II PHYSICAL ENVIRONMENT

K.R. Newbey

Climate

Main features of the climate are cool winters, hot summers and rainfall grading from relatively reliable in the west and south, to irregular in the north-east. According to the classification of Köppen (Dick 1975), the Study Area is Low Latitude Steppe (BSk). Alternatively, most of the Study Area is Xerothermomediterranean, with a small area of Thermomediterranean (accentuated) near Peak Charles (UNESCO-FAO 1963). Average monthly recordings of temperature and rainfall for the Study Area are presented in Figure 3. Climatic data are summarised from Hyden, Lake King, Salmon Gums and Norseman.

No manned weather recording stations have been or are present in the Study Area. From 1960 onwards, long-period rain guages have been read at irregular intervals of 1-6 months by the Department of Agriculture. These rain guages are on the Hyden-Mt Day and Frank Hann National Park roads (Newbey 1983).

Temperature

The average monthly temperature range grades from highest in the north to lowest in the south. Summer maximum (January) is 33°C in the north and 31°C in the south. Summer minimum grade from 16°C to 14°C; winter minimum from 5°C to 4.2°C. Extremes recorded are Norseman (44.9°C and -2.8°C), and Hyden (44.6°C and -2.6°C). Closely correlated with temperature is the average annual evaporation which generally decreases from 2450 mm on the northern boundary to 2200 mm on the southern boundary (Anon. 1981).

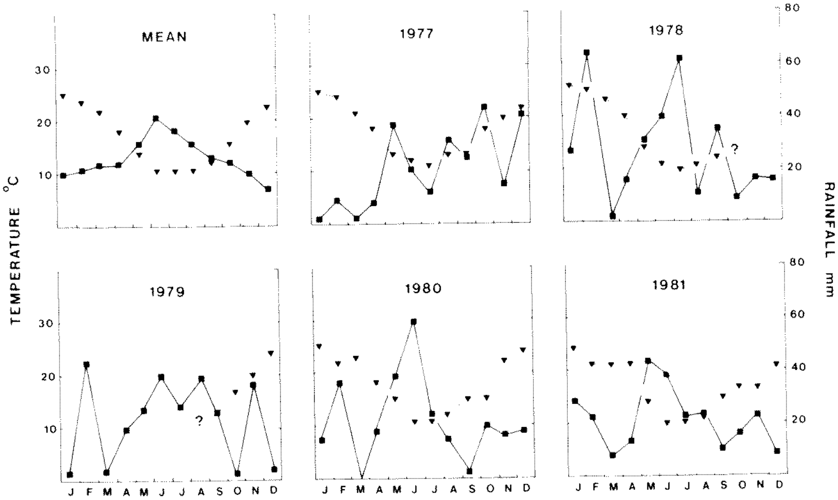

Figure 3 Ombrothermic diagrams showing the mean monthly rainfall and average monthly temperature for the years 1977-1981 and the long term mean. These figures incorporate data from the Hyden and Norseman meteorological stations.

Rainfall

Most rain falls during the period of May to August (Figure 3). Average annual rainfall, and reliability decreases from south-west (Lake King 347 mm) to north-east (Norseman 276 mm). Annual rainfall reliability decreases similarly and varies as follows: Norseman (152-613 mm), Salmon Gums (159-568 mm), Lake King (212-486 mm), and Hyden (216-572 mm). Winter rains are mainly from cold fronts associated with sub-Antarctic lows. Falls from cold fronts rarely exceed 10 mm but may reach 40 mm if supplemented by moist tropical air. Summer falls (up to 50 mm) are highly erratic and occur from thunderstorms sometimes associated with troughs. Heaviest falls (to 160 mm) occur from tropical cyclones which have degenerated into rain-bearing depressions. Snow has not been recorded in the Study Area.

Winds

A wind speed summary is only available for Norseman. At 0900 and 1500 hours wind speeds were similar: spring and summer (6-20 km/hour), and autumn and winter (0-20 km/hour). Wind directions were variable at both 0900 and 1500 hours: summer (NE-S, E-W), autumn (NE-SE), winter (W-NE, W-N) and spring (N–SE, SW-NW). There were no sightings during field work of physical damage to the vegetation caused by strong winds.

Radiation

The average daily radiation during January grades from south (740 mWh. cm^{-2}) to north (765 mWh. cm^{-2}). During July the gradient is similar in direction (320-340 mWh. cm^{-2})(Anon. 1975).

Geology and Landforms

The geology of the Study Area has been mapped and described in detail: Lake Johnston 1 : 250 000 sheet (Gower and Bunting 1976), and Hyden 1 : 250 000 sheet (Chin *et al.* 1982). The Study Area has been tectonically stable since the Proterozoic. The following elements are fundamental to understanding landscape development and associated vegetation:

(a) Most of the Study Area is underlain by Archaean or Proterozoic granites, and associated rocks, which have been eroded into gentle undulating plains and broad valleys covered with Tertiary soils.

(b) There are two small areas of Archaean greenstone: a narrow north-south belt from Hatters Hill to Mt Holland, and a broad area in the Bremer Range-Mt Day area.

(c) In the south-eastern corner of the Study Area is a Proterozoic intrusion forming the conspicuous Peak Charles and Peak Eleanora.

The term "granite", as used in this report, refers to all granitoid rocks. They all weather into similar soil types supporting similar types of vegetation without marked differences in species composition. "Gravel" refers to concentric concretions of iron oxides developed in the A horizon of soils during laterization of their profiles over deeply weathered granite.

The Study Area consists almost entirely of gentle undulating uplands dissected by broad valleys containing chains of salt lakes, and occurs within the Salinaland of Jutson (1950). There is a very gentle regional slope from north to south. The whole landscape is very subdued with only one chain of low hills – Bremer Range. Prominent above the subdued terrain are a few hills: Peak Charles (658 m), Peak Eleanora (503 m), the Ironcaps (South, Middle and North), Mt Day and Round Top Hill. Some granite bedrock exposures are prominent in the eastern half of the Study Area e.g. McDermid Rock. The Study Area has not experienced marine transgression, nor glaciation since the Permian (van de Graaff *et al.* 1977).

Much of the Study Area has indistinct drainage lines in broad valleys eroded when the rainfall was higher than at present (possibly Cretaceous). With lower rainfall, the drainage lines have been largely filled with alluvium and colluvium. They are now reduced to strings of flat-floored salt lakes (van de Graaff *et al.* 1977). Some of the aeolian features of broad valleys have developed during the last major arid period, i.e. about 15 000 years ago (Bowler 1976).

West of the Hatters Hill-Mt Holland greenstone belt, drainage lines are less filled with alluvium and colluvium than further east and most flow for short periods following more than 50 mm of rain.

Widespread laterization of deeply weathered granite is believed to have occurred during the Cainozoic (Mulcahy 1973). The widespread occurrence of gravel ridges and rare small breakaways are evidence of laterization.

Soils

The soils of the Study Area have been discussed briefly by Northcote *et al.* (1968), and will be described in detail by Newbey and Milewski.

On the Sandplains the soil groups are dominated by Deep Sands, Shallow Sands and Gravelly Sands. Shallow Sandy Clays are less common. All have been formed largely by *in situ* weathering of granite. They are highly leached and well-drained with pH less than 6.5. Siliceous sands dominate their A horizons.

Well-drained Deep Calcareous Earths are common on the floors of Broad Valleys. The B horizon always has pH of 8.0, or greater, but the A horizon pH varies between 7.0 and 8.5. Even though the pH may exceed 8.0 and carbonate nodules may be present in either horizon, the soil is not always calcareous i.e. effervesces when a few drops of HCl are added. Extensive thin sheets of Aeolian Sands are sometimes present. The floors of salt lakes consist of Saline Soils of lacustrine origin, and any surrounding damp flats consist of Sub-saline Soils. Peripheral to most salt lakes are dunes and broad flats of Aeolian Sands.

Soils of the Undulating Plains, over greenstone, are high in Mg and Ca. Colluvial flats consist of Deep Calcareous Earths while Shallow Calcareous Earths occur on the low ridges. Granitic Soils, neutral to slightly acid, occur as skeletal or shallow deposits on or peripheral to exposures of granite bedrock or granite hills. Somewhat similar Gritty Loams occur on Breakaways. Red Sands were present on hills of banded ironstone formation as skeletal to shallow veneers. Some minor lateritization on Greenstone occurred in small patches on some hills.

A summary profile for each soil group is presented in Table 1, and the correlations between geology, landform units and elements, soil groups and vegetation are presented by Table 2.

Table 1 Soil Groups occurring on the Landform Units of the Lake Johnston-Hyden area.

Soil Group	A horizon	B horizon	Bedrock
BREAKAWAY (B)			
Gritty Loams	5-35 cm, pH 6.0-6.5	If present, 10-40 cm, clay content higher than in A horizon	Kaolinized granite
GRANITE EXPOSURE (G)			
Granitic Soils	Loamy sands to sandy loams, 3-30 cm, pH 6.0-6.5	If present, 10-90 cm, sandy clay	Granite
Meta-granitic Soils	Loamy sands 30-50 cm, pH 8.0	>50 cm, carbonate nodules present	Granite
HILL, Granite (HG)			
Granitic Soils	Loamy sands to sandy loams, 3-30 cm, pH 6.0-6.5	If present, 10-90 cm, sandy clay	Granite
HILL, BANDED IRONSTONE FORMATION (HI)			
Red Sands	Loamy sands, 5-100 cm, pH 6.0-6.5	Rarely present	Banded Ironstone Formation
SALT LAKE FEATURE (L)			
Aeolian Sands	Sands to loams, 5-400 cm, pH 6.0-7.0	If present, clay content higher than in A horizon	Unknown
Deep Calcareous Earths	10-20 cm, pH 7.5-8.25	>100 cm, pH 8.0-8.25, carbonate nodules usually present	Greenstone
Saline Soils	2-15 cm, pH 7.0	Multi-strata	Unknown
Sub-saline Soils	As above	As above	Unknown
SANDPLAIN (S)			
Alluvium	Silts to clays, 2-100 cm, pH 6.0-6.5	If present, multistrata	Unknown
Deep Sands	50->200 cm, pH 6.0-6.5	Sandy clay, pH <6.5	Granite
Gravelly Sands	15-100 cm, 20-70% gravel, pH 6.0-6.5	Sandy Clay, pH <6.5	Granite
Shallow Sands	10-50 cm, pH 6.0-6.5	Sandy clay, pH <6.5	Granite
Shallow Sandy Clays	Clayey sand to sandy clay	Sandy clay, pH 6.0-6.5	Granite
UNDULATING PLAIN, greenstone (UN)			
Deep Calcareous Earths	10-20 cm, pH 7.5-8.25	>100 cm, pH 8.0-8.25, carbonate nodules usually present	Greenstone
Shallow Calcareous Earths	5-30 cm, pH 8.0-8.25	Rarely present	Greenstone
Cracking Red Clays	5-10 cm, pH 8.0-8.25	Medium clay, >100 cm, pH 8.25	Mafic rock

Table 1 (Contd.)

Soil Group	A horizon	B horizon	Bedrock
BROAD VALLEY (V)			
Aeolian Sands	15-30 cm, pH 6.5-7.0	>100 cm, pH 8.0, carbonate nodules often present	Unknown
Alluvium	Silts to clays, 2-100 cm, pH 6.0-6.5	If present, multistrata	Unknown
Cracking Red Clays	5-10 cm, pH 8.0-8.25	Medium clay, >100 cm, pH 8.25	Mafic rock
Deep Calcareous Earths	10-20 cm, pH 7.0-7.55	>100 cm, pH 8.0-8.25, carbonate nodules often present	Unknown
Deep Sands	50->200 cm, pH 6.0-6.5	Sandy clay, pH <6.5	Granite
Shallow Sandy Clays	Clayey sand to sandy clay, 5-15 cm	Sandy clay, pH 6.0-6.5	Granite

A summary profile for each soil group is present in Table 1, and the correlations between geology, landform units and elements, soil groups and vegetation are presented by Table 2.

Landform Units

Newbey and Milewski (in prep.) have developed a classification of 10 units to describe the landscapes of Eastern Goldfields. Seven of these were present in the Study Area (Figure 2) and they are briefly described below. The units not present in the Study Area were Drainage Line, Dune Field and Calcareous Plain.

Breakaways (B): Breakaways occurred where the deeply weathered granite that underlies the Sandplains was exposed. The exposure was truncated by a free face of bare rock that was vertical (1 m). Skeletal deposits of Gritty Loams occurred on the rim, either filling small pockets or as sheets that graded into soils of the Sandplain. A pediment of colluvium had developed at the base of the exposure. Runoff from the exposure increased the moisture content of the pediment. Breakaways were rarely seen during field work.

Granite Exposure (G): Exposures of granite ranged in topography and size from flat and a few metres across, to the domed McDermid Rock rising about 20 m above the surrounding landforms, and covering about 20 ha. The surfaces of exposures were mainly bare with scattered small pieces of exfoliated flat stone. Sheet-deposits of skeletal soil had developed in the low-lying areas of the exposure. Due to the thinness of deposits (up to 30 cm), the soil became easily waterlogged and dried out more rapidly than thicker soil profiles of surrounding plains. Runoff also increased the rate of waterlogging. Peripheral to the bedrock exposures were aprons of soils, to 1.5 m thick, that had primarily weathered *in situ* from the underlying granite. The rate of change in soil moisture content decreased as soil depth increased. Large exposures usually had 1-3 faint drainage lines where the soil

Table 2 The Relationships between Geology, Landform Units, Soils and Vegetation Types

Geological Surface HY	LJ	Landform Element	Soil	Vegetation Type
BREAKAWAY (B)				
Czo		Whole feature	Gritty Loams	Breakaway Complex
GRANITE EXPOSURE (G)				
Agm, Amv, Anv	Agb, Agg, Agl, Pgs	Skeletal soils sheets and inner apron	Granitic Soils	Granite Complex
		Outer apron	Granitic Soils	*A. lasiocalyx* Low Woodland *Allocasuarina huegeliana* Low Woodland *E. grossa* Mallee *E. loxophleba* Mallee *A. acuminata* Tall Shrubland *A. sessilispica* Tall Shrubland *Allocasuarina campestris* ssp. *campestris* Tall Shrubland *Malaleuca uncinata* Tall Shrubland
			Meta-granitic Soils	*E. loxophleba* Mallee
HILL, granite (HG)				
	Pgs	Soil sheets on hill slope	Granitic Soils	*Allocasuarina campestris* ssp. *campestris* Tall Shrubland
		Outer apron	Granitic Soils	*Allocasuarina huegeliana* Low Woodland *E. loxophleba* Mallee *A. acuminata* Tall Shrubland
		Inner apron & skeletal soils	Granitic Soils	Granite Complex
HILL, Banded Ironstone Formation (HI)				
Aiw	Ahw	Whole feature	Red Sands	*Allocasuarina campestris* ssp. *campestris* Tall Shrubland BIF Complex

Table 2 (Contd.)

Geological Surface HY	LJ	Landform Element	Soil	Vegetation Type
SALT LAKE FEATURES (L)				
	Qpk, Qrm	Aeolian sheets	Deep Calcareous Earths	*E. salmonophloia* Woodland
	Qpf	Sub-saline flats	Sub-saline Soils	*E.* sp. (KRN 9710) Low Woodland
	Qpk	Sub-saline flats	Sub-saline Soils	*E. pileata* Mallee
Q1	Qrm	Aeolian soil sheets	Sub-saline Soils	*M. uncinata* Tall Shrubland
	Qpk	Low-lying flats	Sub-saline Soils	*Atriplex vesicaria* ssp. *variabilis* Low Shrubland
Q1	Qpk, Qra, Qrm	Lake floors	Saline Soils	*Halosarcia* Low Shrubland
SANDPLAIN (S)				
Czl	Czg	Plain	Shallow Sandy Clays	*E. salmonophloia* Woodland *E. celastroides* var. *virella* Mallee
	Qpa	Plain	Shallow Sandy Clays	*E. salubris* Low Woodland
Czg, Czl	Czg, Czs	Plain	Shallow Sands	*E. redunca* Mallee *E. transcontinentalis* Mallee *Melaleuca* spp. Tall Shrubland
Czg	Czs, Czg, Qps	Thick soil sheets on plain	Deep Sands	*E.* aff. *decipiens* Mallee *E.* aff. *occidentalis* Mallee *E. tetragona* Mallee *A. beauverdiana* Tall Shrubland *Grevillea eriostachya* ssp *excelsior* Tall Shrubland
Czg	Czg	Slight rises	Gravelly Sands	*A. signata* Tall Shrubland *Allocasuarina acutivalvis* Tall Shrubland *Allocasuarina campestris* ssp. *campestris* Tall Shrubland *Callitris preissii* ssp. *verrucosa* Tall Shrubland
Czg		Plain	Gravelly Sands	*Hakea* cf. *falcata* Low Shrubland
Qa		Small depression	Alluvium	*E. georgei* Low Woodland
UNDULATING PLAIN (UN)				
Aab		Low rises & colluvial flats	Deep Calcareous Earths	*E. flocktoniae* Low Woodland *E. ovularis* Low Woodland
	Alb	Low rises	Shallow Calcareous Earths	*E.* sp. (KRN 5603) Low Woodland
Pd in Aab		Low rises	Cracking Red Clays	Greenstone Complex

Table 2 (Contd.)

Geological Surface HY	LJ	**Landform Element**	**Soil**	**Vegetation Type**
BROAD VALLEY (V)				
	Qqf	Colluvial flats	Deep Calcareous Earths	*E. dundasii* Woodland
	Qps	Colluvial flats	Deep Calcareous Earths	*E. longicornis* Woodland
				E. longicornis Low Woodland
				E. incrassata Mallee
				E. spathulata ssp. *grandiflora* Mallee
Qa	Qpl, Qps, Qqs	Colluvial flats	Deep Calcareous Earths	*E. salmonophloia* Woodland
				E. diptera Low Woodland
				E. flocktoniae Low Woodland
				E. longicornis Low Woodland
				E. ovularis Low Woodland
				E. salubris Low Woodland
				E. sheathiana Low Woodland
				E. transcontinentalis Low Woodland
				E. aff. *occidentalis* Mallee
Qa		Colluvial flats	Shallow Sandy Clays	*E. salmonophloia* Woodland
Qa, Qe		Colluvial flats	Deep Calcareous Earths	*E. cylindrocarpa* Mallee
				E. redunca Mallee
				E. transcontinentalis Mallee
	Qqs	Colluvial flats	Deep Calcareous Earths	*E. cylindriflora* Mallee
	Qqf	Colluvial flats	Cracking Red Clays	*E. salubris* Low Woodland
Qe	Qps	Colluvial flats	Deep Calcareous Earths	*E. pileata* Mallee
Qa, Qd	Qps	Sand sheets	Aeolian Sands	*E. leptophylla* Mallee
				E. pileata Mallee
				A. jennerae Tall Shrubland
	Qps	Sand sheets	Deep Sands	*E. tetragona* Mallee
	Qps	Sand sheets	Aeolian Sands	*E.* aff. *foecunda* Low Woodland
Qa	Qrp	Claypan	Alluvium	*Malaleuca* aff. *preissiana* Tall Shrubland
				Muehlenbeckia cunninghamii Low Shrubland

1.Geological surface: HY = Hyden (Chin et al. 1982). For explanation of codes, see Table 20 (Appendix I).
LJ = Lake Johnston (Gower & Bunting 1976)

2. *A.* = *Acacia*, *E.* = *Eucalyptus*

Note that greenstone and granite surfaces are presented as groups because vegetation is not specific.

was damp to waterlogged during winter. Others lacked drainage lines and the run-off was shed relatively evenly around the perimeter resulting in a narrow zone of soil (3-15 m) that could be damp or waterlogged for long periods during winter. Ephemeral pools, up to a few metres across and rarely more than 30 cm deep, occurred on the exposures. Granite exposures were scattered throughout the Study Area with the highest concentration in the eastern section.

Hill: Two sub-units were present based on bedrock type.

a. Hill (granite): Peak Charles and Peak Eleanora rose about 300 m out of a Broad Valley floor. They were basically conical in shape with slopes of 5-30 degrees. Extensive areas of bare bedrock were present on steeper slopes. Soils, where present were Granitic Soils.

b. Hill (banded ironstone formation): Mt Day, Round Top Hill and the Ironcaps were generally rounded in shape and rising 20-50 m above the surrounding landscape. Slopes varied from 5 to 20 degrees with bare bedrock common.

Salt Lake Feature (L): Salt lakes had flat floors of saline loams to clays that were rarely covered with more than 15 cm of water. Peripheral dunes, 1-5 m high and stabilised by vegetation, were most common on the eastern and southern margins of lakes. The remainder of most lake margins consisted of a gentle slope. The soil types of both dunes and gentle slopes were Aeolian Sands. Often marginal to salt lakes were flats consisting of alluvial or aeolian material. Two distinct types of flats were observed but intergrading was frequent. The main distinguishing factor was height above the salt lake floor (and saline water-table) which controlled salinity and waterlogging.

(a) Saline flats – up to 30 cm above the salt lake floor, highly saline and damp to waterlogged.

(b) Well-drained flats – 30-120 cm above the salt lake floor and primarily of aeolian origin.

Salt Lake Features occurred throughout most of the Study Area, mainly as continuous belts on the floors of major Broad Valleys.

Sandplain (S): The undulating uplands, including the upper and middle valley slopes rarely exceeded 2° and the soil profiles were thick and laterised. Similar Broad Valley was the change of slope from erosional to colluvial. Sandplain slopes rarely exceeded 2° and the soil profiles were thick and laterized. Similar soil profiles in the Belka Valley, extending north-west from the Study Area's north-western boundary, were over 20 m thick (Bettenay and Hingston 1964). The high areas of Sandplain were the result of *in situ* weathering and consisted of Gravelly Sands or Shallow Sands. The soils of low areas of Sandplain (Deep Sands) had a thicker A horizon with a colluvial component derived from high areas. Due to the loose and sandy A horizon, run-off only occurred over short distances following heavy and intense falls of rain. Shallow Sandy Clays occurred as belts across some Sandplain areas. They were 50-120 m wide and possibly had developed *in situ* over bedrock more mafic than granite. Sandplains were a dominant landform unit of the Study Area.

Undulating Plain, *(greenstone)* (UN): Both areas within the Study Area consisted of series of low rises mainly 10-15 m high but sometimes large rises were up to 30 m high. Slopes varied from 2 to 8 degrees with some bedrock exposures on steeper slopes. Shallow Calcareous Earths covered the rises while, on the intervening flats, colluvial deposits of Deep Calcareous Earths developed. These flats rarely exceeded 200 m in width.

Broad Valley (V): The major valleys of a previous landscape had become filled with colluvium and alluvium. This material had been frequently reworked – including by aeolian action. Valley floors are now almost flat and the same soils extend up the valley slopes from 5 m to 20 m above floor level. Internal slopes rarely exceeded 2°. A range of soil types form a mosaic in most places but the B horizon was always calcareous. Deep Calcareous Earth was the major soil group on the Broad Valley unit. Aeolian Sands formed extensive sheet deposits that sometimes contained subdued sand dunes stabilised by vegetation. Broad Valleys were dominant and widespread within the Study Area.

Freshwater

Lake Cronin was an almost permanent freshwater source. However, the lake is only about 1.6 m deep when full and dries up during consecutive years with well below average rainfall. On the Sandplains were a few small depressions and claypans. Heavy falls in excess of 75 mm are required to fill them (to 100 cm). These falls only occur about once every seven years. Water remains 9-18 months after filling without additional run-off.