Geology and soils of the Warra LTER Site: a preliminary description

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Abstract

The bedrock geology of the Warra LTER Site has been mapped at 1:25 000 scale. It is dominated by Jurassic dolerite and derived Quaternary slope deposits that together cover about two-thirds of the area. Sedimentary and metamorphic rocks, comprising Precambrian quartzite, dolomite, slate and phyllite together with Permo-Carboniferous sedimentary rocks of the Parmeener Supergroup (mudstone, siltstone, sandstone, tillite, conglomerate) predominate in the west. Cambrian volcanic-ultramafic rocks and Quaternary alluvium and morainal deposits cover only minor areas.

The soil pattern is diverse and shows strong links to geology and vegetation. Organic soils characterised by reddish-black fibrous peats are invariably associated with a vegetation cover of heath or scrub. These soils are predominant on quartzites, and they also occur sporadically on dolomite, slate, phyllite and dolerite. Where the vegetation cover is forest, mineral soils with gradational texture-profiles are prevalent. Texture-contrast profiles are mainly confined to soils formed on Permo-Carboniferous sandstones and conglomerates. Soils formed on Quaternary slope deposits derived from dolerite have been described and sampled in some detail from a limited area in the south-eastern part of Warra, but elsewhere only cursory descriptions are available and the distribution of the soils has not been mapped.

Introduction

The bedrock geology of the area has been mapped recently at 1:25 000 scale (Mineral Resources Tasmania 1997, 2001) and at this scale provides reasonably reliable data on the spatial distribution and broad composition of geological units. Further information on the geology and geomorphology is given by Sharples (1994).

Over most of the area, information on the properties and spatial distribution of soils is sparse. The soils have not yet been systematically mapped, and only generalised information on soil properties is available from previous land system surveys (Davies 1988; Pemberton 1989). However, a relatively detailed soil study has been carried out recently on a small area of undulating and easy rolling land used for silvicultural trials in the south-eastern part of Warra.

Pre-harvesting soil and site surveys together with intensive sampling for laboratory analysis were carried out during 1997–1998 in four of the coupes (WR001B, WR008B, WR008C, WR008H) used for testing various harvesting techniques adjacent to Manuka road. Transects with sampling points established at intervals of either 25 m or 50 m were established along access tracks cut within each coupe. A total of 150 observations of substrate material, soil drainage class and understorey vegetation were completed for the four coupes. The soil observations were made using a hand auger to depths between 0.8–1.0 m, or shallower if impeded by rock. Soil samples were collected for determination of bulk density and selected chemical properties (pH, organic carbon, total nitrogen, total and available phosphorus, exchangeable calcium, magnesium, potassium and sodium). Soil drainage class was inferred from colour

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patterns observed in soil samples obtained from auger borings at each site.

Geology

This section gives a brief overview of the main geological units described in the 1:25 000 scale map sheets (*Nevada, Weld* and *Picton*) covering Warra. The geological assemblage includes a wide range of sedimentary rocks (mudstone, siltstone, sandstone, tillite, conglomerate, dolomite, quartzite, coal), metamorphic rocks (slate and phyllite) and basic igneous rocks (basaltic volcanic rocks, ultramafic rocks, dolerite). They are outlined in chronological order from the oldest to the youngest.

Precambrian rocks (c. > 580 million years)

This group comprises three main rock types: (1) quartzite, (2) dolomite and (3) slate and phyllite. The quartzite occurs mainly in the western part of Warra on Gallagher Plateau, with a small inlier adjacent to Glovers Bluff in the east. At Glovers Bluff the quartzites are hard, white, fine-grained siliceous rocks.

Dolomite, slate and phyllite occur mainly in the western part adjacent to the quartzites of Gallagher Plateau. The dolomite is generally fine-grained, pale-grey coloured and relatively pure apart from the presence of secondary silica.

Cambrian rocks (c. 580–500 million years)

This mainly volcanic-ultramafic association occupies only a very small area south-east of Glovers Bluff, where it comprises basaltic volcanic rocks, ultramafic igneous rocks, tuffs, and derived conglomerate, sandstone and shale.

Permo-Carboniferous rocks (c. 300–250 million years)

This group comprises sedimentary rocks of the Parmeener Supergroup and includes mudstone, siltstone, sandstone, tillite and conglomerate with lenses of coal in places. They occur in the western part of the region in association with older Precambrian rocks and in the north-east and south adjacent mainly to younger rocks of Jurassic age.

Jurassic dolerite (c. 170 million years)

Jurassic dolerite dominates the eastern part of Warra, covering about one-third of the total area. The dolerite is typically a very hard, dark bluish-grey crystalline rock, varying in grain size from very fine to medium. It weathers to form a distinctive yellow-brown or orange-coloured rind around exposed basement rocks and floaters.

Quaternary deposits (c. < 1.8 million years)

This unit includes alluvial deposits associated with the floodplains and terraces of the Huon and Weld Rivers and major tributary streams, as well as extensive deposits of colluvium on hill slopes, and minor morainal deposits (tills) at higher elevations.

Colluvial deposits derived from Jurassic dolerite form a mantle of varying thickness over a relatively wide area in the central and south-eastern parts of Warra. They cover about one-third of the total area and extend from elevations of about 1200 m near Mount Weld in the north to about 80 m just to the west of the confluence of the Huon and Picton Rivers. These deposits comprise mainly cobbles and boulders derived from dolerite occurring within a clayey matrix, and overlie dolerite bedrock as well as other basements such as the Permo-Carboniferous rocks and Precambrian dolomite. Colluvium derived from other rock types also occurs, but its distribution and properties are poorly known.

The colluvium is attributed to deposition caused by periglacial processes (mainly frost creep and solifluction) during the cold climatic phase of the last ice age, as well as more recent mass movement (landslides). The various Quaternary landforms typical of those occurring at Warra have been described by Sharples (1994).

Soils

The soil pattern of the Warra LTER Site is highly diverse and reflects the marked variation in the environmental factors of geology, topography, vegetation and, to a lesser extent, climate. Geology plays a major role in determining soil characteristics and together they show clear links to the major types of natural vegetation occurring in the area. The soils are described in relation to the main geological units outlined previously. Because of their very limited distribution, soils on Cambrian rocks and Quaternary alluvium are not described here.

Soils on Precambrian rocks and derived Quaternary slope deposits

Organic soils formed under a vegetation cover of sedgeland/heath or scrub predominate on quartzite. Profiles are characterised by 20–50 cm of dark reddish-brown to reddish-black fibrous peat overlying sand and gravels. They have low levels of nutrients and are highly susceptible to erosion, particularly on exposed sites.

On dolomite, slate and phyllite, the soils are highly variable, with organic soils similar to those formed on quartzite occurring under sedgeland/heathland or scrub and relatively deep mineral soils occurring under a forest cover. Wet eucalypt forest predominates with lesser areas of mixed forest and rainforest. The mineral soils generally have gradational texture-profiles characterised by dark-coloured loamy topsoils overlying brown clay loams and clays. Reddish-brown fibrous peat often occurs as a surface layer on soils in gullies and on protected slopes. Nutrient levels are likely to vary from low to medium.

Soils on Permo-Carboniferous rocks and derived Quaternary slope deposits

These soils occur mainly under forest, although sedgeland/heathland and scrub are locally dominant on a relatively small area in the western part of Warra. Profile features are determined largely by texture of the substrate; on sandstones the soils generally have texture-contrast profiles, whereas on siltstone or mudstone gradational texture-profiles predominate. Texture-contrast soils tend to be moderately well drained and have profiles characterised by dark-coloured sandy loams overlying bleached or pale-coloured sands or sandy loams that in turn overlie yellowish-brown sandy clay loams. Nutrient levels are likely to be low, and erodibility is assessed as high. Gradational soils formed on siltstones and mudstones generally have somewhat impeded drainage, and profiles are characterised by loamy topsoils overlying grey and brown-mottled clay loams and clays. Nutrient levels are likely to be higher and erodibility lower than texture-contrast soils on sandstone.

Soils on Jurassic dolerite and Quaternary deposits derived from dolerite

Soils formed on dolerite bedrock and derived colluvium cover the largest area within Warra. They can be subdivided into two main components: (1) soils at high elevation under alpine vegetation (heath, herbfields, scrub) and (2) soils at mid and low elevation under wet forest.

Soils under alpine vegetation.—These soils are generally shallow and extremely stony, and they often occur in association with bare rock fields and scree slopes. Surface layers frequently comprise organic loams or fibrous peats overlying shallow brown or grey-coloured loamy subsoils with abundant rock fragments. Deeper soils formed on glacial till sometimes occur on lower slopes under open woodland. They have gradational profiles characterised by very rocky, loamy topsoils overlying yellowish-brown clayey subsoils with abundant rock fragments. Nutrient levels are likely to be low.

Soils under wet forest.—These soils exhibit a very wide range of stoniness and depth to bedrock. Relatively deep (> 1 m) soils often occur on slope deposits, particularly those at

Table 1. Results of bulk density and some chemical properties for surface and subsurface layers from soils on Quaternary slope deposits derived from dolerite, Manuka Road. (Data are means ± standard deviations.)

	Soil Depth (cm)			
Soil Property	0–5 cm	5–10 cm	0–10 cm	10–20 cm
Bulk density (Mg/m^3)	0.58 ± 0.13[1]	0.84 ± 0.22[1]	0.74 ± 0.14	-
pH	4.8 ± 0.4	5.0 ± 0.4	-	5.1 ± 0.4
Organic C (%)	7.7 ± 2.3	4.0 ± 0.9	-	2.6 ± 0.7
Total N (%)	0.28 ± 0.08	0.18 ± 0.05	-	0.12 ± 0.04
Total P (%)	0.015 ± 0.006	0.012 ± 0.005	-	0.01 ± 0.005
Available P (mg P/kg)[2]	4.6 ± 3.0	2.0 ± 1.2	-	0.6 ± 0.8

[1] Results of 10 samples from one coupe
[2] Colwell extraction method

lower elevation derived from periglacial weathering and accumulation. Conversely, shallow and very stony soils frequently occur on ridge crests and very steep slopes in association with exposed bedrock. Soil drainage is also highly variable, ranging from rapidly drained, extremely stony soils to poorly drained soils in depressions and lower slopes subject to prolonged seepage from sites upslope. Generally, however, most soils are well drained or imperfectly drained with gradational texture-profiles. These soils are described in the following section.

Soils of the silvicultural trial sites, Manuka Road

Results from transects carried out in each of the four compartments show that all the soils are formed on slope deposits derived from Jurassic dolerite. Stones and large boulders of dolerite frequently occur on the soil surface. Permian sedimentary rocks underlie the slope deposits at variable depths but are generally greater than 1.5 m deep. Immediately to the east of the trial sites, Permian rocks outcrop on the soil surface and to the west they are exposed in road batters.

Analysis of the results for drainage class reveals that the majority (56%) of the soils in the trial sites are well drained or moderately well drained, with subdominant (32%) imperfectly drained soils and relatively minor (12%) poorly drained soils. Clear links between soil drainage class and understorey vegetation were recorded during the transects. Well-drained soils often had a cover of Banksia (*Banksia marginata*), whereas imperfectly drained soils frequently had a dense cover of cutting grass (*Gahnia grandis*) and poorly drained soils invariably supported tea-trees (*Leptospermum* spp.) and paper-barks (*Melaleuca* spp.). The poorly drained soils occur mainly in shallow depressions or small hollows formed on gently undulating slopes, whereas freely drained soils occur preferentially on rises and mounds in undulating terrain, and on rolling and steeper slopes at higher elevation.

Well-drained and moderately well-drained soils are characterised by relatively thin (< 10 cm) dark brown, clay loam topsoils overlying yellowish-brown light to medium clays. They are most closely correlated with 'Kermandie' soil profile class (Grant *et al.* 1995). Imperfectly drained soils are characterised by relatively thin (< 10 cm), very dark greyish-brown, humic clay loam topsoils overlying yellowish-brown, light and medium clays with many light grey mottles and few to common dark brown worm casts. They are most closely correlated with 'Murdunna' soil profile class (Grant *et al.* 1995). Full descriptions of a representative profile of both well-drained and imperfectly drained soils are appended.

Analytical data for surface (0–5 cm, 5–10 cm) and subsurface (10–20 cm, 20–30 cm) layers are presented in Pennington and Laffan (2001). Statistical analyses comparing well-drained and imperfectly/poorly drained soils showed that significant differences occur in only two properties; well-drained soils have higher total phosphorus (0–5 cm), and lower exchangeable magnesium (0–5 cm and 5–10 cm) than imperfectly drained soils.

Overall results showing means from 40 surface soil samples from the four coupes are given in Table 1. They show that surface layers are typically very strongly acid (pH < 5.0), and have relatively high levels of total N (> 0.2%) and organic C (> 5.0%), medium levels of total P (0.010–0.025%) and low available P (< 10 mg P/kg). The values for organic C, total N and P, and available P are generally slightly lower than those analysed for the Kermandie and Murdunna soil profile classes (Grant *et al.* 1995). Erodibility varies from low in well-drained soils to moderate in imperfectly drained soils.

Conclusions

Although the bedrock geology of the area has been mapped at a scale of 1:25 000, information on the surficial geology is much less reliable. Apart from a limited area of soils formed on Quaternary slope deposits derived from dolerite in the south-eastern part, only cursory soils information is available for Warra. Further field studies are required to fully characterise the major soils and show their distribution.

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WELL-DRAINED SOIL

Correlation: Most closely related soil profile class is 'Kermandie' (Grant *et al.* 1995).

Location: Warra 001B, near centre of coupe.

Landform: Undulating lower slopes of hill/mountain.

Vegetation: Wet eucalypt forest dominated by *E. obliqua.*

Parent material: Quaternary slope deposits derived from Jurassic dolerite.

Profile description

A1 0–3 cm	Dark brown (7.5YR 3/4) clay loam; very weak strength; moderately developed 2–5 mm subangular blocky structure; < 10% subangular gravels (50–100 mm); many fine and medium roots.
B21 3–55 cm	Yellowish brown (10YR 5/8) light to medium clay; weak strength; moderately developed 10–20 mm subangular blocky breaking to 5–10 mm subangular blocky structure; 20–30% subangular boulders (300–600 mm); few worm casts; few red (2.5YR 4/8) 5–10 mm mottles; common fine and medium roots.
B22 55–90+ cm	Yellowish brown (10YR 5/6) medium clay; few red (2.5YR 4/8) 5–10 mm mottles; weak strength; strongly developed 5–10 mm subangular blocky breaking to 2–5 mm subangular blocky structure; 20–30% subangular boulders (300–600 mm); common fine and medium roots.

Notes: Red mottles in B21 and B22 are probably very strongly, red-weathered dolerite fragments or they may result from previous hot fires in the root zone. Characteristic features: gradational texture profile with thin clay loam A1 horizon overlying uniformly coloured bright yellow-brown clayey subsoils often with red mottling.

IMPERFECTLY DRAINED SOIL

Correlation: Most closely related soil profile class is 'Murdunna' (Grant *et al.* 1995).

Location: Warra 001B, about 50 m north of well-drained profile.

Landform: Undulating lower slope of hill/mountain.

Vegetation: Wet eucalypt forest dominated by *E. obliqua*.

Parent material: Quaternary slope deposits derived from Jurassic dolerite.

Profile description

A1	0–7 cm	Very dark greyish brown (10YR 3/2) humic clay loam; few dark grey (10YR 4/1) 2–5 mm mottles; very weak strength; moderately developed 5–10 mm subangular blocky structure; 5–10% 40–50 mm subangular coarse fragments; many fine and medium roots.
B21	7–30 cm	Yellowish brown (10YR 5/4) light clay; few grey (10YR 5/1) and strong brown (7.5YR 5/6) 2–5 mm mottles; weak strength; moderately developed 10–20 mm angular blocky structure; 10–15% subangular 100–150 mm dolerite fragments; common dark brown (10YR 4/3) worm casts; many fine and medium roots.
B22	30–58 cm	Yellowish brown (10YR 5/4) light to medium clay; many light grey (10YR 6/1) and yellowish red (5YR 5/6) 2–5 mm mottles; weak strength; moderately developed 10–20 mm angular blocky structure; few dark brown (10YR 4/3) worm casts; many fine and medium roots.
B23	55–90+ cm	Yellowish brown (10YR 5/6) medium clay; many greenish grey (5GY 6/1) and yellowish red (5YR 5/6) 2–5 mm mottles; weak strength; moderately developed 5–10 mm angular blocky structure; many fine and medium roots.

Characteristic features: gradational texture profile with humic clay loam A1 horizon overlying grey and orange mottled clayey subsoil.