Structural geology of the Duketon area, northeastern Goldfields

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Abstract

The Duketon area, in the northern part of the Eastern Goldfields of Western Australia, encompasses a multiply deformed and metamorphosed, north-northwesterly trending greenstone belt bordered by deformed high-grade felsic gneiss and granitoids. The greenstone sequences and the gneiss both contain evidence of four phases of deformation. First-generation structures (D_1) have largely been overprinted during subsequent deformation events but a remnant foliation is still preserved in some areas. The second deformation event (D_2) resulted in the formation of upright, tight to isoclinal folds and a pervasive, north-northwesterly trending axial-plane schistosity. It was contemporaneous with the metamorphic peak and the main phase of granitoid intrusion. Continued shortening during D_3 resulted in the development of large-scale, shallow plunging, open to tight folds and north-northwesterly trending ductile shear zones that dominate the regional-scale structure of the greenstone belt. The final deformation (D_4) was a late-stage, low-temperature event that resulted in the kinking, crenulation, and fracturing of all pre-existing structures. The granitoids show complex intrusive relationships with the gneisses and deformed intrusive contacts with the greenstone sequences, which suggests that the granitoids are younger than either rock type and cannot be the basement to the greenstones.

KEYWORDS: Duketon, Eastern Goldfields, geological structures, greenstone, granitic rock.

Regional geological mapping of the DUKETON* 1:100 000 sheet was carried out by the Geological Survey of Western Australia (GSWA) in 1994 as part of the National Geoscience Mapping Accord (Farrell and Langford, in prep.). This work is a continuation of the detailed 1:100 000 mapping of major areas of greenstone within the Norseman–Wiluna belt that has been carried out by the GSWA. This paper is a description of the structural geology of DUKETON, as deduced from the interpretation of outcrop-scale structures and aeromagnetic data.

The DUKETON area lies to the north of Laverton in the Eastern Goldfields Province of the Archaean Yilgarn Craton (Fig. 1). Much of the area is underlain by a north-northwesterly trending greenstone belt, which is flanked by intermingled biotite monzogranite and quartzo-feldspathic gneiss in the west, and by biotite monzogranite in the east. The greenstone belt contains a deeply weathered, metamorphosed succession of ultramafic, mafic, and felsic volcanic rocks with associated volcanogenic sedimentary rocks and thin units of banded chert. The cherts form conspicuous strike ridges that can be used to delineate structures and stratigraphic trends in some parts of the area. Apart from a few notable exceptions, most of the sequence is poorly exposed.

Large-scale structure

The Duketon greenstone belt is a structurally complex, north-northwesterly trending tectonic unit characterized by sheared, elongate fault slices and dismembered folds (Fig. 2). The dominant stratigraphic/structural trend is north-northwesterly, parallel to the length of the belt. In the southeast corner and on the northern border of the area, the granitoids and the greenstones have been coaxially folded, but show locally discordant contacts suggesting that the granitoids were intruded prior to the folding event. Most of the larger folds are upright and shallow plunging with north-northwesterly trending axial surfaces (e.g. Christmas Well Anticline; Fig. 2). On aeromagnetic images, the limbs appear to be sheared off along the major shear zones.

There are a number of smaller scale, asymmetric folds in chert marker units and on aeromagnetic images, but it is difficult to integrate these folds into a structural model for the greenstone belt due to uncertainty over the amount of displacement on the major shear zones, the lack of detailed structural control, and poor outcrop. Locally coherent sequences are present in some parts of the area; however, it is thought that these are discrete, structurally-bound stratigraphic packages, and thus

* Capitalized names refer to standard 1:100 000 map sheets.

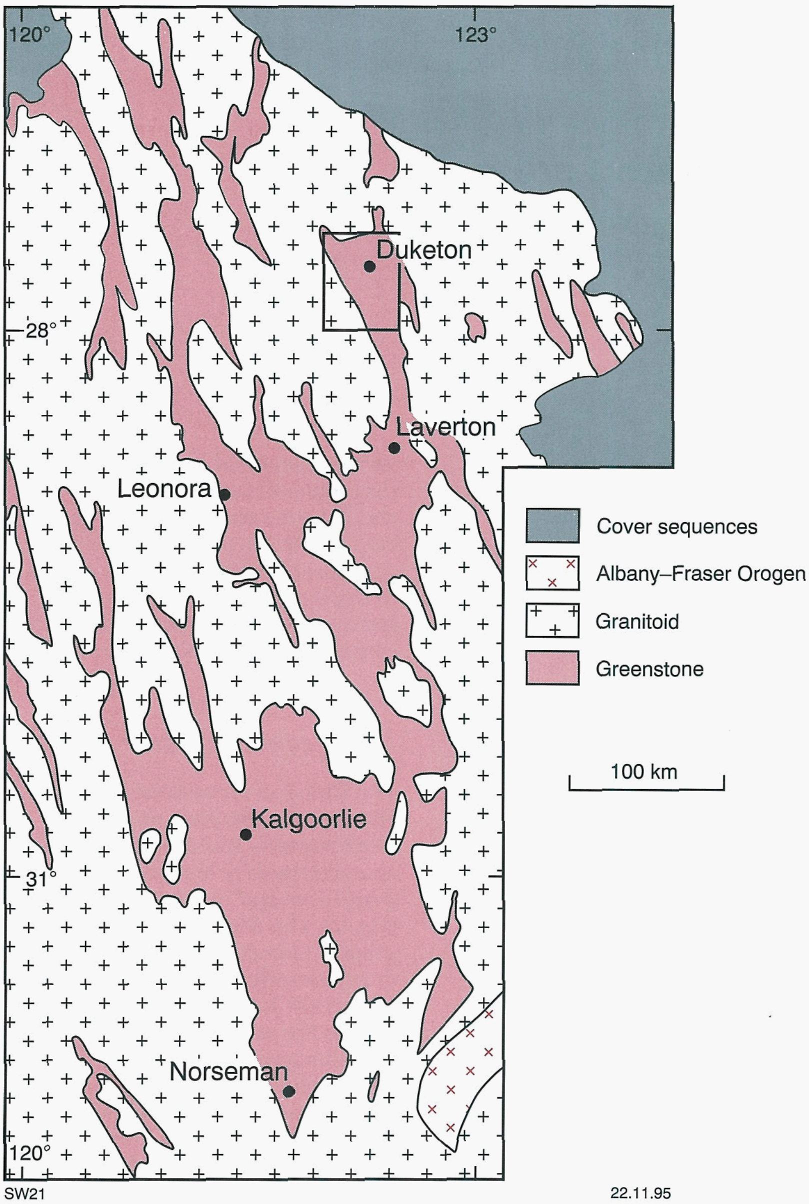

Figure 1. Location of DUKETON

their correlation with other parts of the greenstone belt is uncertain.

Deformation sequence

Four phases of deformation (D_1–D_4) have been recognized on the basis of the overprinting relationships between small-scale folds, foliations, and lineations. These deformation events have been numbered sequentially and may not be directly correlatable with events recognized in the southern or central parts of the Eastern Goldfields (e.g. Williams and Whitaker, 1993; Passchier, 1994; Swager et al., 1995).

D_1

First generation (D_1) structures have largely been overprinted during subsequent deformation events but relict D_1 fabrics are still preserved in gneisses and in the greenstone sequence. No large-scale D_1 features have been recognized. The dominant D_1 structure is a well-developed, steeply-dipping, east- to northeast-trending schistosity. In quartzofeldspathic gneiss at Lizzars Soak, in the western part of the area (Fig. 2), S_1 is tightly to isoclinally folded and largely transposed into S_2. S_1 is best preserved in F_2 fold hinges, particularly in low-strain zones where the F_2 folds are more open. It is defined by the alignment of biotite, quartz, and quartz–feldspar aggregates, and by thin discontinuous leucosomes (typically less than 4 cm thick).

S_1 is also preserved in some silicified ultramafic cumulates at Baneygo (Fig. 2), in the southern part of the area, where it is defined by the preferred alignment of flattened olivine grains (now replaced by silica and iron-oxides). It is a steeply dipping, well-defined, anastomosing fabric, which is cut by the regional S_2 fabric. Similar S_1–S_2 relationships are present in talc–carbonate schist after ultramafic rock, in which S_1 is defined by the alignment of flattened carbonate aggregates (now largely weathered). In both rock types the intersection of S_1 and S_2 results in the formation of a steeply plunging intersection lineation that is parallel to the F_2 fold axes.

D_2

D_2 was a pervasive shortening event associated with peak metamorphism and the main phase of granitoid intrusion. Its effects are recognizable throughout the area but are most pronounced in amphibolite-facies zones adjacent to the granitoids. The identification of large-scale D_2 features is uncertain but some of the rootless folds that are apparent on aeromagnetic images may be D_2 structures. The characteristic D_2 structure is a pervasive, regionally extensive, north- to northwest-trending axial-plane foliation (S_2), which occurs in most rock types, including granitoids. In high-grade areas, S_2 is a well-defined, continuous schistosity, whereas in lower grade areas, primary igneous textures are commonly preserved and S_2 is only poorly to moderately developed. In quartzofeldspathic gneiss at Lizzars Soak (Fig. 2), S_2 is a composite fabric comprising newly crystallized folia and reoriented S_1 surfaces.

F_2 folds are typically open to isoclinal, and moderately to steeply plunging with a flattened concentric

Figure 2. Simplified tectonic interpretation map of DUKETON

geometry. The fold axes are parallel to a well-defined, relatively coarse-grained mineral lineation (L_2), which is particularly well-formed in the fold-hinge zones. In some fold hinges the rocks have a distinctly linear fabric. The original orientation of the F_2 folds is uncertain because it is likely that they have been reoriented during subsequent deformation; particularly in areas that have been strongly affected by D_3 shearing.

D_3

The third deformation episode (D_3) resulted in further east- to northeast-directed shortening and the formation of north- to northwest-trending ductile shear zones (Fig. 2). These are broad zones of high, but variable strain, within which D_2 structures are largely overprinted by a planar, mylonitic fabric (S_3) containing a shallow-plunging mineral-elongation lineation (L_3). The shallow plunge of the lineation is indicative of subhorizontal extension and suggests that the movement on these zones was largely strike-slip. Moreover, in some granitoid rocks to the southwest of the Hootanui Fault (Fig. 2), the asymmetry of S–C fabrics (Lister and Snoke, 1984) and σ-porphyroclasts is suggestive of dextral movement. However, S–C fabrics are not commonly developed, and where they are present the S-folia contain highly elongate quartz grains and are much better developed than the C-folia suggesting that the deformation in D_3 involved a large component of flattening, and that the amount of lateral displacement may not have been large. The sense of movement on the other shear zones is not known, but the asymmetry of the large-scale structures shown on aeromagnetic images along the eastern side of the greenstone belt points to sinistral movement on the Turnback and Lulu Faults (Fig. 2).

Although the rocks are strongly deformed in the D_3 shear zones, earlier structures are still recognizable. For example, in strongly sheared gneisses close to the granite–greenstone contact in the Murphy Hills (Fig. 2) the presence of a steeply plunging, coarse-grained intersection lineation on S_3 surfaces is evidence for the presence of an earlier fabric. This lineation appears to be due to the intersection of S_3 with an S_1–S_2 gneissic layering that has been transposed into S_3.

D_4

The last recognizable deformation event (D_4) involved kinking and crenulation of all earlier structures. The kinks and crenulations are commonly associated with small-scale faults, fractures, and quartz veins, and they occur in all rock types in the area. Both structures are variable in orientation.

Timing of granitoid emplacement

There are a number of structural features relevant to the timing of the main phase of granitoid emplacement that have been used to constrain the age of the granitoids. Firstly, the gneisses in the Lizzars Soak area on the western side of DUKETON contain folded S_1 fabrics that are cut by small granitoid veins, pods, and larger bodies implying that granitoid emplacement must have occurred after D_1.

Secondly, the granitoid on the west side of DUKETON is a composite unit that shows varying degrees of deformation. Most parts contain a foliation that is parallel and contiguous with S_2 in the gneisses and greenstones, and this is therefore interpreted to be a D_2 fabric. Many of the granitoid veins in the gneisses are folded to varying degrees about F_2 axes, and some of these granitoids are very tightly folded and cross cut by more gently folded granitoids. Moreover, most of the larger granitoid bodies are only weakly deformed. These relationships suggest that granitoid emplacement occurred progressively during D_2 and may have peaked after the deformation ceased.

Thirdly, in a number of areas, the granitoids and gneisses contain D_3 mylonitic fabrics that overprint the earlier D_1 and D_2 fabrics implying that the main phase of granitoid emplacement occurred prior to solid-state deformation in D_3.

Finally, the presence of granitoid clasts in sheared (D_3) felsic conglomerates in the Murphy Hills is also consistent with granitoid emplacement prior to D_3. These conglomerates lie close to the western margin of the greenstone belt, and if the clasts have been sourced from the granitoids to the west, as seems likely, then there must also have been uplift, erosion, and deposition of granitic detritus prior to D_3.

There is evidence on the aeromagnetic images for the presence of some minor, late-stage granitoids. An even-textured unit that cuts both the Lulu Fault and the prominent north-northwesterly trending structures to the west (Fig. 2) is interpreted to be a post-D_3 granitoid.

Granite–greenstone relationships

The nature of the contact between the granitoids and the greenstones is of considerable interest as it is one of the keys to understanding the tectonic development of the Yilgarn Craton. It has previously been suggested that the granitoids and gneisses may be basement to the greenstone sequences (e.g. Williams, 1993), but not much is known in detail about granitoid, gneiss, and greenstone relationships due mainly to the poor outcrop in critical locations.

There are a number of locations in the Murphy Hills area (Fig. 2) where granite–greenstone contacts can be examined. Rocks on both sides of the contact are typically strongly deformed and well-foliated (combined S_2–S_3 fabric), but at one location the contact is deformed into a tight to open fold. Here the greenstones are intruded by narrow granitoid dykes that emanate from the main granitoid body, suggesting that it is a deformed intrusive contact. Additionally, the dominant fabric on both sides of the contact (S_2) is also axial planar to the fold, indicating that intrusion probably occurred during D_2. This is also consistent with the timing of granitoid emplacement inferred by structural relationships in the gneisses at Lizzars Soak. On the basis of these observations it is suggested that the granites in the DUKETON area are younger than both the greenstones and the quartzofeldspathic gneisses and therefore cannot be basement material.

The relationships between the gneisses and the greenstones is problematical as there is no outcrop of the contact between the two rock units. Gneissic rocks to the west of the greenstone belt show the same structural record as the greenstones, and therefore have probably undergone the same sequence of deformation events. The origin of the quartzofeldspathic gneiss is obscured by the high-grade metamorphism and deformation, but it is possible that they are simply part of the greenstone sequence that has undergone higher grade metamorphism and partial melting, as suggested by Bunting and Chin (1979). This is supported by the fact that the gneisses contain remnants of banded iron-formation (Bunting and Chin, 1979), layers or lenses of amphibolite and metapelitic rocks, and have a diffuse decimetre- to metre-scale compositional layering.

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