Pieces of Laurentia in East Antarctica

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Summary Geologic, age and isotopic data from the central Transantarctic Mountains provide a unique test of the Rodinia fit between East Antarctica and Laurentia. Evidence supporting a SWEAT-type fit includes: (1) similar Nd-isotope crustal age provinces; (2) similarity of ~1.7 Ga crustal events; (3) provenance link between ~1.4 Ga detrital zircons in Antarctic rift-margin strata and Mesoproterozoic A-type granites in Laurentia; (4) associated 1.8-1.6 Ga detrital zircons in these strata; and (5) similarity in ages of rift-margin formation. New isotopic and age data include: (6) ~1.4 Ga Antarctic-margin detrital zircons have Hf-isotopic compositions matching the A-type Laurentian granites; and (7) a newly discovered A-type rapakivi granite boulder in glacial till at Nimrod Glacier has a U-Pb zircon age of ~1440 Ma, indicating the presence of Mesoproterozoic granites beneath the East Antarctic ice sheet. We suggest that these detrital-mineral and rock clasts represent distinctive pieces of Laurentia in East Antarctica.

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Introduction

Since geological reconstructions of the Neoproterozoic supercontinent Rodinia first appeared (Moores, 1991; Dalziel, 1991; Hoffman, 1991), East Antarctica has figured prominently as a central cratonic block, but its position within Rodinia has subsequently been a matter of contention. Different reconstructions have variously positioned East Antarctica next to (so-called SWEAT fit), or distant from, the western margin of Laurentia. Thus, although it is generally thought that Rodinia was assembled between about 1.3 and 1.1 Ga, there remains little agreement about its paleogeographic configuration. Paleomagnetic data to constrain the position of East Antarctica are lacking for the time period between assembly and subsequent breakup by 700-650 Ma, and there remains uncertainty about the reliability and/or applicability of data for either Laurentia or Australia (Wingate et al., 2002). Recent paleopole positions from central Australia, for example, appear to equally well fit either the SWEAT or AUSMEX models, whereas the AUSWUS geometry is less well supported (Pisarevsky et al., 2007). Despite contradictory paleomagnetic data from western Australia (Wingate et al., 2002), there remain several lines of geological evidence in support of a SWEAT fit between western Laurentia and Austral-East Antarctica, as described below.

Existing geologic correlations

Geological arguments for a SWEAT connection between western Laurentia and Austral-East Antarctica, highlighted in Figure 1, include the following:

(1) Similar Nd-isotope crustal age provinces in East Antarctica (Borg & DePaolo, 1994) and western Laurentia (Bennett & DePaolo, 1987; Wooden & Miller, 1990).

(2) Age and isotopic similarity between specific ~1.7 Ga Paleoproterozoic crustal events recorded in the Nimrod Group of the central Transantarctic Mountains (Goodge & Fanning, 1999; Goodge et al., 2001) and the Mojave province of Laurentia (Barth et al., 2000).

(3) A provenance link between distinctive ~1.4 Ga detrital zircons in Antarctic rift-margin sedimentary rocks and the A-type Mesoproterozoic magmatic province in Laurentia (Goodge et al., 2004). Sedimentological arguments indicate that the source for the zircons in these late Neoproterozoic to Lower Cambrian rock units lies in East Antarctica.

(4) Associated 1.8-1.6 Ga detrital zircons in these same Neoproterozoic successions, consistent with a source of composite Proterozoic crust like that in western Laurentia (Goodge et al., 2004).

(5) A similarity in ages of rift-margin formation and onset of sedimentation in the central Transantarctic Mountains (by 668 Ma; Goodge et al., 2002) and western Laurentia (~717-685 Ma; Ross et al., 1992; Lund et al., 2003; Fanning & Link, 2004), as originally suggested by Moores (1991) and Dalziel (1991).

In addition to these existing links, we summarize here new isotopic and age data from material collected in the central Transantarctic Mountains that lend considerable strength to these correlations.

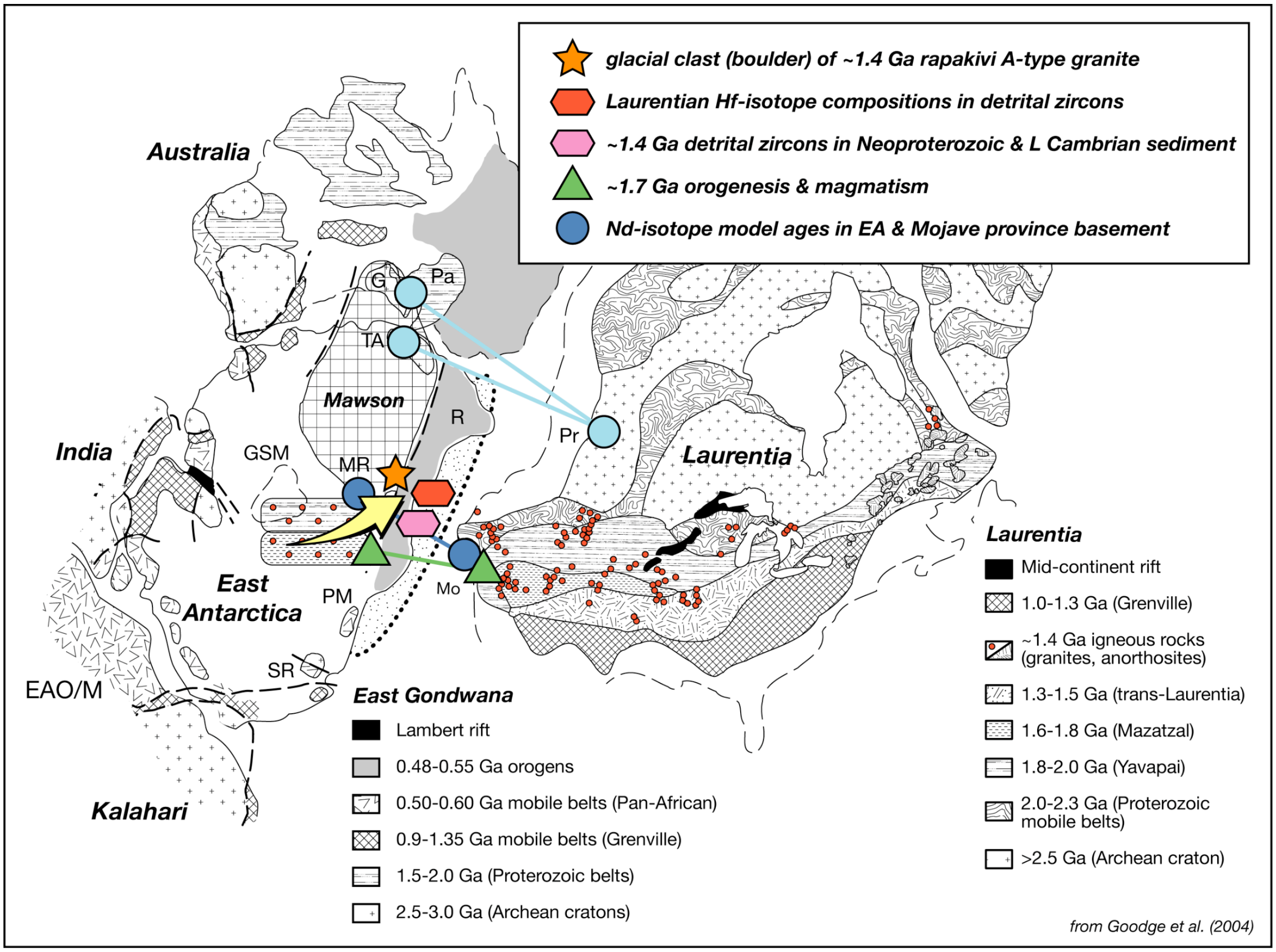

Figure 1. Paleogeographic reconstruction of central Rodinia (from Goodge et al., 2004), emphasizing postulated fit of East Antarctica-Australia and western Laurentia prior to rift separation, based on geologic, age and isotopic correlations discussed in text (shown by the colored symbols). Fit shown is consistent with a variety of geological (Ross et al., 1992; Borg & DePaolo, 1994; Barth et al., 2000; Goodge et al., 2001, 2002, 2004) and paleomagnetic data (Meert, 2003; Pisarevsky et al., 2007), although East Antarctica-Australia could be rotated or translated to permit a slightly different fit. Also shown are Neoproterozoic and Lower Cambrian craton-margin sedimentary units of Antarctica (stippled) and postulated extension of Proterozoic Laurentian crustal provinces into the East Antarctic shield (shown as patterned rectangles with round corners), including the ~1.4 Ga trans-Laurentian igneous province (small red circles). Sedimentary provenance connection between Pandurra Formation (Pa) and Prichard Formation (Pr), indicated by light blue symbols. GSM = Gamburtsev Subglacial Mountains; M = Mawson Province; Mo = Mojave Province; MR = Miller Range; PM = Pensacola Mountains; R = Ross Orogen; SR = Shackleton Range; TA = Terre Adélie.

New evidence for pieces of Laurentia in East Antarctica

Geochronological age similarities by themselves do not provide unique geotectonic correlations, because common rock-forming processes could occur at the same time in different places within different geotectonic settings. However, when coupled with unique isotopic tracers and distinctive rock types, such age correlations are firmer.

Detrital zircon Hf-isotope data

Locally-derived siliciclastic rift- and passive-margin sedimentary rocks of late Neoproterozoic and Early Cambrian age in the central Transantarctic Mountains contain significant proportions of ~1.4 Ga detrital zircon (up to 22%; Goodge et al., 2004). Geologic provinces of ~1.4 Ga age are uncommon globally, and the most significant potential source of sediment of this age is the widespread trans-Laurentian A-type igneous province (Anderson & Morrison, 2005; Goodge & Vervoort, 2006). Detritus of this age cannot have originated in Laurentia directly, as paleogeographic models indicate East Antarctica and Laurentia were separated prior to Early Cambrian time. Therefore, the persistent signature of ~1.4 Ga material in rift-margin sandstones from the central Transantarctic Mountains suggests that the primary source of this material is a Proterozoic geologic province within the central East Antarctic shield containing rocks of ~1.4 Ga age. The detrital-zircon age data from autochthonous passive-margin and platform units in the central Transantarctic Mountains therefore support a paleogeographic link between East Antarctic basement and crust of similar age in western Laurentia.

Further support for this provenance linkage between East Antarctica and Laurentia comes from Hf-isotope compositions of the ~1.4 Ga detrital zircons from Antarctica, which closely match distinctive isotopic compositions in the Laurentian granites (Goodge & Vervoort, 2006). New Hf-isotope measurements from detrital zircons of this age have initial eHf(*i*) values (-2 to +7) that closely match those from the Laurentian granites. The Hf-isotope data from these detrital zircons indicate that their igneous source formed by melting of crust that evolved from an initial mantle separation event between about 2.0-1.6 Ga. Crust of this type is not known from present rock exposures in Antarctica but is well represented in the Proterozoic orogenic provinces of southwestern Laurentia. These detrital-zircon age and isotopic data, therefore, together indicate that rift-margin sediment deposited on the paleo-Pacific margin of East Antarctica had a crustal provenance of similar age and isotopic character to that found in Laurentia. Such a crustal province may be an extension of Proterozoic belts in Laurentia, including the 1.4 Ga igneous rocks and their hosts in the Yavapai, Mazatzal and Mojave provinces, into central East Antarctica (Fig. 1). This interpretation is consistent with the occurrence of 1.8-1.6 Ga zircons in the detrital populations.

Glacial clasts of rapikivi A-type granite

In an ongoing study of glacial provenance, we recently collected large clasts and matrix material from Pleistocene tills in the central Transantarctic Mountains (Brecke & Goodge, 2007). Among the rock clasts are abundant granitoids of various compositions and textures, along with phyllites, schists, gneisses, sedimentary diamictites (Beacon) and dolerite (Ferrar). One of the granitoid clasts is a coarse-grained, red, porphyritic, rapakivi-type muscovite-biotite granite with a weak foliation and A-type geochemistry. This rock has high values of Zr, Y, Nb, Ce, and K_2O+Na_2O, similar to A-type within-plate granites, including the Mesoproterozoic Laurentian suite. The clast has a subangular shape and 24 cm diameter (large cobble or small boulder). It was collected from a till deposited at Turret Nunatak near the upper Nimrod Glacier (Fig. 1) and was glacially transported from the direction of the present-day polar ice cap. A new SHRIMP U-Pb zircon age of ~1440 Ma indicates that this rock is a Mesoproterozoic A-type granite. Zircons from this granite are prismatic and clear, with broad growth bands observable in cathodoluminescence and no visible inherited cores, which is consistent with an origin of Laurentian A-type granites from high-temperature Fe-rich melts (Anderson & Morrison, 2005). This clast represents the *first piece of rock in Antarctica with demonstrable ties to Laurentia*, and adds considerable strength to the geological, lithologic, geochemical, stratigraphic and correlations listed above.

Figure 1 summarizes the main geologic, age and isotopic links between East Antarctica and Laurentia in a modified SWEAT reconstruction of Rodinia. It highlights the similarities of various ages between the two cratonic domains, including similarities in crustal isotopic signature, basement igneous and metamorphic events, development of sedimentary successions, sedimentary provenance linked by age and isotopic character, and matching of modern glacial clasts to distinctive igneous provinces. In addition to these multiple correlations between central East Antarctica and southwestern Laurentia, this correlation is also consistent with detrital zircon evidence of a common source in the Gawler Craton of southern Australia for isotopically unique 1590 Ma volcanic detritus found in Mesoproterozoic sandstones of the Pandurra Formation (Australia) and the Prichard Formation (Laurentia) (Fanning & Link, 2003).

Summary

In summary, we suggest there is abundant geological evidence for a Rodinian connection between East Antarctica and Laurentia. These two areas share similar crustal, rift-margin, and sedimentary histories, and there are several lines of lithologic correlation strengthened by distinctive age and isotopic signatures. From these integrated geological, isotopic and geochronological datasets we can also infer that some significant part of the East Antarctic shield is comprised of Paleoproterozoic orogenic belts punctuated by geochemically and temporally distinctive 1.4 Ga A-type rapikivi granites. Although various other reconstructed geometries have been suggested, none appear as geologically compelling as our modified SWEAT model. The correlations presented here make specific predictions about the nature of lithosphere hidden beneath the East Antarctic ice sheet, which will be testable by future geophysical, geochemical and drilling projects.

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