 0% denotes a concordant analysis.

Table 8. Summary of SHRIMP U-Pb zircon results for sample 03-403A, Hbl-Bt orthogneiss, Mt. Albright, Geologists Range.

Grain. spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total Ratios				Radiogenic Ratios						r	Age (Ma)				% Disc
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±		²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	
1.1	277	142	0.51	70	0.000084	0.13	3.394	0.041	0.1077	0.0006	0.2942	0.0035	4.323	0.060	0.1065	0.0008	0.862	1663	18	1741	13	5
2.1R	153	20	0.13	11	0.000825	1.04	12.431	0.176	0.0655	0.0012	0.0796	0.0012						493.8	6.9			
3.1R	138	230	1.66	17	0.001992	3.26	7.120	0.103	0.1163	0.0014	0.1359	0.0022	1.657	0.132	0.0884	0.0069	0.200	821	12	1392	149	41
3.2	205	114	0.56	51	0.000083	0.13	3.471	0.043	0.1053	0.0007	0.2877	0.0036	4.131	0.062	0.1041	0.0009	0.835	1630	18	1699	15	4
4.1	126	121	0.96	33	0.000106	0.17	3.281	0.044	0.1070	0.0009	0.3043	0.0041	4.430	0.074	0.1056	0.0010	0.813	1712	20	1725	18	1
5.1	138	116	0.84	35	0.000070	0.11	3.377	0.045	0.1059	0.0009	0.2958	0.0039	4.279	0.070	0.1049	0.0010	0.808	1670	20	1713	18	2
6.1R	136	227	1.66	19	0.000544	0.88	6.081	0.083	0.0990	0.0011	0.1630	0.0022	2.054	0.063	0.0914	0.0025	0.450	973	12	1455	52	33
7.1R	134	16	0.12	12	0.000216	1.96	9.492	0.158	0.0769	0.0013	0.1033	0.0018						633.6	10.4			
8.1	210	194	0.92	55	0.000062	0.10	3.303	0.041	0.1051	0.0007	0.3024	0.0038	4.347	0.063	0.1042	0.0008	0.855	1703	19	1701	14	0
9.1R	304	202	0.67	71	0.000041	0.06	3.680	0.044	0.1045	0.0006	0.2715	0.0032	3.890	0.053	0.1039	0.0007	0.874	1549	16	1695	12	9
10.1R	101	23	0.22	6	0.000251	1.64	14.586	0.238	0.0685	0.0018	0.0674	0.0011						420.7	6.9			
10.2	144	135	0.93	38	0.000041	0.06	3.224	0.042	0.1056	0.0009	0.3100	0.0041	4.489	0.071	0.1050	0.0009	0.834	1741	20	1715	16	-1
11.1R	97	44	0.45	14	0.000220	0.36	5.973	0.111	0.0972	0.0013	0.1668	0.0031	2.166	0.053	0.0942	0.0015	0.758	995	17	1512	30	34
12.1R	181	10	0.05	12	0.000240	0.39	12.798	0.251	0.0600	0.0011	0.0778	0.0016						483.2	9.3			
13.1	180	99	0.55	46	0.000059	0.09	3.402	0.043	0.1073	0.0008	0.2936	0.0038	4.312	0.070	0.1065	0.0011	0.789	1660	19	1740	18	5
14.1R	198	82	0.42	41	0.000090	0.14	4.165	0.052	0.1016	0.0010	0.2398	0.0030	3.319	0.053	0.1004	0.0010	0.784	1386	16	1631	19	15
15.1	155	101	0.65	39	0.000223	0.35	3.458	0.044	0.1090	0.0008	0.2882	0.0037	4.208	0.072	0.1059	0.0012	0.758	1632	19	1730	20	6
16.1R	341	94	0.27	22	0.001498	2.50	13.341	0.167	0.0763	0.0010	0.0731	0.0010						454.7	5.8			
17.1R	35	7	0.20	5	0.000243	0.40	6.053	0.121	0.0937	0.0021	0.1645	0.0033	2.049	0.089	0.0903	0.0035	0.465	982	18	1432	73	31
18.1	206	121	0.59	54	0.000052	0.08	3.278	0.041	0.1065	0.0007	0.3048	0.0038	4.448	0.064	0.1058	0.0008	0.869	1715	19	1729	13	1
19.1	163	119	0.73	43	-	<0.01	3.257	0.042	0.1053	0.0008	0.3070	0.0040	4.456	0.067	0.1053	0.0008	0.860	1726	20	1719	14	0
20.1	309	227	0.74	80	0.000031	0.05	3.317	0.039	0.1054	0.0006	0.3014	0.0036	4.361	0.059	0.1050	0.0007	0.878	1698	18	1713	12	1
21.1	269	279	1.04	71	0.000067	0.10	3.251	0.039	0.1067	0.0008	0.3073	0.0037	4.485	0.066	0.1058	0.0009	0.816	1728	18	1729	16	0

Notes :

1. R = rim or grain tip. Uncertainties given at the one σ level.
2. Error in FC1 reference zircon calibration was 0.35% for the analytical session.
(not included in above errors but required when comparing ²⁰⁶Pb/²³⁸U data from different mounts).
3. f₂₀₆ % denotes the percentage of ²⁰⁶Pb that is common Pb.
4. For areas older than ~800 Ma correction for common Pb made using the measured ²⁰⁴Pb/²⁰⁶Pb ratio.
5. For areas younger than ~800 Ma correction for common Pb made using the measured ²³⁸U/²⁰⁶Pb and ²⁰⁷Pb/²⁰⁶Pb ratios following Tera and Wasserburg (1972) as outlined in Williams (1998).
6. For % Disc, 0% denotes a concordant analysis.

Table 9. Summary of SHRIMP U-Pb zircon results for sample 03-404, Grt metafelsite, Mt. Albright, Geologists Range.

Grain. spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total Ratios				Radiogenic Ratios						ρ	Age (Ma)				% Disc
							²³⁸ U/ ²⁰⁶ Pb	²⁰⁷ Pb/ ²⁰⁶ Pb		²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁶ Pb/ ²³⁵ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U		±	²⁰⁷ Pb/ ²⁰⁶ Pb	±		
1.1	1396	9	0.01	102	0.000009	0.02	11.745	0.130	0.0583	0.0004	0.0851	0.0009	0.682	0.009	0.0581	0.0004	0.855	527	6	535	15	2
2.1	498	306	0.62	116	0.000017	0.03	3.673	0.045	0.1042	0.0005	0.2722	0.0033	3.901	0.051	0.1039	0.0005	0.930	1552	17	1696	9	8
3.1	383	176	0.46	83	0.000045	0.07	3.982	0.047	0.1036	0.0006	0.2509	0.0029	3.564	0.047	0.1030	0.0006	0.892	1443	15	1679	11	14
4.1	287	133	0.46	65	0.000037	0.06	3.815	0.046	0.1026	0.0007	0.2620	0.0032	3.689	0.051	0.1021	0.0007	0.871	1500	16	1663	13	10
5.1	401	277	0.69	104	0.000029	0.05	3.298	0.038	0.1067	0.0005	0.3031	0.0035	4.442	0.057	0.1063	0.0006	0.904	1707	17	1737	10	2
6.1	1039	6	0.01	77	0.000024	0.04	11.668	0.131	0.0577	0.0004	0.0857	0.0010	0.678	0.009	0.0574	0.0004	0.829	530	6	506	17	-5
7.1	1018	7	0.01	74	0.000016	0.03	11.842	0.133	0.0577	0.0004	0.0844	0.0009	0.669	0.009	0.0575	0.0004	0.823	522	6	510	17	-3
8.1	382	267	0.70	100	0.000019	0.03	3.282	0.038	0.1054	0.0005	0.3046	0.0035	4.416	0.056	0.1051	0.0005	0.915	1714	18	1717	9	0
9.1	331	182	0.55	75	0.000052	0.08	3.813	0.047	0.1033	0.0006	0.2620	0.0032	3.707	0.051	0.1026	0.0007	0.880	1500	16	1672	12	10
9.2	1073	8	0.01	77	0.000020	0.04	12.004	0.134	0.0586	0.0004	0.0833	0.0009	0.670	0.009	0.0583	0.0004	0.840	516	6	543	16	5
10.1	415	272	0.66	108	0.000018	0.03	3.308	0.038	0.1052	0.0005	0.3023	0.0035	4.374	0.055	0.1049	0.0005	0.919	1702	17	1713	9	1
11.1	256	167	0.65	63	0.000077	0.12	3.518	0.043	0.1051	0.0007	0.2839	0.0035	4.073	0.060	0.1040	0.0009	0.828	1611	17	1697	15	5
12.1	1528	10	0.01	112	0.000035	0.06	11.760	0.129	0.0581	0.0003	0.0850	0.0009	0.675	0.009	0.0576	0.0004	0.845	526	6	516	15	-2
13.1	222	116	0.53	57	0.000046	0.07	3.351	0.042	0.1055	0.0007	0.2982	0.0037	4.314	0.063	0.1049	0.0008	0.857	1682	18	1713	14	2
14.1	454	303	0.67	119	0.000016	0.02	3.282	0.038	0.1058	0.0005	0.3046	0.0035	4.434	0.056	0.1056	0.0005	0.922	1714	17	1724	9	1
15.1	593	116	0.20	78	0.000004	0.01	6.564	0.076	0.0874	0.0006	0.1523	0.0018	1.834	0.025	0.0873	0.0006	0.857	914	10	1368	13	33
16.1	288	159	0.55	75	0.000049	0.08	3.323	0.040	0.1057	0.0006	0.3007	0.0036	4.355	0.060	0.1051	0.0007	0.879	1695	18	1715	12	1
17.1	516	379	0.73	136	0.000012	0.02	3.263	0.037	0.1068	0.0005	0.3064	0.0035	4.506	0.055	0.1067	0.0005	0.931	1723	17	1743	8	1
18.1	246	111	0.45	58	0.000027	0.04	3.626	0.044	0.1056	0.0007	0.2757	0.0034	3.999	0.056	0.1052	0.0007	0.876	1570	17	1718	12	9
19.1	405	242	0.60	94	0.000038	0.06	3.705	0.043	0.1025	0.0006	0.2697	0.0032	3.793	0.050	0.1020	0.0006	0.893	1539	16	1661	11	7

Notes :

1. Uncertainties given at the one σ level.
2. Error in FC1 reference zircon calibration was 0.35% for the analytical session.
(not included in above errors but required when comparing ²⁰⁶Pb/²³⁸U data from different mounts).
3. f₂₀₆ % denotes the percentage of ²⁰⁶Pb that is common Pb.
4. Due to high U concentration of the younger areas, correction for common Pb made throughout using the measured ²⁰⁴Pb/²⁰⁶Pb ratio.
5. For % Disc, 0% denotes a concordant analysis.

Table 10. Summary of SHRIMP U-Pb zircon results for sample 10MR-11, foliated Hbl-Bt orthogneiss, Camp Ridge, Miller Range.

Grain. spot	U (ppm)	Th (ppm)	Th/U	²⁰⁶ Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Radiogenic Ratios						ρ	Age (Ma)				% Disc
							²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U		±	²⁰⁷ Pb/ ²⁰⁶ Pb	±		
1.1	772	293	0.38	142	0.000028	0.05	0.2139	0.0022	2.931	0.033	0.0994	0.0004	0.940	1250	12	1612	7	22
2.1	108	107	0.99	28	0.000031	0.05	0.3031	0.0037	4.372	0.065	0.1046	0.0009	0.825	1707	18	1707	16	0
2.2	952	352	0.37	157	0.000196	0.33	0.1910	0.0020	2.517	0.029	0.0955	0.0004	0.914	1127	11	1539	9	27
3.1	410	188	0.46	97	0.000237	0.38	0.2743	0.0030	3.880	0.050	0.1026	0.0007	0.843	1563	15	1671	13	6
4.1	811	417	0.51	145	0.000032	0.05	0.2080	0.0022	2.833	0.032	0.0988	0.0004	0.927	1218	12	1601	8	24
5.1	528	266	0.50	133	-	<0.01	0.2943	0.0038	4.180	0.059	0.1030	0.0005	0.931	1663	19	1679	9	1
6.1	397	175	0.44	90	0.000378	0.61	0.2637	0.0030	3.703	0.056	0.1018	0.0010	0.749	1509	15	1658	18	9
7.1	979	403	0.41	122	0.000270	0.47	0.1441	0.0015	1.751	0.024	0.0881	0.0007	0.792	868	9	1385	16	37
8.1	524	202	0.38	117	0.000234	0.38	0.2599	0.0028	3.728	0.050	0.1040	0.0008	0.807	1489	14	1697	15	12
9.1	632	312	0.49	137	0.000022	0.03	0.2514	0.0027	3.535	0.040	0.1020	0.0004	0.934	1446	14	1660	8	13
10.1	830	349	0.42	124	0.000075	0.13	0.1732	0.0018	2.224	0.028	0.0931	0.0006	0.849	1030	10	1491	12	31
11.1	648	281	0.43	111	0.000098	0.16	0.1984	0.0022	2.685	0.032	0.0982	0.0005	0.900	1167	12	1590	10	27
12.1	744	270	0.36	142	0.000027	0.04	0.2225	0.0024	3.066	0.035	0.1000	0.0004	0.929	1295	12	1623	8	20
13.1	444	197	0.44	107	0.000060	0.10	0.2804	0.0031	4.026	0.049	0.1041	0.0005	0.906	1594	15	1699	9	6
14.1	589	309	0.52	116	0.000026	0.04	0.2300	0.0025	3.192	0.038	0.1007	0.0005	0.916	1334	13	1636	9	18
15.1	765	205	0.27	151	0.000204	0.34	0.2297	0.0026	3.135	0.041	0.0990	0.0007	0.848	1333	13	1606	13	17

Notes :

1. Uncertainties given at the one σ level.
2. f₂₀₆ % denotes the percentage of ²⁰⁶Pb that is common Pb.
3. Correction for common Pb made using the measured ²⁰⁴Pb/²⁰⁶Pb ratio.
4. For % Disc., 0% denotes a concordant analysis.

Table 11. Summary of SHRIMP U-Pb zircon results for sample 99-298, Bt quartzite from Gerard Bluffs, Miller Range.

Grain. spot	U (ppm)	Th (ppm)	Th/U	²⁰⁶ Pb* (ppm)	²⁰⁶ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total Ratios			Radiogenic Ratios						Age (Ma)				% Disc		
							²³⁸ U/ ²⁰⁶ Pb	²⁰⁷ Pb/ ²⁰⁶ Pb	²⁰⁶ Pb/ ²³⁸ U	²⁰⁷ Pb/ ²³⁵ U	²⁰⁷ Pb/ ²⁰⁶ Pb	²⁰⁷ Pb/ ²⁰⁶ Pb	²⁰⁷ Pb/ ²⁰⁶ Pb	²⁰⁶ Pb/ ²³⁸ U	²⁰⁷ Pb/ ²⁰⁶ Pb	²⁰⁷ Pb/ ²⁰⁶ Pb						
							±	±	±	±	±	±	±	±	±	±						
1.1	96	65	0.68	17	0.000119	0.20	4.742	0.060	0.0818	0.0008	0.2105	0.0027	2.325	0.041	0.0801	0.0010	0.720	1231	14	1200	24	-3
2.1	178	86	0.48	32	0.000081	0.13	4.719	0.055	0.0822	0.0006	0.2116	0.0025	2.366	0.037	0.0811	0.0008	0.749	1238	13	1224	20	-1
3.1	66	58	0.88	11	0.000121	0.20	5.220	0.082	0.0809	0.0013	0.1912	0.0030	2.086	0.057	0.0791	0.0018	0.580	1128	16	1176	44	4
3.2	871	30	0.03	70	0.000114	0.29	10.738	0.113	0.0615	0.0003	0.0929	0.0010						572	6			
4.1	219	13	0.06	17	0.000191	0.29	11.313	0.138	0.0607	0.0007	0.0881	0.0011						545	6			
4.2	133	164	1.24	21	0.000277	0.47	5.450	0.079	0.0786	0.0009	0.1826	0.0027	1.879	0.047	0.0746	0.0015	0.578	1081	15	1058	41	-2
5.1	105	80	0.76	19	0.000016	0.03	4.826	0.069	0.0824	0.0010	0.2072	0.0030	2.346	0.044	0.0821	0.0010	0.764	1214	16	1249	24	3
6.1	37	41	1.09	6	0.000556	0.93	5.065	0.100	0.0889	0.0018	0.1956	0.0039	2.187	0.110	0.0811	0.0037	0.399	1152	21	1223	90	6
6.2	251	25	0.10	18	0.000135	0.22	11.676	0.136	0.0597	0.0007	0.0855	0.0010						529	6			
7.1	361	171	0.47	42	0.000213	0.37	7.336	0.087	0.0725	0.0007	0.1358	0.0016	1.300	0.025	0.0694	0.0011	0.613	821	9	912	32	10
8.1	186	128	0.69	52	0.000031	0.05	3.092	0.038	0.1106	0.0007	0.3233	0.0040	4.909	0.071	0.1101	0.0008	0.854	1806	19	1802	14	0
9.1	125	242	1.94	48	-	<0.01	2.224	0.029	0.1733	0.0010	0.4497	0.0059	10.747	0.153	0.1733	0.0010	0.917	2394	26	2590	10	8
10.1	200	118	0.59	34	0.000011	0.02	5.028	0.061	0.0809	0.0008	0.1988	0.0024	2.214	0.034	0.0807	0.0008	0.784	1169	13	1215	19	4
11.1	108	173	1.60	16	0.000074	0.13	5.868	0.084	0.0798	0.0011	0.1702	0.0024	1.849	0.039	0.0788	0.0012	0.677	1013	13	1166	31	13
12.1	225	113	0.50	37	0.000026	0.04	5.256	0.063	0.0806	0.0007	0.1902	0.0023	2.104	0.032	0.0802	0.0008	0.790	1122	12	1203	18	7
13.1	93	34	0.37	19	-	<0.01	4.235	0.056	0.0874	0.0009	0.2362	0.0031	2.853	0.047	0.0876	0.0009	0.799	1367	16	1374	19	1
14.1	144	126	0.87	35	0.000042	0.07	3.560	0.049	0.1046	0.0010	0.2807	0.0039	4.026	0.068	0.1040	0.0010	0.814	1595	19	1697	18	6
15.1	133	104	0.78	37	0.000022	0.03	3.078	0.042	0.1146	0.0009	0.3248	0.0044	5.119	0.082	0.1143	0.0010	0.855	1813	22	1869	15	3
16.1	203	168	0.83	57	0.000033	0.05	3.075	0.038	0.1146	0.0007	0.3251	0.0040	5.115	0.073	0.1141	0.0008	0.872	1814	20	1866	13	3
17.1	227	248	1.09	90	0.000033	0.05	2.177	0.026	0.1580	0.0007	0.4591	0.0055	9.972	0.129	0.1576	0.0008	0.929	2435	24	2430	8	0
18.1	61	28	0.47	12	0.000211	0.35	4.236	0.073	0.0925	0.0014	0.2352	0.0041	2.904	0.083	0.0895	0.0021	0.599	1362	21	1415	44	4
19.1	81	41	0.50	13	0.000135	0.23	5.376	0.160	0.0811	0.0013	0.1856	0.0055	2.027	0.077	0.0792	0.0019	0.780	1098	30	1177	47	7
20.1	169	158	0.94	28	0.000158	0.26	5.109	0.139	0.0789	0.0009	0.1952	0.0053	2.064	0.074	0.0767	0.0018	0.761	1150	29	1113	46	-3
21.1	93	49	0.53	17	0.000095	0.16	4.604	0.078	0.0785	0.0018	0.2168	0.0037	2.306	0.073	0.0771	0.0021	0.534	1265	19	1124	53	-13
22.1	188	86	0.46	37	0.000131	0.22	4.420	0.067	0.0956	0.0011	0.2257	0.0034	2.920	0.063	0.0938	0.0014	0.700	1312	18	1504	29	13
23.1	103	134	1.30	22	0.000048	0.08	4.007	0.207	0.0956	0.0013	0.2493	0.0129	3.263	0.175	0.0949	0.0014	0.963	1435	66	1526	27	6
23.2	188	12	0.07	13	0.000320	0.62	12.169	0.268	0.0624	0.0016	0.0817	0.0018						506	11			
24.1	619	19	0.03	45	-	0.22	11.935	0.221	0.0595	0.0005	0.0836	0.0016						518	9			
25.1	171	77	0.45	42	-	<0.01	3.491	0.048	0.1078	0.0023	0.2865	0.0040	4.258	0.107	0.1078	0.0023	0.550	1624	20	1762	38	8
26.1	121	71	0.58	32	0.000068	0.11	3.239	0.051	0.1116	0.0019	0.3084	0.0049	4.706	0.116	0.1107	0.0021	0.644	1733	24	1810	34	4
27.1	249	246	0.99	64	-	<0.01	3.332	0.040	0.0947	0.0053	0.3001	0.0577	3.919	0.785	0.0947	0.0053	0.959	1692	286	1523	106	-11
28.1	45	104	2.28	6	0.000764	1.32	6.992	0.181	0.0980	0.0027	0.1411	0.0037	1.699	0.122	0.0873	0.0058	0.370	851	21	1367	128	38
29.1	252	126	0.50	41	-	<0.01	5.322	0.063	0.0923	0.0006	0.1879	0.0022	2.393	0.032	0.0924	0.0006	0.873	1110	12	1475	12	25
30.1	186	116	0.62	43	0.000009	0.01	3.698	0.045	0.0969	0.0006	0.2703	0.0033	3.606	0.050	0.0967	0.0006	0.881	1543	17	1562	12	1
31.1	116	149	1.28	20	-	<0.01	4.864	0.067	0.0794	0.0008	0.2057	0.0028	2.263	0.039	0.0798	0.0008	0.793	1206	15	1191	21	-1
32.1	113	88	0.78	23	0.000034	0.06	4.322	0.058	0.0927	0.0008	0.2312	0.0031	2.941	0.050	0.0922	0.0010	0.789	1413	16	1473	20	9
33.1	86	65	0.75	18	0.000084	0.14	4.074	0.060	0.0894	0.0009	0.2452	0.0036	2.983	0.067	0.0882	0.0015	0.658	1431	19	1388	32	-2
34.1	58	29	0.50	17	0.000118	0.18	2.964	0.048	0.1115	0.0011	0.3368	0.0055	5.102	0.111	0.1099	0.0016	0.745	1871	26	1797	26	-4
35.1	307	221	0.72	52	0.000025	0.04	5.090	0.059	0.0788	0.0005	0.1964	0.0023	2.123	0.030	0.0784	0.0006	0.823	1156	12	1157	16	0
36.1	281	20	0.07	108	-	<0.01	2.248	0.025	0.1837	0.0014	0.4451	0.0050	11.313	0.154	0.1843	0.0014	0.831	2374	22	2692	13	12
37.1	67	30	0.45	13	-	<0.01	4.491	0.072	0.0873	0.0011	0.2232	0.0036	2.743	0.078	0.0891	0.0021	0.569	1299	19	1407	45	8
37.2	327	16	0.72	24	0.000923	1.75	11.554	0.127	0.0722	0.0005	0.0850	0.0010						526	6			
38.1	307	115	0.37	61	-	<0.01	4.322	0.050	0.0858	0.0005	0.2315	0.0027	2.758	0.038	0.0864	0.0006	0.842	1342	14	1347	14	0
39.1	194	127	0.65	39	0.000020	0.03	4.251	0.053	0.0895	0.0006	0.2352	0.0029	2.895	0.042	0.0893	0.0007	0.855	1362	15	1410	14	3
40.1	175	111	0.63	54	0.000032	0.05	2.767	0.033	0.1614	0.0007	0.3612	0.0043	8.020	0.104	0.1610	0.0008	0.915	1988	20	2467	9	19
40.2	496	25	0.05	42	0.000135	1.42	10.054	0.107	0.0716	0.0005	0.0980	0.0011						603	6			
41.1	206	103	0.50	53	-	<0.01	3.330	0.040	0.1092	0.0009	0.3004	0.0036	4.534	0.067	0.1095	0.0010	0.808	1693	18	1791	16	5
42.1	76	41	0.54	17	0.000035	0.06	3.799	0.058	0.0917	0.0010	0.2631	0.0040	3.307	0.064	0.0912	0.0011	0.784	1506	20	1450	23	-4
43.1	54	45	0.83	10	-	<0.01	4.622	0.076	0.0888	0.0012	0.2166	0.0035	2.675	0.058	0.0896	0.0013	0.754	1264	19	1416	27	111

Table 12. Summary of SHRIMP U-Pb zircon results for sample 03-415, Bt-Ms quartzite from Lookout Dome, Miller Range.

Grain. spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total Ratios				Radiogenic Ratios				r	Age (Ma)				% Disc		
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±		²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±			
1.1	247	153	0.62	74	0.000022	0.03	2.850	0.037	0.1243	0.0008	0.3508	0.0046	5.997	0.087	0.1240	0.0008	0.891	1938	22	2014	12	4
2.1	651	255	0.39	198	0.000003	0.01	2.832	0.034	0.1241	0.0005	0.3531	0.0042	6.041	0.077	0.1241	0.0005	0.945	1949	20	2016	7	3
3.1	645	160	0.25	252	0.000004	0.01	2.198	0.026	0.1640	0.0006	0.4549	0.0054	10.284	0.128	0.1640	0.0006	0.961	2417	24	2497	6	3
4.1	370	37	0.10	153	0.000045	0.06	2.077	0.026	0.1654	0.0007	0.4812	0.0060	10.935	0.144	0.1648	0.0007	0.941	2532	26	2506	7	-1
5.1	353	79	0.22	176	0.000011	0.01	1.720	0.021	0.2329	0.0008	0.5814	0.0072	18.662	0.241	0.2328	0.0008	0.959	2955	29	3071	6	4
6.1	93	23	0.24	51	-	<0.01	1.577	0.024	0.2441	0.0015	0.6343	0.0095	21.367	0.348	0.2443	0.0016	0.920	3167	38	3148	10	-1
7.1	281	115	0.41	142	0.000017	0.02	1.698	0.022	0.2326	0.0009	0.5887	0.0075	18.866	0.251	0.2324	0.0009	0.953	2984	30	3069	6	3
8.1	528	74	0.14	200	0.000011	0.02	2.268	0.027	0.1629	0.0007	0.4409	0.0053	9.894	0.128	0.1628	0.0007	0.936	2354	24	2485	8	5
9.1	312	153	0.49	97	0.000033	0.05	2.763	0.035	0.1240	0.0007	0.3617	0.0046	6.164	0.087	0.1236	0.0008	0.896	1990	22	2009	11	1
10.1	165	66	0.40	67	0.000044	0.06	2.118	0.029	0.1645	0.0010	0.4719	0.0065	10.665	0.161	0.1639	0.0010	0.908	2492	28	2497	11	0
11.1	1170	399	0.34	361	-	<0.01	2.781	0.033	0.1235	0.0004	0.3596	0.0042	6.128	0.075	0.1236	0.0004	0.963	1980	20	2009	6	1
12.1	196	46	0.24	79	-	<0.01	2.139	0.028	0.1641	0.0010	0.4677	0.0062	10.592	0.154	0.1643	0.0010	0.915	2473	27	2500	10	1
13.1	191	58	0.30	99	0.000020	0.03	1.667	0.022	0.2357	0.0013	0.5999	0.0080	19.477	0.280	0.2355	0.0013	0.924	3029	32	3090	9	2
14.1	557	323	0.58	286	0.000003	<0.01	1.674	0.020	0.2371	0.0007	0.5972	0.0072	19.516	0.243	0.2370	0.0007	0.970	3019	29	3100	5	3
15.1	419	244	0.58	209	0.000009	0.01	1.722	0.021	0.2315	0.0008	0.5805	0.0071	18.519	0.237	0.2314	0.0008	0.962	2951	29	3062	6	4
16.1	218	119	0.55	68	0.000046	0.07	2.752	0.036	0.1238	0.0009	0.3631	0.0048	6.165	0.093	0.1231	0.0009	0.874	1997	23	2002	13	0
17.1	109	58	0.54	48	-	<0.01	1.954	0.029	0.1839	0.0013	0.5118	0.0075	12.980	0.212	0.1839	0.0013	0.899	2664	32	2689	12	1
18.1	478	487	1.02	152	-	<0.01	2.693	0.033	0.1235	0.0006	0.3714	0.0046	6.328	0.084	0.1236	0.0006	0.930	2036	21	2008	9	-1
19.1	917	250	0.27	309	0.000121	0.17	2.547	0.030	0.1570	0.0005	0.3920	0.0046	8.403	0.105	0.1555	0.0006	0.952	2132	22	2407	6	11
20.1	188	76	0.41	92	0.000049	0.06	1.763	0.025	0.2472	0.0014	0.5669	0.0081	19.281	0.296	0.2467	0.0014	0.929	2895	33	3164	9	8
21.1	259	129	0.50	82	0.000032	0.05	2.704	0.035	0.1234	0.0008	0.3696	0.0048	6.269	0.090	0.1230	0.0008	0.897	2028	22	2000	11	-1
22.1	228	67	0.30	97	0.000042	0.06	2.013	0.026	0.1639	0.0009	0.4964	0.0065	11.183	0.158	0.1634	0.0009	0.922	2598	28	2491	9	-4
23.1	174	139	0.80	87	-	<0.01	1.711	0.023	0.2317	0.0012	0.5846	0.0079	18.675	0.270	0.2317	0.0012	0.936	2967	32	3064	8	3
24.1	136	56	0.41	67	0.000010	0.01	1.760	0.025	0.2177	0.0013	0.5680	0.0080	17.041	0.259	0.2176	0.0013	0.924	2900	33	2963	9	2
25.1	76	25	0.33	37	0.000068	0.09	1.750	0.028	0.2020	0.0016	0.5710	0.0091	15.840	0.283	0.2012	0.0017	0.886	2912	37	2836	13	-3
26.1	302	187	0.62	118	0.000039	0.05	2.206	0.030	0.1649	0.0008	0.4531	0.0061	10.272	0.149	0.1644	0.0008	0.935	2409	27	2502	9	4
27.1	366	107	0.29	142	0.000063	0.09	2.209	0.028	0.1636	0.0008	0.4523	0.0057	10.152	0.137	0.1628	0.0008	0.926	2405	25	2485	9	3
28.1	576	271	0.47	174	-	<0.01	2.840	0.035	0.1229	0.0006	0.3521	0.0043	5.968	0.078	0.1229	0.0006	0.937	1945	20	1999	8	3
29.1	495	115	0.23	168	0.000033	0.05	2.533	0.031	0.1609	0.0007	0.3945	0.0049	8.731	0.114	0.1605	0.0007	0.941	2144	22	2461	8	13
30.1	531	198	0.37	169	0.000045	0.06	2.708	0.035	0.1591	0.0007	0.3690	0.0047	8.067	0.110	0.1586	0.0007	0.945	2025	22	2440	8	17
31.1	253	195	0.77	79	0.000053	0.08	2.750	0.036	0.1231	0.0008	0.3633	0.0048	6.133	0.092	0.1224	0.0009	0.873	1998	22	1992	13	0
32.1	379	166	0.44	142	0.000058	0.08	2.293	0.029	0.1725	0.0008	0.4358	0.0054	10.323	0.138	0.1718	0.0008	0.936	2332	24	2575	8	9
33.1	78	37	0.48	36	-	<0.01	1.877	0.030	0.1995	0.0020	0.5330	0.0085	14.670	0.277	0.1996	0.0020	0.847	2754	36	2823	16	2
34.1	775	237	0.31	295	0.000017	0.02	2.254	0.028	0.1619	0.0005	0.4436	0.0056	9.887	0.129	0.1617	0.0005	0.965	2367	25	2473	6	4
35.1	354	187	0.53	140	0.000014	0.02	2.170	0.027	0.1649	0.0008	0.4607	0.0058	10.463	0.141	0.1647	0.0008	0.938	2443	26	2505	8	2
36.1	667	160	0.24	262	0.000011	0.02	2.189	0.026	0.1641	0.0006	0.4568	0.0055	10.328	0.130	0.1640	0.0006	0.960	2425	24	2497	6	3
37.1	352	152	0.43	180	-	<0.01	1.682	0.021	0.2343	0.0009	0.5945	0.0075	19.206	0.252	0.2343	0.0009	0.957	3008	30	3082	6	2
38.1	239	150	0.63	75	-	<0.01	2.750	0.036	0.1230	0.0008	0.3639	0.0048	6.196	0.093	0.1235	0.0009	0.878	2001	23	2007	13	0
39.1	183	86	0.47	97	0.000016	0.02	1.624	0.022	0.2364	0.0013	0.6156	0.0083	20.050	0.293	0.2362	0.0013	0.924	3092	33	3095	9	0
40.1	295	106	0.36	122	0.000018	0.03	2.082	0.028	0.1658	0.0008	0.4802	0.0065	10.964	0.158	0.1656	0.0008	0.939	2528	28	2514	8	-1
41.1	131	84	0.64	70	0.000012	0.02	1.604	0.023	0.2368	0.0013	0.6234	0.0088	20.342	0.310	0.2367	0.0013	0.928	3123	35	3098	9	-1
42.1	405	75	0.19	159	0.000012	0.02	2.192	0.027	0.1660	0.0007	0.4562	0.0057	10.432	0.138	0.1659	0.0007	0.944	2423	25	2516	7	4
43.1	181	73	0.41	74	0.000019	0.03	2.113	0.055	0.1650	0.0010	0.4732	0.0123	10.749	0.289	0.1647	0.0011	0.969	2498	54	2505	11	0
44.1	311	296	0.95	96	0.000022	0.03	2.772	0.036	0.1244	0.0007	0.3606	0.0046	6.171	0.088	0.1241	0.0008	0.903	1985	22	2016	11	2
45.1	330	82	0.25	124	-	<0.01	2.283	0.029	0.1679	0.0008	0.4381	0.0056	10.148	0.138	0.1680	0.0008	0.932	2342	25	2538	8	8
46.1	266	121	0.46	107	-	<0.01	2.133	0.029	0.1646	0.0009	0.4689	0.0065	10.650	0.157	0.1647	0.0009	0.935	2479	28	2505	9	1
47.1	225	105	0.47	88	0.000019	0.03	2.207	0.031	0.1658	0.0009	0.4531	0.0064	10.340	0.157	0.1655	0.0009	0.929	2409	28	2513	9	4
48.1	561	201	0.36	211	0.000004	0.01	2.287	0.028	0.1625	0.0006	0.4372	0.0053	9									

Table 13. Summary of SHRIMP U-Pb zircon results for sample 03-422, fuchsite quartzite from Camp Ridge, Miller Range.

Grain. spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total Ratios				Radiogenic Ratios				Age (Ma)				% Disc			
							²³⁸ U/ ²⁰⁶ Pb	²⁰⁷ Pb/ ²⁰⁶ Pb	²⁰⁶ Pb/ ²³⁸ U	²⁰⁷ Pb/ ²³⁵ U	²⁰⁷ Pb/ ²⁰⁶ Pb	²⁰⁶ Pb/ ²³⁸ U	²⁰⁷ Pb/ ²⁰⁶ Pb	²⁰⁶ Pb/ ²³⁸ U								
							±	±	±	±	±	±	±	±								
1.1	357	225	0.63	93	0.000021	0.03	3.299	0.037	0.1076	0.0006	0.3031	0.0034	4.482	0.057	0.1073	0.0006	0.890	1706	17	1754	11	3
2.1	459	176	0.38	143	0.000044	0.06	2.748	0.031	0.1460	0.0006	0.3637	0.0041	7.294	0.089	0.1454	0.0007	0.929	2000	19	2293	8	13
3.1	375	222	0.59	97	0.000048	0.07	3.309	0.037	0.1071	0.0006	0.3020	0.0034	4.434	0.057	0.1065	0.0006	0.885	1701	17	1740	11	2
4.1	79	60	0.76	16	-	<0.01	4.115	0.062	0.0947	0.0015	0.2430	0.0037	3.172	0.068	0.0947	0.0015	0.698	1402	19	1522	29	8
5.1	84	48	0.58	11	-	<0.01	6.801	0.107	0.0685	0.0014	0.1471	0.0023	1.398	0.038	0.0689	0.0015	0.584	885	13	897	45	1
6.1	833	420	0.50	189	0.000167	0.26	3.789	0.040	0.1063	0.0006	0.2632	0.0028	3.774	0.049	0.1040	0.0008	0.827	1506	14	1696	13	11
7.1	1548	916	0.59	147	0.000668	1.16	9.033	0.113	0.0756	0.0005	0.1094	0.0014	0.995	0.032	0.0659	0.0019	0.398	669	8	805	61	17
8.1	277	167	0.60	74	0.000099	0.15	3.232	0.038	0.1065	0.0007	0.3090	0.0036	4.479	0.062	0.1051	0.0008	0.854	1736	18	1717	13	-1
9.1	258	182	0.71	69	0.000029	0.05	3.210	0.038	0.1049	0.0008	0.3114	0.0037	4.488	0.063	0.1045	0.0008	0.853	1748	18	1706	13	-2
10.1	38	15	0.38	9	-	<0.01	3.828	0.081	0.0989	0.0019	0.2612	0.0055	3.561	0.103	0.0989	0.0019	0.731	1496	28	1603	37	7
11.1	273	114	0.42	70	-	<0.01	3.359	0.040	0.1069	0.0007	0.2977	0.0035	4.395	0.060	0.1071	0.0007	0.861	1680	17	1750	13	4
12.1	166	81	0.49	44	-	<0.01	3.234	0.044	0.1047	0.0009	0.3094	0.0042	4.481	0.074	0.1051	0.0010	0.824	1738	21	1715	17	-1
13.1	516	398	0.77	133	0.000019	0.03	3.327	0.038	0.1066	0.0006	0.3005	0.0034	4.406	0.057	0.1063	0.0006	0.885	1694	17	1738	11	3
14.1	159	92	0.58	38	0.000193	0.31	3.611	0.047	0.1048	0.0010	0.2761	0.0036	3.888	0.073	0.1021	0.0014	0.687	1572	18	1663	25	6
15.1	210	173	0.82	56	-	<0.01	3.198	0.039	0.1054	0.0008	0.3128	0.0039	4.556	0.067	0.1056	0.0009	0.837	1754	19	1725	15	-2
16.1	462	232	0.50	117	0.000090	0.14	3.409	0.038	0.1060	0.0006	0.2930	0.0033	4.230	0.055	0.1047	0.0007	0.855	1656	16	1709	13	3
17.1	180	125	0.69	47	-	<0.01	3.297	0.050	0.1065	0.0009	0.3033	0.0046	4.451	0.078	0.1065	0.0009	0.864	1707	23	1740	16	2
18.1	259	178	0.69	44	0.000018	0.03	5.061	0.060	0.0812	0.0007	0.1975	0.0023	2.203	0.034	0.0809	0.0008	0.781	1162	13	1219	19	5
19.1	418	25	0.06	115	0.000030	0.05	3.135	0.035	0.1118	0.0005	0.3188	0.0035	4.897	0.060	0.1114	0.0006	0.902	1784	17	1822	10	2
20.1	121	50	0.41	32	-	<0.01	3.289	0.043	0.1072	0.0010	0.3040	0.0040	4.493	0.073	0.1072	0.0010	0.811	1711	20	1752	17	2
21.1	350	177	0.51	92	0.000023	0.04	3.270	0.037	0.1067	0.0006	0.3057	0.0034	4.483	0.057	0.1063	0.0006	0.887	1720	17	1738	11	1
22.1	314	178	0.57	75	0.000026	0.04	3.594	0.041	0.1046	0.0006	0.2781	0.0032	3.998	0.053	0.1043	0.0007	0.863	1582	16	1701	12	7
23.1	209	176	0.84	56	-	<0.01	3.191	0.055	0.1067	0.0008	0.3134	0.0054	4.615	0.086	0.1068	0.0008	0.923	1757	26	1745	13	-1
24.1	350	144	0.41	82	0.000018	0.03	3.690	0.043	0.1042	0.0006	0.2709	0.0032	3.883	0.051	0.1040	0.0006	0.887	1545	16	1696	11	9
25.1	217	223	1.03	86	0.000014	0.02	2.158	0.027	0.1604	0.0008	0.4633	0.0057	10.235	0.137	0.1602	0.0008	0.923	2454	25	2458	9	0
26.1	228	128	0.56	60	0.000040	0.06	3.276	0.041	0.1047	0.0008	0.3051	0.0039	4.382	0.065	0.1042	0.0008	0.851	1716	19	1700	14	-1
27.1	154	104	0.68	66	-	<0.01	2.012	0.027	0.1670	0.0010	0.4973	0.0066	11.475	0.168	0.1674	0.0010	0.911	2602	28	2531	10	-3
28.1	152	76	0.50	45	0.000016	0.03	2.914	0.039	0.1166	0.0009	0.3431	0.0046	5.503	0.086	0.1163	0.0009	0.857	1901	22	1901	14	0
29.1	193	109	0.56	50	0.000142	0.22	3.313	0.040	0.1070	0.0008	0.3011	0.0037	4.362	0.070	0.1051	0.0011	0.763	1697	18	1715	19	1
30.1	196	148	0.75	50	0.000127	0.20	3.342	0.041	0.1077	0.0008	0.2986	0.0037	4.363	0.069	0.1060	0.0011	0.774	1684	18	1731	18	3
31.1	77	30	0.39	29	0.000078	0.11	2.246	0.033	0.1833	0.0016	0.4448	0.0066	11.184	0.195	0.1823	0.0017	0.851	2372	30	2674	15	11
32.1	251	148	0.59	65	0.000024	0.04	3.309	0.039	0.1078	0.0008	0.3021	0.0036	4.479	0.062	0.1075	0.0008	0.859	1702	18	1758	13	3
33.1	64	26	0.40	11	0.000204	0.34	4.959	0.082	0.0819	0.0015	0.2010	0.0033	2.188	0.057	0.0790	0.0016	0.636	1181	18	1171	40	-1
34.1	156	89	0.57	40	0.000028	0.04	3.349	0.043	0.1057	0.0009	0.2985	0.0038	4.334	0.071	0.1053	0.0011	0.778	1684	19	1719	19	2
35.1	271	61	0.23	131	0.000019	0.02	1.774	0.020	0.2297	0.0009	0.5637	0.0065	17.834	0.218	0.2295	0.0009	0.942	2882	27	3048	7	5
36.1	376	213	0.57	90	0.000087	0.14	3.589	0.040	0.1058	0.0005	0.2782	0.0031	4.015	0.050	0.1047	0.0006	0.892	1582	15	1708	10	7
37.1	486	258	0.53	106	0.000036	0.06	3.929	0.043	0.0949	0.0005	0.2544	0.0028	3.309	0.042	0.0944	0.0006	0.864	1461	14	1515	12	4
38.1	162	95	0.59	44	0.000025	0.04	3.169	0.040	0.1071	0.0012	0.3155	0.0040	4.645	0.079	0.1068	0.0012	0.748	1767	20	1745	21	-1
39.1	415	189	0.46	105	0.000088	0.14	3.408	0.038	0.1059	0.0006	0.2931	0.0033	4.230	0.056	0.1047	0.0007	0.848	1657	16	1709	13	3
40.1	38	59	1.53	15	-	<0.01	2.154	0.039	0.1590	0.0020	0.4642	0.0085	10.179	0.226	0.1590	0.0020	0.824	2458	37	2445	21	-1
41.1	232	77	0.33	48	0.000294	0.43	4.115	0.050	0.1390	0.0019	0.2419	0.0029	4.508	0.092	0.1351	0.0022	0.594	1397	15	2166	29	36
42.1	332	206	0.62	86	0.000028	0.04	3.326	0.038	0.1066	0.0007	0.3005	0.0034	4.403	0.058	0.1062	0.0007	0.875	1694	17	1736	12	2
43.1	243	136	0.56	59	0.000013	0.02	3.546	0.054	0.1040	0.0008	0.2819	0.0043	4.035	0.069	0.1038	0.0008	0.894	1601	22	1693	14	5
44.1	184	112	0.61	48	0.000039	0.06	3.315	0.044	0.1060	0.0009	0.3015	0.0040	4.386	0.070	0.1055	0.0009	0.826	1699	20	1723	16	1
45.1	174	112	0.64	45	0.000066	0.10	3.339	0.042	0.1056	0.0009	0.2992	0.0038	4.321	0.066	0.1047	0.0009	0.826	1687	19	1710	16	1
46.1	302	174	0.58	76	0.000048	0.07	3.414	0.041	0.1070	0.0007	0.2927	0.0035	4.293	0.061	0.1064	0.0008	0.858	1655	18	1738	13	5
47.1	268	144	0.54	68	0.000031	0.05	3.380	0.040	0.1072	0.0007	0.2957	0.0035	4.353	0.060	0.1068	0.0008	0.848	1670	17	1745	13	4
48.1	393</																					

Table 14. Summary of geologic events in the Nimrod Complex dated by U-Pb zircon methods.

	Event	Age (Ma)	U-Pb Method ^a	Reference ^b
	High-P/T metamorphism, deformation & orogenic magmatism (Ross Orogeny)	520-540	SHRIMP & ID/TIMS	1, 3, 4, 5
	Clastic sedimentation	≤990 ≤1050 ≤2000	SHRIMP	5
Nimrod Complex	Magmatism, metamorphism & eclogite formation (Nimrod Orogeny)	1700-1740	SHRIMP	1, 2, 5
	Anatectic magmatism	~2500	SHRIMP	2, 5
	Metamorphism	2900-2955	SHRIMP	1, 5
	Juvenile magmatism	~2950-3150	SHRIMP	1, 2, 5

^a SHRIMP = Sensitive High-Resolution Ion MicroProbe; ID/TIMS = Isotope dilution/thermal ionization mass spectrometry

^b 1, Goodge & Fanning (1999); 2, Bennett & Fanning (1993); 3, Goodge et al. (1993a); 4, Goodge et al. (2012); 5, this study