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# Flora and vegetation of banded iron formations of the Yilgarn Craton: Brooking Hills area

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## ABSTRACT

The Brooking Hills and the South Cook Well Greenstone Belt are banded ironstone ranges located within the Southern Cross Granite-Greenstone Terrane in the eastern Murchison Interim Biogeographic Regionalisation for Australia (IBRA) sub-region. Recent increases in the value of iron ore has made the mining of banded iron formations economically prospective. A flora and vegetation survey of on these ranges recorded 104 taxa. These included a single range extension and no flora of conservation significance. Hierarchical classification identified four communities with the main floristic difference between upper slope and crest communities (upland) and lower and colluvial slopes communities (lowland). Soil nutrients, elevation and landform were correlated with the three dimensional ordination. The ranges within the survey were floristically different to previously surveyed ranges to the north indicating a species turnover from north to south, due to decreasing aridity. Ranges are currently under mining exploration and no part of the range is within conservation estate.

## INTRODUCTION

Banded iron formations (BIF) are iron rich deposits composed of alternating layers of iron and silica rich layers, formed 3.8 to 2.5 billion years ago by deposition in quiet, deep water (Page 2001). Within the Yilgarn Craton, BIFs are associated with greenstone belts, forming prominent strike ridges due to a greater resistance to erosion than the surrounding landscape. Pastoralism and mining are the main land uses within the Yilgarn Craton, with the latter focussed on gold and nickel. Recent increases in the value of iron ore have made the mining of BIF economically viable.

Previous floristic and vegetation surveys on the Yilgarn craton have been undertaken on the ironstone ranges on Cashmere Downs and the Mount Forrest-Mt Richardson area to the north of this current survey. Both surveys found unique floristic communities associated with different substrates and positions in the landscape (Meissner *et al.* 2009a, 2009b). The aim of this paper is to describe the flora and vegetation of Brooking Hills and the adjacent range on the South Cook Well Greenstone Belt and their relationships with environmental variables to provide baseline information for future management.

## Geology

The Brooking Hills and the adjacent range to the west are located within the Southern Cross Granite-Greenstone domain of the Youanmi Terrane. The ranges occur on two separate greenstone belts; the Illaara and South Cook Well Greenstone Belt (Chen 2004; Cassidy *et al.* 2006).

Brooking Hills represents the central part of the Illaara Greenstone Belt, which continues further north as the Mt Forrest-Mt Richardson area and was surveyed in 2006 (Meissner *et al.*, 2009b). The Illaara Greenstone Belt is dominated by BIF and metamorphosed mafic and ultramafic volcanic rocks (Chen 2004). Brooking Hills has two prominent parallel strike ridges of BIF and minor banded chert running north-south. Associated at the flanks of the ridges are metamorphosed mafic rock, metabasalt and quartzite, quartz metasiltsone formations (Chen 2004).

The main strike ridges of banded ironstone on the South Cook Well Greenstone Belt run in a north- south direction and occur approximately 12km to the west of Brooking Hills. Metagabbro, a coarse grained mafic rock, is commonly exposed on the flanks of the ironstone ridges or intercalated with the banded ironstone formations (Chen 2004).

## Climate

The climate of the region is Semi-desert Mediterranean with a mild wet winter and hot dry summers (Beard 1990). Mean annual rainfall at Cashmere Downs Station (ca 40km west of Brooking Hills) is 252.9mm, with moderate seasonal variation over the 83 years of record (1919–2002: decile 1, 128.5mm; decile 9, 426.9mm). Mean rainfall is spread throughout the year, with little winter-summer bias. The highest maximum temperatures occur during summer (January mean maximum temperature 36°C and mean 6.2 days above 40°C). Winters are mild with lowest mean maximum temperatures recorded for July of 17.5 °C. Temperatures occasionally fall below 0°C in winter (a mean 0.9 days below 0°C), with a mean minimum of 5.9°C in July.

## Vegetation

Past surveys of the Eastern Murchison IBRA sub-region have described the dominant species in the vegetation (Beard 1976; Milewski & Dell 1992; Keighery *et al.* 1995). The vegetation associations by Beard (1976) described the Brooking Hills and South Cook Well Greenstone Belt as shrubland of *Acacia aneura* (mulga) and *Acacia quadrimarginea* scrub. Pringle *et al.* (1994) mapped land systems of the eastern goldfields, incorporating information on soils, geology and vegetation. The Brooking Hills and South Cook Well ranges were mapped as part of the Brooking Land system, which is described as prominent ridges of banded ironstone formation supporting *A. aneura* shrublands with occasional minor halophytic communities in the south east. This land system was characterised by Stony Ironstone Mulga Shrublands (SIMS), a vegetation type characterised by shrublands of *A. aneura*, *Acacia ramulosa* and *Acacia tetragonophylla* and *Eremophila* spp. (*E. fraseri*, *E. forrestii*), *Senna* spp. over shrublands of *Sida calyxhymenia*, *Solanum lasiophyllum* and *Spartothamnella teucriiflora* (Pringle *et al.* 1994).

A flora and vegetation survey of the northern Illaara Greenstone Belt (Mount Forrest -Mount Richardson Range), approximately 5 km north of Mount Alfred, described seven vegetation communities (Meissner *et al.* 2009b). The most common community on the Mount Forrest – Mount Richardson range occurred on the crests and upper slopes and was described as *A. aneura*, *A. quadrimarginea*, *A. cockertoniana*, *Callitris columellaris* and *Grevillea berryana* over sparse to open shrubland of *Eremophila glutinosa*, *Drummondita microphylla*, *Thryptomene decussata*, *Baeckea* sp. Melita Station (H. Pringle 2738), *Dodonaea petiolaris*, *Aluta aspera* subsp. *hesperia* over sparse fernland of *Cheilanthes sieberi* subsp. *sieberi*.

# METHODS

The Brooking Hills and the South Cook Well Greenstone Belt are located in the Murchison IBRA region on Perrinvale pastoral station, approximately 240km north-west of Kalgoorlie, adjacent to the eastern tip of Lake Barlee (Fig. 1). Fifty 20 x 20 m quadrats were established on the crests, slopes and foot slopes of ranges on Brooking Hills and South Cook Well Greenstone Belt in August 2007 (Fig. 1). The quadrats were established using an environmentally stratified approach to cover the major geographical, geomorphologic and floristic variation but biased (non random) as there were restrictions in access to the range. Each quadrat was permanently marked with four steel fence droppers and its position was determined using a Global Positioning System (GPS) unit. All vascular plants within the quadrat were recorded and collected for later identification at the Western Australian Herbarium.

Data on topographical position, disturbance, abundance, size and shape of coarse fragments on surface, the amount of exposed bedrock, cover of leaf litter and bare ground were recorded following McDonald *et al.* (1990). Additionally, growth form, height and cover were recorded for dominant taxa in each stratum (tallest, mid and lower).

Twenty soil samples were collected from the upper 10cm of the soil profile within each quadrat. The soil was bulked and the 2mm fraction analysed for B, Ca, Co, Cu, Fe, K, Mg, Mn, Na, Ni, P, S and Zn using the Mehlich No. 3 procedure (Mehlich 1984). The extracted samples were then analysed using Inductively Coupled Plasma - Atomic Emission Spectrometer (ICP-AES). This procedure is an effective and cost efficient alternative to traditional methods for evaluating soil fertility and has been calibrated for Western Australian soils (Walton & Allen 2004). pH was measured in 0.01M $CaCl_2$ at soil to solution ratio of 1:5. Organic carbon was measured on soil ground to less than 0.15mm using Metson's colorimetric modification of the Walkley and Black method 6A1 (Metson 1956; Walkley 1947). Total Nitrogen was measured using the Kjeldahl method 7A2 (Rayment & Higgenson 1992). Electrical conductivity (EC) was based on a 1:5 soil/deionised water extract and measured by a conductivity meter at 25°C (Rayment & Higgenson 1992).

Quadrats were classified on the basis of similarity in species composition on perennial species only, to be consistent with previous studies of banded ironstone ranges (Gibson 2004 a, b). The quadrat and species classifications were undertaken using flexible Unweighted Pair-Group Mean Average (UPMGA) of Bray and Curtis similarities (? = 0; Belbin 1989). The quadrat classification was followed by similarity profile (SIMPROF) testing to determine the significance of internal group structures using permutation testing (Clarke & Gorley 2006).

Similarity percentages (SIMPER), based upon Bray Curtis similarities, was used to determine typifying species for each community. SIMPER analyses the contribution of individual species to the average similarity within groups and average dissimilarity between groups (Clarke & Warwick 2001).

Quadrats were ordinated using semi-strong hybrid (SSH) multidimensional scaling. Correlations between the environmental variables and SSH axis were determined using Prinicipal Component Correlation (PCC) analysis. The significance of theses correlations was determined by Monte-Carlo Attributes in Ordination (MCAO) routine in PATN (Belbin 1989). PCC is a routine that runs multiple linear regressions on the variables and the ordination coordinates, resulting in a vector for each variable within the ordination plot. The MCAO is a Monte-Carlo permutation test that determines the robustness of the PCC results by randomly assigning values of variables to objects and then running the PCC routine (Belbin 1989). The significance differences between quadrat groups for each environmental variable were tested

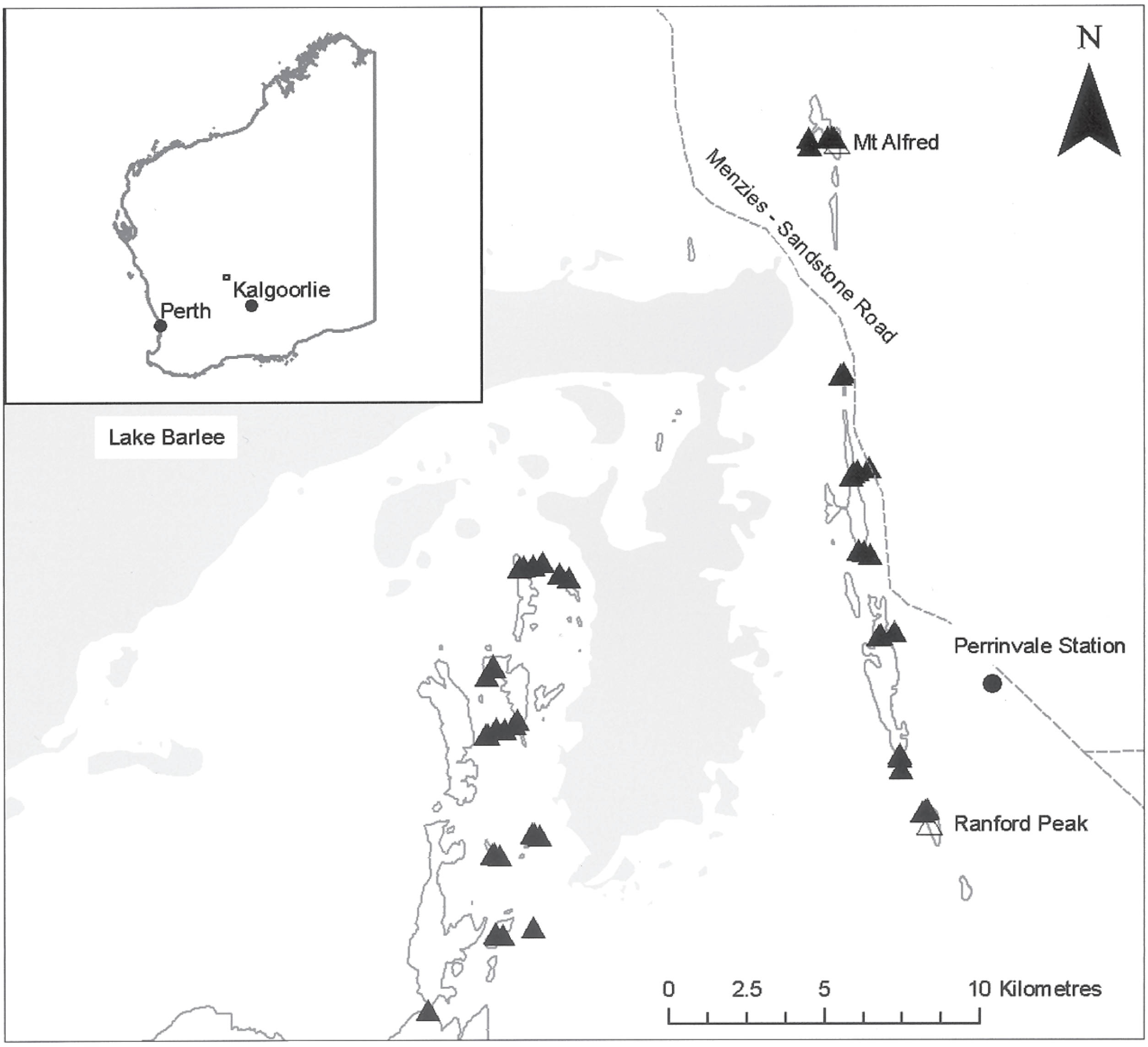


*Figure 1. Location of the Brooking Hills (right) and South Cook Well greenstone belt (left) study area, showing the location of 50 sites (▲). The 440m contour is shown with the highest peaks, Mt Alfred (495m) and Ranford Peak (487m).*

using Kruskall-Wallis non parametric analysis of variance (Siegel 1956), followed by non-parametric comparison (Zar 1999).

Taxonomic nomenclature generally follows Paczkowska and Chapman (2000).

## RESULTS

### Flora

A total of 104 taxa were recorded from the Brooking Hills and South Cook Well Greenstone Belt represented by 56 genera within 32 families. The dominant families were Caesalpiniaceae (nine taxa), Chenopodiaceae (eight), Mimosaceae (13), Myoporaceae (eight), and Poaceae (10). No flora of conservation significance and twenty two ephemerals, including one introduced species, were recorded from the ranges.

### Range Extensions

A single range extension, defined as any new record more than 200km from the nearest population, was collected during the survey. *Trachymene pilosa* is an annual herb to 30cm with small white flowers and heteromorphic fruit, with one bristly and one tuberculate mericarp (Hart & Henwood 2006). The nearest population is 200km to the south. It was found growing on the midslope of South Cook Well GB in open woodland of *A. aneura* and *Grevillea berryana* over *Eremophila forrestii.*

### Plant Communities

Ephemerals and singletons were removed resulting in a total of fifty one taxa used in the final analysis. Similarity profile (SIMPROF) analysis identified four significant groups ($p < 0.05$; Clarke & Warwick 2001). The first division in the dendrogram separated Community 4, found on the lower slopes of the ranges, from Community 1, 2, and 3, indicating a greater level of floristic dissimilarity between Community 4 and the other groups. The next division occurred between Community 3, found only on Brooking Hills, from Communities 1 and 2, found on midslopes and crests of both ranges.

Community 1 represented sites found on the midslopes to crests of Brooking Hills and South Cook Well range with higher cover of surficial bedrock. It was described as open to sparse shrublands of *A. aneura*, *Acacia quadrimarginea* and *Acacia cockertoniana* over open shrublands to shrublands of *Eremophila latrobei*, *D. petiolaris*, *Dodonaea rigida*, and *Eremophila georgei* over isolated to sparse shrublands of *Eremophila georgei*, *Ptilotus obovatus* and *Sida chrysocalyx*. Typical species were *E. latrobei* subsp. *latrobei*, *A. aneura* var. cf. *microcarpa*, *E. georgei*, *Sida chrysocalyx*, *D. rigida*, *P. obovatus* and *A. quadrimarginea* (Table 1). This community had the lowest mean species richness of 12.3 taxa (±0.4 SE) per plot.

Community 2 was found on the upper slopes and crests on Brookings Hills, with all sites except one located on Mt Alfred in the northeast of the survey area. It is described as open to sparse shrubland of *A. aneura* over open shrubland of *E. georgei*, *Philotheca brucei* subsp. *brucei* and *P. obovatus*. The typical species of this community were *D. petiolaris*, *E. georgei*, *P. obovatus* and *S. chrysocalyx* (Table 1). The species richness was 12.5 taxa (±2.4) per plot.

Community 3 was represented by 4 sites found on slopes and a crest of Brooking Hills. It was characterised by open to sparse shrublands of *A. aneura* and *A. quadrimarginea* over sparse shrublands of *P. obovatus* and *E. latrobei* subsp. *latrobei*. The characteristics species of the community were *E. latrobei* subsp. *latrobei*, *P. obovatus*, *Solanum lasiophyllum*, *Abutilon cryptopetalum*, *A. quadrimarginea*, *A. tetragonophylla* and *C. sieberi* subsp. *sieberi* (Table 1). This community had the highest mean species richness of 13.8 (±1.0) taxa per plot.

Community 4 was a common community encountered found on both ranges, mainly on lower and simple slopes of the ranges. It is described as open to sparse shrubland of *A. aneura*, *A. quadrimarginea*, and *A. ramulosa* var. *ramulosa* over open to sparse shrubland of *E. forrestii* subsp. *forrestii*, *Senna* spp. (*S. glaucifolia*, *S. artemisioides* subsp. *filifolia*), *D. rigida* and *E. georgei*. Typical species are *E. forrestii*, *P. obovatus*, *D. rigida*, *A. tetragonophylla*, *A. ramulosa* var. *ramulosa*, *A. aneura* var. cf. *aneura* and *Solanum lasiophyllum* (Table 1). Mean species richness is 13.6 taxa (±0.7) per plot.

### Environmental variables

Non-parametric analysis found significant differences between 12 of the 17 soil attributes, mainly differentiating Community 1 from Communities 3 and 4 (Table 2). Community 2 shows intermediate soil parameters between these communities. It occurs on intermediate soil acidity, but similar fertility to Community 1 and intermediate trace elements. However, Community 2 had the highest phosphorus and iron soil concentrations, which were significantly different to Community 4 (Table 2).

Community 1, a common community, occurred on the most acidic sites and fertile soil (Table 3). The community had significantly higher organic carbon and total nitrogen than Community 4 but lower magnesium than Community 3. Community 1 had significantly lower concentrations of the minor trace elements, cobalt, copper, manganese and nickel than Community 3 and 4 and significantly lower concentration of iron and sulphur than Community 4 (Table 2).

All the site attributes, except land type, showed a significant difference between communities (Table 3). Similar to the results of the soil nutrients, the main differences occurred between Community 1, on the midslopes and crests, and Community 4, lower and colluvial slopes of the ranges. Community 1 occurred at higher elevations, had a greater abundance of coarse fragment, greater coarse fragment size, rock outcrop cover, steeper slopes and runoff, and shallower soils than Community 4. Community 1 sites tended to occur on crest and upper slopes while Community 4 on lower and simple slopes.

The three dimensional SSH ordination (stress = 0.1840) substantiates the univariate results (Fig. 2). Community 1 and 2, both typical of sites on upper slopes and crests of the range, occur in the upper half of Fig. 2a, and correlate with high coarse fragment abundance and size, elevation, rock outcrop abundance, iron and organic carbon are higher in the upper right quadrant of axes 1and 2 (Fig. 2c). In contrast, Community 4, characterised sites from lower slopes, occurs separately from Community 1 and 2 and correlates with deeper soil, higher concentrations of several soil nutrients. Axes 2 and 3 show a clearer separation of the communities and that Community 3 is intermediate between Communities 1 and 4 (Fig. 2b, 2d).

## DISCUSSION

### Flora

A total of 104 taxa were recorded from Brooking Hills and South Cook Well Greenstone Belt, a number similar number to the 116 taxa recorded on Mount Forrest -Mt Richardson range (Meissner *et al.* 2009b). However, the areas shared 42 taxa even though Brooking Hills is only 15km to the south. The low number of common taxa indicates a species turnover progressing south on the greenstone belt. Shifts in species composition have been observed on other ironstone ranges where species composition was very different between two adjacent parts of the same range (Meissner & Caruso 2008c). This north-south change in species is correlated with a gradient of decreasing aridity and increasing influence of flora from the South West Province (Beard 1976; Beard *et al.* 2000).

No endemic or taxa of conservation significance were recorded for these ranges. The paucity of endemic or

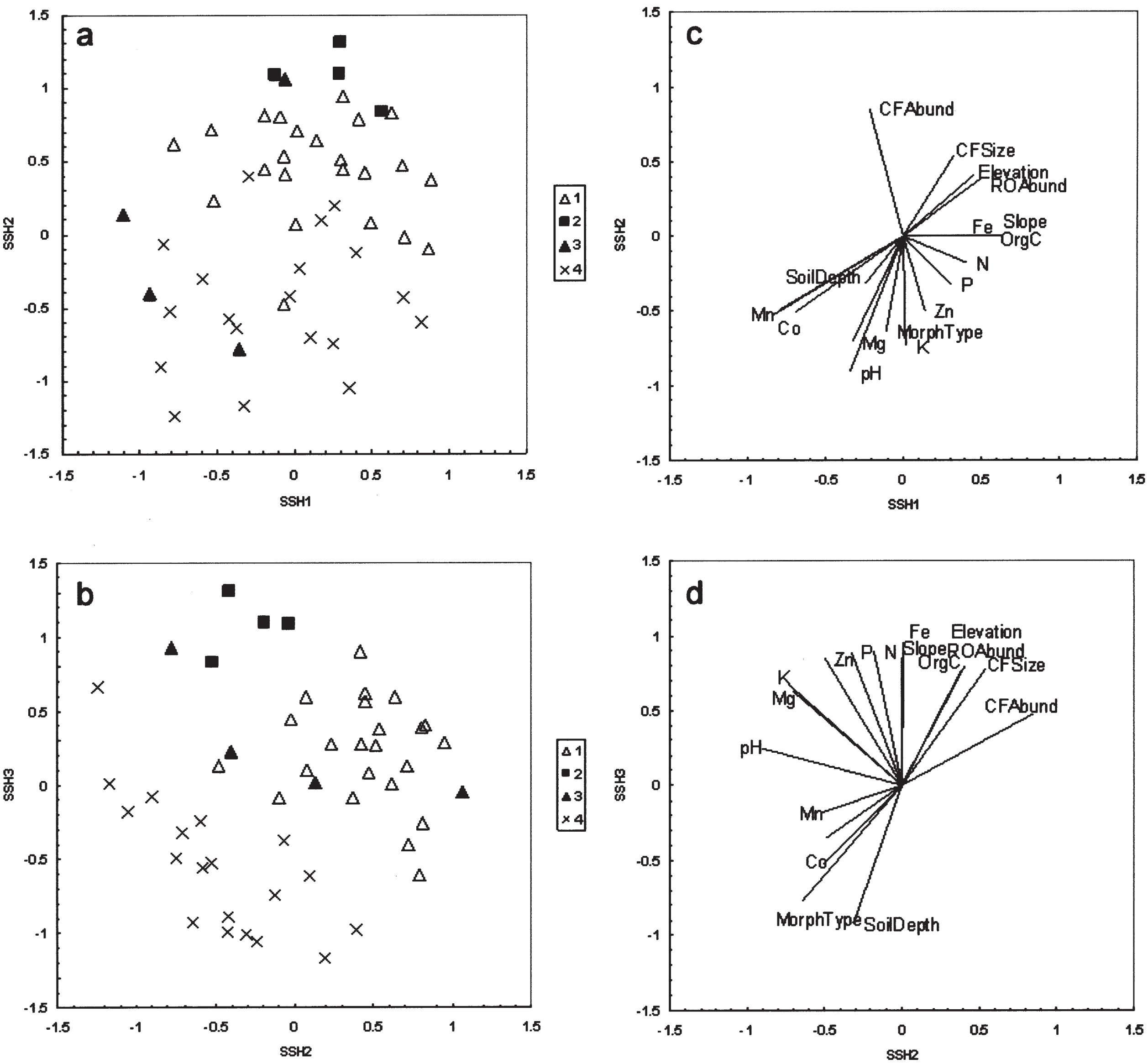


*Figure 2. Three dimensional ordination showing Axis 1, 2 and 3 of the 50 quadrats established on Brooking Hills and South Cook Well greenstone belt. The four plant communities and lines showing the strength and direction of the best fit linear correlated variables (P<0.05) are shown.*

conservation taxa is not unusual for ironstone ranges, and low numbers have been recorded on other ranges within the Eastern Murchison (Markey & Dillon in press; Meissner *et al.* 2009b). In contrast, ranges within the South Western interzone (Beard *et al.* 2000) and Yalgoo IBRA subregion, show a high level of endemic and rare species (Gibson *et al.* 1997; Markey & Dillon 2008a; Meissner & Caruso 2008b). These latter ranges are found in areas that intergrade between Eremaeum and South West flora (Beard *et al.* 2000).

## Plant Communities

This survey described four communities on the Brooking Hills and South Cook Well Greenstone Belt. Unlike the Mount Forrest – Mount Richardson Range to the north (Meissner *et al.* 2009b), there were no restricted communities. Communities 1 and 4 were widespread, occurring on both ranges, while the remaining communities (2 & 3) were found only on Brooking Hills. These communities appear to be a continuum between the upland (Community 1) and lowland community (Community 4). Community 2, occurring on upper slopes and crests, showed floristic affinities with Community 1, also on midslopes to crests of the ranges. As well as similar soils and site parameters, Community 2 shares three characteristic species, *E. georgei*, *S. chrysocalyx* and *P. obovatus*, with Community 1. This relationship is shown in the ordination and classification, with both communities occurring close in three dimensional space. In contrast, Community 3, occurring on slopes and crest has a closer affinity to Community 4, on the lowlands. Similarly, Community 3 and 4 have similar soil nutrients, being less acidic and higher concentrations of trace elements, and occurring lower in the landscape with deeper soils and less and smaller coarse fragments. They also shared three characteristic species, *Solanum lasiophyllum*, *A. tetragonophylla* and *Ptilotus obovatus*.

Communities 1 and 4 generally correlate to the vegetation type mapped within the Brooking Land system (Pringle *et al.* 1994). The Brooking Land system encapsulated all four landforms; ridges, hillslopes, stony plains and drainage tracts, and all, except the drainage tracts, were sampled in the survey of the Brooking Hills area. The vegetation types within these landforms were all described under one broad vegetation type: Stony Ironstone Mulga Shrublands is a broad vegetation type which encompasses the upland and lowland community types from this survey.

The main floristic difference found in this survey occurred between upland (Community 1) and lowland (Community 4) communities. This is similar to patterns found on other ironstone ranges (Markey & Dillon 2008 a, b; Meissner & Caruso 2008a, 2008b, 2008c). These floristic differences were reflected in differences in soils and site characters, though these may not necessarily drive the floristic communities. The upland community occurred at higher elevations on steeper slopes with a greater cover of surficial rock and shallower soil. Many of the mobile soil nutrients, Mg, Ca, Cu, Mn, Na, Ni and S, were all lower in upland and higher in the lowland sites, attributed to leaching and weathering in the soil (Britt *et al.* 2001).

A preliminary analysis of the floristic communities between the Mount Forrest- Mount Richardson range (Meissner *et al.* 2009b) and the ranges in this survey, found that the ranges were significantly different (ANOSIM Global R = 0.379, $P < 0.01$, Clarke & Warwick 2001). This indicates a rapid species turnover from north to south, confirming the differences found in the flora. The two ranges are part of the same greenstone belt but are not continuous and are separated by several breaks in the strike ridges. The Illaara Greenstone Belt continues further south, with the next expression of low strike ridges 15km south of Ranford Peak. If an additional survey was undertaken on the southern part of the Illaara Greenstone Belt further species turnover will be expected.

The difference between the north and south ranges was not found in eastern and western ranges in this survey. The communities in this survey occurred on both greenstone belts (Illaara and South Cook Well) which are separated by 15km in an east-west direction. This adds support for the presence of an environmental gradient such as increasing rainfall and decreasing aridity (Beard 1976).

## Conservation

The BIFs of the Brooking Hills and South Cook Well Greenstone Belt are currently under prospective mining interest. Unlike the Mount Forrest-Mount Richardson range, the ranges within this survey are not within secure Western Australian Conservation Estate.

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## APPENDIX

Floristic list for Brooking Hills, including all taxa from the sampling quadrats and adjacent areas. Nomenclature follows Paczkowska and Chapman (2000), * indicates introduced taxon.

**Adiantaceae**
*Cheilanthes brownii*
*Cheilanthes sieberi* subsp. *sieberi*

**Amaranthaceae**
*Ptilotus aervoides*
*Ptilotus obovatus*

**Apiaceae**
*Trachymene ornata*
*Trachymene pilosa*

**Asclepiadaceae**
*Marsdenia australis*
*Rhyncharrhena linearis*

**Asteraceae**
*Olearia humilis*
*Olearia stuartii*
*Rhodanthe battii*
*Streptoglossa liatroides*

**Brassicaceae**
*Lepidium oxytrichum*

**Caesalpiniaceae**
*Senna artemisioides* subsp. *filifolia*
*Senna artemisioides* subsp. *helmsii*
*Senna artemisioides* subsp. x *sturtii*
*Senna cardiosperma*
*Senna charlesiana*
*Senna glaucifolia*
*Senna glutinosa* subsp. *chatelainiana*
*Senna pleurocarpa* var. *pleurocarpa*

**Casuarinaceae**
*Casuarina obesa*

**Chenopodiaceae**
*Chenopodium melanocarpum*
*Chenopodium saxatile*
*Enchylaena tomentosa* var. *tomentosa*
*Maireana convexa*
*Maireana pyramidata*
*Maireana suaedifolia*
*Rhagodia eremaea*
*Sclerolaena gardneri*

**Cucurbitaceae**
**Cucumis myriocarpus*

**Euphorbiaceae**
*Euphorbia tannensis* subsp. *eremophila*

**Geraniaceae**
*Erodium crinitum*
*Erodium cygnorum*

**Goodeniaceae**
*Scaevola spinescens*

**Lamiaceae**
*Prostanthera althoferi* intergrade
*Prostanthera althoferi*
*Spartothamnella teucriiflora*

**Lobeliaceae**
*Isotoma petraea*

**Loranthaceae**
*Amyema fitzgeraldii*
*Amyema gibberula* var. *gibberula*
*Amyema preissii*
*Lysiana murrayi*

**Malvaceae**
*Abutilon cryptopetalum*
*Abutilon oxycarpum* subsp. *prostratum*
*Sida chrysocalyx*
*Sida* sp. unisexual (N.H. Speck 574)

**Mimosaceae**
*Acacia* cf. *aneura*
*Acacia aneura* var. cf. *aneura*
*Acacia aneura* var. cf. *argentea*
*Acacia aneura* var. cf. *microcarpa*
*Acacia burkittii*
*Acacia cockertoniana*
*Acacia* cf. *cockertoniana*
*Acacia craspedocarpa*
*Acacia minyura*
*Acacia quadrimarginea*
*Acacia ramulosa* var. *ramulosa*
*Acacia tetragonophylla*

**Myoporaceae**
*Eremophila alternifolia*
*Eremophila forrestii* subsp. *forrestii*
*Eremophila georgei*
*Eremophila latrobei* subsp. *latrobei*
*Eremophila metallicorum*
*Eremophila oldfieldii* subsp. *angustifolia*
*Eremophila platycalyx* subsp. *platycalyx*

**Myrtaceae**
*Thryptomene decussata*

**Nyctaginaceae**
*Boerhavia coccinea*

**Phormiaceae**
*Dianella revoluta* var. *divaricata*

**Poaceae**
*Aristida contorta*
*Austrostipa platychaeta*
*Austrostipa scabra*
*Enneapogon caerulescens*
*Eragrostis dielsii*
*Eragrostis eriopoda*
*Eriachne helmsii*
*Eriachne pulchella*
*Monachather paradoxus*
*Paspalidium basicladum*

**Portulacaceae**
*Calandrinia eremaea* complex

**Proteaceae**

*Grevillea berryana*
*Grevillea nematophylla* subsp. *supraplana*
*Hakea preissii*

**Rubiaceae**

*Psydrax latifolia*
*Psydrax rigidula*
*Psydrax suaveolens*

**Rutaceae**

*Philotheca brucei* subsp. *brucei*

**Santalaceae**

*Santalum spicatum*

**Sapindaceae**

*Dodonaea lobulata*
*Dodonaea petiolaris*
*Dodonaea rigida*
*Dodonaea viscosa* subsp. *angustissima*

**Solanaceae**

*Nicotiana* cf. *rotundifolia*
*Solanum ashbyae*
*Solanum ellipticum*
*Solanum lasiophyllum*
*Solanum nummularium*

**Sterculiaceae**

*Brachychiton gregorii*

**Urticaceae**

*Parietaria cardiostegia*

**Table 1**

Sorted two-way table of quadrats established on Brooking Hills and the South Cook Well greenstone belt showing species by plant community. Taxa shaded grey within a community are typifying species identified by SIMPER (Clarke & Warwick 2001) at the 4group level (P< 0.05).

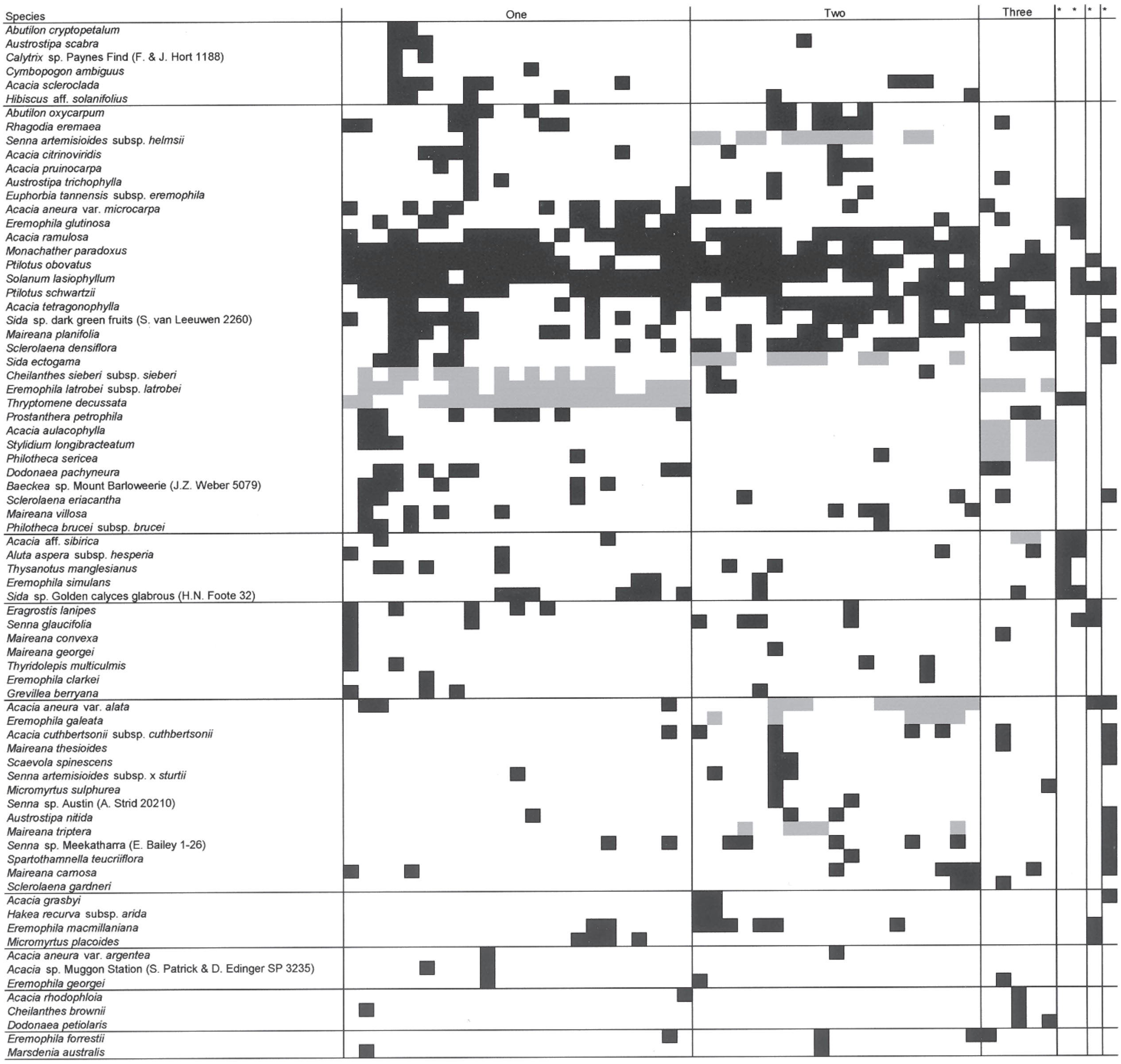

**Table 2**

Mean values for soil attributes (measured in mg/kg except EC and pH) by plant community type. Differences between ranked values tested using Kruskall –Wallis non-parametric analysis of variance. Standard error in parentheses. a and b represent significant differences between community types at P < 0.05 (n = number of quadrats, P = probability).

| | Community Type | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | P |
| EC | 4.3 (0.4) | 27.0 (20.4) | 6.5 (3.8) | 6.1 (3.5) | **0.0212** |
| pH | 4.3 (0.1)a | 5.3 (0.6)ab | 5.5 (0.4)b | 5.0 (0.2)b | **<0.0001** |
| P | 25.9 (7.4)ab | 87.0 (52.0)a | 36.0 (31.3)ab | 8.8 (1.8)b | **0.0167** |
| K | 173.4 (16.6) | 335.0 (66.5) | 282.5 (76.3) | 203.6 (21.6) | **0.0357** |
| Mg | 63.3 (6.1)a | 260.8 (153.6)ab | 292.5 (136.2)b | 128.5 (29.0)ab | **0.0008** |
| Org C | 1.3 (0.1)a | 2.0 (0.8)a | 0.7 (0.3)ab | 0.7 (0.1)b | **0.0005** |
| Total N | 0.09 (0.01)a | 0.17 (0.08)a | 0.08 (0.03)ab | 0.06 (0.01)b | **0.0033** |
| B | 0.28 (0.04) | 1.09 (0.84) | 0.45 (0.23) | 0.31 (0.04) | 0.9197 |
| Ca | 300.9 (29.0) | 777.5 (407.9) | 580.0 (208.3) | 616.3 (229.6) | 0.1490 |
| Co | 0.59 (0.17)a | 0.48 (0.29)ab | 2.62 (0.69)b | 1.94 (0.30)b | **0.0002** |
| Cu | 0.89 (0.03)a | 0.95 (0.18)ab | 1.58 (0.18)b | 1.57 (0.18)b | **<0.0001** |
| Fe | 98.7 (15.2)a | 144.5 (39.8)a | 66.5 (24.6)ab | 49.1 (4.8)b | **0.0008** |
| Mn | 40.4 (5.0)a | 55.8 (6.2)ab | 147.5 (18.8)b | 97.3 (13.8)b | **0.0002** |
| Na | 2.5 (0.4)a | 66.3 (61.3)ab | 11.3 (2.8)b | 3.1 (1.2)a | **0.0019** |
| Ni | 0.55 (0.14)a | 0.35 (0.03)ab | 1.48 (0.50)b | 1.15 (0.20)b | **0.0014** |
| S | 12.4 (0.6)a | 21.5 (12.4)ab | 8.5 (2.6)ab | 20.6 (12.8)b | **0.0143** |
| Zn | 1.7 (0.2) | 7.2 (3.8) | 3.3 (1.7) | 1.7 (0.2) | 0.1699 |
| n | 23 | 4 | 4 | 19 | |

**Table 3**

Mean values for site attributes by plant community type; Elevation (m); Soil depth (1 – skeletal, 2 – shallow, 3 – deep); Coarse fragment (CF) abundance (0 – no coarse fragments to 6 very abundant coarse fragments); Maximum size of coarse fragments (1 – fine gravely to 7 large boulders); Rock outcrop (RO) abundance (0 – no bedrock exposed to 5 – rockland); Slope (degrees), runoff ( 0 – no runoff, 1 – very slow, 2 – Slow, 3 – Moderately rapid); Morphology type (1 – crest, 2 – upper slope, 3 – mid slope, 4 – lower slope, 5 – simple slope, 6 – hillock); Land Type (1 – hillcrest, 2 – hill slope, 3 – footslope, 4 – summit, 5 – mount, 6 – breakaway). Differences between ranks tested using Kruskall –Wallis non-parametric analysis of variance. Standard error in parentheses. a, b and c represent significant differences between community types at P < 0.05 (n = number of quadrats, P = probability, ns = not significant).

| | **Community Type** | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **P** |
| Elevation (m) | 450.9 (3.6)a | 470.5 (10.5)a | 433.0 (4.9)ab | 424.2 (3.3)b | **<0.0001** |
| Soil Depth | 1.5 (0.1)a | 1.5 (0.3)ab | 1.8 (0.3)ab | 2.2 (0.1)b | **0.0062** |
| Coarse Fragment Size | 5.6 (0.2)a | 5.8 (0.3)a | 4.5 (0.6)ab | 3.6 (0.3)b | **<0.0001** |
| Rock outcrop abundance | 2.6 (0.4)a | 1.5 (0.9)ab | 1.0 (1.0)ab | 0.5 (0.3)b | **0.0020** |
| Slope | 9.2 (1.1)a | 12.5 (2.7)ab | 8.5 (3.4)ab | 4.9 (1.1)b | **0.011** |
| Runoff | 2.5 (0.2)a | 2.5 (0.6)ab | 2.8 (0.3)ab | 1.6 (0.2)b | **0.0208** |
| CF Abundance | 4.7 (0.1)a | 4.3 (0.3)ab | 4.5 (0.3)ab | 3.6 (0.3)b | **0.0038** |
| Land Type | 2.1 (0.2) | 2.0 (0.6) | 2.5 (0.5) | 2.8 (0.2) | 0.0685 |
| Morph Type | 1.9 (0.2)a | 1.8 (0.5)ab | 2.8 (0.6)ab | 3.6 (0.3)b | **0.0005** |
| n | 23 | 4 | 4 | 19 | |