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Tectonic evolution of the Eastern Pilbara, Australia (extended abstract)

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The Archean granite greenstone terrains of the Pilbara craton, with a structural pattern of ovoid granitoids and skirting supracrustal sequences (Figure 1), invites the interpretation that vertical tectonics have dominated its development. This has found expression in the view that solid-state diapirism is the principal cause of the development of such a structural pattern (Hickman 1981, 1983, 1984; Collins 1989; Collins & Teyssier 1990; Williams & Collins 1990). Closely allied to this interpretation is the view that the supracrustal stratigraphic sequence is not significantly disrupted (Hickman 1981, 1983). However, there are opposing views. Bickle et al. (1980, 1985) and Boulter et al. (1987) concluded that horizontal tectonics, in the form of thrusting and associated strike-slip activity, were more important than solid-state diapirism in the tectonic evolution of the Eastern Pilbara. Krapez (1993) noted structural repetition in the supracrustal sequences and concluded that tectonic interleaving was common, especially along bedding-plane and strike-parallel shears. He concluded that the supracrustals formed a lithotectonic complex.

The results reported in this contribution are based on structural and kinematic studies undertaken by the senior author and a number of Ph.D., masters and undergraduate students from Utrecht University, in conjunction with geochronological studies by J. Wijbrans and masters and students from the Vrije Universiteit Amsterdam, in the period 1992 to 1996. The work was supported by the Schürmann Foundation. Our results support the view of Krapez (1993) that supracrustals of the Eastern Pilbara form lithotectonic complexes assembled or accreted during two periods of collisional tectonics with a possible earlier, third event. These periods of collisional tectonics are interposed, and perhaps finally superceded, by phases of extensional and strike-slip tectonic activity during which granitoid emplacement occurred.

What may be the earliest collisional event is preserved in the Coonterunah Succession (Figure 1), consisting chiefly of folded bimodal volcanics, in which folded banded ferruginous cherts with the characteristics of banded iron mylonites occur. If these cherts do mark folded shears, then an early phase of shearing and of folding must have occurred between the deposition of the volcanics (3515 ± 2.7 Ma, Buick et al. 1995) and the deposition of the unconformably overlying Warrawoona Group.

The first widely recognised event in the Eastern Pilbara is an approximately E-W extension (Zegers 1996, Zegers et al. 1996; Van Haaften & White 1998) during the deposition of the Duffer Fm (chiefly felsic volcanics) at 3470–3450 Ma (Zegers 1996). This extension led to core-complex development and the intrusion of the early granitoid suite (N. Shaw Suite), and has associated with it mafic as well as felsic volcanism and clastic and carbonate sedimentation. It was followed by a prolonged phase of folding and thrusting in the period ranging, at least, from 3398 Ma to 3222 Ma. The former age is given by the thermal imprint of a granite intruding isoclinally folded Warrawoona Group rocks in the Coongan Greenstone Belt (Davids et al. 1997) and the latter by post-tectonic amphiboles overprinting the main shear within the Coongan Belt (Zegers 1996). The resultant structures are exemplified by the Coongan Belt where tectonic slices of the above isoclinally folded supracrustals were transported over relatively undeformed slices containing the Wayman Fm, dated elsewhere at 3329 Ma (McNaughton et al. 1993). In turn, they are allochthonous to slices containing well-preserved growth faults from the earlier phase (3470–3450 Ma) of extension. These last slices are in the hanging wall of a major detachment formed during the above extension, and which most likely formed the sole to the thrust pile that constitutes the Coongan Belt.

During the thrusting there is kinematic evidence that some of the N-S trending shears steepened and

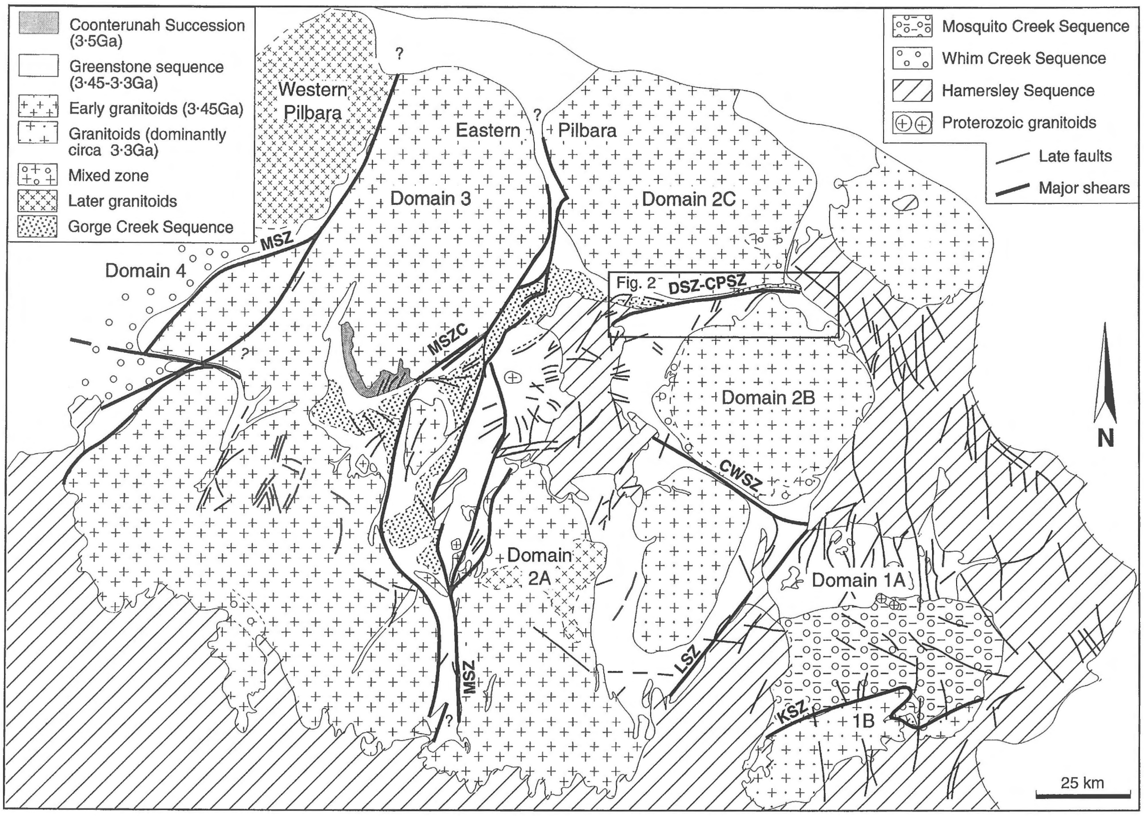

Figure 1. Sketch map showing the main geological elements of the Eastern Pilbara. Standard stratigraphic sub-divisions have been used. Major shears are indicated. MSZ – Mallina Shear Zone, MSZC – Mulgandinnah Shear Zone Complex, LSZ – Lionel Shear Zone, DSZ-CPSZ – Doolena-Coppin Cap Shear Zones, CWSZ – Central Warrawoona Shear Zone, KSZ – Kurrana Shear Zone. They divide the Eastern Pilbara into three domains: 1. Nullagine, 2. Marble Bar, 3. Pilgangoora. The Nullagine and Marble Bar Domains are subdivided into subdomains.

underwent transcurrent and transtensional movements resulting in localized escape and probably a second phase of core-complex development. This led to the emplacement of part of the circa 3300 Ma granitoid suite along with felsic and mafic volcanism (Wayman Fm) and clastic sedimentation (part of the Gorge Creek Group). The involvement of the Wayman Fm with the thrusting indicates that a phase of the escape and core-complex formation occurred within the overall thrust event and the products became involved in the event. In such a scenario, the above sediments and volcanics became incorporated into the thrust pile along with those clastic sediments deposited in front of or behind the emerging thrust sheets. All have been incorporated, stratigraphically, into the Gorge Creek Group. There is a later phase of localized post-tectonic granitoid emplacement associated with this event. An alternative scenario is that there were two separate thrust events separated, and perhaps finally followed by phases of core complex formation during the period 3.4 Ga to 3.2 Ga. Irrespective of either scenario, at the end of this period, the Eastern Pilbara was subdivided by major N-S to NE-SW shears into three domains, the Nullagine, Marble Bar and Pilgangoora (Figure 1; see also Krapez & Barley 1987).

The second main phase of thrusting (circa 3000–2900 Ma) post-dated the above and involved the approximately NNW to SSE transport of allochthonous tectonic slices of dominantly metasedimentary rocks, also regarded as belonging to the Gorge Creek Group, over tectonic slices accreted in the above event (Figure 2). The autochthon responded to this by conjugate strike-slip shearing (Figure 2). It is not certain when the slices within the allochthon were assembled. The later stages, circa 2930 Ma (Zegers 1996; Zegers et al. 1996), of this event were accompanied by a phase of transcurrent transfer-shearing which reactivated some of the N-S trending shears in the underlying

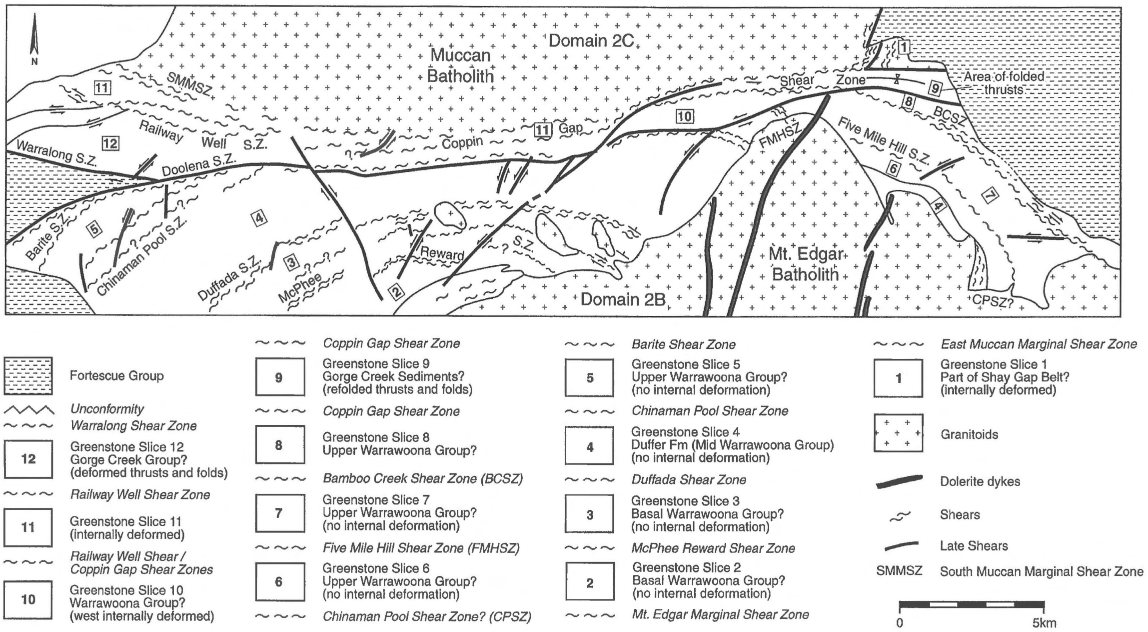

Figure 2. Shear-zone-bounded lithological Slices 1–12 in the supracrustal rocks between the Mt Edgar and Muccan Batholiths. The shears separating the slices are indicated. Age constraints are minimal. Only the age of the Duffer Fm is known for this area (McNaughton et al. 1993). The relative statigraphic ages of all other rock units are related to the Duffer Fm as if the regional sequence was tectonically undisturbed. These supposed ages are indicated with a question mark, as it is possible that inaccuracies exist. The relative amount of internal deformation within each slice is also indicated. Traditional stratigraphic assignments are indicated and questioned.

autochthon, and which may have been accompanied by strike-slip-related sedimentation represented by the Lalla Rookh sediments (Krapez 1993). This phase of reactivation is especially well seen in the Mulgandinnah Shear Complex (Zegers 1996; Zegers et al. 1998; Van Kranendonk & Collins 1998). In addition, some strike-slip activity on the E-W trending shears may have had an escape function, associated with thinning of the 3.0 Ga orogen and the emplacement of the late granitoids (see also Krapez 1993).

Some of the above shears may have formed terrane boundaries (see also Tyler et al. 1992). The chief of these is the Mallina Shear which formed the terrane boundary between the Eastern and Western Pilbara. That is, accretion of the Eastern and Western Pilbara occurred at this time, circa 30 GA (see also Smith et al. 1998). It is not clear if other major shears are terrane boundaries. The structural trends within the Nullagine Domain differ markedly from these in the adjacent southern Marble Bar Domain, but are similar to those in the northern Marble Bar Domain (discussed below); this indicates that the Lionel Shear may have been another terrane boundary. However, the kinematics of this shear would better fit the earlier accretionary event. But there are insufficient geochronological data and no firm conclusion can be reached about the Lionel Shear and, for that matter, about any other of the domain boundary shears apart from the Mallina Shear.

An example of the nett result of the two main accretionary events in the Eastern Pilbara is seen in the Marble Bar Greenstone Belt between the Mt Edgar and Muccan Batholiths, and is illustrated in Figure 2. Twelve, shear-bounded, lithological slices are recognised. They are mainly bordered by strike-parallel shears. Slice 1 has the characteristics of the Shay Gap Belt including Gorge Creek type sediments unconformably overlying the eastern sheared marginal zone to the Muccan Batholith. Slices 2 to 8 show little internal deformation and form a major domal or culmination structure (Talga Talga Antiform) initially formed during the first, namely the E-W, accretionary event but with evidence for earlier extensional movements on some of the shears (Van Haaften & White 1998). Some shears also underwent later reactivation (Van Haaften & White 1998) as a result of tectonic escape and localized extension that led to the emplacement of the adjacent plutons within the Mt Edgar Batholith at circa 3.3 Ga (Williams & Collins 1990). These shear-bounded slices were subsequently over-ridden by Slices 9 to 12, which are characterized by metasediments and which are deformed internally, and possibly by Slice 1, containing the Muccan Batholith, during the second accretionary event. The juxtaposition of slices of two different events divides the Marble Bar Domain into at least two subdomains, each of which is further subdivided into a number of tectonic slices. A third subdomain may occur across the Central Warrawoona Shear (Figure 1). The E-W trending shears, especially the Doolena Shear Zone, steepened and underwent late transcurrent movements, some of which postdate the deposition of the Hamersley Basin infill.

Figure 2 reinforces the view first expressed by Krapez (1993) that the supracrustals forming the Archean greenstones in the Eastern Pilbara form a lithotectonic complex, or a number of complexes that can be grouped into a hierarchy of domains. The Eastern and Western Pilbara constitute superdomains. Each has within it domains, and these in turn have subdomains of accreted tectonic slices. Barley (1997) recognizes 25 structurally integral subdomains in the Pilbara. In the Eastern Pilbara some of the domains do constitute terranes (Smith et al. 1998) and it is likely that the same occurs in the Western Pilbara. The hierarchy of domains seen in the Pilbara resembles that seen for the terranes in the Superior Province (Scott 1997).

We conclude, firstly, that horizontal movements have played a significant role in the tectonics of the Eastern Pilbara. Any solid-state diapirism has had only a secondary effect. Secondly, the two phases of accretion, probably involving terranes, place uncertainties upon stratigraphic correlations based on a continuous succession broken only by unconformities. This applies to the Warrawoona Group and, especially, to the Gorge Creek Group, as rocks in both have been correlated spatially and temporally across the two accretionary events and most probably across accreted terranes.

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