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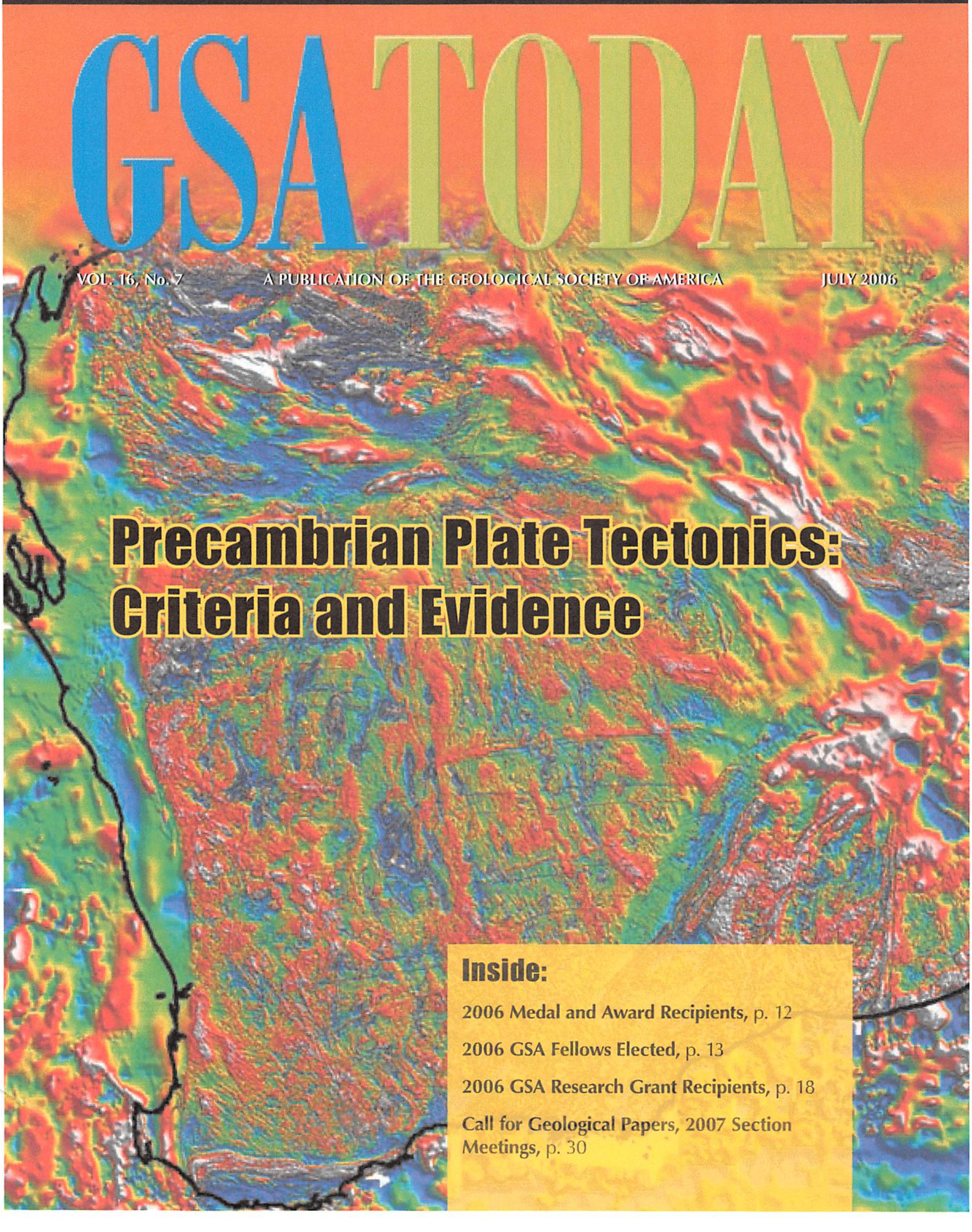

Precambrian Plate Tectonics: Criteria and Evidence

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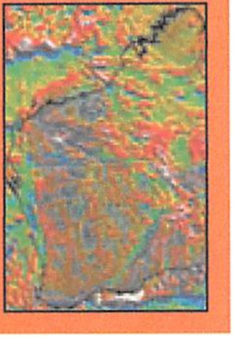

Cover: Magnetic anomaly map of part of Western Australia, showing crustal blocks of different age and distinct structural trends, juxtaposed against one another across major structural deformation zones. All of the features on this map are Precambrian in age and demonstrate that plate tectonics was in operation in the Precambrian. Image copyright the government of Western Australia. Compiled by Geoscience Australia, image processing by J. Watt, 2006, Geological Survey of Western Australia. See "Precambrian plate tectonics: Criteria and evidence" by Peter A. Cawood, Alfred Kröner, and Sergei Pisarevsky, p. 4–11.

SCIENCE ARTICLE

Precambrian plate tectonics: Criteria and evidence

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ABSTRACT

Paleomagnetic, geochemical, and tectonostratigraphic data establish that plate tectonics has been active since at least 3.1 Ga. Reliable paleomagnetic data demonstrate differential horizontal movements of continents in Paleoproterozoic and Archean times. Furthermore, the dispersal and assembly of supercontinents in the Proterozoic requires lateral motion of lithosphere at divergent and convergent plate boundaries. Well-preserved ophiolites associated with island-arc assemblages and modern-style accretion tectonics occur in the Paleoproterozoic Trans-Hudson orogen of the Canadian Shield, the Svecofennian orogen of the Baltic Shield and in the Mazatzal-Yavapai orogens of southwestern Laurentia. These rocks have trace element signatures almost identical to those found in rocks of modern intra-oceanic arcs and include ore deposits typical of modern subduction settings. The discovery of Archean eclogites in the eastern Baltic Shield; the presence of late Archean subduction-related Kuroko-type volcanogenic massive sulfide deposits in the Abitibi greenstone belt of the Canadian Shield; the discovery of mid-Archean island arc volcanics, including the oldest known boninites and adakites; and isotopic data from the world's oldest zircons all argue for modern-style subduction processes possibly back to the Hadean. Seismic images of preserved Paleoproterozoic and Archean suture zones further support this view. These data require a tectonic regime of lithospheric plates similar to the Phanerozoic Earth.

INTRODUCTION

Earth's surface is sculptured by plate tectonics and reflects the presence of a rigid surface layer, the lithosphere, which is broken into a series of plates that move horizontally with respect to each other. This motion is a response to heat loss and cooling within Earth's interior, and also occurs through episodic emplacement of mantle-derived magma in large igneous provinces. The relative contribution of, and control exerted by, these two mechanisms of heat loss may have varied through time perhaps in response to decreasing heat flow (e.g., Davies, 1999). Thus, how long plate tectonics has been Earth's modus operandi is debated (Eriksson et al., 2004). We outline criteria and evidence for the operation of plate tectonics in the Precambrian[1].

Arguments against plate tectonics generally invoke either the absence of specific features (e.g., ophiolites, ultrahigh-pressure rocks) or differences between modern and ancient rock associations (e.g., komatiites generally only found in the Archean) and structural styles, and cite temporal changes in Earth's heat flow as an underlying cause for these differences (e.g., Davies, 1999). Such comparisons ignore or minimize the significant similarities in data sets between modern and ancient rock sequences and, by inference, tectonic processes (Windley, 1995).

CRITERIA

Establishing evidence for or against the operation of plate tectonics requires a clear understanding of its distinctive and unique features, which are preserved within the rock record. We consider the most crucial feature to be the differential horizontal motion of plates, resulting in significant changes in their spatial relationship over time. Many geological features, such as rift zones, continental margin depositional environments, calc-alkaline volcanic-plutonic belts, lithospheric sutures, and orogenic belts follow from this plate motion process.

Differential plate motion gives rise to divergent, transform, and convergent plate boundaries. Divergent motion results in the development of rifts and passive margins on continental lithosphere and oceanic lithosphere at mid-oceanic-ridge spreading centers. Convergent motion through subduction leads to growth of continental lithosphere through the addition of magmatic arc systems (Fig. 1) and, ultimately, to collision between buoyant pieces of lithosphere. Orogenic belts initiated, formed, and deformed within a Wilson cycle tend to be linear, in contrast to tectonic elements formed through non–plate tectonic processes, such as large igneous provinces, which tend to be more equidimensional. However, not all features generated through plate motion are unique to this process. For example, lithospheric extension and dike emplacement could also occur in a mantle plume–dominated environment (Fig. 1). We suggest that paleomagnetic evidence for independent lateral motion of lithospheric blocks, geochemical data for magmatic arc activity and associated ore deposits related to subduction of oceanic-type lithosphere, seismic imaging of fossil subduction zones, and tectonostratigraphic associations indicating assembly of continental lithosphere along linear orogenic belts demonstrate that plate tectonics has been an active component of Earth processes possibly since the formation of the first continental crust at >4.3 Ga.

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[1] The Precambrian covers the period of Earth's history prior to 542 Ma and consists of the Hadean (pre-3.8 Ga), Archean (3.8–2.5 Ga), and Proterozoic (2.5–0.54 Ga).

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PALEOMAGNETIC EVIDENCE

Phanerozoic apparent polar wander paths are reasonably well established for major continental blocks, but this is not the case for the Precambrian due to a propensity for overprinting by younger processes. Despite a significant Precambrian paleomagnetic database (Pisarevsky, 2005), only a few Precambrian paleopoles can be considered reliable and well dated.

Nevertheless, several paleomagnetic results from Archean and Paleoproterozoic rocks, supported by field tests, suggest that the geomagnetic field has existed since at least 3.5 Ga (Merrill et al., 1998), and paleomagnetism is a valuable tool for ancient paleogeographic reconstructions. Additionally, recent paleointensity studies, estimates of secular variations of the Archean-Paleoproterozoic geodynamo (Smirnov and Tarduno, 2004), and magnetostratigraphy patterns in Paleoproterozoic sedimentary rocks (Pisarevsky and Sokolov, 2001) all indicate that the Archean and Paleoproterozoic geomagnetic field had characteristics similar to the present field.

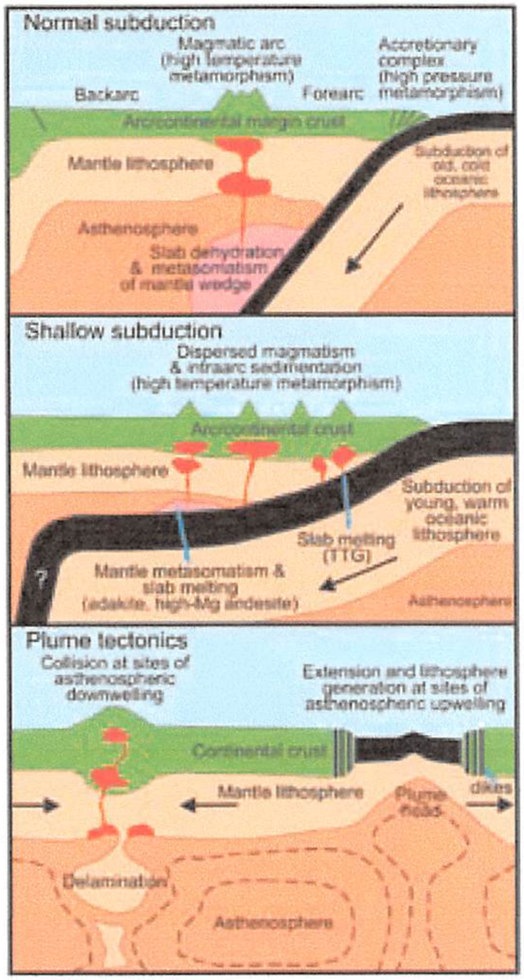

Figure 1. Precambrian tectonic regimes may have ranged from normal subduction similar to Phanerozoic Earth (top panel), to a modified form involving shallow subduction of thickened, more buoyant, oceanic lithosphere (middle panel), to a setting dominated by mantle plumes (bottom panel). On modern Earth, both plate- and plume-related mechanisms operate, and it is likely that a similar relationship existed on early Earth. In three dimensions, plate tectonic boundaries for linear belts are tied to, and influence, asthenospheric convection, whereas in plume settings, the lithosphere moves over generally fixed zones of asthenospheric upwelling.

Table DR1[2] contains selected paleopoles from the Archean Kaapvaal and Superior cratons and from the two Paleoproterozoic continents of Baltica and Australia, which were assembled in the late Paleoproterozoic. We selected only those poles that allow coeval comparisons of these blocks at two different time intervals (Fig. 2). Most of these poles were retrieved from stratified rocks, undeformed and layered igneous intrusions, or near-vertical dikes, so their paleohorizontals are interpreted as either barely changed or easily restorable. The primary nature of these results is supported by field tests, rock magnetic studies, and/or evidence such as bipolar magnetization especially with a magnetostratigraphy pattern. For each of the pole pairs shown in Figure 2, one continent is fixed and the two polarity options are shown for the alternate block. Longitude is unconstrained for both blocks, meaning that they could occur at any longitude at the prescribed latitude for that time interval. Even with these restrictions, Figure 2A demonstrates a significant difference between the relative paleopositions of Kaapvaal and Superior at 2680 and 2070 Ma, with both latitudinal displacement and azimuthal rotation occurring during this time interval. Figure 2B also suggests that displacements and rotations occurred between Baltica and Australia between 1770 and 1500 Ma. Both examples demonstrate that continents drifted independently, requiring the generation and consumption of lithosphere between these blocks on a constant-radius Earth. Importantly, in both examples, angular and latitudinal differences show minimal relative movements and maximum age range for movements between the two pairs of continents. Real movements were likely more complicated and occurred over shorter time frames. Other examples are given in Pesonen et al. (2003).

The development of several linear ca. 1.8 Ga and ca. 1.0 Ga collisional orogenic belts was instrumental in the formation of proposals for global late Paleoproterozoic and end Mesoproterozoic supercontinents (Zhao et al., 2002; Hoffman, 1991), but their exact configuration is disputed because of the paucity of reliable well-dated paleomagnetic poles.

EVIDENCE FOR PRE-NEOPROTEROZOIC SUBDUCTION, OPHIOLITES, AND SEAFLOOR SPREADING

The Paleoproterozoic Trans-Hudson orogen in Canada, the Svecofennian orogen in SW Finland, and the Mazatzal-Yavapai orogens in southwestern Laurentia provide excellent examples of modern-style subduction tectonics. The Trans-Hudson orogen contains an accretionary collage of distinct tectonostratigraphic terranes consisting of ocean floor, ocean plateau, and island-arc assemblages that record ongoing subduction and accretion at 1.92–1.84 Ga (Lucas et al., 1996). This history is corroborated by field observations, petrological, chemical, and isotopic data (e.g., Stern et al., 1995), as well as suture-zone

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[2] GSA Data Repository Item 2006141, Table DR1: Selected Archean and Proterozoic paleomagnetic poles, is available on the Web at www.geosociety.org/pubs/ft2006.htm. You can also obtain a copy of this item by writing to editing@geosociety.org.

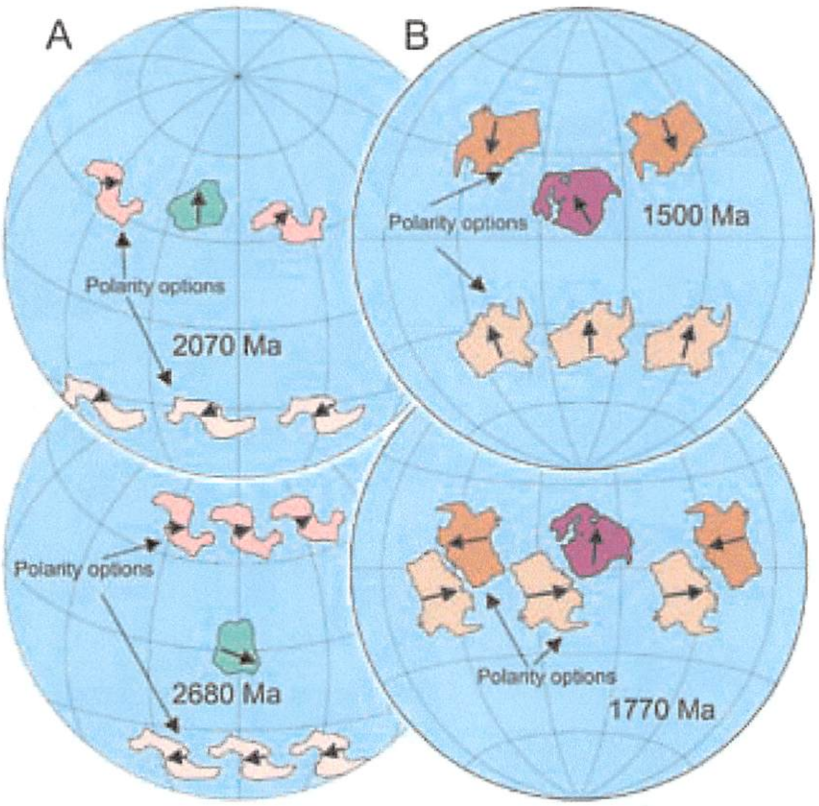

Figure 2. (A) Paleolatitudinally constrained positions for Kaapvaal (green) and Superior (pink) cratons at 2070 Ma and 2680 Ma, based on data in Table DR1 (see text footnote two). For each time interval, the position of the Kaapvaal craton is fixed, and the two polarity options are shown for Laurentia (light and dark pink). (B) Paleolatitudinally constrained positions for Baltica (purple) and Australia (orange) at 1500 Ma and 1770 Ma, based on data in Table DR1. For each time interval, the position of Baltica is fixed, and the two polarity options are shown for Australia (light and dark orange). Multiple copies of Superior and Australia for each option shown in (A) and (B) highlight latitudinal uncertainty in craton position. Lines of longitude and latitude are shown in 30° increments. Arrows indicate present-day north. Reconstructions prepared using utilities from the Visual Paleomagnetic Database (Pisarevsky and McElhinny, 2003).

geometry recording final collision with the Superior craton as revealed by seismic reflection profiling (White et al., 2002). Paleomagnetic data from the Trans-Hudson orogen were interpreted by Symons and Harris (2005) to suggest that the Archean Hearne and Superior cratons were separated by the ~5500-km-wide Manikewan ocean during ca. 1875–1855 Ma but that this ocean had closed by ca. 1815 Ma because of subduction beneath the Hearne craton and generation of a continental margin arc. The Trans-Hudson orogen also contains one of the best-preserved and most unequivocal Paleoproterozoic ophiolites, the Purtuniq complex (Scott et al., 1992). This shows that seafloor spreading and associated oceanic-crust formation was an established mechanism of plate tectonics by at least 2 Ga. The Svecofennian orogen in SW Finland is interpreted to involve opening of an ocean around 1.95 Ga and progressive accretion of arc complexes to the Karelian craton ca. 1.91–1.87 Ga, followed by extensional collapse (Nironen, 1997). Some of the accreting terranes probably had older cores that acted as crustal indentors during the collision; extensional collapse at a late stage, as seen in modern orogens, has also been inferred (Korja and Heikkinen, 2005). The belt contains a dismembered suite of mafic and ultramafic rocks, known as Jormua ophiolite, interpreted to represent a practically unbroken sample of seafloor from an ancient ocean-continent transition zone (Peltonen and Kontinen, 2004).

Between 1.8 and 1.2 Ga, a series of well-developed convergent margin accretionary orogens formed along the margin of a combined Laurentia and Baltica (e.g., Karlstrom et al., 2001). Geochemical and isotopic data from the accretionary Mazatzal and Yavapai provinces indicate that juvenile volcanic sequences formed in oceanic arcs or arcs built on only slightly older crust and include the 1.73 Ga Payson ophiolite, which is interpreted to have formed in an intra-arc basin (Dann, 1997).

The Trans-Hudson, Svecofennian, and Mazatzal-Yavapai orogens provide evidence for plate convergence lasting tens of millions of years and producing rock assemblages strikingly similar in rock type, structural evolution, and tectonic setting to modern plate boundary zones such as those in the southwest Pacific. Such similarities for these and other Precambrian orogens have been pointed out by many authors (see summaries in Windley, 1995; Condie, 2005). Ophiolites such as those at Purtuniq, Jormua, and Payson occur within this convergent plate margin framework, and we argue against the ideas of Stern (2005) that such ophiolites only record short-lived or aborted seafloor spreading, as well as those of Moores (2002) that ophiolites older than ca. 1 Ga are fundamentally different from those of younger times.

Ocean-crust subduction in the present plate tectonic regime ultimately produces high-pressure metamorphic assemblages (Fig. 1, top panel), including eclogites, and such rocks are now increasingly recognized in pre-Neoproterozoic terranes. Examples of Paleoproterozoic and inferred Archean eclogites derived from a mid-oceanic-ridge–type protolith and prescribed to oceanic lithosphere subduction have been described from Tanzania and Russia, respectively (Konilov et al., 2005; Möller et al., 1995; Volodichev et al., 2004). Exhumation rates of the Tanzanian examples are similar to Phanerozoic eclogite and blueschist terranes (Collins et al., 2004). M. Brown (2006, personal commun.) has pointed out that ultrahigh temperature granulite metamorphism occurs from the late Neoarchean to early Paleozoic and is inferred to have developed in settings analogous to modern backarc and arc settings. Complementary belts of medium-temperature eclogite–high-pressure granulite metamorphism span a similar time range and are related to subduction or collision zone metamorphism. The presence of these dual Precambrian high-pressure and high-temperature assemblages is similar to the metamorphic patterns of modern convergent plate settings.

There have been numerous attempts to link Archean granite-greenstone terranes to modern-style plate tectonic processes (e.g., Kerrich and Polat, 2006), and although unambiguous Archean ophiolites with sheeted dyke complexes have not been convincingly documented, the Superior Province of the Canadian Shield is arguably the best documented example for late Archean arc formation and accretion (Kerrich and Polat, 2006). The various components of this province were assembled progressively from north to south during discrete orogenic events. There is also seismic evidence for a late Archean subducted slab beneath part of the Abitibi belt (Fig. 3; Calvert et al., 1995).

Cook et al. (1999) seismically documented what can be interpreted as a frozen east-dipping subduction surface associated with magmatic arc development as a result of Paleoproterozoic plate convergence on the margin of the Slave craton in the northern Canadian Shield. Seismic data also reflect arc accretion in the Svecofennian orogen of Finland (Korja and Heikkinen, 2005).

Hamilton's (2003) view of greenstone belts representing anastomosing networks of upright synforms between large, diapiric, composite batholiths is not compatible with many field relationships, particularly those in West Greenland (e.g., Myers and Kröner, 1994; Friend and Nutman, 2005) and southern Africa (De Wit and Ashwal, 1997), which show significant horizontal shortening consistent with horizontal plate tectonic motion. A particularly well-documented example occurs in the Nuuk region of southwest Greenland and shows evidence for extensive late Archean thrust imbrication (Fig. 4). Both vertical and horizontal tectonic processes are likely to have operated in the Archean, and plate tectonic processes can also be assumed from linear structural patterns that extend for hundreds, if not thousands, of kilometers across some Archean cratons (Van Kranendonk, 2004).

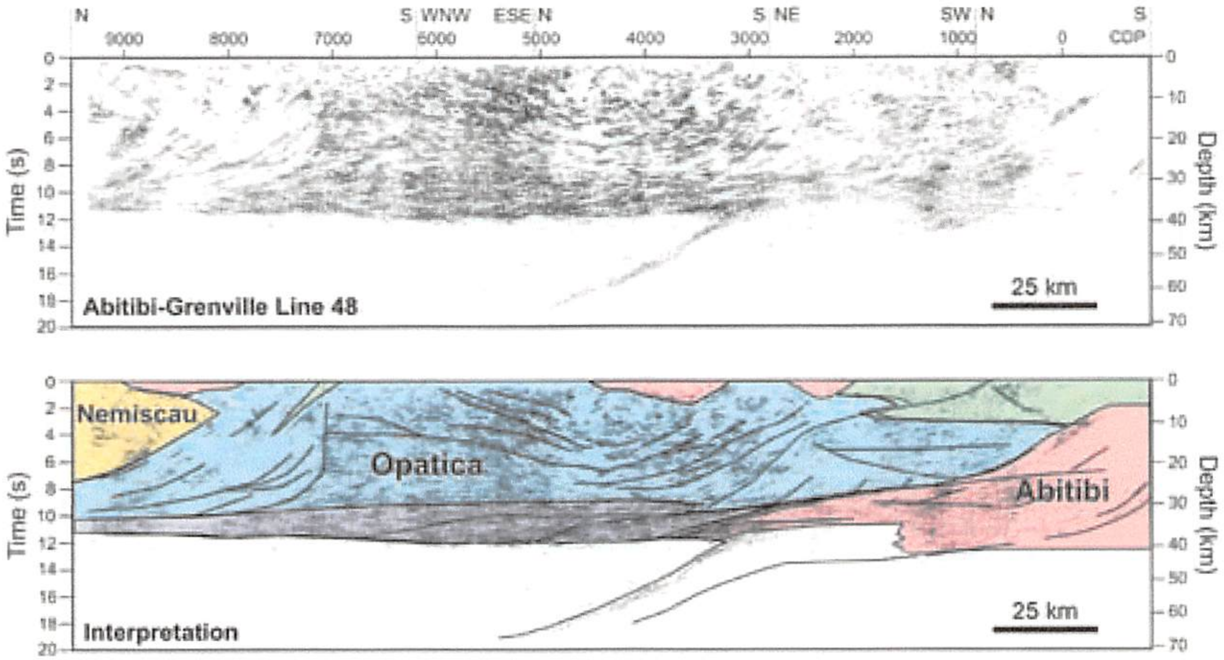

Figure 3. Top: Coherency filtered migrated stack of lithoprobe seismic reflection profile 48 displayed at true scale and extending from the northern Abitibi granite-greenstone subprovince across the largely plutonic Opatica belt and terminating in the metasedimentary Nemiscau subprovince, southeastern Superior Province, Canada. Depth is approximate, converted from two-way travel times with velocities of 6.5 km/s to 40 km and 8.0 km/s below 40 km. Numbers along top border are common depth point (CDP) locations along the line. Letters along top border show line directions for this crooked line profile. Bottom: Interpretation of the seismic section at true scale. The section shows the signature of a collision between a younger, oceanic arc terrane (the 2.76–2.72 low-grade Abitibi subprovince) and an older continental arc block (the ca. 2.83 Ga amphibolite-grade Opatica belt). The subduction zone across which the collision occurred is preserved as a fossil subducted oceanic slab. The features are identical to those expected from a modern collisional orogen. Unlabeled colors: green—greenstone belts; pink—plutons; blue—tonalitic gneiss and mid-lower crust of the Opatica belt; yellow—metasedimentary rocks of the Nemiscau subprovince. Lines indicate interpretation of major features between and within the major tectonic elements crossed. The dipping slab in white, bounded by lines, should be identified as a relict Archean oceanic slab. Modified from Calvert et al. (1995); image provided by Ron Clowes.

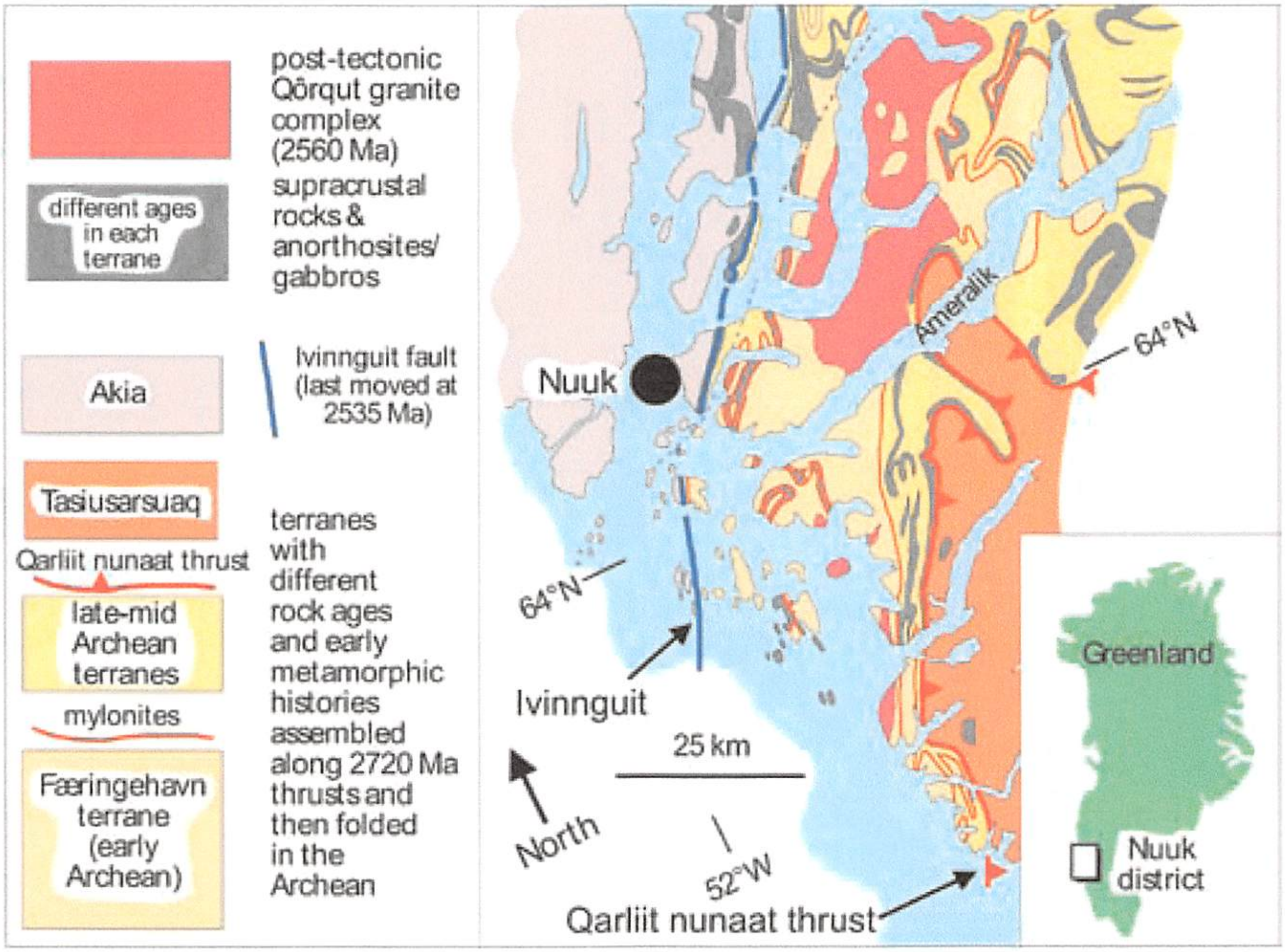

Figure 4. Map of the southern part of the Nuuk district of SW Greenland showing an extensive thrust stack formed at 2720 Ma, subsequently affected by isoclinal folding. Topmost to the SE is the Tasiusarsuaq terrane (2920–2800 Ma orthogneisses with 2800 Ma granulite facies metamorphism—restricted to that terrane), then the Tre Brødre terrane (yellow) with 2825 Ma orthogneisses, and no granulite facies, even though they are structurally overlain by a terrane with 2800 Ma granulite facies. Deepest is the Færingehavn terrane of early Archean rocks. The lower parts of this stack show polybaric 2720–2700 Ma metamorphism during exhumation. Dating of granite sheets intruded synkinematically along the bounding mylonites indicate juxtaposition ca. 2720 Ma. The Akia terrane to the west (3225–2970 Ma orthogneisses with 2970 Ma granulite facies) reached its final disposition as late as 2530 Ma via last movement on the Ivinnguit fault. Figure drafted and provided by Allen Nutman. Additional information available from Friend and Nutman (2005, and references therein).

GEOCHEMICAL EVIDENCE

Many Precambrian magmatic sequences show remarkable geochemical, petrological, and isotopic similarities to modern subduction environments (Condie, 2005), implying formation in an analogous setting. The paucity of well-developed forearc basin and subduction complex assemblages in association with some pre-Neoproterozoic magmatic arcs likely reflects their erosion and recycling through subduction erosion (D.W. Scholl and R. von Huene, 2006 personal commun.) rather than the absence of convergent plate margin processes. Indeed, given that subduction erosion may have operated through time, as proposed by these authors, the preservation of any Precambrian arc systems is remarkable.

A particularly well-documented example is the Paleoproterozoic Trans-Hudson orogen of the Canadian Shield, where subduction-related assemblages have trace element signatures almost identical to those found in rocks of modern intra-oceanic arcs (e.g., Stern et al., 1995). Boninitic rocks, similar to those occurring in modern forearc settings, were also reported from this orogen (Wyman, 1999), from the 3.12 Ga Whundo assemblage in the Pilbara (Smithies et al., 2005), and from the >3.7 Ga Isua greenstone belt (Polat and Kerrich, 2004). Other examples of subduction zone settings are the Svecofennian terranes of SW Finland and Sweden (Lahtinen and Huhma, 1997), the Paleoproterozoic Capricorn Orogen of Western Australia (Cawood and Tyler, 2004), the ca. 2.1 Ga Birimian oceanic plateau and arc terranes of West Africa (Abouchami et al., 1990), the 2.45–1.9 Ga Pechenga-Varzuga belt in the Kola Peninsula of Russia (Sharkov and Smolkin, 1997), and the 1.8–1.6 Ga Mazatzal and Yavapai provinces of the southwestern United States (Karlstrom et al., 2001).

Finally, chemical and oxygen isotope systematics in diamond-bearing eclogites from the mantle underneath the Archean Man and Guyana Shields suggest that subduction was operating at least since the Neoarchean because anomalously high oxygen isotope values are interpreted to reflect alteration on the ancient seafloor prior to subduction and deep tectonic burial (Schulze et al., 2003).

Undoubtedly, conditions in the early Earth differed from the Phanerozoic (e.g., Davies, 1999; Condie, 2005). For example, higher mantle temperatures probably led to great degrees of melting at mid-oceanic ridges, which, in turn, resulted in thicker oceanic crust of likely picritic composition and perhaps flatter-dipping subduction zones (Fig. 1; Foley et al., 2003; Smithies et al., 2003). However, numerous studies involving geochemical modeling have also emphasized the role that subduction of oceanic lithosphere played in magma generation and construction of continental lithosphere in the Archean (e.g., McCulloch and Bennett, 1994; Foley et al., 2003). Generation of tonalite and trondhjemite, the most widespread and oldest rocks in the Archean (Hamilton, 2003), requires melting of hydrated oceanic crust, and seafloor spreading and subduction are the most efficient mechanisms for this process (Kerrich and Polat, 2006). Furthermore, Kerrich and Polat (2006) summarized the occurrence of Cenozoic-type active margin associations in the Archean, including boninites, Mg-andesites, and adakites and concluded that arc-trench migration occurred at this time. Although heat flow is inferred to have been higher in the Archean, numerical modeling by van Thienen et al. (2005) shows that for a steadily (exponentially) cooling Earth, plate tectonics is capable of removing all the required heat at a rate similar to, or even lower than, the current rate of plate movement.

METAL DEPOSIT EVIDENCE

Ore deposits are a consequence of the tectonic setting in which they occur, and numerous examples have been described where pre-Neoproterozoic mineralizations resemble Phanerozoic deposits related to subduction environments (Kerrich et al., 2005). Examining global orogenic gold deposits, Goldfarb et al. (2001) observed that the important periods of Precambrian orogenic gold deposit formation, ca. 2.8–2.55 and 2.1–1.8 Ga, correlate well with episodes of growth of juvenile continental crust. Similar characteristics of the Precambrian orogenic gold ores to those of Phanerozoic age have led to the premise that Cordilleran-style plate tectonics were also ultimately responsible for these deposits (Kerrich et al., 2005).

Porphyry Cu deposits show one of the clearest relationships to subduction magmatism (Kerrich et al., 2005) and are found back to 3.3 Ga in age (Barley, 1982). Their metallogenetic, petrologic, and structural features seem to have changed little through time, suggesting that broadly similar tectonomagmatic processes were responsible for their formation (Seedorf et al., 2005).

Other deposits that have a well-defined tectonic and environmental signature reflecting a subduction setting are the 2.7 Ga volcanogenic massive sulfide (VMS) Cu-Zn deposits such as Kidd Creek and Noranda in the Abitibi belt in the Canadian Shield (Wyman et al., 1999a, 1999b) and the Paleoproterozoic VMS deposits in the Trans-Hudson orogen (Syme et al., 1999) and in the Svecofennian of Sweden (Allen et al., 1996). The oldest known subduction-related VMS deposit is probably the 3.46 Ga Big Stubby deposit in the Warrawoona Group of the Pilbara craton, Western Australia (Barley, 1992).

A synthesis of metallogenetic provinces of all ages led Kerrich et al. (2005) to conclude that plume intensity was more widespread and voluminous in the Archean than in later times, but that many ancient metal deposits have remarkable affinities to modern plate margin processes, suggesting that some form of plate tectonics has operated.

WHEN DID PLATE TECTONICS BEGIN?

The accretion of Earth ca. 4.55 Ga, its differentiation into core, mantle, and crust, and its consequent thermal history requires an evolving tectonic regime. Horizontal movement, a component of plate tectonics, becomes important at the surface following the formation of a stiff lithosphere. Although no record of Earth's lithosphere during its first 550 m.y. is preserved, Ti-thermometry and oxygen isotope data for the oldest known detrital zircons from Jack Hills, Western Australia, imply that a cool water–laden surface may have existed by ca. 4.4 Ga (Watson and Harrison, 2005). This suggests that a rigid lithosphere, a prerequisite for plate tectonics, also existed by this time. The isotopic systematics of these old Jack Hills zircons indicate formation in a continental environment characterized by calc-alkaline magmatism and crustal anatexis, features seen in modern Earth in convergent margin settings, implying that subduction may have been established by 4.4 Ga (Harrison et al., 2005). Contrary to Hamilton (2003), structural styles in the oldest tonalite-trondhjemite-granodiorite (TTG) gneiss assemblages resemble those in younger orogenic belts (Myers and Kröner, 1994; Windley, 1995; Nutman et al., 2002), and although there are Archean greenstone sequences resting on older TTG crust, the majority of greenstone-gneiss contacts is tectonic, and the oldest known greenstone sequences, in southwest Greenland, do not have a felsic basement (Appel et al., 2003). The scarcity or absence of ≥3.5 Ga detrital zircons in early Archean greenstone sediments suggests these rocks formed in juvenile accretionary environments (e.g., Nutman et al., 2004). The well-preserved 3.0 Ga Ivisaartoq greenstone belt in West Greenland is interpreted as one of the best documented examples of Archean forearc crust (Polat et al., 2006).

Condie (2005) argued that the major phases of juvenile continental crust generation at 2.7 and 1.8 Ga were mantle plume–related and thus overlapping with evidence for plate tectonic regimes, which likely existed since at least the Mesoarchean (Smithies et al., 2005; Barley, 1992) but perhaps back to the early Archean (Nutman et al., 2002; Polat and Kerrich, 2004), as supported by boninitic komatiites from the Barberton greenstone belt (Parman et al., 2003). This suggests a spatial and temporal variation in the switch from a plume to plate regime and is consistent with geodynamic modeling that implies a period of oscillation between the two modes before plate tectonics became dominant (Muhlhaus and Regenauer-Lieb, 2005).

CONCLUSIONS

Paleomagnetic, geological, geochemical, metamorphic, seismic reflection, and geochronological data from Archean and Paleoproterozoic rock units require relative lateral movement of lithosphere and the subduction of oceanic lithosphere to generate arc magmas, mineral deposits, and eclogites. These data, in our view, require a tectonic regime of lithospheric plates similar to the Phanerozoic Earth; any arguments against a plate tectonics scenario must provide viable alternative mechanisms for their generation.

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