

Stratigraphic correlations in the Wiluna greenstone belt

by S. F. Liu, A. H. Hickman, and R. L. Langford

Abstract

A stratigraphic sequence is recognized in the Wiluna greenstone belt in the northern part of the Eastern Goldfields Province. This sequence, from bottom to top, comprises five units: unit A — metabasalt and metagabbro; unit B — metabasalt; unit C — metamorphosed felsic volcanic and sedimentary rocks; unit D — metamorphosed ultramafic rock; and unit E — metamorphosed felsic sedimentary and volcanic rocks. The Wiluna sequence is somewhat similar to the greenstone sequence in the Kalgoorlie Terrane and this suggests a similar depositional and tectonic environment.

KEYWORDS: Eastern Goldfields, Wiluna, greenstone, stratigraphy.

Stratigraphic successions within greenstone belts of the Eastern Goldfields Province are difficult to establish because of poor exposure, deep weathering, complex deformation, and lack of stratigraphic markers. As a result, a regional greenstone stratigraphy is rarely well established. One exception is in the Kalgoorlie Terrane, where good stratigraphic markers, extensive exploration activity, and associated detailed geological mapping have led to the establishment of a relatively simple regional greenstone stratigraphy (Swager and Griffin, 1990; Swager et al., 1995).

As part of the National Geoscience Mapping Accord project between the Geological Survey of Western Australia (GSWA) and the Australian Geological Survey Organisation (AGSO) in the Eastern Goldfields, geological mapping of the WILUNA* 1:100 000 sheet by the GSWA is currently in progress. In

addition, the area surrounding the Wiluna gold mines has recently been mapped as part of a regional study of the gold resources in the Wiluna-Leonora region (Hickman, in prep.). The current geological mapping is based on the 1:25 000 aerial photographs taken late in 1994 in conjunction with enhanced Landsat Thematic Mapper images produced at aerial-photograph scale. Regional geological modelling includes interpretation of aeromagnetic data acquired on a 400 m line spacing.

Based on the work to date, a simple stratigraphic sequence for the greenstones can be outlined for the Wiluna greenstone belt.

Regional geological setting

The Wiluna greenstone belt is one of the northwesternmost greenstone belts in the Eastern Goldfields of the Yilgarn Craton (Griffin, 1990, figure 2-87), and lies to the east of the Erawalla Fault. This fault on WILUNA was previously referred to

as the Perseverance Fault (Elias and Bunting, 1982). However, in the absence of detailed mapping on MOUNT KEITH and YEELIRRIE the northward correlation along the length of the Perseverance Fault has not been verified. This fault trends diagonally through the middle of WILUNA (Fig. 1). The Wiluna greenstone belt extends south onto YEELIRRIE and MOUNT KEITH, and is probably an extension of the Mount Keith – Perseverance belt on SIR SAMUEL (Liu et al., in prep.).

The Wiluna greenstone belt has also been referred to as the Wiluna domain (Morgan and El-Raghy, 1990; Hagemann et al., 1992, 1995). Most rocks in the belt, particularly around Wiluna, are less deformed than those of the Coles Find belt, which lies to the west of the Erawalla Fault. Structures in the Wiluna greenstone belt are mainly faults (Fig. 1), although areas of tight folding have also been identified. Hagemann et al. (1995) interpret their Wiluna and Matilda (Coles Find) domains as segments from different crustal levels juxtaposed by the Perseverance Fault.

Stratigraphic correlations

The Wiluna greenstone belt is 8–15 km wide and strikes north-northwest on WILUNA. The sequence both dips steeply and youngs towards the west. Both metamorphosed tholeiitic and high-Mg basalts outcrop in the Wiluna greenstone belt, but tholeiitic basalt dominates. The southwest boundary of the belt is the Erawalla Fault, and the poorly exposed northeast boundary is a

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

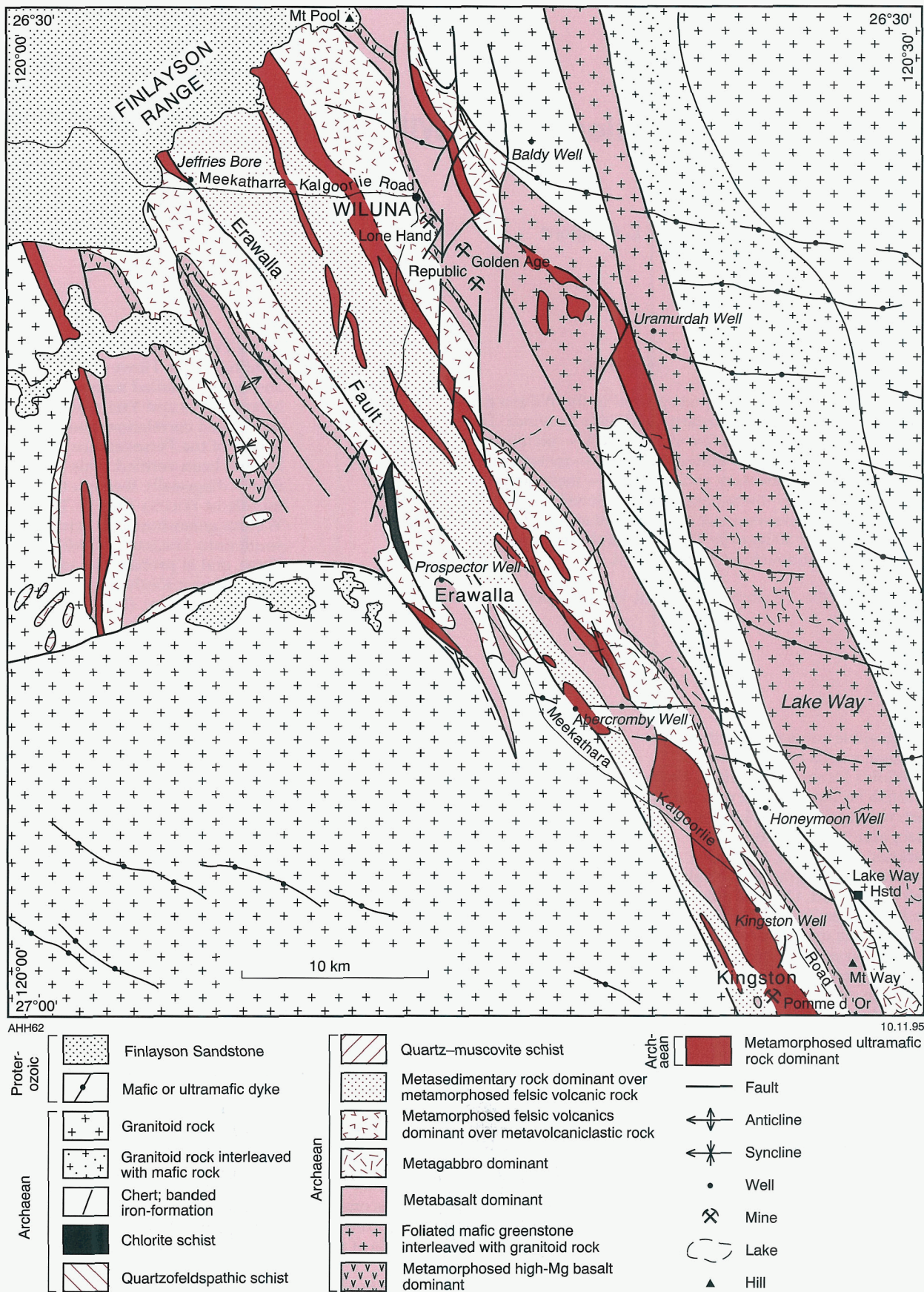


Figure 1. Tectonic sketch of the Archaean geology on Wiluna

tectonic contact with regional granitoids (Fig. 1).

Mapping and interpretation of magnetic data have shown that two units can be used as stratigraphic markers in the Wiluna greenstone belt (Figs 1 and 2). One is composed of metamorphosed ultramafic rock, and extends over 150 km southeast to the Mount Keith and Perseverance nickel mines; this unit shows as a prominent high on aeromagnetic images (Mackey et al., 1995). This is consistent with the models for komatiite as extensive lava flows in the Wiluna–Norseman greenstone belt (Hill et al., 1990). The other unit comprises high-Mg metabasalt, and also results in a significant high anomaly on aeromagnetic images. The high-Mg metabasalt can be traced from about 10 km north-northwest of Wiluna, through Lake Way, passing west of Mount Way onto YEELIRRIE and MOUNT KEITH.

Regional folds have not been identified in the Wiluna greenstone belt, although minor folds have been mapped in the area west of Lake Way and a larger fold has been found in the southeast corner of WILUNA. The continuity of the metamorphosed ultramafic and high-Mg basalt marker units indicates that there is a simple greenstone sequence in this belt.

A simple stratigraphic division is therefore proposed for the Wiluna greenstone belt. The belt is divided, from east (bottom) to west (top), into five units: unit A — metabasalt and metagabbro; unit B — metabasalt; unit C — metamorphosed felsic volcanic rocks and sedimentary rocks; unit D — metamorphosed ultramafic rock; and unit E — metamorphosed felsic sedimentary and volcanic rocks (Fig. 3). The greenstones at different locations within the Wiluna greenstone belt are described below.

Wiluna

The greenstone sequence in the Wiluna greenstone belt is best illustrated in a transect through Wiluna from Baldy Well at the contact with granitoids in the northeast, to Jeffries Bore near the Erawalla Fault in the west (Fig. 1). This sequence is presented schematically in a stratigraphic column in Figure 3.

Unit A — metabasalt and metagabbro

Metabasalt and metagabbro form the lowest unit of the Wiluna sequence (unit A), which also includes some metamorphosed ultramafic rock, and cherty siliceous and ferruginous metasedimentary rock. The lowest part of this unit has a sheared contact with the adjacent granitoids, and consists of sheared pyroxenite and talc schist overlain by amphibolite, which is thought to be derived from metamorphosed gabbro and basalt.

The relatively high metamorphic grade of these rocks (upper greenschist to amphibolite facies) is probably the result of their close proximity to a large granitoid intrusion immediately to the east. Above the amphibolitized gabbro and basalt is a thin horizon of cherty siliceous and ferruginous metasedimentary rock, which is in turn overlain by metagabbro and metabasalt of lower greenschist to prehnite–pumpellyite facies. At the top of the metabasalt and metagabbro unit is a thin but laterally extensive ultramafic unit consisting of variably silicified talc schist that may have been derived from sheared peridotite.

Unit B — metabasalt

Unit B is dominantly composed of metabasalt, and is in faulted contact with sheared metamorphosed ultramafic rocks at the top of the underlying unit A. Close to Wiluna these metabasalts are well documented (Edwards, 1953; Hagemann et al., 1992). The metabasalts strike north-northwest and dip steeply to the west. Pillow structures in these rocks indicate that they also young towards the west. The total thickness of the unit at Wiluna is up to 4 km. Most of the rocks are apparently unstrained, and the metamorphic grade is low (prehnite–pumpellyite facies; Binns et al., 1976).

The lowest part of unit B is a 1.5 km-thick sequence of metamorphosed tholeiitic basalt lava flows. This sequence is overlain by 100–200 m of metamorphosed felsic tuff and volcanoclastic rocks. Above these rocks is a 300 m-thick sequence of metamorphosed tholeiitic basalt with pillowed flows and horizons of flow breccia. This is overlain by 50–100 m of metamorphosed felsic tuff and volcanoclastic rocks, exposed at the

Golden Age mine. Above these felsic rocks is 50–100 m of metamorphosed tholeiitic basalt, which is overlain by a 10 m-thick unit of metamorphosed, banded, fine-grained sedimentary rock and felsic tuff, with local sills of felsic porphyry. These rocks are overlain by 500 m of metamorphosed tholeiitic basaltic flows in the area southwest of the Republic mine.

The metamorphosed high-Mg basalt near the top of unit B has well-developed sheaf and random spinifex textures, and includes thin flows of metapyroxenite. The metamorphosed high-Mg unit is typically about 300 m thick, and because the rock is strongly magnetic it forms a useful marker on regional aeromagnetic images (Figs 1 and 2). To the south of Lone Hand the metamorphosed high-Mg basalt is overlain by a 100 m-thick metagabbro, which is absent northwest of Wiluna.

South of Wiluna the metagabbro is overlain by metamorphosed massive and pillowed tholeiitic basalt less than 1 km thick, containing thin interflow metasedimentary rocks and thin metamorphosed felsic sills. The metabasalt is not exposed northwest of Wiluna and may not be present in that area, where the metamorphosed high-Mg basalt is overlain by metamorphosed felsic volcanoclastic rocks that form a horizon at least 100 m thick. This horizon could be a local felsic interval in the mafic succession, or could represent the lowest part of the overlying felsic sequence.

Unit C — metamorphosed felsic volcanic and sedimentary rocks

Unit C comprises metamorphosed felsic volcanic and sedimentary rocks, and minor metabasalt. Although very poor, there are exposures around Wiluna airport, 4 km south of the town, and between Mount Pool and the Finlayson Range, 12 km northwest of Wiluna. Assuming constant steep to moderate dips southwestwards, the unit may be about 2.5 km thick. Along the south side of the Finlayson Range, Elias and Bunting (1981) have identified graded bedding in metasedimentary rocks that has a southwest younging direction that is consistent with that recorded in unit B.

Unit D — metamorphosed ultramafic rock

The metamorphosed ultramafic rocks of unit D form a sequence of variable thickness, possibly the result of localized tight folding and

transcurrent faulting, and are mainly composed of metamorphosed peridotite and dunite extruded as lava flows. This unit is the host of major nickel deposits between Honeymoon Well and Perseverance. This ultramafic unit

is strongly magnetic, and therefore forms an important regional marker on aeromagnetic images (Figs 1 and 2). It appears to bifurcate locally, which may indicate multiple lava flows or tectonic repetition.

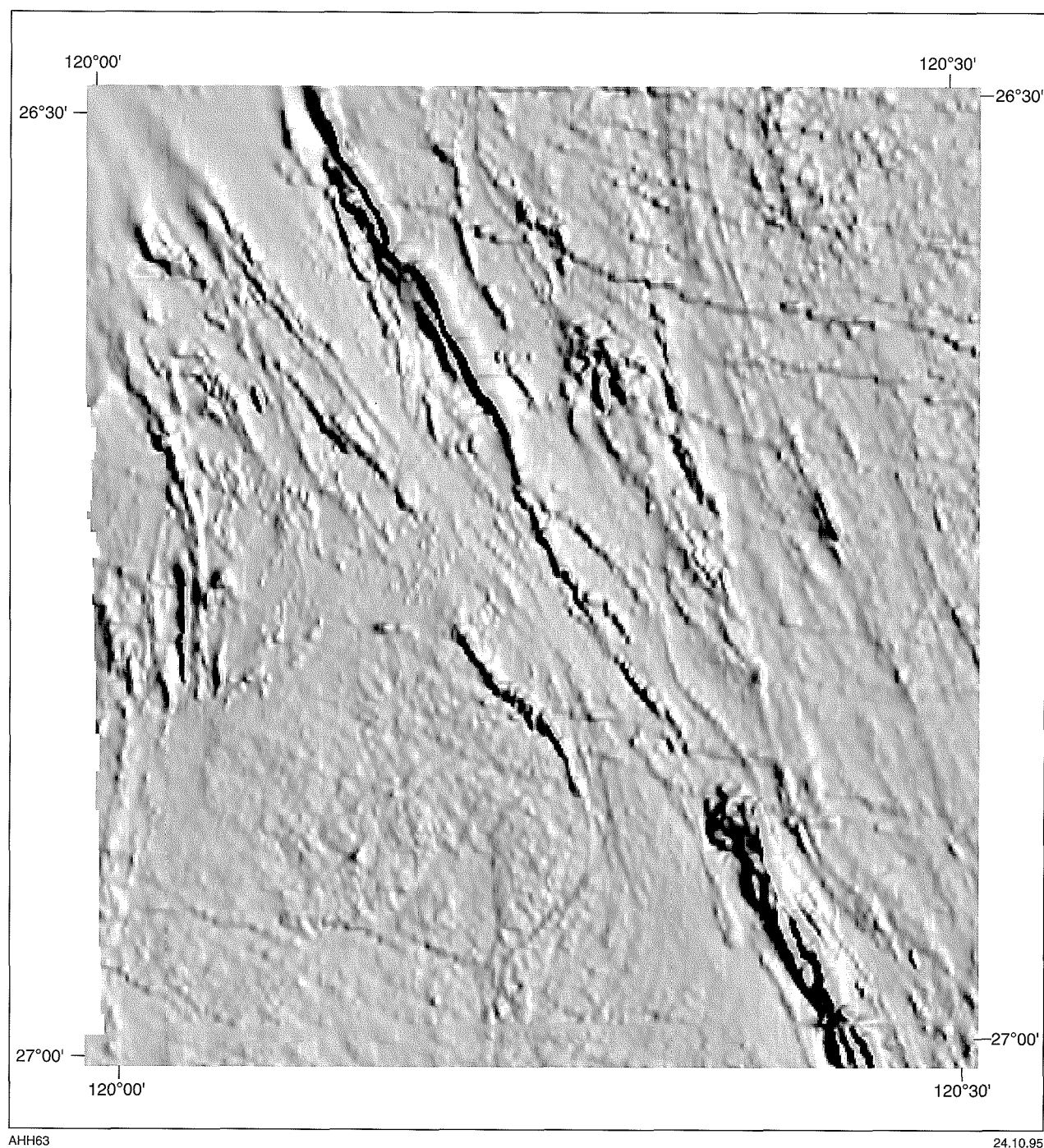


Figure 2. Grey-scale aeromagnetic map of total magnetic intensity for WILUNA

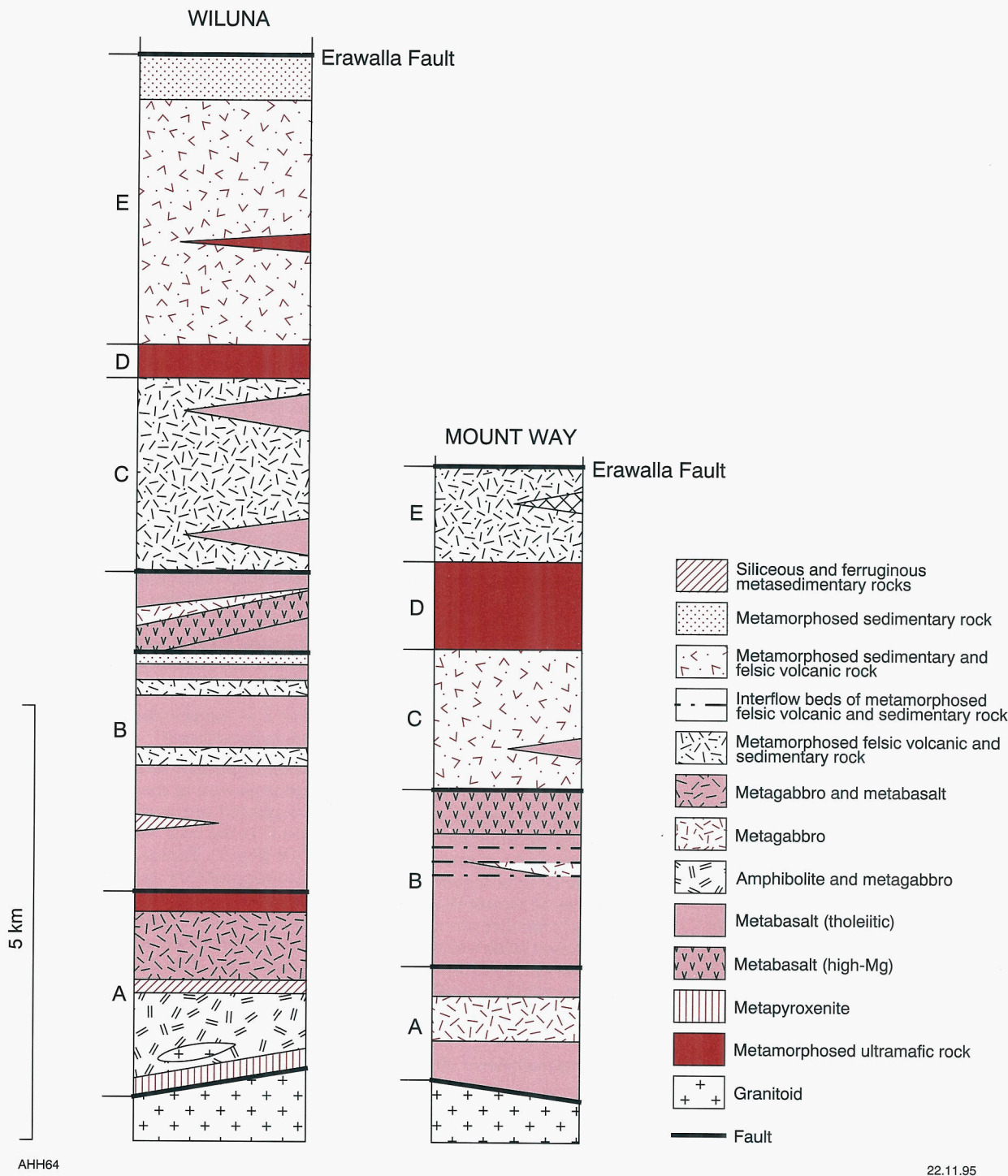


Figure 3. Stratigraphic columns

Unit E — metamorphosed sedimentary and felsic volcanic rocks

Above the ultramafic unit is a poorly exposed, 3 km-thick unit of metamorphosed sedimentary and felsic volcanic rocks (unit E). There are good exposures in the area south of the Finlayson Range, but these are

commonly highly weathered. A narrow, highly magnetic strip in the centre of the unit can be correlated with exposures on the southern slopes of the Finlayson Range, where Elias and Bunting (1981) mapped metamorphosed ultramafic rock. Cherty rocks exposed 3 km east of

Jeffries Bore may be silicified shales. The top of the unit appears to be mainly metasedimentary rocks. Metaconglomerate exposed at Jeffries Bore and mapped as 'deformed chert pebbles in wacke matrix' by Elias and Bunting (1981) has been included in unit E.

Mount Way

The five units of the Wiluna greenstone belt described above are also recognized in the Mount Way – Kingston area in the south of WILUNA (Fig. 3). The two magnetically anomalous marker units in the Wiluna area can be correlated with similar units in the Mount Way – Kingston area (Figs 1 and 2). These are the metamorphosed ultramafic rock (unit D) and the strongly magnetic metamorphosed high-Mg basalt (unit B).

Unit A – metabasalt and metagabbro

The easternmost outcrop of the greenstones in the Mount Way area comprises a zone of metabasalt, metagabbro, and minor granitoid over 1 km wide (Fig. 1). On the basis of lithology and position of the sequence, these rocks can be correlated with unit A in the Wiluna area.

Most rocks in this zone are only weakly or little deformed, although a cleavage is developed in discrete zones typically a few metres wide. The mafic rocks near the contact with the granitoid to the east have been metamorphosed to amphibolite facies, and are commonly highly deformed. The metamorphic grade decreases to greenschist facies away from the contact.

There is a strongly deformed zone over 100 metres wide between these rocks (unit A) and the massive metabasalt (unit B) at Mount Way to the west. The rocks in this deformed zone include metabasalt, metagabbro, and granitoid, and have developed a prominent north-northwesterly trending cleavage that dips steeply to the west. The contact between unit A and unit B is probably a shear zone.

Unit B – metabasalt

A massive metabasalt about 1.5 km wide outcrops in the area around Mount Way. This metabasalt lies west of unit A. Thin interflow beds of metamorphosed felsic volcanic and sedimentary rocks occur within the metabasalt. The metabasalt and felsic interflow beds strike north-northwest and dip steeply to the west. Most rocks in this unit show little deformation, but a closely spaced cleavage is developed in discrete zones.

Metamorphosed high-Mg basalt exposures immediately west of the massive metabasalt are highly deformed and have a well-developed foliation in the form of a cleavage or a schistosity that trends north-northwest and is almost vertical. Associated with the metamorphosed high-Mg basalt is a silica cap rock that may have been derived from metamorphosed ultramafic rocks. The high-Mg basalt can be traced on aeromagnetic images to the Wiluna area in the north (Figs 1 and 2), and to the south onto YEELIRRIE and MOUNT KEITH.

Both the massive metabasalt and the high-Mg basalt are correlated with unit B in the Wiluna area.

Unit C – metamorphosed sedimentary and felsic volcanic rocks

Metamorphosed sedimentary and felsic volcanic rocks are exposed west of the metamorphosed high-Mg basalt on both sides of the Wiluna–Leinster Road. The intense deformation in the high-Mg basalt about 3 km southwest of Lake Way Homestead indicates that unit C is probably in shear contact with unit B. The metamorphosed sedimentary rocks are fine-grained and phyllitic, with a schistosity striking north-northwest that is nearly vertical or dipping steeply to the east. These sedimentary and felsic volcanic rocks correlate with unit C of the Wiluna sequence, but the exposures at Mount Way contain a significantly smaller amount of metamorphosed felsic volcanic rock, probably due to lateral facies changes from north to south along the Wiluna belt.

Unit D – metamorphosed ultramafic rock

The metamorphosed ultramafic rocks of unit D are informally referred to as the Honeymoon Well ultramafic complex by mining companies in the area. The unit is about 2 km wide (Fig. 1), and outcrops about 3.5 km west-northwest of Honeymoon Well and in the area between Kingston Well and Pomme d'Or. Unit D appears as a prominent high on aeromagnetic images, extending northwestwards to correlate with unit D west of Wiluna (Figs 1 and 2). This ultramafic unit also extends to the south onto YEELIRRIE, MOUNT KEITH, and SIR SAMUEL (Mackey et al., 1995).

The complex consists of metamorphosed ultramafic cumulates, some metakomatiite, and minor metabasalt and metamorphosed felsic volcanic rocks. The rocks strike north-northwest, and commonly dip steeply to the east (Naldrett and Turner, 1977; Gole, M. J., 1995, pers. comm.); however, they young to the west, although east-younging rocks occur locally (Gole, M. J., 1995, pers. comm.).

Aeromagnetic data indicate that the Honeymoon Well ultramafic complex terminates sharply about halfway between Honeymoon Well and Abercromby Well (Figs 1 and 2). Drilling has revealed metamorphosed basaltic rocks in this area, and it is likely that the local absence of the metamorphosed ultramafic rocks here is due to faulting or folding rather than primary lithological changes.

West of the Honeymoon Well ultramafic complex, and in the areas between the Abercromby and Kingston wells, there is a small area about 1 km wide of metabasalt.

Unit E – metamorphosed sedimentary rock and metabasalt

Metamorphosed sedimentary rock outcrops west of the metamorphosed ultramafic rocks of unit D in the area west of Pomme d'Or (Fig. 1). Exploration-company data suggest that there are also ultramafic rocks in this area. The metamorphosed sedimentary rock may be correlated with unit E in the Wiluna area. The small area of metamorphosed ultramafic rock within unit E near the Erawalla Fault can be correlated with similar rocks within unit E to the west of Wiluna (Fig. 1).

Erawalla

The Erawalla area lies between the Wiluna and Mount Way areas. The greenstones east of the Erawalla Fault and west of Lake Way are largely composed of metamorphosed felsic volcanoclastic rocks, with some metamorphosed tholeiitic basalt, and minor metamorphosed ultramafic rocks. The metamorphic grade is greenschist facies. Most rocks in this area trend north-northwest and dip steeply to the east.

The metamorphosed felsic sedimentary rocks can be correlated with

unit E. Small metamorphosed ultramafic bodies near the west edge of Lake Way can be correlated with unit D. Along the Erawalla Fault there are small metamorphosed ultramafic bodies exposed as silica cap rock and talc schist. There is less metamorphosed ultramafic rock in this area than in the Wiluna and Mount Way areas.

An approximately 1 km-wide metabasalt outcrop about 1 km east of the Erawalla Fault correlates with the metabasalt within unit D west of the Honey-moon Well ultramafic complex.

Minor folds are common in the metamorphosed felsic sedimentary rocks, with fold axes plunging to the north-northwest. An isoclinal fold about 200 m across is mapped about 2.1 km northeast of Prospector Well. Such deformation can be recognized in pelitic meta-sedimentary rocks about 3 km north-northwest of Abercromby Well. Here, a well-developed schistosity is folded to form a tight fold, which is again overprinted by a later deformation, producing a crenulation cleavage.

Uramurdah Well

There is no exposure in the area immediately north of Lake Way and west of Uramurdah Well; however, aeromagnetic data show significant positive anomalies in this area (Fig. 2). A 2 km-long, narrow, north-northwesterly trending anomaly 2 km west-northwest of Uramurdah Well corresponds to siliceous and ferruginous metasedimentary rock revealed by drilling. Another 5 km-long, narrow anomaly 4 km south-southwest of Uramurdah Well corresponds to metamorphosed ultramafic rock revealed by drilling. The other three small areas of ultramafic rock shown in Figure 1 about half way between Wiluna and Uramurdah Well are interpreted from aeromagnetic data, as is a small area of mafic rock 4 km south-west of Uramurdah Well.

The metamorphosed ultramafic, mafic, and siliceous and ferruginous sedimentary rocks in the area west and south of Uramurdah Well may correlate with unit A at Wiluna.

Discussion

We propose a simple stratigraphic sequence, the Wiluna sequence, for the Wiluna greenstone belt. From its lowest stratigraphic position in the east to its highest position in the west, the sequence consists of five units: (unit A) metabasalt and metagabbro; (unit B) metabasalt; (unit C) metamorphosed felsic volcanic and sedimentary rocks; (unit D) metamorphosed ultramafic rock; and (unit E) metamorphosed felsic sedimentary and volcanic rocks. These units can be identified in the Wiluna, Mount Way, and Erawalla areas, although their thickness varies and the boundaries between these units are commonly sheared. Strike-parallel faults are present in the Wiluna greenstone belt, but at present there is no evidence for regional tectonic repetition of the greenstone

sequence. However, faults and internal tight folding have possibly modified the thickness of the units.

The stratigraphic sequence in the Wiluna greenstone belt is broadly similar to the sequence described by Swager et al. (1995) for the greenstones in the Kalgoorlie Terrane 600 km to the south. This indicates that the depositional and tectonic environments were probably similar.

Acknowledgments

We wish to thank Wiluna Mines and CRA Exploration for their generous support. These studies benefited greatly from numerous discussions with geologists working in this area, particularly Martin Gole and Aning Zhang, to whom we are grateful.

References

- BINNS, R. A., GUNTORPE, R. J., and GROVES, D. I., 1976, Metamorphic patterns and development of greenstone belts in the eastern Yilgarn Block, Western Australia, in *The Early History of the Earth* edited by B. F. WINDLEY: London, John Wiley and Sons, p. 303–313.
- EDWARDS, A. B. (editor), 1953, Gold deposits of Wiluna, in *Geology of Australian Ore Deposits: 5th Empire Mining and Metallurgical Congress*, Melbourne, p. 215–223.
- ELIAS, M., and BUNTING, J. A., 1981, Wiluna, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series.
- ELIAS, M., and BUNTING, J. A., 1982, Wiluna, W.A.: Western Australia Geological Survey, 1:250 000 Geological Series Explanatory Notes, 20p.
- GRIFFIN, T. J., 1990, Eastern Goldfields Province, in *Geology and mineral resources of Western Australia: Western Australia Geological Survey, Memoir 3*, p. 77–119.
- HAGEMANN, S. G., GROVES, D. I., and BROWN, P. E., 1995, Juxtaposition of fault bounded, disparate greenstone belt segments and implications for Archean lode-gold mineralization: Wiluna greenstone belt, Yilgarn Craton, Western Australia: Precambrian '95 (International Conference on Tectonics and Metallogeny of Early/Mid Precambrian Orogenic Belts), Montreal, Canada, 1995, Program and Abstracts, p. 119.
- HAGEMANN, S. G., GROVES, D. I., RIDLEY, J. R., and VEARNCOMBE, J. R., 1992, The Archean lode gold deposits at Wiluna, Western Australia: high-level brittle-style mineralization in a strike-slip regime: *Economic Geology*, v. 87, p. 1022–1053.
- HICKMAN, A. H., in prep., Gold mineralization in the Wiluna–Leonora region, Eastern Goldfields: Western Australia Geological Survey, Report.
- HILL, R. E. T., BARNES, S. J., GOLE, M. J., and DOWLING, S. E., 1990, Physical volcanology of komatiites: a field guide to the komatiites of the Norseman–Wiluna Greenstone Belt, Eastern Goldfields Province, Yilgarn Block, Western Australia: Geological Society of Australia, W.A. Division, Excursion Guide no. 1, 100p.
- LIU, S. F., GRIFFIN, T. J., WYCHE, S., and WESTAWAY, J., in prep., Sir Samuel, W.A.: Western Australia Geological Survey, 1:100 000 Geological Series.
- MACKEY, T. E., WHITAKER, A., and RICHARDSON, L. M., 1995, Total magnetic intensity, reduced to the geomagnetic pole, with northerly illumination colour pixel-image map of the northern Eastern Goldfields, W.A.: Australian Geological Survey Organisation, 1:1 000 000 map.

MORGAN, P. J., and EL-RAGHY, S., 1990, Matilda gold deposits, Wiluna, *in* Geology of the Mineral Deposits of Australia and Papua New Guinea, Volume 1 *edited by* F. E. HUGHES: Australasian Institute of Mining and Metallurgy, Monograph 14, p. 313–318.

NALDRETT, A. J., and TURNER, A. R., 1977, The geology and petrogenesis of a greenstone belt and related nickel sulphide mineralization at Yakabindie, Western Australia: *Precambrian Research*, v. 5, p. 43–103.

SWAGER, C., and GRIFFIN, T. J., 1990, Geology of the Archaean Kalgoorlie Terrane (northern and southern sheets): Western Australia Geological Survey, 1:250 000 Geological Map.

SWAGER, C., GRIFFIN, T. J., WITT, W. K., WYCHE, S., AHMAT, A. L., HUNTER, W. M., and MCGOLDRICK, P. J., 1995, Geology of the Archaean Kalgoorlie Terrane — an explanatory note: Western Australia Geological Survey, Report 48, 26p. (reprint of Record 1990/12).