Event stratigraphy applied to 700 million years of Archaean crustal evolution, Pilbara Craton, Western Australia

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Abstract

New geochronological and geochemical data from the pre-2.80 Ga granite–greenstone basement of the northern Pilbara Craton have been used to (a) erect a formal suite/supersuite stratigraphic scheme for its intrusive igneous rocks, and (b) revise the lithostratigraphy of its supracrustal succession. Previous divisions of the chiefly granitic intrusive rocks were informal, very generalized, and almost entirely based on intrusive and structural relationships. The three generations of granitic rocks recognized previously have now been replaced by eight supersuites and three suites. Four mafic intrusive suites have also been defined. Advances in the interpretation of the lithostratigraphy have come from a combination of detailed mapping and the acquisition of a large amount of precise geochronological data (chiefly from SHRIMP U–Pb zircon dating). Intrusive, volcanic, and mineralization events can be correlated with tectonic events, and major differences between the crustal evolution of the component terranes of the craton are recognized.

The pre-2.80 Ga basement in the northern Pilbara Craton evolved in four main phases: an early, largely cryptic phase of crust formation from 3.72 to 3.53 Ga; a major phase of crustal development from 3.52 to 3.24 Ga, involving construction of a volcanic plateau from a succession of mantle plumes; a period of rifting of the margins of the nucleus of the craton at c. 3.24 – 3.16 Ga; and a late phase of crustal growth involving horizontal (arc-accretion) tectonics from 3.13 to 2.90 Ga. Several distinct tectono-thermal events are recognized from 3.53 Ga onwards. These include: partial convective overturn of the middle and upper crust during mantle plume events at 3.43, 3.31, and 3.27 Ga; rifting of the Pilbara crust between 3.24 and 3.16 Ga to produce three separate granite–greenstone terranes; intra-oceanic arc construction at 3.12 Ga (Whundo Group); terrane accretion at c. 3.07 Ga; episodes of arc–continent collision between 3.02 and 2.90 Ga; and emplacement of post-tectonic granites at 2.89 – 2.83 Ga.

KEYWORDS: Archaean, Pilbara Craton, lithostratigraphy, suite, supersuite, event stratigraphy.

Introduction

This paper presents the latest lithostratigraphic scheme for Archaean granite–greenstone rocks of the northern Pilbara Craton, and the first suite/supersuite scheme for its intrusive igneous rocks. The new interpretation is based on information from geological mapping, geochronology (more than 200 precise SHRIMP U–Pb zircon age dates), and geochemical studies. These new data have been mainly acquired since 1995 during a joint Geological Survey of Western Australia (GSWA) – Geoscience Australia (GA) project, with additions from external researchers. All ages, except where specifically referenced, are from GSWA records published by D. R. Nelson, as cited in Van Kranendonk et al. (2002), and in Geological Survey of Western Australia (2004).

Geology of the Pilbara Craton

The Pilbara Craton comprises two major tectonic units: an assemblage of pre-2.80 Ga granite–greenstone terranes, and an unconformably overlying succession of volcanic and sedimentary rocks that were deposited in the 2.77 – 2.40 Ga Hamersley Basin (Trendall, 1990). About 65% of the granite–greenstone basement is concealed by the generally flat-lying Hamersley Basin succession; only in the northern part of the craton is this basement exposed over a very large area (Fig. 1). Here,

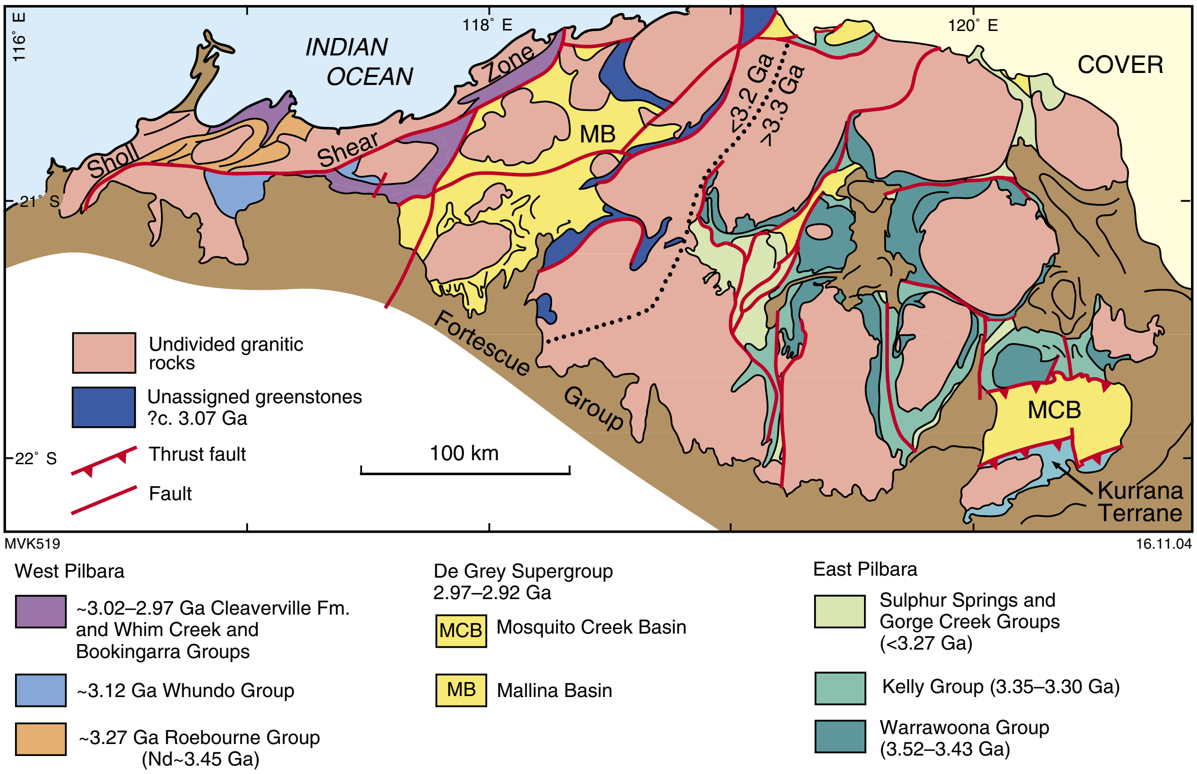

***Figure 1.** Generalized geology of the northern Pilbara Craton, showing main lithostratigraphic divisions of the West Pilbara and East Pilbara Granite–Greenstone Terranes and Kurrana Terrane, and the distribution of the De Grey Supergroup. Dotted line indicates a change in Nd-model age values within the east Pilbara (D. Champion, Geoscience Australia, 2004, written comm.)*

the craton contains three granite–greenstone terranes separated by younger clastic sedimentary basins (Hickman, 2001; Van Kranendonk et al., 2002.). The c. 3.27 – 2.92 Ga West Pilbara Granite–Greenstone Terrane (WPGGT) is separated from the c. 3.72 – 2.83 Ga East Pilbara Granite–Greenstone Terrane (EPGGT) by the c. 2.97 – 2.94 Ga Mallina Basin. Southeast of the EPGGT, the c. 2.95 – 2.92 Ga Mosquito Creek Basin is faulted against the dominantly granitic, and as yet poorly documented, Kurrana Terrane.

Previous models of Pilbara evolution

Hickman (1983, 1984) interpreted the granite–greenstone basement of the northern part of the Pilbara Craton as a single coherent crustal unit that had been deformed in episodes of vertical tectonics (D_1, D_2), and a late phase of horizontal deformation (D_3). Based on intrusive relationships and their structural history, Hickman (1983) recognized three main generations of granitic rocks, but further subdivision and detailed correlations between the various domical granitic complexes was prevented by a lack of precise radiometric age dating and geochemical data.

Tectonic models for the Pilbara Craton have evolved from the original concept of dominantly vertical tectonics (Hickman, 1983, 1984), to models of dominantly horizontal tectonics (Bickle et al., 1985; Krapez, 1993; Barley, 1993, 1997; Krapez and Eisenlohr, 1998; Smith et al., 1998), to more complex models involving intervals of both vertical-dominated (i.e. mantle-plume driven: Hickman and Van Kranendonk, 2004; Sandiford et al., 2004; Van Kranendonk et al., 2004a) and horizontal-dominated tectonics (e.g. Van Kranendonk et al., 2002; Hickman, 2004).

Van Kranendonk et al. (2002) described the EPGGT as the ancient nucleus of the craton, with a geological history from 3.72 to 2.83 Ga. The structural style of this terrane, dominated by ovoid granitoid complexes mantled by synclinal greenstone belts, has been attributed to several episodes of partial convective overturn of middle and upper crust (Collins et al., 1998; Hickman and Van Kranendonk, 2004; Sandiford et al., 2004; Van Kranendonk et al., 2004a).

Granitic rocks in the Pilbara Craton outcrop within large, domical areas that were referred to as ‘batholiths’ by Hickman (1983), although he emphasized that these structures were tectonically domed complexes containing granitic intrusions of widely differing ages. Griffin (1990) referred to these structural domes as ‘granitoid complexes’. Van Kranendonk (1998) described the domical granitic complexes as litho-tectonic elements that did not necessarily reflect the original distribution of multi-component granitic rocks prior to deformation, as shown in a subsequent compilation of age data (Van Kranendonk et al., 2002, fig. 5).

Stratigraphy

The lithostratigraphy of the Pilbara Craton has been divided into two supergroups and several unassigned groups and formations, as shown in Figure 2. The Pilbara Supergroup is developed in the EPGGT, where autochthonous relationships can be demonstrated through unconformable contacts and precise age dating. The WPGGT contains groups and formations that are not assigned to a supergroup, although the Roebourne Group is provisionally correlated with the Pilbara Supergroup for reasons described below. The De Grey Supergroup is correlated across the entire Pilbara Craton, as it lies with an unconformable basal contact on rocks of the EPGGT and WPGGT (Fig. 1).

Pilbara Supergroup

The Pilbara Supergroup in the EPGGT comprises four groups deposited between c. 3.52 Ga and c. 3.0 Ga. The oldest group is the Warrawoona Group, which spans 100 m.y. from 3.52 to 3.43 Ga. The group is herein defined as comprising four subgroups: the Coonterunah (previously Coonterunah Group), Talga Talga, Coongan (new name), and Salgash Subgroups (Fig. 2).

Previously, the uppermost part of the Warrawoona Group included the Strelley Pool Chert, Euro Basalt, Wyman Formation, and Charteris Basalt in the Kelly Subgroup (Van Kranendonk et al., 2002), but these formations are now collectively ascribed to the Kelly Group because the base of the Strelley Pool Chert is a regional unconformity (Van Kranendonk et al., 2002 and M. Van Kranendonk, unpublished data). The rocks of these two groups contain inherited and detrital zircons as old as 3.72 Ga (Van Kranendonk et al., 2002, fig. 4), and basaltic rocks show geochemical evidence for crustal contamination (Green et al., 2000; Van Kranendonk and Pirajno, 2004), indicating the presence of an older basement.

The c. 3.25 – 3.24 Ga Sulphur Springs Group was deposited unconformably on the Kelly Group (Van Kranendonk, 2000; Buick et al., 2002), and comprises, from base to top, the Leilira Formation, Kunagunarinna Formation, and Kangaroo Caves Formation (Van Kranendonk et al., 2002). The Six Mile Creek Formation of Van Kranendonk and Morant (1998), formerly included at the base of the group (Van Kranendonk, 2000), is now considered to belong to the Euro Basalt, based on similar geochemistry between these units and the fact that the unconformity marking the base of the group elsewhere is well defined as the base of the Leilira Formation (Van Kranendonk, 2000).

The Gorge Creek Group (Lipple, 1975; Hickman, 1983, 1990; Van Kranendonk and Morant, 1998) is herein redefined as consisting of, from base to top, the Tank Pool Quartzite, Nimingarra Iron Formation, Pincunah Hill Formation, Corboy Formation, Paddy Market Formation, Honeyeater Basalt, and Pyramid Hill Formation (Fig. 2). The age of the group is unconstrained other than the base of the formation, which is gradational with the Sulphur Springs Group at Sulphur Springs, indicating a lower age of c. 3.235 Ga (Buick et al., 2002). The basal contact of the group varies from conformable to unconformable on older rocks. The top contact of the group is an unconformity with either the De Grey Supergroup or Mount Bruce Supergroup (Hamersley Basin).

The Golden Cockatoo Formation in the southwestern part of the EPGGT consists of metamorphosed clastic sedimentary rocks and banded iron-formation (BIF) that lie in (probable) unconformable contact with basement rocks of the Yule Granitoid Complex and in faulted contact with the Sulphur Springs Group (Van Kranendonk, 2003). Unpublished geochronological data from a quartzite horizon near the base of the formation suggest a maximum depositional age of 3192 ± 74 Ma (Nelson, D. R., Geological Survey of Western Australia, 2004, written comm.), which is close to the age of the Flat Rocks Suite of granitoid rocks emplaced during an interpreted rifting event (see **Events in the northern Pilbara Craton**) and within the age range of the Gorge Creek Group (Fig. 2).

The Budjan Creek Formation in the southeastern part of the EPGGT is a succession of clastic and felsic volcaniclastic rocks that unconformably overlies the Kelly Group (Bagas et al., 2004b). A volcaniclastic sample of the formation contains detrital zircons as young as 3228 ± 6 Ma, which is slightly younger than the age of the youngest components of the Sulphur Springs Group (c. 3235 Ma; Buick et al., 2002).

The undated Copper Gorge Formation is also restricted to the southeastern part of the EPGGT (Bagas, in prep.). The formation consists of pillowed basalt and komatiitic basalt. It lies in unconformable contact with rocks of the Warrawoona and Kelly Groups to the north and is in fault contact with the younger De Grey Supergroup of the Mosquito Creek Basin to the south (Bagas, in prep.).

West Pilbara Granite–Greenstone Terrane

Supracrustal rocks in the WPGGT range in age from 3.27 to 3.01 Ga (Fig. 2). The WPGGT has a distinctly different structural style than the EPGGT, characterized by a prominent northeasterly structural grain (Fig. 1; Krapez, 1993; Hickman, 1997; Smith et al., 1998; Van Kranendonk et al., 2002; Hickman, 2004). This terrane is a collage of three separate, fault-bounded tectono-stratigraphic domains, each of which contains a unique stratigraphic succession and structural history that differs from that of EPGGT (Hickman, 2004), as well as two overlying sedimentary

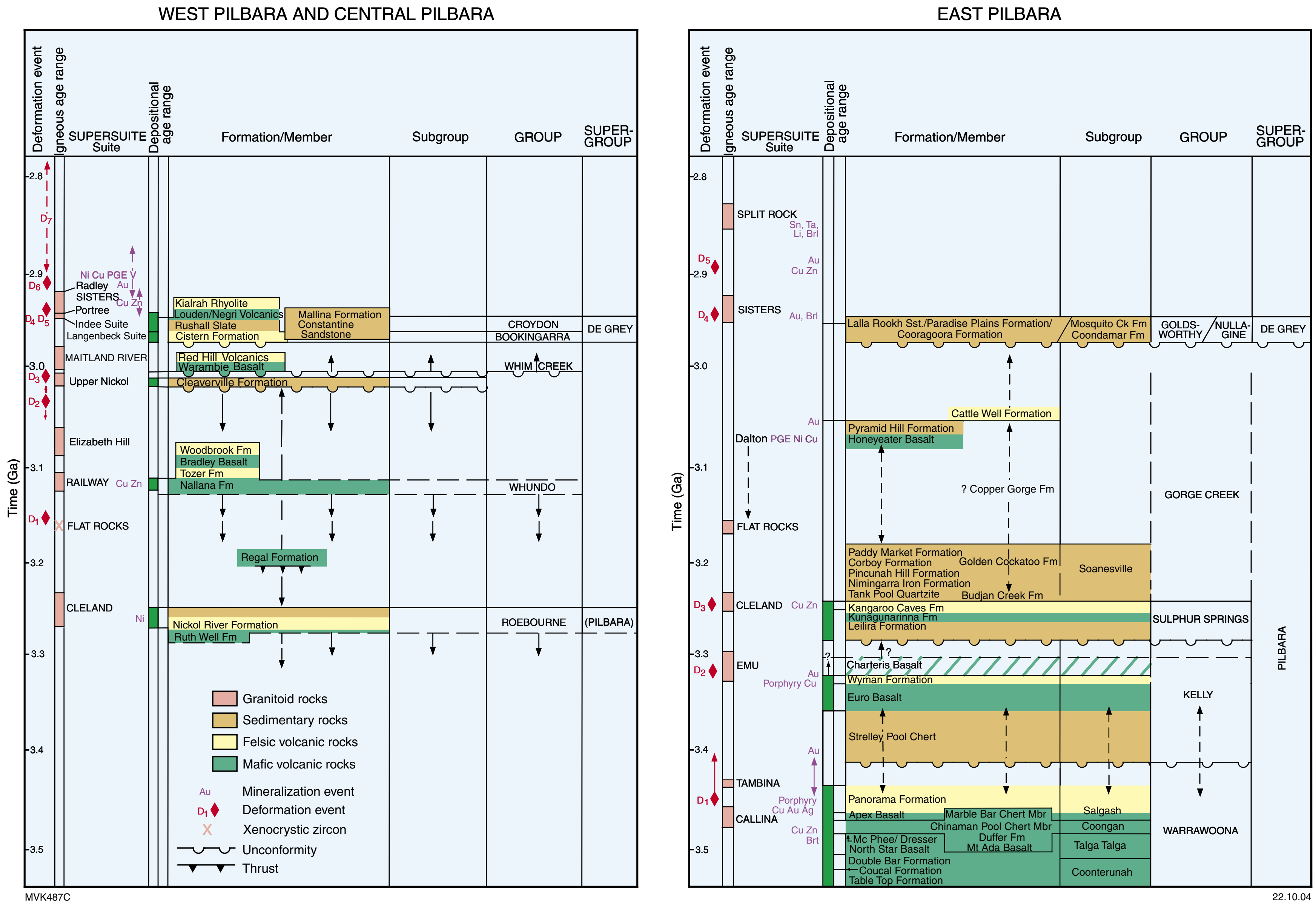

Figure 2. Event histories for the West Pilbara and East Pilbara Granite–Greenstone Terranes and central Pilbara, showing deformational events, igneous supersuites and suites, lithostratigraphic units, and mineralization events

basins, the Cleaverville and Whim Creek Basins. Designation of the Whim Creek Basin to the WPGGT is new, and based on geological data outlined below.

The main part of the terrane is transected by the 1 km-wide Sholl Shear Zone (SSZ) — a long-lived zone of early sinistral, and later dextral, transpressional shear strain (Hickman, 2004). North of the SSZ is the c. 3.28 – 3.25 Ga Roebourne Group, which is an ultramafic–felsic volcanic succession with overlying, subordinate clastic metasedimentary rocks. Isotopic data indicate that the group was deposited on c. 3.48 Ga crust, or was derived from a source region of this age (Sun and Hickman, 1998), but the basal contact of the group is obscured by intrusive 3.27 Ga tonalite and granodiorite, including the Karratha Granodiorite (K on Fig. 3).

South of the SSZ is the c. 3.13 – 3.11 Ga (Horwitz and Pidgeon, 1993; Smith et al., 1998) Whundo Group — a juvenile stratigraphic assemblage of bimodal basaltic and felsic volcanic rocks that shows no evidence of contamination by crust older than 3.28 Ga (Smith et al., 1998; Sun and Hickman, 1998) and that has no equivalent in the EPGGT succession. The Whundo Group (Fig. 2) is at least 10 km thick (Hickman, 1997), but neither the base nor the top is preserved. Hickman (1997) divided the group into four formations, based on lithostratigraphy. However, detailed geochemical analysis shows that the group consists of a much more complex volcanic succession, including a basal package of boninites that is interbedded with two distinct assemblages of calc-alkaline basalt to andesites (Smithies et al., in press). This package is overlain by a thick pile of tholeiitic basalts with arc to back-arc compositions. The tholeiites are in turn overlain by further calc-alkaline lavas with well-defined negative correlations between large ionic lithofile elements (and La/Sm) and high field strength elements (Smithies et al., in press). Calc-alkaline andesites are overlain by rhyolites, derived primarily through prolonged fractionation of tholeiitic magmas, and interbedded with adakitic lavas and Nb-enriched basalts — an association characteristic of arcs where slab melting contributes to metasomatism of the mantle wedge. This compellingly arc-like association, combined with the absence of felsic basement, the lack of any continental influence, the persistence of low Th/La ratios, and the faulted margin with a distinct terrane (Roebourne Group), points to an intra-oceanic arc setting for the Whundo Group.

The Roebourne Group is in tectonic contact across the Regal Thrust with the third domain, consisting of oceanic-type crust of the Regal Formation. Both the Roebourne Group and the Regal Formation include rocks at amphibolite facies metamorphic grade and were affected by D_1 deformation (Hickman, 2001; Kiyokawa et al., 2002).

Cleaverville Basin

The Regal Formation and the Whundo Group are unconformably overlain by BIF, chert, and clastic sedimentary rocks of the c. 3.02 Ga Cleaverville Formation, which is unaffected by D_1 deformation. The Cleaverville Formation lies both north and south of the SSZ, and thus provides a minimum age for the juxtaposition of the two domains and early sinistral shear deformation across the SSZ (Hickman, 1997, 2004; Kiyokawa et al., 2002). The Cleaverville Formation was previously correlated with the Gorge Creek Group of the EPGGT (Hickman, 1997), but new isotopic evidence for a c. 3.18 Ga crustal break in the western part of the EPGGT — an interpreted rift margin (see **Events in the northern Pilbara Craton**) — casts doubt on east–west correlations of any units deposited after this rifting event and prior to collision at c. 2.99 Ga. Thus the Cleaverville Formation is now interpreted to have been deposited in a separate basin, immediately preceding deposition of the Whim Creek Group.

Whim Creek Basin

The Whim Creek Group is a succession of a c. 3.01 Ga volcano-sedimentary rocks deposited unconformably on the Cleaverville Formation and the Whundo Group in the Whim Creek Basin (Fig. 2; Smithies et al., 2001). The Whim Creek Group represents an arc-related basin fill deposited on continental crust (Pike et al., 2002), and has no known counterparts in the EPGGT. These rocks are unconformably overlain by the volcanic Bookingarra Group and clastic sedimentary rocks of the De Grey Supergroup within the intracratonic Mallina Basin (see below).

Kurrana Terrane

The Kurrana Terrane, immediately south of the Mosquito Creek Basin, includes undated greenstones within granitoid orthogneiss dated at c. 3.18 Ga. These rocks are tightly folded and are faulted against the Mosquito Creek Basin. Only the northernmost exposures of the Kurrana Terrane are shown on Figure 1, and larger exposures of the same terrane are interpreted to be present 150 km to the south within the Sylvania Inlier (Hickman, 2004). The Sylvania Inlier was not remapped during the GSWA–GA project, and precise geochronological and geochemical data are very limited.

De Grey Supergroup

The c. 2.97 – 2.92 Ga De Grey Supergroup (redefined from the De Grey Group, as used by Van Kranendonk et al., 2002) is an intracontinental succession that was unconformably deposited on deformed and deeply eroded rocks of the Pilbara Supergroup and rocks of the WPGGT across the Pilbara Craton. Rocks of the supergroup are present in three major depositional basins, including the Lalla Rookh Basin in the EPGGT, the Mallina Basin between the EPGGT and the WPGGT, and the Mosquito Creek Basin that separates the EPGGT from the Kurrana Terrane (Fig. 1).

Lalla Rookh Basin

Eroded and deformed remnants of the supergroup in the EPGGT are referred to as the Goldsworthy Group (Van Kranendonk et al., 2002), and consist dominantly of

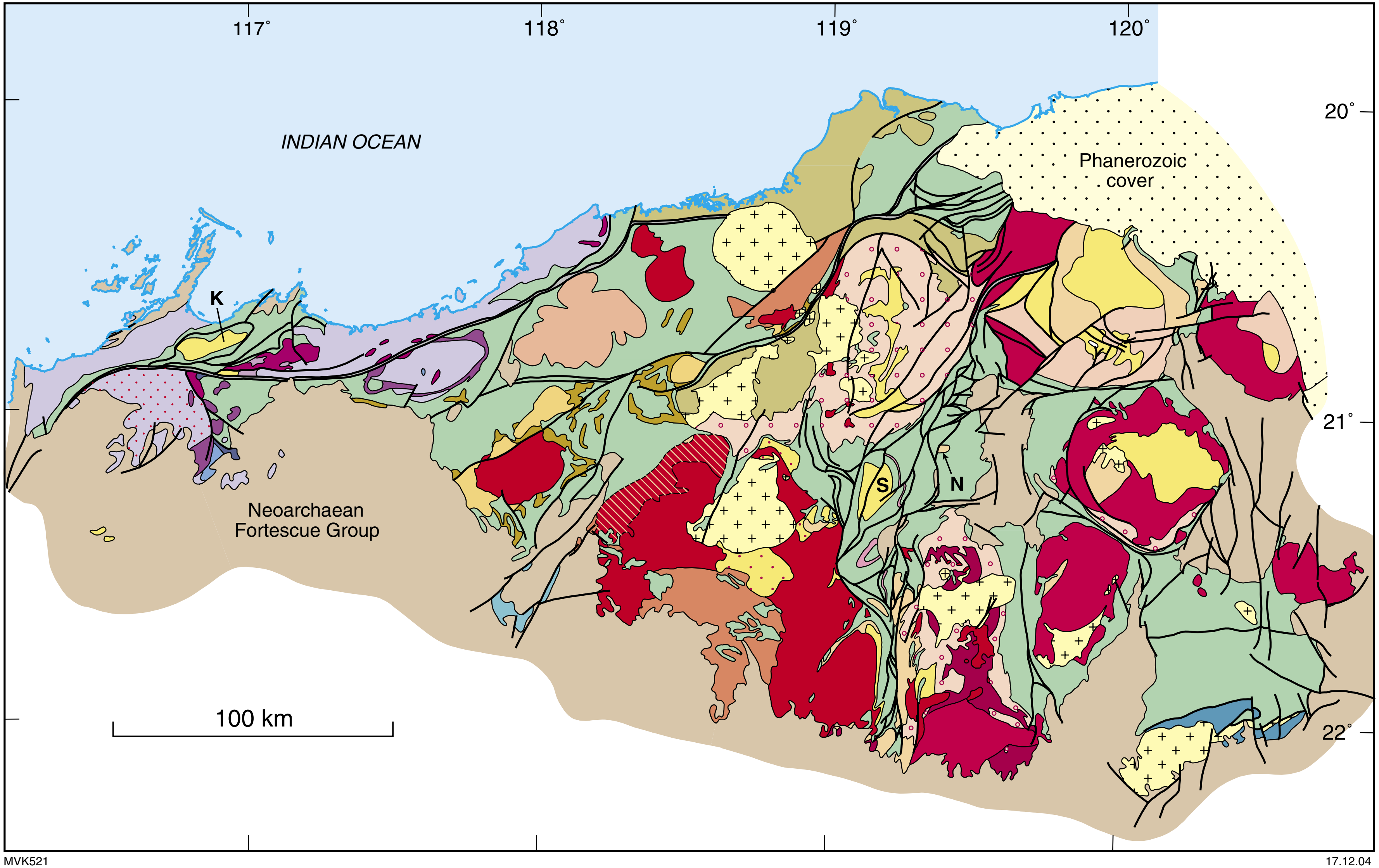

Figure 3. Simplified geological map showing the distribution of igneous suites and supersuites in the northern Pilbara Craton. N = North Pole Monzogranite, S = Strelley Monzogranite, K = Karratha Granodiorite

Phanerozoic cover

Neoarchaean Fortescue Group

Greenstones, undivided 3515–2940 Ma

SPLIT ROCK SUPERSUITE 2880–2830 Ma

SISTERS SUPERSUITE 2970–2925 Ma

Undivided

Radley Suite ultramafic layered intrusions 2925 Ma

monzogranite 2945–2930 Ma; with inclusions of TAMBINA SUPERSUITE

monzogranite 2955–2945 Ma

Portree Suite 2946 Ma (alkaline granite)

Indee Suite 2954–2945 Ma (high-Mg diorite)

Langenbeck Suite (intrusive equivalent of Bookingarra Group)

MAITLAND RIVER SUPERSUITE 3006–2970 Ma; with SISTERS SUPERSUITE

Upper Nickol Suite 3024–3012 Ma

ultramafic intrusions

Dalton Suite (?3070 Ma)

Elizabeth Hill Suite 3093–3068 Ma

RAILWAY SUPERSUITE 3130–3114 Ma

FLAT ROCKS SUPERSUITE 3170–3160 Ma

Golden Eagle Orthogneiss c. 3178 Ma

CLELAND SUPERSUITE 3270–3235 Ma

CLELAND SUPERSUITE and SISTERS SUPERSUITE

EMU SUPERSUITE 3324–3292 Ma

leucogranite 3445–3410 Ma

CALLINA and/or TAMBINA SUPERSUITES

TAMBINA SUPERSUITE 3435–3420 Ma

CALLINA SUPERSUITE 3490–3450 Ma

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coarse-grained clastic sedimentary rocks. It is uncertain to what degree these sequences originally formed parts of a single intracratonic basin. Van Kranendonk and Collins (1998) presented evidence from structural geology for deposition of the Lalla Rookh Sandstone of the group during regional sinistral transpression dated at c. 2.940 Ga, but otherwise the Goldsworthy Group is undated.

Mallina Basin

The north-northeasterly trending Mallina Basin is more than 200 km long and up to 90 km wide (Fig. 1) and consists of the c. 2.97 – 2.94 Ga Bookingarra and Croydon Groups. The basal c. 2.97 Ga Bookingarra Group consists of volcaniclastic sedimentary rocks, siliciclastic sedimentary rocks, and basalts that unconformably overlie the Whim Creek Basin of the WPGGT (Pike and Cas, 2002). The overlying Croydon Group consists of largely siliciclastic rocks of the Constantine Sandstone and the Mallina Formation, and is dated at c. 2.95 – 2.94 Ga (Smithies et al., 1999, 2001).

Mosquito Creek Basin

The Nullagine Group, comprising the 2.95 – 2.92 Ga Mosquito Creek and Coondamar Formations (Fig. 2), was deposited in the shallow- to deep-water Mosquito Creek Basin between the EPGGT and the Kurrana Terrane (Fig. 1), possibly in a rift setting analogous to that of the Mallina Basin (see below). The group lies with unconformable contact on the EPGGT (Kelly Group) and Copper Gorge Formation along the northern margin of the basin, but is in faulted contact with the Kurrana Terrane to the south. Bagas (2004a — this Annual Review) discusses the composition and provenance of the Mosquito Creek Basin.

Intrusive rocks

Granitic rocks of the Pilbara Craton are herein divided into supersuites and suites, based on crosscutting relationships and structural fabric elements, geochronology, and geochemistry (Fig. 3; Van Kranendonk et al., 2004b). A supersuite scheme has been introduced following isotopic confirmation that different domical granitic complexes in the EPGGT contain similar age plutonic components (Van Kranendonk et al., 2002; Hickman and Van Kranendonk, 2004). The granitic complexes of the WPGGT lack evidence for tectonic doming, but are also multi-component bodies containing intrusions of similar age and chemistry. In addition to the multi-component granitic complexes, both terranes contain examples of single-component, subvolcanic intrusions (e.g. 3.46 Ga North Pole Monzogranite and 3.24 Ga Strelley Monzogranite in the EPGGT, and 3.27 Ga Karratha Granodiorite in the WPGGT — N, S, and K respectively on Fig. 3). Significant results from the suite/supersuite classification scheme include the recognition that the 3.48 – 3.45 Ga Callina Supersuite, the 3.44 – 3.42 Ga Tambina Supersuite, and the 3.32 – 3.29 Ga Emu Supersuite are exposed only in the EPGGT. The 3.27 – 3.24 Cleland Supersuite is present in both the EPGGT and the WPGGT, north of the SSZ, further supporting continuity of the two terranes at c. 3.24 Ga.

Granitic rocks with intrusive ages of 3.18 – 3.16 Ga (Flat Rocks Supersuite and Golden Eagle Orthogneiss) are restricted to the margins of the EPGGT and in the Kurrana Terrane, and probably relate to early rifting of the margins of the EPGGT in the present areas of the Mallina and Mosquito Creek Basins respectively (see **Events in the northern Pilbara Craton**).

A widespread suite of granitic rocks emplaced in the WPGGT at c. 3.01 – 2.97 Ga (the Maitland River Supersuite) is probably cogenetic with arc volcanism of the Whim Creek Group (Pike and Cas, 2002; Hickman, 2004) and subsequent collision between the WPGGT and EPGGT (Fig. 4). Intrusive rocks within the Mallina Basin include a 2.95 Ga suite of high-Mg diorite (sanukitoid) intrusions (Smithies and Champion, 2000), now collectively referred to as the Indee Suite, and widespread c. 2.95 Ga mafic–ultramafic sills and rocks with boninite-like compositions (Smithies, 2002), now assigned to the Langenbeck Suite. Light rare earth element enrichments in the parent magmas of these intrusions cannot be explained through assimilation of crust, and have been attributed to a mantle source. Smithies and Champion (2000) suggested that the mantle source was metasomatically enriched during a pre-3.00 Ga subduction event; subduction processes have previously been applied to both the c. 3.01 Ga Whim Creek Group (Pike and Cas, 2002) and the c. 3.12 Ga Whundo Group (Smith, 2003). Both groups are interpreted to underlie parts of the Mallina Basin.

Late- to post-tectonic (2.89 – 2.83 Ga), Sn–Ta–Li bearing monzogranites of the Split Rock Supersuite form a northwest–southeast linear array of intrusions across the Kurrana Terrane and EPGGT (Fig. 3). These intrusions were emplaced immediately following north–south compressional deformation and gold mineralization in the Kurrana Terrane in the southeast at c. 2.90 Ga (Huston et al., 2002).

Events in the northern Pilbara Craton

The recent advances in subdivision of the supracrustal and intrusive igneous rocks across the northern Pilbara Craton has led to a much better understanding of the event history of the craton, as summarized in Figures 2 and 4. Events prior to 3.27 Ga are restricted to the EPGGT.

Following an early, largely unpreserved history from 3.72 to 3.53 Ga, the main phase of crustal construction in the EPGGT began at 3.52 Ga with the development of a thick volcanic plateau (Warrawoona Group), founded on crust to 3.72 Ga (Van Kranendonk et al., 2002; Van Kranendonk and Pirajno, 2004). Volcanic plateau formation was the result of nearly 100 m.y. of nearly continuous, dominantly basaltic volcanism that was erupted in mafic–felsic cycles of about 15 m.y. duration (Hickman and Van Kranendonk, 2004). Within this history, felsic volcanism at 3.47 – 3.46 Ga was

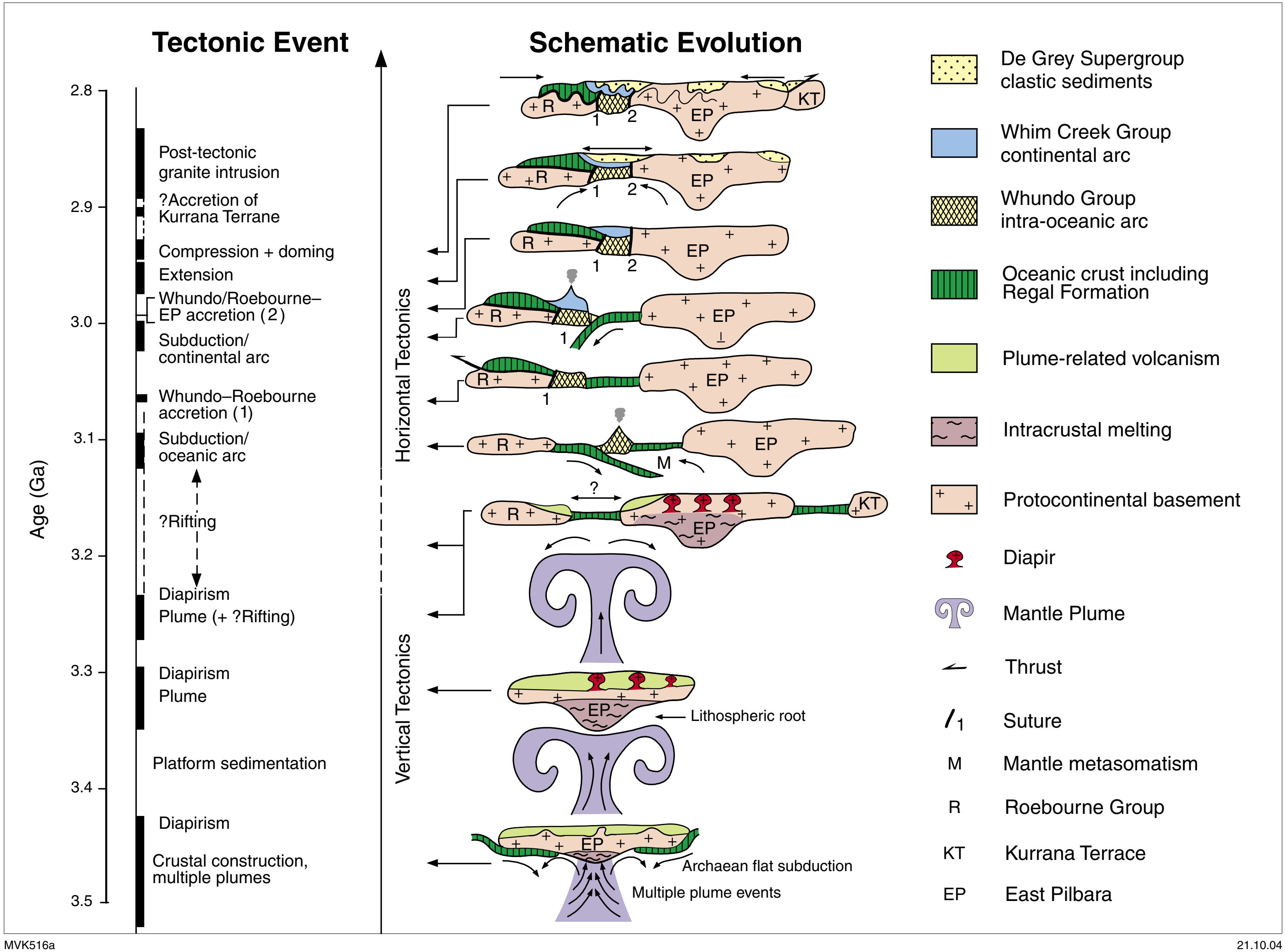

Figure 4. Schematic event history for the northern Pilbara Craton between 3.5 and 2.8 Ga

accompanied by the intrusion of Callina Supersuite tonalite–trondhjemite–granodiorite (TTG) magmas as a sheeted sill complex to produce local crustal thickening and instigate the development of volcanic domes. Magmas were derived through melting of basalt, possibly during flat subduction around the margins of the developing plateau (Fig. 4; Smithies et al., 2003). The final stages of plateau construction at 3.46 – 3.43 Ga involved early stages of doming of some of the granitoid complexes, high-pressure melting of mafic crust (Cullers et al., 1993), and resultant felsic magmatism including intrusive rocks of the 3.44 to 3.42 Ga Tambina Supersuite (TTG) and rhyolites of the Panorama Formation. This felsic magmatism was followed by regional subaerial erosion (Buick et al., 1995) over a 75 m.y. period, in the absence of volcanism (Fig. 4). Quartz sandstone and stromatolitic carbonates of the Strelley Pool Chert were deposited on a regional unconformity as Earth's oldest continental-shelf sequence at this time (Lowe, 1983; Buick et al., 1995; Van Kranendonk et al., 2002).

Volcanism recommenced at c. 3.35 Ga and continued to 3.31 Ga with eruption of the Kelly Group, which is a sequence, more than 8 km thick, of basal olivine-spinifex-textured komatiite, middle tholeiitic and komatiitic basalt, and upper K-rich rhyolite. The components of this succession are typical products of a mantle plume erupted through pre-existing continental crust. Widespread melting of pre-existing granitic rocks and the generation of the voluminous Emu Supersuite accompanied the end of Kelly Group volcanism at 3.32 – 3.29 Ga, and accompanied major doming at c. 3.31 Ga (Collins et al., 1998; Van Kranendonk et al., 2004a).

The third major event in the Pilbara commenced at c. 3.27 Ga with deposition of the Sulphur Springs Group above a regional unconformity. As with the Kelly Group, the Sulphur Springs Group consists of a komatiite–basalt–rhyolitic succession that is interpreted to represent the product of a mantle plume erupted through, and contaminated by, continental crust. Heat from this event caused widespread melting of pre-existing granitic rocks, generation of the 3.27 to 3.24 Ga Cleland Supersuite, and local high-amplitude doming of granitic complexes. Volcanogenic massive sulfide deposits were also developed at this time (Morant, 1998).

Rifting may have commenced at this time (Vearncombe et al., 1998; Hickman, 2004), and by c. 3.16 Ga had probably evolved to produce northwest–southeast separation of the older part of the WPGGT (Roebourne Group) and possibly the Kurrana Terrane. Evidence for this event comes from a distinct supracrustal succession; and the Flat Rocks Supersuite in the southwestern part of the EPGGT: and Nd-isotope data that show a distinct change in Nd-model ages obtained from dominantly 2.9 – 2.8 Ga granites down the middle of the Yule and Carlindie Granitoid Complexes of the EPGGT (Fig. 1). The data indicate that granitoid rocks to the west of this line were generated from crust younger than 3.2 Ga, as opposed to granitoid rocks to the east that have model ages generally in the range 3.4 – 3.7 Ga, with a few that have slightly younger ages to c. 3.3 Ga (Champion, D., Geoscience Australia, 2004, written comm.). The data also imply that greenstones of the Pilbara Well and Wodgina greenstone belts may not be part of the Pilbara Supergroup, and thus they have been left as unassigned on Figure 1 until more information is obtained from these rocks.

Isotopic evidence indicates involvement of a c. 3.5 to 3.4 Ga crust in the evolution of the 3.28 to 3.25 Ga Roebourne Group and the Karratha Granodiorite of the WPGGT north of the SSZ (Sun and Hickman, 1998). On this basis, and because of similarities in the broad stratigraphy and age of eruption, the Roebourne Group and the Karratha Granodiorite of the WPGGT have been interpreted to be a rifted segment of the Sulphur Springs Group and Cleland Supersuite of the EPGGT (Hickman, 2004).

From 3.24 Ga, the WPGGT evolved in isolation from the EPGGT, and underwent a different geological history (Smith et al., 1998; Van Kranendonk et al., 2002; Hickman, 2004). At c. 3.13 Ga, the Whundo Group was erupted as an intra-oceanic arc (Smithies et al., in press). This exotic terrane was subsequently juxtaposed with the Roebourne Group and Karratha Granodiorite along the SSZ probably at c. 3.07 Ga, prior to deposition of the Cleaverville Formation. The continental-arc volcanism of the c. 3.01 Ga Whim Creek Group marks a period of subduction preceding oblique collision between the WPGGT and the EPGGT (Fig. 4). Smith et al. (1998) proposed subduction from the west during arc accretion, but an alternative possibility is closure of the ocean between Roebourne/Whundo amalgam and the EPGGT through west-dipping subduction. Collision between the WPGGT and the EPGGT is interpreted to have occurred at c. 2.99 Ga, which is the age of widespread granitoid rocks in the WPGGT (Maitland River Supersuite) and abundant detrital zircons in the Mallina Basin (Smithies et al., 2001). Subsequent phases of extension and compression from 2.97 to 2.94 Ga were accompanied by deposition of the clastic rocks of the De Grey Supergroup in the Mallina Basin, and intrusion of the geochemically varied rocks of the Sisters Supersuite across the central Pilbara and western parts of the EPGGT. This series of events was accompanied by diverse mineralization, including platinum-group elements and gold.

Compressional deformation continued to c. 2.90 Ga along both the northwestern and southeastern margins of the EPGGT. During this period the Kurrana Terrane was tectonically juxtaposed against the Mosquito Creek Basin flanking the southeastern margin of the EPGGT. Isoclinal folding and thrusting within the basin was accompanied by epigenetic gold mineralization, and was followed by the emplacement of post-tectonic, highly fractionated, Sn–Ta–Li bearing granites of the 2.89 to 2.83 Ga Split Rock Supersuite. The linear northwest–southeast trend of these intrusions suggest emplacement within a failed rift in the foreland to compressional orogeny across the Mosquito Creek Basin.

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