Structural evolution of the Marda–Diemals area, Southern Cross Province

by J. E. Greenfield[1] and S. F. Chen

Abstract

Initial basin formation (D_e) and deposition of the Marda–Diemals greenstones took place at c. 3.0 Ga. The first recognizable deformation event (D_1) was north–south compression that resulted in easterly trending recumbent folds and ductile strike-slip movement along major shear zones. During the waning stages of D_1, the formation of a restricted sedimentary basin (Diemals Formation), extrusion of a calc-alkaline volcanic succession (Marda Complex), and the intrusion of the Pigeon Rocks Monzogranite are inferred to have occurred penecontemporaneously at c. 2.73 Ga. Upright, northerly trending folds that overprint D_1 structures formed during D_2 east–west compression. During late D_2, westward-directed differential compression reoriented D_2 structural trends and reactivated the major shear zones. Post-dating all these structures are conjugate north-northeasterly trending dextral and east-southeasterly trending sinistral brittle faults.

KEYWORDS: Archaean, granite, greenstone, geological structure, Yilgarn Craton.

The Southern Cross Province (Griffin, 1990) of the Yilgarn Craton is characterized by strongly deformed, lenticular greenstone belts. Greenstone lithologies are dominated by mafic–ultramafic volcanic successions intercalated with banded iron-formation (BIF) units, and intruded by voluminous monzogranites. The Marda–Diemals area (Fig. 1) contains the key elements of a structural model based on recent geological mapping of the JOHNSTON RANGE* (Wyche et al., in prep.), LAKE GILES (Greenfield, in prep.), BUNGALBIN (Chen and Wyche, in prep.), and JACKSON (Riganti and Chen, in prep.) 1:100 000 sheets.

Geological setting

The Marda–Diemals greenstone belt is a wide, arcuate tectonic unit (Fig. 1) containing a lower, mafic-dominated sequence, and an upper sequence of felsic volcanic and clastic sedimentary rocks. It contains three distinct, ovoid granitoid plutons — the Pigeon Rocks and Butcher Bird Monzogranites, and the Chatarie Well Granite (Fig. 1). The Pigeon Rocks Monzogranite has a SHRIMP U–Pb zircon age of 2729 ± 4 Ma (Nelson, 1999). There is also a lenticular granite–gneiss body, the Rainy Rocks Monzogranite (Fig. 1), which has a SHRIMP U–Pb zircon age of 2678 ± 14 Ma (Dalstra, 1995).

Lower greenstones

The lower greenstone sequence comprises a basal quartzite overlain by high-Mg basalt and ultramafic rocks, followed by tholeiitic basalt, and two major units of BIF and chert intercalated with mafic and ultramafic volcanic and intrusive rocks. Felsic intrusive and pyroclastic rocks outcrop locally, but their absolute position within the stratigraphy is not clear. A minimum age for the lower greenstone sequence is provided by a SHRIMP U–Pb zircon age of 3023 ± 10 Ma for an intrusive quartz–feldspar porphyry at Deception Hill (Fig. 1; Nelson, 1999). This age is within error of a SHRIMP U–Pb zircon age of 3013 ± 16 Ma for a thin felsic unit, interpreted as volcanic, within the greenstones near Jackson Homestead (Dalstra, 1995).

Upper greenstones

A major unconformity separates the lower greenstone sequence from an upper greenstone sequence comprising the Diemals Formation and the Marda Complex.

The Diemals Formation (Walker and Blight, 1983) is a thick sequence of heterogeneously deformed, clastic sedimentary rocks. The formation is present in a roughly triangular basin with sharp, faulted contacts on its western and southeastern margins, and an unconformity on the northern margin (Fig. 2). The western margin has been metamorphosed up to greenschist facies; however, most of the formation has undergone very low grade metamorphism. The sequence changes upwards, from silty argillite interbedded with polymictic conglomerate, to coarse-grained quartz arenite. Common sedimentary structures include graded bedding and cross-bedding.

[1] j.greenfield@dme.wa.gov.au

* Capitalized names refer to standard map sheets

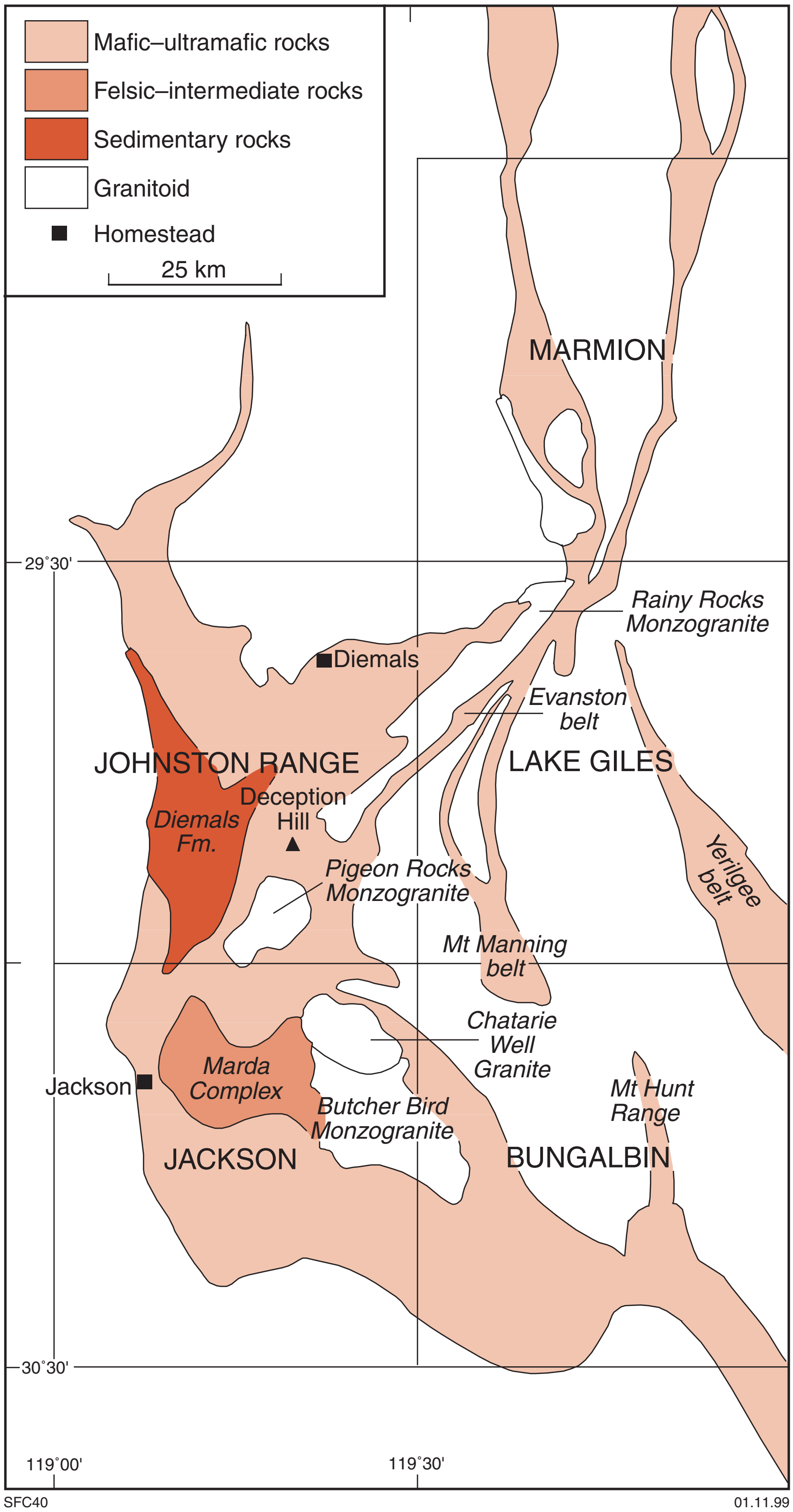

Figure 1. Locality map showing the central Southern Cross Province and localities described in the text

The conglomerates contain mainly BIF and vein-quartz clasts, but there are also granitoid boulders in the north. BIF in clasts has been tightly to isoclinally folded prior to reworking. The greenstone clasts are inferred to be locally derived, and suggest the Diemals Formation was deposited in a restricted basin.

The calc-alkaline Marda Complex (Hallberg et al., 1976; Chin and Smith, 1983) contains a range of extrusive acid to intermediate rock types. Pidgeon and Wilde (1990) obtained a conventional zircon U–Pb age of 2735 ± 2 Ma from fragmental rhyolite. Hallberg et al. (1976) examined the geochemistry of the Marda Complex, and inferred a magmatic source unrelated to the mafic volcanics that underlie the complex. They interpreted the complex as being at least partly subaerial. Intercalated sedimentary units along the northwestern margin may be correlated with the upper units of the Diemals Formation, suggesting that the Diemals Formation and the Marda Complex may have been coeval.

Structure

Early fold structures (D_1/F_1)

The earliest recognized structures are tight to isoclinal folds, ranging from centimetre-scale, rootless, isoclinal folds defined by quartz-rich layers in BIF to kilometre-scale, isoclinal folds that have been overprinted by F_2 (Fig. 2).

In the Evanston belt (Fig. 1), F_1 folds are refolded by large-scale F_2 folds into isoclinal folds that plunge steeply (doubly) to the northwest and southeast. In the northern Diemals area, repetition of BIF units has been recognized for approximately 2 km across strike. This is interpreted as being the result of D_1 faulting and folding that has been refolded by kilometre-scale upright F_2 folding (Fig. 2). A regional-scale, gently inclined D_1 antiform east of the Butcher Bird Monzogranite (Fig. 2) is refolded by open, kilometre-scale F_2 folds.

Before F_2, the F_1 folds were northerly verging and easterly trending, and gently inclined to recumbent, with shallowly plunging axes. Other than D_1 repetitions of BIF units, there appears to be no regional-scale D_1

disruption of the stratigraphy of the Marda–Diemals greenstones.

Regional-scale fold structures (D_2/F_2)

D_2 fold structures are dominated by megascale, upright, open to tight folds that trend northerly in the northwest, and northeasterly to southeasterly in the east and south (Fig. 2). Asymmetric S- and Z-folds are recognized on the limbs of regional-scale folds. They may be up to hundreds of metres in wavelength, but are more commonly at smaller (<1 m) scales.

The limbs of F_2 folds are typically steeply dipping. The axes of antiforms and synforms in the northwest have moderate to steep plunges to the south, whereas those in the northeast plunge moderately to the northeast. This pattern is repeated in the Evanston, Mount Manning, and Yerilgee belts, where poles to bedding have great circle distributions that indicate a general plunge to the northeast and northwest (Fig. 2).

S_2 fabrics associated with D_2 high-strain zones are pervasive and penetrative, but are mostly restricted to shear zones on greenstone margins. F_2 axial planar fabrics have developed under greenschist- to amphibolite-facies conditions, and regional metamorphism is interpreted to be syn-D_2 (Dalstra, 1995).

Late brittle faults

North-northeasterly and east-southeasterly trending conjugate brittle faults cut across all fold structures. North-northeasterly trending faults dominantly produce dextral offsets up to 200 m, whereas east-southeasterly trending faults are sinistral with offsets less than 50 m. The fault zones contain narrow quartz veins, with or without magnetite, and although up to 30 m wide, are commonly less than 5 m.

Major easterly trending aeromagnetic lineaments, possibly fractures filled by Proterozoic mafic dykes, cut across the brittle faults (Fig. 3).

Major shear zones

The Koolyanobbing Shear is a northwesterly trending, crustal-scale

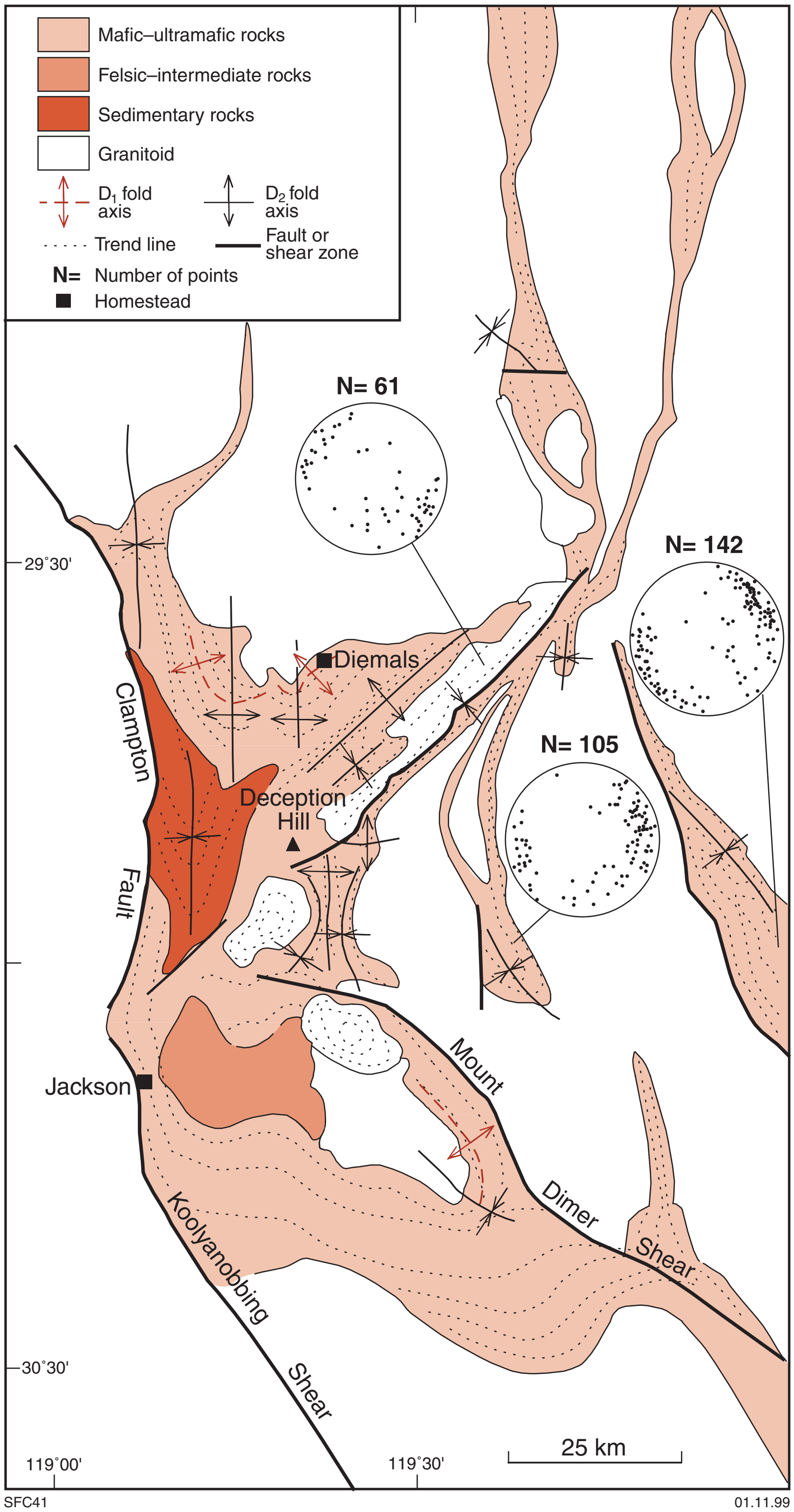

Figure 2. Major structural components of the central Southern Cross Province. Equal-area stereonet projections show poles to bedding for the Evanston, Yerilgee, and Mount Manning greenstone belts

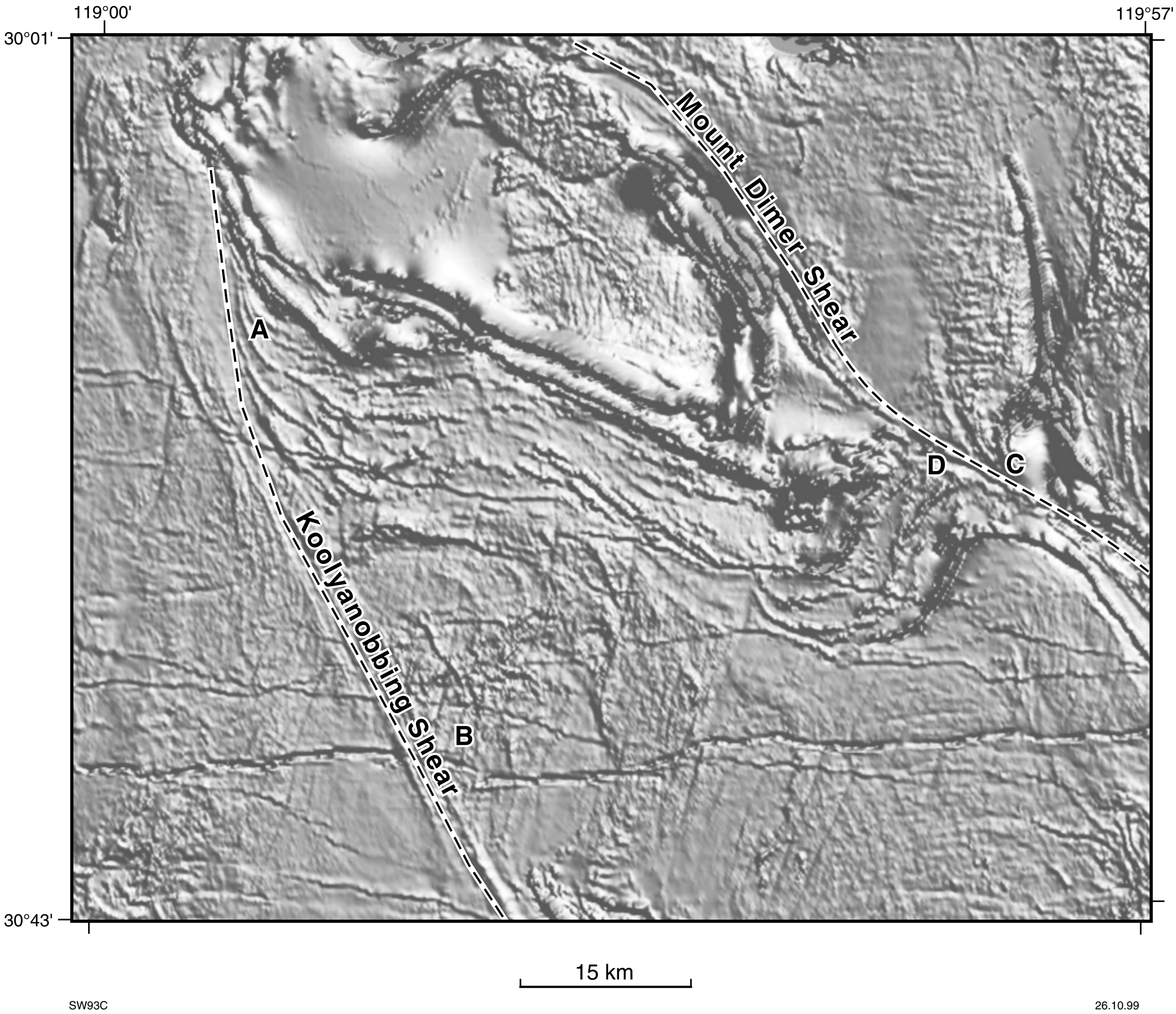

Figure 3. Total magnetic intensity image of the central Southern Cross Province. Dashed lines highlight interpreted shear zones. Letters indicate localities of interpreted movement sense along shear zones: A = dextral drag into the Koolyanobbing Shear; B = sinistral movement sense along the Koolyanobbing Shear; C = sinistral drag into the Mount Dimer Shear; D = dextral drag into the Mount Dimer Shear. Image derived from Kevron Geophysics multi-client data and used with permission

ductile shear zone (Fig. 2), 6–15 km wide (Libby et al., 1991), and approximately 450 km long. Strain increases towards the centre of the structure. Shallow-plunging mineral lineations and kinematic indicators (S–C, C–C´ fabrics) suggest dominantly sinistral transcurrent movement. However, at least one well-exposed pavement contains dextral S–C fabrics (Libby et al., 1991). Similarly, aeromagnetic images show ambiguous, large-scale kinematic indicators on the Koolyanobbing Shear. Dextral drag is inferred from tapering greenstone units south of the Marda Complex, whereas sinistral drag of granitoid is inferred farther to the south (Figs 2 and 3). Libby et al. (1991) interpreted a continuation of the Koolyanobbing Shear north of Jackson, coinciding with the Clampton Fault (Fig. 2). However, aeromagnetic data suggest the Koolyanobbing Shear terminates west of the Marda Complex (Fig. 3). In the Clampton area, the Clampton Fault consists of a 200 m-wide easterly dipping zone of sheared quartz veins at the granite–greenstone contact. Dalstra (1995) recognized downdip stretching lineations in the Clampton Fault zone.

The Mount Dimer Shear is a poorly exposed, northwesterly trending structure approximately 150 km long. Interpretation of aeromagnetic images suggests that, like the Koolyanobbing Shear, it has both sinistral and dextral kinematic indicators (Fig. 3). For example, the southern end of the Mount Hunt Range appears to have been displaced sinistrally by the shear zone, whereas greenstone units to the south of the Mount Dimer Shear have a dextral shear sense (Figs 1 and 3).

The Evanston Shear is a north-easterly trending ductile shear zone, approximately 100 km long and 2–6 km wide (Fig. 2). Most shear fabrics are penetrative and defined by upper greenschist- to lower amphibolite-facies minerals in sheared mafic rocks. S–C fabrics and en echelon quartz veins in the deformed Rainy Rocks Monzogranite and adjacent amphibolites indicate dextral transcurrent movement, with plunges of lineations subhorizontal to the northeast and southwest.

Synthesis

The interpreted structural evolution of the Marda–Diemals area is summarized in Table 1.

The earliest inferred event (D_e) may have involved the development of extensional growth faults at the margins of the developing greenstone basins. These growth faults may have been reactivated during later events.

Structures ascribed to D_1 reflect a north–south compressive regime. Ductile transcurrent movement along the Koolyanobbing Shear is consistent with north–south compression, which suggests that this structure could have been either initiated or reactivated during D_1. If that was the case, dextral displacement at the northwestern termination of the Koolyanobbing Shear may also have caused tectonic downwarping that facilitated the deposition of the Diemals Formation and extrusion of the Marda Complex. Isoclinal folds in BIF boulders from the Diemals Formation indicate at least one folding deformation event prior to deposition. Thus the Diemals Formation was deposited after D_1 folding. The intrusion of the Pigeon Rocks Monzogranite at 2729 ± 4 Ma and the eruption of the Marda Complex at 2735 ± 2 Ma give a minimum age for D_1.

East–west compression dominated during early D_2 upright folding. However, reorientation of folds into northeast and southeast trends in the eastern part of the Marda–Diemals greenstones may be due to westward-directed compression during late D_2. This would also account for the intense buckling of greenstones observed on the eastern side of the Pigeon Rocks Monzogranite.

Late D_2 differential compression probably reactivated the major shear zones. Westward-directed compression would result in sinistral displacement along the Koolyanobbing and Mount Dimer Shears, and dextral displacement along the Evanston Shear. Pre- to syn-kinematic intrusion of the Rainy Rocks Monzogranite took place at 2678 ± 14 Ma.

In the final stage of this tectonic cycle, east-northeasterly–west-southwesterly compression produced brittle conjugate north-northeasterly and east-southeasterly faults prior to cratonization and the development of crustal-scale, easterly trending fractures.

Table 1. Structural evolution of the Marda–Diemals greenstones

Age (Ma)	*Label*	*Strain regime*	*Event*	*Structure*
>3023 ± 10	D_e	E–W extension	Basin-forming event; deposition of lower greenstones	N- and NNW-trending growth faults
	Early D_1	N–S compression	–	E-trending folds and thrust faults; dextral movement on NNW-trending shear zones
c. 2730	Late D_1	N–S compression	Intrusion of Pigeon Rocks Monzogranite; deposition of Diemals Formation; extrusion of Marda Complex	–
	Dextral movement on NNW-trending shear zones	–	–	–
2678 ± 14	Early D_2	E–W compression	Intrusion of Rainy Rocks Monzogranite	N–S folds
	Late D_2	E to W compression	–	Reorientation of N-trending folds; sinistral movement on NNW-trending shear zones; dextral movement on NE-trending shear zone
		ENE–WSW compression	–	Brittle NNE and SSE faults
		E–W ?compression	Dolerite dyke emplacement	Craton-scale E–W faulting

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