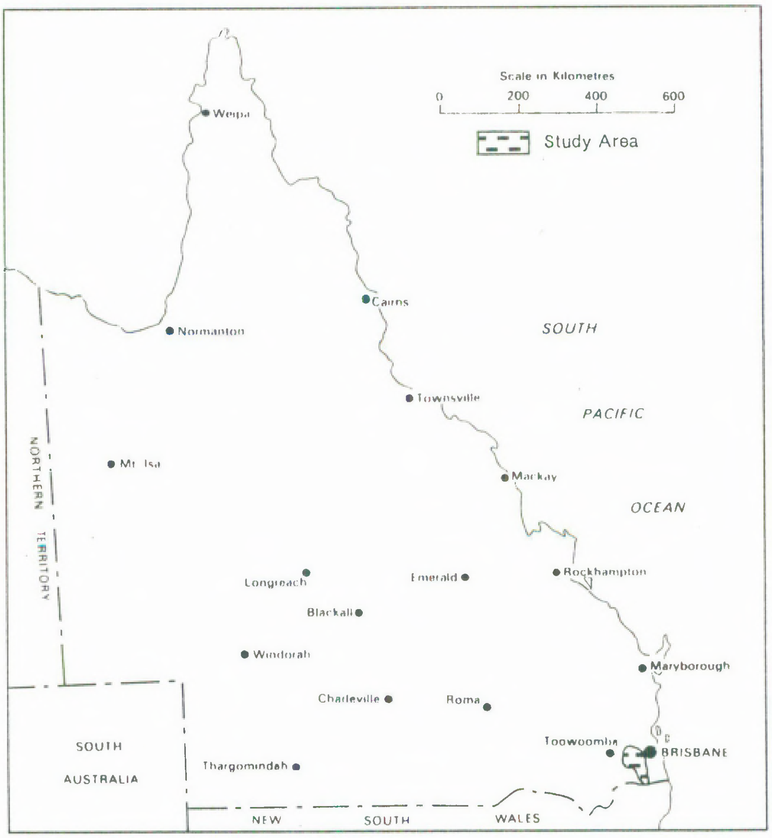
INVESTIGATION OF STUDY AREA

4. DESCRIPTION OF STUDY AREA

4.1. Location

The study area occupies a section of the Lockyer Valley catchment, located east of the Great Dividing Range in south-east Queensland (Fig. 4.1). The area is part of the 300 000 ha Lockyer Valley, which has major southern tributaries draining north into the 100 km long Lockyer Creek, which in turn drains north-east into the Brisbane River. It covers approximately 120 000 ha in area and was selected because it includes areas representative of the major alluvial soil landscapes in the Lockyer Valley. It includes the terraced alluvia of Tenthill Creek and its tributaries extending downstream to the Lockyer Creek alluvial plain. These streams are associated with extensive alluvial landscapes (up to 6 km wide) in comparison to the size of their channels (i. e. underfit streams) suggesting periods of great discharge in the past.

Downstream of the study area, the alluvial plains widen where alluvia from Sandy Creek and Laidley Creek meet the alluvia of Lockyer Creek. Further downstream the alluvial plain of Lockyer Creek progressively narrows to about 1.6 km before meeting the Brisbane River alluvia. This reach of the Brisbane River is equally as narrow but has alluvia distributed on two terraces. The wide alluvial plain of Lockyer Creek appears to have developed because of a hard rock constriction in the downstream reaches which caused an extensive buildup of alluvial sediment in the Lockyer Valley catchment. This suggestion is unproven however, and the causal factors responsible for widespread alluviation in the Lockyer Valley are not understood. Further investigations are required to determine the influence of climatic, tectonic, eustatic or other events on Lockyer Valley alluviation.



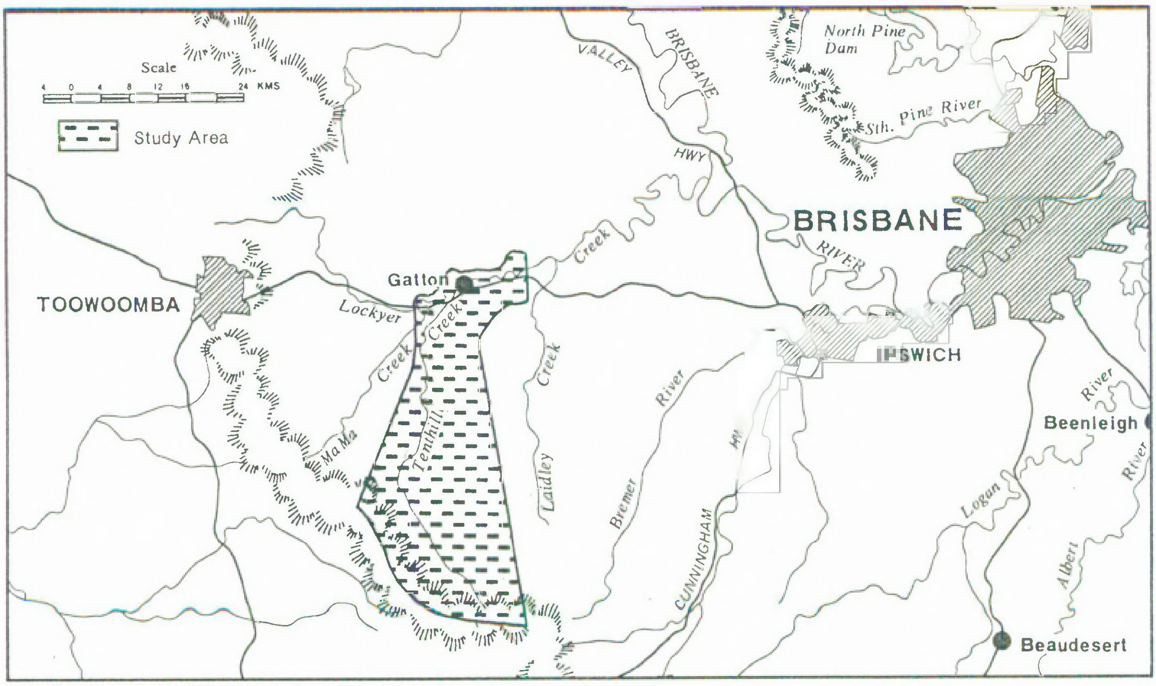


Fig. 4.1. Location map.

4.2. Physiography and geology (catchment source materials)

The headwater regions consist of steep ranges with V-shaped valleys in the south (Plate 4.1), which abruptly flatten out to gently sloping rolling low hills with wide terraced tributary valleys developing in the middle reaches (Plate 4.2). Downstream tributary valleys widen further, and an extensive alluvial plain has developed surrounded by an upland landscape of undulating rises (Plate 4.3). The physiography of the study area includes the watershed (W) and riverine (R) components of a WRO river system (see Section 3.3). The main features of the river patterns encountered are summarised in Table 4.1 using the classification developed by Pickup (1984), Morisawa (1985) and Tricart (1960) (see Section 1.3.4).

Table 4.1. River patterns in the study area.

Study area component	Reach classification (Pickup 1984)	River type (Morisawa 1985)	Channel type (Tricart 1960)
Upper reaches	source and armoured reaches	braided	periodic major channel
Middle reaches	mobile zones	sinuous to meandering	exceptional major channel
Lower reaches	mobile zones	meandering	exceptional major channel

An understanding of the geology of the area is essential for this study as the rocks in the catchment are source materials for the valley alluvia, the parent material of the soils under investigation. Geology has been broadly mapped by Cranfield *et al.* (1976) and McTaggart (1963). Zahawi (1975), and Shaw (1979) have discussed and mapped the geology in more detail (see enclosed map) and Beckmann and Stevens (1978) have described the geological history of the Brisbane River System, which includes the Lockyer Valley. The geological history of the region from the Palaeozoic to the Tertiary is discussed below. It is also discussed in further detail in Chapter 6 where the source materials of alluvia are described. The reader is referred to Table 6.1 and Fig. 6.1 where the stratigraphy of the study area is summarised.

Plate 4.1. Headwaters with V-shaped valleys.

Plate 4.2. Wide terraced tributary valley of Tenthill Creek.

4.2.1. Palaeozoic blocks and Mesozoic sediments

The study area is part of the New England Fold Belt, which represents the youngest tectonic cycle in the evolution of the Tasman Geosyncline (refer to Section 3.1.2). Devonian to Carboniferous blocks were uplifted in the Late Permian to form mountain ranges. These rocks, originally marine sediments and basic volcanics, are now low grade metamorphics, which, with intrusive granites make up the D'Aguilar, Beenleigh and Yarraman Blocks (Cranfield *et al.* 1976) as shown in Fig. 4.2.

Plate 4.3. Extensive alluvial plain of Lockyer Creek.

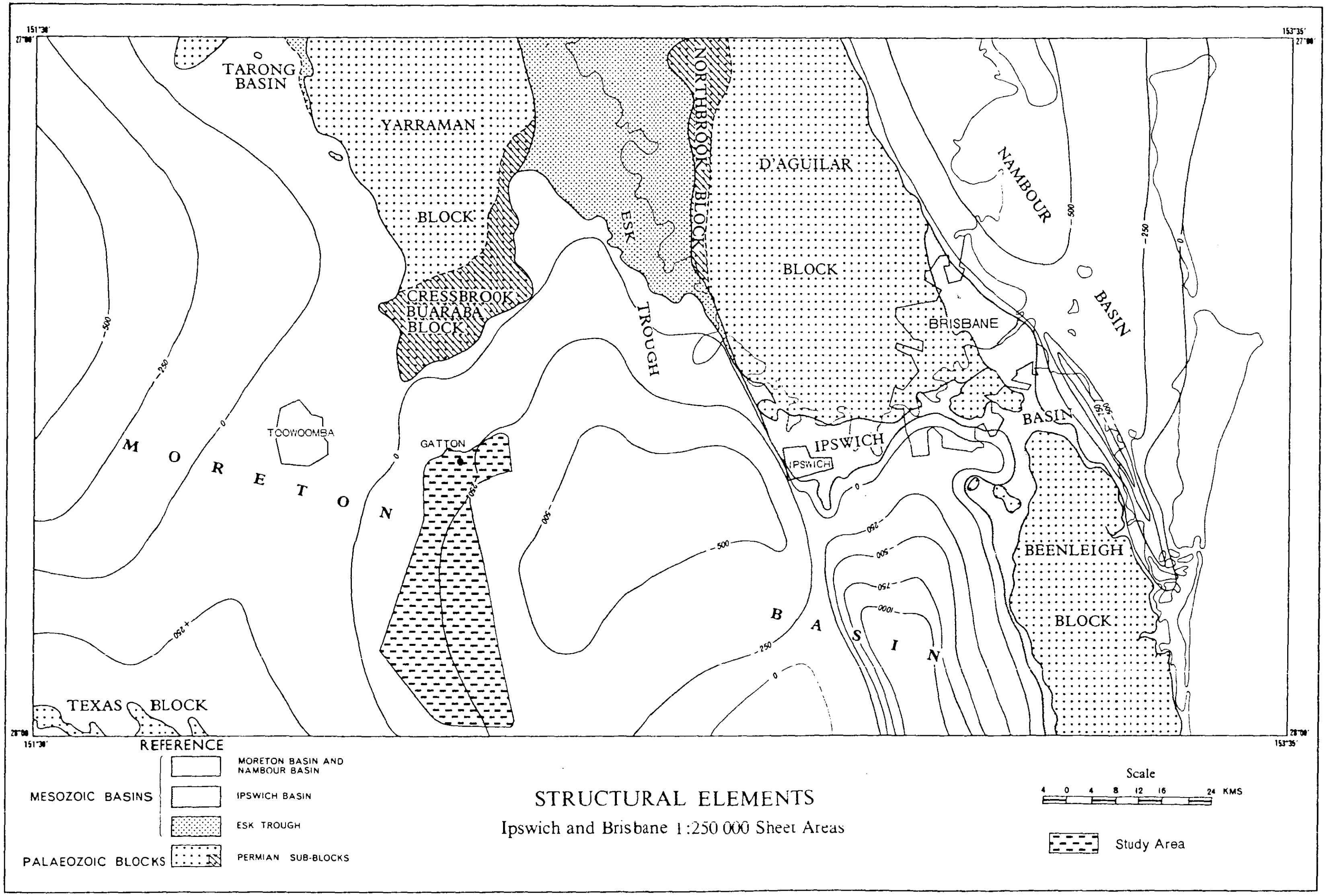


Fig. 4.2. Major Palaeozoic and Mesozoic blocks and sedimentary basins (after Cranfield *et al.* 1976, Fig. 4).

The resultant intermontane Esk Trough, north of the study area, received freshwater sediments (Bryden and Esk Beds) and volcanics, during the Early to Middle Triassic. Sometime in the Middle Triassic, the Esk Trough strata were folded and subsidence initiated the Ipswich Basin east of the study area. This basin received sediments in the Late Triassic from the Palaeozoic highlands (Beckmann and Stevens 1978).

Earth movements in the Late Triassic Period extended the area of sedimentation to produce the Clarence-Moreton Basin, of which the Lockyer Valley was a part (Fig. 4.2).

The Clarence-Moreton Basin was a large shallow freshwater lake linked to the Great Artesian Basin. Sandstones, shales and conglomerates were deposited in beds that now dip slightly in a southerly direction (McTaggart 1963). The characteristics of the main strata within this basin are summarised below and are listed in stratigraphical order beginning with the oldest.

The first deposit, laid down in the Late Triassic, was the approximately 300 m thick *Helidon Sandstone*, consisting of siliceous sandstone and accessory siltstone, and is exposed north of Lockyer Creek outside the study area. The Helidon Sandstone was named the Woogaroo Sub-Group by Cranfield and Schwarzbock (1972) and is equivalent to the lower beds of the Bundamba Group.

This was followed by the *Marburg Formation* which is 440 to 770 m thick within the Lockyer Valley (Gray 1975). McTaggart (1963) recognised four major beds; in ascending order these are the Gatton Sandstone, the Winmill Conglomerate, the Ma Ma Creek Sandstone and the Heifer Creek Sandstone.

Conformably overlying the Heifer Creek Sandstone are the 200 m thick argillaceous *Walloon Coal Measures* of grey shales, siltstones and sandstones with interbedded coal seams.

Significant changes in lithology between early deposits of the Moreton Basin suggest that a major fault west of the study area between Toowoomba and Helidon was active during Late Triassic - Early Jurassic times followed by more stable conditions during the Middle Jurassic (Gray 1975).

The region was uplifted in post-middle Jurassic times and toward the close of the Jurassic; minor faulting and folding of the sediments occurred (Beckmann and Stevens 1978). A major structural feature of the Moreton Basin in the study area is an anticline known as the Gatton Arch, which has developed over a buried basement ridge extending roughly north-south from the Texas Block to the Yarraman Block (see Soils Map). The Gatton Arch does not appear to have affected sedimentation in the Lockyer region of the Moreton Basin. This indicates that it may be a post-sedimentation feature (Gray 1975).

There is no record of sedimentation from the Middle Jurassic to the Early Tertiary and the landsurface developed a moderate to rugged relief. By this time the structurally controlled Lockyer Valley drainage had probably established its north-easterly direction and position by following the strike of the more readily eroded exposures of Gatton Sandstone (Fig. 6.1), i.e. it became a strike valley.

4.2.2. Tertiary basalt

During the Late Oligocene to Early Miocene (26 to 22 million years ago), basaltic lavas erupted from vents in the western and southern regions of the Lockyer Valley (Webb *et al.* 1967, Stevens 1969). The lava was mainly olivine basalt with some rhyolite, trachyte and interbasaltic tuff. These rocks collectively form part of the Main Range Volcanic Province (Wilkinson *et al.* 1969), or the Toowoomba Igneous Province of Ollier (1978).

This area is designated a central volcano province by Wellman and McDougall (1974) with vents located largely along the Great Eastern Escarpment. A series of at least 13, possibly 16, lava flows has been found where a thick sequence of lavas has accumulated near Toowoomba (Stevens 1969). Interbedded basaltic tuffs are also common (Schafer 1981). The average thickness of individual flows is between 10 and 13 m (Stevens 1969). Basalt flows built up cumulatively to 200 to 450 m thick to form a plateau sloping gently to the east and west (Beckmann and Stevens 1978) and these form the upper catchment of the study area (Fig. 6.1).

4.2.3. Valley floor erosion and deposition

Within the study area, the main source materials that contributed to the valley alluvium include the weathering products of Tertiary basalt, Jurassic Walloon Coal Measures and the Marburg Formation. The upper beds of the Marburg Formation, i.e. the Heifer Creek and Ma Ma Creek Sandstones, were more likely to have contributed to the alluvia than the lower beds because of their higher position in the catchment and their greater areal extent (see Table 6.1).

During the Pleistocene, there were periods of deep incision of valley floors, commonly to 20 to 30 m with depth decreasing upstream, and downcutting appears to have occurred as several stages (Beckmann and Stevens 1978). Major episodes of erosion and deposition are most likely due to eustatic changes but other episodes of sediment redistribution in the valleys may have been induced by climatic change. The coarser deeper layers of valley fill, which include gravel beds, indicate high stream velocities, while fine textured surface layers indicate a progressive dwindling in stream capacity and competence.

Alluvium was deposited by all streams and in adjacent fans as the valleys filled in the Late Quaternary. Narrow floodplains and terraces are found along tributary streams, where deposition was confined to the incised area. Downstream, alluvium overflowed from the incised valley onto the surrounding valley margins so that a wide alluvial plain has developed as streams meandered across the floodplain. Relict levees of prior streams are still in evidence on the alluvial plain surface. Large scale floodplain aggradation and erosion ceased in the Holocene, presumably under climatically stable conditions.

Lockyer Creek and its tributary streams in the lower reaches now have a deep meandering channel with a gentle levee extending to an alluvial plain 3 to 6 km wide. The alluvial plain is interspersed with discontinuous relict levees of prior streams and is fringed by backswamp depressions at the valley margins. In the upper reaches a flood plain has developed along the Tenthill Creek tributary. This occurs below a terrace which in places gradually ascends to adjacent fan deposits. The floodplain progressively widens and the terrace narrows with increasing distance upstream.

4.3. Climate

The Lockyer Valley experiences a subhumid and subtropical climate with long hot summers and short mild winters. It is classified as a Cfa type of climate in the Koeppen (1931) climatic classification, i.e. a humid mild winter with hot summers and rainfall evenly distributed throughout the year. Climatic data for the Queensland Agricultural College, Lawes are presented in Table 4.1.

In summer heat waves up to 40°C may occur (Table 4.1). During winter, frosts are possible on the valley floors from May to September, but are most common during June, July and August.

Table 4.1. Climatic data - Lawes (Australian Bureau of Meteorology 1975).

Elevation 89.6 M   Latitude 27 Deg 33 Min S   Longtitude 152 Deg 20 Min E

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
9 am Mean Temperatures (C) and Mean Relative Humidity (%)													
Dry Bulb	25.6	25.2	23.8	21.2	16.7	13.9	12.1	14.5	18.0	21.8	24.0	25.1	20.2
Wet Bulb	21.4	21.3	20.1	17.6	13.8	11.5	9.6	11.5	14.2	17.6	18.6	20.4	16.5
Dew Point	19.0	19.0	18.0	15.0	11.0	9.0	7.0	9.0	11.0	15.0	15.0	18.0	14.0
Humidity	67.0	69.0	70.0	68.0	71.0	73.0	70.0	68.0	64.0	64.0	57.0	63.0	67.0
Daily Maximum Temperature (C)													
Mean	30.9	30.4	29.1	27.3	23.4	21.1	20.1	21.9	24.6	27.6	30.0	30.2	26.4
86 Percentile	33.9	33.5	32.2	30.3	26.1	23.3	22.5	24.4	28.0	30.6	34.2	34.2	
14 Percentile	27.8	27.2	26.1	24.4	20.8	18.6	17.2	19.2	21.7	23.9	26.0	26.7	
Daily Minimum Temperature (C)													
Mean	19.4	19.1	17.1	13.6	9.9	7.7	5.6	7.3	9.2	13.6	15.6	18.4	13.0
86 Percentile	22.0	22.2	20.0	16.7	14.7	12.2	9.7	11.1	13.3	17.2	19.5	21.7	
14 Percentile	16.7	16.4	14.4	10.6	5.6	4.4	0.6	3.9	5.0	9.7	11.7	15.5	
Rainfall (mm)													
Mean	118.0	101.0	85.0	46.0	40.0	47.0	41.0	28.0	37.0	68.0	73.0	101.0	785.0
Median	100.0	84.0	74.0	36.0	27.0	28.0	27.0	23.0	29.0	57.0	69.0	90.0	786.0
Raindays (No)													
Mean	11	11	10	7	6	6	6	5	5	8	9	9	93

Two thirds of the annual rainfall is received in the summer months between October and March. During the summer months, rains which are often associated with the southward movement of tropical low pressure systems or cyclones commonly cause flooding (Shaw 1979). The annual average evaporation rate is high, about double the annual average rainfall (Shaw 1979).

4.4. Vegetation

Most of the study area has been cleared of vegetation for cultivation and clear associations of vegetation with soil landscape cannot be completely elucidated. Structural terminology follows current usage in south-east Queensland.

Eucalypt open forest communities with predominantly grassy understories are in evidence on the uncleared remnants of the extensive alluvial plains. Dominant tree species are silver-leaved ironbark (*Eucalyptus melanophloia*), Moreton Bay ash (*E. tesselaris*) and blue gum *E. tereticornis*). Occasionally narrow-leaved ironbark (*E. crebra*) is also encountered. On fans and local alluvial plains associated with Gatton sandstone and Winwill Conglomerate, there are open forest communities of dominantly narrow-leaved ironbark and Moreton Bay ash with sub-dominant silver-leaved ironbark and blue gum. Prior to cultivation fans and local plains out of Ma Ma Creek and Heifer Creek Sandstones supported softwood scrub communities of complex mixed composition.

On older elevated alluvial terraces, brigalow (*Acacia harpophylla*) dry scrub communities occur, with minor belah (*Casuarina cristata*) and soft wood scrub species.

Table 4.2. Soil - vegetation associations.

Soils	Vegetation
Basaltic well drained soils	mixed eucalypt open forest of silver-leaved ironbark, Moreton Bay ash and bluegum.
Basaltic poorly drained soils	bluegum open forest
Gatton Sandstone and Winwill Conglomerate derived soils	narrow-leaved ironbark or Moreton Bay ash or open forest
Ma Ma Creek Sandstone derived soils	softwood scrub
Elevated basaltic-sandstone mixed alluvia derived soils	brigalow/belah dry scrub
Walloon Coal Measures derived soils	brigalow/belah dry scrub
Heifer Creek sandstone derived soils	softwood scrub with brigalow dominant on interbedded shales

Clearing for pastures has facilitated the invasion of woody weeds on all landscapes of the study area. Lantana (*Lantana camara*) infestation is particularly severe and willow wattle (*A. Salicina*) has become common along fence lines. Common soil-vegetation associations observed in the area are listed in Table 4.2. Further information on vegetation in a regional perspective is provided by Durrington (1974).

4.5. Land use

The study area is intensively cropped, and most of the alluvial landscape is under irrigation (Plate 4.4). Irrigation is concentrated on the trunkstream alluvia where the bulk of irrigation water is drawn from underground bores. Water quality is highly variable with salinities ranging from 0.7dSm^{-1} to 6.6dSm^{-1} although the sodium adsorbtion ratio is generally low (<4).

Because of the mild climate a wide variety of vegetable and field crops is grown throughout the year with 2 to 3 crops harvested annually. Crop choice is largely constrained by limitations of water quality, soil permeability and site drainage.

The Lockyer Valley is a major production area for potatoes, onions and pumpkins, processing beans, peas, carrots, sweetcorn and beetroot, as well as fresh vegetables such as broccoli, lettuce, cabbage and cauliflower. Lucerne production is also substantial with soybeans and grain sorghum being the main summer field crops. Some winter barley and wheat are also grown.

Backswamp depression areas and local alluvial plains out of lower Marburg Sandstone beds are mostly used for dryland pasture (Plate 4.5). Local alluvial plains and fans out of basalt and upper Marburg Sandstones are also commonly cultivated and irrigated if water quality and supply are adequate (Plate 4.6). Dryland farming is practised on small alluvial areas of favourable soils without suitable irrigation water supplies. These include the Wonga Creek and Deep Gully alluvia.

The surrounding uplands are generally used for rangeland cattle pastures, with hobby farms increasing in number. Minor cropping occurs on the gentler slopes that are accessible, and some areas are irrigated.

Widespread clearing of upland areas has resulted in accelerated sheet and gully erosion, landslides (Plate 4.6) and outbreaks of dryland salinity. The incidence of land degradation in the study area has been documented and mapped by Shaw (1979). Detailed hydrogeological investigations into landslides in the Lockyer Valley have been carried out by Zahawi and Trezise (1981) and into salinity by Hughes (1984), Shaw (1985) and Gardner (1985). Using a water balance model, Gardner (1985) predicted that the mean chloride concentration of the Tenthill aquifer will increase from 292 ppm in 1985 to 300 ppm in 2015 to an eventual value of 340 ppm.

Plate 4.4. Irrigated crops on the Lockyer Valley alluvia with sandstone rise in background.

Plate 4.5. Backswamp depression in foreground fringing low sandstone rise.

Plate 4.6. Cultivated alluvial fan in foreground below landslip on cleared Heifer Creek Sandstone.

5. METHODS

A study of soil genesis and distribution depends on an understanding of the genesis of the landscape. In this study, a combination of field, laboratory and statistical methods were used to investigate soil properties and their spatial variability. Data collected from catchment source materials and from soils on various components of the alluvial landscape were used to construct a soil geomorphic framework for the alluvial landscape.

5.1. Field methods

5.1.1. Soil survey

A semi-detailed soil survey at 1:50 000 scale was conducted to identify and map the distribution of soils on the alluvial landscape. Delineation of soil boundaries was assisted by air photo interpretation of 1:24 000 colour photos taken in February 1974 following major flooding. Sites were described and soil data coded using the system developed by the Queensland Department of Primary Industries (unpublished) that was largely modelled on Northcote (1974) and Soil Survey Staff (1951). A sample description sheet and summary of the decoded classes is presented in Appendix 2. Coded site data is stored on hard disk at the Land Resources Branch, Queensland Department of Primary Industries.

A legend of soil profile classes was established after examining profiles throughout the Lockyer alluvial landscape. These were observed along transects covering a wide range of landforms. Soils were inspected every 150 m along transects at right angles to the direction of the stream channels in the expectation of observing the maximum soil variability. Inspection interval was reduced if landsurface features suggested soil changes occurred over shorter distances.

Once the soil legend was established, the study area was mapped by free survey. Soil profiles were examined by either using a hydraulically operated 50 mm diameter soil corer or by studying erosion and road cuttings to a depth of 1.5 m (less if coarse gravel, boulders or consolidated rock were encountered). The density of profiles examined was approximately 5 sites per

km^2 and a total of 571 sites were described for the survey area. At each site, soil profiles were described together with landform, landsurface and vegetation features. The original legend was refined as new information became available.

Soils were grouped into soil profile classes which are defined as a group of soil profiles, not necessarily contiguous, grouped on their similarity of morphological characteristics (Beckett 1971, Beckett and Burrough 1971, Beckett and Webster 1971, Burrough *et al.* 1971). When used as soil mapping units they are representative of bodies of soil with similar parent materials, topography and vegetation but may include up to 30% of other profile classes. The internal soil variability of soil profile classes in this study approximates the level of soil series* as defined by Soil Survey Staff (1951).

* Soil series: a group of soils having soil horizons similar in differentiating characteristics and arrangements in the soil profile, except for the texture of the surface soil, and developed from a particular type of parent material (Soil Survey Staff 1951).

In the Queensland Department of Primary Industries, the term soil profile class is used in preference to soil series, because of the lack of consistency in Australian usage of taxonomic terms (McDonald 1975).

5.1.2. Detailed transect examination

To evaluate the variability of soils in detail across the Lockyer Creek alluvial plain, soils were described at 25 m intervals along a transect near Lawes (see soil map). Data collected was subjected to selected numerical analyses. The methods used in the transect are given in Section 8.

5.1.3. Detailed site examination

In order to examine the source materials and the stratigraphic relationships of soils on alluvia, 23 sites were selected for detailed investigation and sampled for laboratory analysis (Section 5.2). Sites were representative of either the principal source materials in the study area catchment or the principal landforms and soil profile classes on the alluvial landscape. The location of sites is shown on the soil map and sampling details are summarised in Table 5.1.

Table 5.1. Sampling site details.

Location	Site	Type of sample	Method of sampling
Lawes	1	Levee bank of Lockyer Creek	excavation pit, deep soil core
	2	Alluvial plain of Lockyer Creek	excavation pit, deep soil core
	3	Relict levee of prior stream	excavation pit, deep soil core
Lower Tenthill	4	Saprolite of Ma Ma Creek Sandstone	farm track exposure
	5	Alluvial fan out of Upper Marburg beds	soil core
	6	Alluvial fan-terrace interface	soil core
	7	Alluvial terrace	soil core
	8	Floodplain	soil core
	9	Landslip outwash	gully channel material
Ropeley	10	Elevated dissected terrace	soil core
Deep Gully	11	Alluvial plain	eroded stream channel wall
Mt Sylvia	12	Colluvium - toe slope	soil core
	13	Elevated terrace	soil core
	14	Elevated terrace-pediment edge	deep soil core
	15	Alluvial terrace	soil core
	16	Floodplain	soil core
Mt Vale	17	Lower slope of Heifer Creek Sandstone	rock drill
Woodbine	18	Brown basalt saprolite	dam exposure
	19	Prairie soil developed on basalt	road cutting
	20	Grey clay developed on Walloon Coal Measures	quarry exposure
	21	Red podzolic soil developed on Heifer Creek Sandstone	quarry exposure
	22	Elevated dissected alluvial fan	soil core
Las Piedras	23	Alluvial fan out of basalt	road cutting

Three representative sites located at Lawes were excavated to 1.8 m with a backhoe. At other sites soil profiles were collected as 15 cm diameter cores up to 1.5 m deep using a Proline soil corer. Two profiles from Woodbine were examined and sampled from road and quarry cuttings. Soil profiles from these sites are described in Appendix 3.

To investigate stratigraphic relationships, sites 1, 2 and 3 near Lawes on the Lockyer Creek alluvial plain were drilled to approximately 10 m. Deep drilling was also attempted on elevated sites at Mt Sylvia and Woodbine along Tenthill Creek. However gravel layers prevented drilling beyond 1.4 m at Woodbine. Deep cores are described in Appendix 4.

In addition samples were taken from a buried palaeosol, and from weathered materials (saprolites) of Tertiary olivine basalt, Jurassic Ma Ma Creek Sandstone and a shale member in the Jurassic Heifer Creek Sandstone.

5.2. Laboratory methods

5.2.1. Particle size analysis

About 25 g of air-dried soil was dispersed with 10 ml of 5 % sodium hexameta phosphate and 150 ml of distilled water by end-over-end shaking overnight. International particle sizes were measured by the sieve-pipette method described by Day (1965).

Samples high in organic matter were not pretreated with hydrogen peroxide to promote dispersion because:

(i) treatment with hydrogen peroxide showed no significant effect on particle size analysis for a wide range of Queensland surface soils (R. J. Shaw, personal communication). Shaw suggests two reasons for this:

(a) the presence of manganese in the soil which decomposes hydrogen peroxide and reduces its effect; and

(b) in clay soils, clay binding (except for a very small proportion of A1 horizon samples) is a more important obstacle to clay dispersion than organic matter.

(ii) hydrogen peroxide may alter clay structure (Rich and Barnhisel 1977).

In fact, the results for a limited number of samples in this study showed no effects of peroxide on clay mineral diffraction patterns.

5.2.2. Mineral composition of the clay fraction

Orientated samples of the clay fraction ($< 2\ \mu$m) from the particle size analysis were prepared for x-ray diffraction by sedimenting onto glass tiles using a modification of the Jackson (1965) method.

Magnesium was chosen as the saturating cation for all samples as it allows relatively uniform adsorbtion of water by expandable layer silicates. Potassium saturation, which specifically restricts interlayer adsorbtion of water by vermiculite, was also carried out on a limited number of samples.

Enough suspension for at least 25 mg of clay was three times saturated, centrifuged and the supernatent discarded with 10 ml of 0.5 M of $MgCl_2$ or 10 ml of 1 M KCL. To remove chloride salts, the suspension was then three times washed, centrifuged and supernatent discarded with 10 ml of 50% ethanol. The clay was mixed into a viscous suspension with distilled water, pipetted onto a glass tile and allowed to air-dry.

The magnesium samples on glass tiles were then solvated with ethylene glycol in petri dishes at 80 °C for 4 hours. This was followed by two separate heat treatments of 325 °C and 550 °C for 4 hours. Potassium samples were subjected to the same heat treatment and in some cases to 110 °C as well. After each treatment the tiles were scanned on a Siemens x-ray diffractometer using CoKα radiation (λ = 1.79021 Å) with instrument setting of 30 kV and 16 m.a. in conjunction with iron filters. Following heat treatments samples were placed in a dessicator to prevent rehydration.

Interpretation of x-ray diffraction trace patterns is based on spacings and heights and areas of the diffraction peaks of treated specimens as described by Brindley and Brown (1980) and Dixon and Weed (1977).

For diffractometry the method of preparation should provide a specimen having maximum preferred orientation of basal planes parallel to its surface and which is also sufficiently thick and homogeneous. Unfortunately these aims conflict to some extent. Thin films prepared by allowing a thin dispersion to dry slowly on a glass slide, give good orientation but often are too thin and/or inhomogeneous to provide relative intensites representative of the sample material (Brindley 1980).

A semi-quantitative estimation is shown in Table 5.2 together with the abbreviations used to designate clay mineral types.

Table 5.2. Symbols used to report clay mineral results.

Clay mineral type		Relative abundance	
Symbol	Clay mineral	Symbol	Amount
C	chlorite	++++	dominant constituent
I	illite	+++	abundant or co-dominant
K	kaolinite	++	subdominant constituent
Q	quartz	+	minor constituent
RIM	randomly interstratified mineral	tr	trace
S	smectite		
SI	interlayered smectite		
V	vermiculite		

The sedimentation method used here was compared with the paste method in which a thick paste of the clay sample is smeared onto class slides. This method is believed to give a thick homogeneous sample (Gibbs 1965, Theison and Harward 1962).

The ratios of peak area at 17 A to that at 7 A peaks for sedimented samples were found to be 20 to 40% higher than for the smear samples. Gibbs (1965) found similar trends and suggested two reasons for the increase in this ratio. Firstly, in sedimented samples the coarser kaolinite crystals quickly settle towards the bottom of the slide while predominantly fine smectite crystals stay in suspension longer and concentrate near the surface. Secondly, at low 2 Θ angles the major portion of the diffraction pattern is derived from the upper surface of this sample; this surface bias decreases as Θ increases. For these reasons the sedimentation method produced a bias towards smectite in the estimation of clay mineral composition. Unfortunately, the writer only became aware of this bias at the end of this study; in retrospect, the paste method would have been adopted had this bias been known at the onset. However, the bias is present in all samples and, since the relative differences in clay mineralogy are the prime concern in this study, the method is considered valid.

In samples containing smectite minerals, diffraction patterns showed evidence of varying degrees of interlayering within the smectite (see Figs 5.1 and 5.2). Although these clay minerals when magnesium saturated usually expanded to 17-18 A on solvation with ethylene glycol (a few expanded to 23 A, indicating interstratification) they did not collapse to 10 A on heating at 325 °C, broad peaks with diffraction spacings in the range of 11-13 A being recorded. This incomplete collapse suggests that interlayer components were present. Further heating to 550 ° C usually showed more effective collapse of these clays to 10 A, but the diffraction peak was usually skewed towards the higher basal spacings (Fig. 5.1b). Incomplete collapse on heating was also demonstrated for potassium saturated samples (Fig. 5.2). Such behaviour is characteristic of hydroxy interlayered forms of smectite (Barnhisel 1977). According to Barnhisel (1977) the higher the temperature required to cause collapse (or partial collapse) of the 14 A peak towards 10 A, the larger the degree of filling by interlayer materials.

Interlayer materials most commonly consist of polymerised hydroxy-hydrates of aluminium and magnesium ions (iron or interlayered organic material may also be present) (MacEwan and Wilson 1980). To remove interlayer materials, selected samples were pretreated with ammonium oxalate (Fitzpatrick and Le Roux 1977). Oxalate treatment was found to enhance the diffraction peak (Fig. 5.2) indicating that some interlayer materials had been removed.

A gradation was observed from weakly interlayered smectite to strongly interlayered smectite. X-ray diffraction patterns indicating the gradation from weakly interlayered smectite (S) to strongly interlayered smectite (SI) together with randomly interstratified minerals (RIM) are shown in Fig. 5.1.

In Fig. 5.1 (a), the weakly interlayered smectite shows sharp peaks indicating strong crystallinity. The only indication of interlayering is the incomplete collapse on heating (325 ° C) to 12.2 A, and a very slight skewing of the peak to higher basal spacings for the 550 ° C peak at 10 A. Because they show only weak interlayering, these clays are referred to hereafter as smectites.

In contrast, Fig. 5.1 (b) shows evidence of a strongly interlayered smectite with less well defined peaks and only partial collapse on heating and broader, more skewed peaks.

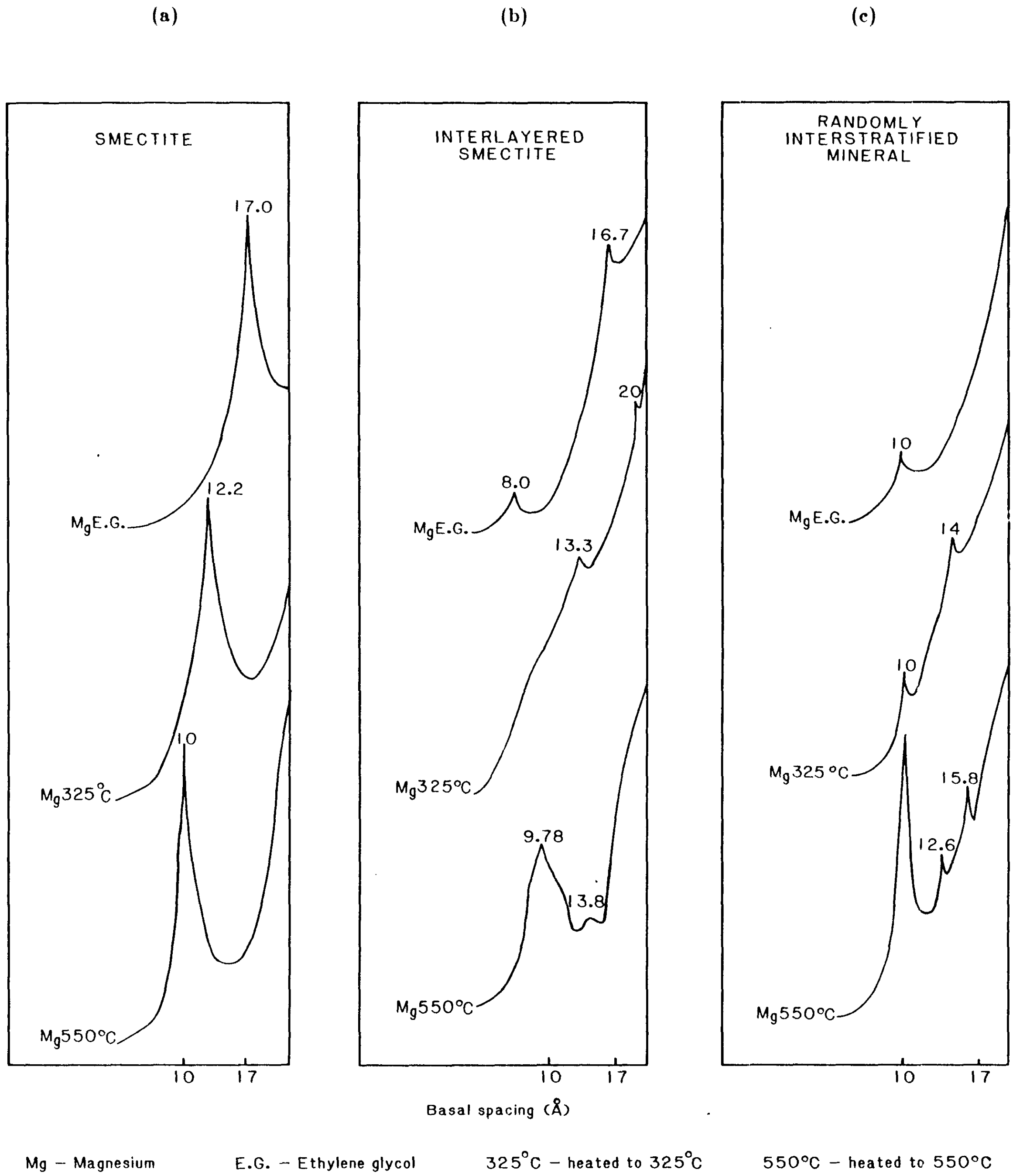
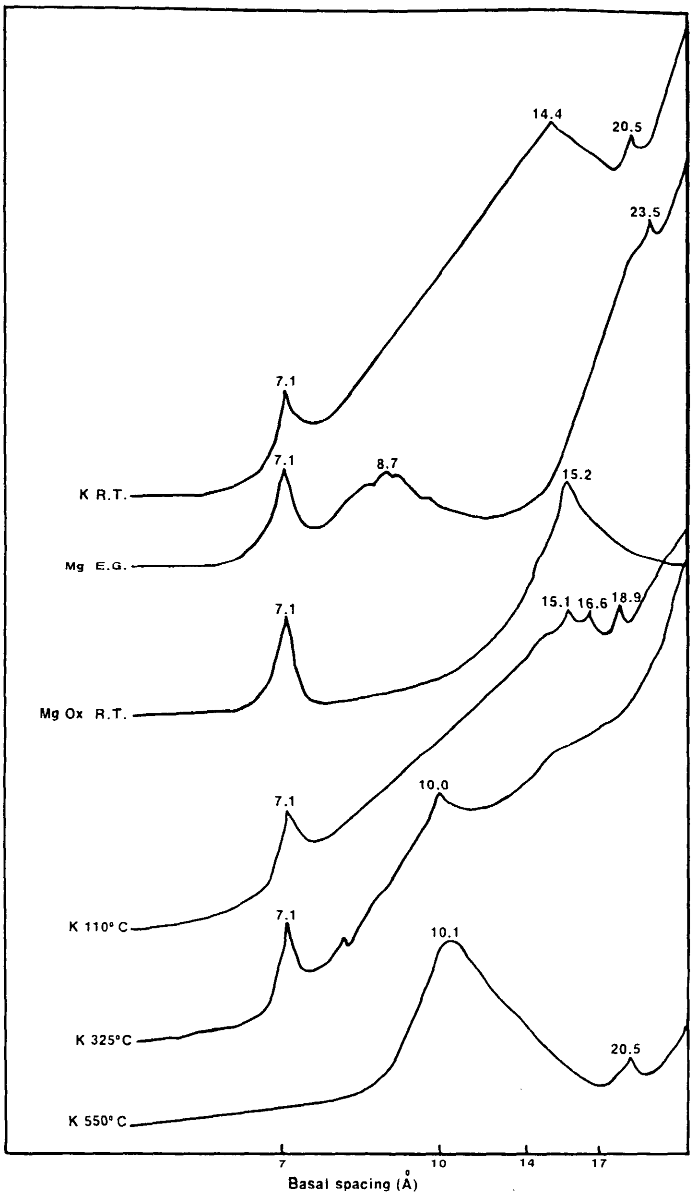


Fig. 5.1. Typical smoothed x-ray diffraction patterns for interlayered smectites and randomly interstratified mineral.



K = potassium saturated
Mg = magnesium saturated
Ox = ammonium oxalate
R.T. = room temperature
E.G. = ethylene glycol
110 ° C = heated to 110 ° C
325 ° C = heated to 325 ° C
550 ° C = heated to 550 ° C

Fig. 5.2. Smoothed x-ray diffractogram Spellman Prairie Soil (0-0.13 m).

Fig. 5.1 (c) differs from the others by the absence of a peak at 17 Å following treatment with ethylene glycol, and a number of peaks are revealed on heating. This reflects some of the structural components of this randomly interstratified mineral.

Vermiculite present in the clay fraction of saprolite from Ma Ma Creek Sandstone also showed only partial collapse on heating to 325 °C. It appears likely that this mineral is also interlayered in a manner similar to the smectite.

5.2.3. Mineral composition of the fine sand fraction

The 53 to 106 μm fraction of the fine sand fraction was collected from particle size analysis and separated by dry seiving. To remove coatings from grains, a 1 g sub-sample was then treated with 20% citric acid for 10 minutes in a boiling water bath agitating frequently. If grains were still coated, the procedure was repeated using 2N hydrochloric acid. Samples were then washed with deionized water until free from acid. After drying for 12 hours at 105 °C samples were separated into light and heavy mineral fractions using bromoform (S.G. 2.9), washed with ethanol, oven-dried and weighed.

Sub-samples were then mounted on a slide with "Lakeside 70" and examined with a polarising microscope.

Minerals in the heavy fraction were generally found to be clearly identifiable and counts of all grains were made. The number of grains counted were made according to Brewer (1964), who suggests acceptable levels of accuracy, probable errors and confidence intervals for various counts of mineral species. The number of grains counted was usually between 300 and 500.

The minerals in the light fraction were largely quartz but in many samples a variety of partially weathered unidentifiable grains were present. Because local basalt contains significant amounts of plagioclase (Stevens 1969), it was suspected that many weathered grains were pseudomorphic feldspars which develop in weathering basalt (Glassman and Simonson 1985). However a trial test of samples using a staining technique (Bruce-Smith 1972) revealed significant amounts of feldspars (up to 30%) in only one profile (site 1). In other profiles, feldspars are believed to have been more weathered and were destroyed by etching with HF prior to staining. Therefore feldspars were determined indirectly by measuring the calcium content of the light fraction. A limitation to this approach is that on weathering of feldspars, calcium is released and removed. Thus the calcium content will vary with the degree of weathering as well as the initial plagioclase content. However, calcium as an index of the relative degree of weathering is a useful measure to distinguish between soils.

Calcium was determined by x-ray flourescence. Fused glass discs were prepared using a 1:5 dilution of sample in a lanthanum oxide-lithium tetraborate glass (Johnson Matthey Spectroflux^{R} Type 105), with sodium nitrate as an oxidising agent. Samples were analysed on a Philips PW1540 x-ray flourescence spectrometer using a Cr - target x-ray tube, 30 KV/10 mA, LIF200 crystal and flow proportional detector. Count time was 40 seconds per sample (N. Donnellan, personal communication). International Reference Samples (G2 = Granite, BRC1 - Basalt, PCC1 = Peridotite and AGV1 = Andesite) and a specpure silica blank were used for calibration. No inter-element corrections were made.

0.0.1. Radio carbon dating

Three buried palaeosol samples from deep cores near Lawes (sites 1, 2 and 3 on soils map) were radiocarbon dated by the N.W.G. McIntosh Centre for Quaternary Dating, University of Sydney. The material used was the total soil organic carbon and the age reported is the mean residence time. Ages reported are years b.p., which is defined as the radiocarbon years before 1950 A.D. Methods of pretreatment and counting procedure are described in Appendix 5.

6. GEOMORPHOLOGY AND COMPOSITION OF ALLUVIAL SOURCE MATERIALS

The valley alluvia of any area are derived from the weathering regolith of upland catchment rocks, which may have a range of lithologies. The composition of the alluvia will be dominated by catchment source materials which are being most actively eroded and transported by water at the time of formation of the alluvial landform. To understand the origin, nature and distribution of soils on the valley alluvia of the study area, a range of potential upland source materials was investigated. Comparison of the properties of potential source materials in the uplands of the catchment with the properties of soils and sediments in the valley alluvia should help clarify relationships between the two materials.

6.1. Lithology and extent

The relative landscape positions of the various source materials are presented in cross-section in Fig. 6.1, and their distribution is shown on the enclosed geological map. The lithology and extent of the source materials which contribute to the Tenthill catchment alluvia have already been described in Section 4.2 and are summarised in Table 6.1. On an area basis, regolith derived from basalt (54%) and Heifer Creek Sandstone (22%) would appear to be the major materials contributing to the alluvia. These are also the rocks which show the most landslide activity (Shaw 1979), making an abundance of material available for transport, unimpeded by vegetation cover.

Zahawi and Trezise (1981) found landslides to occur on Heifer Creek Sandstones where sandstone and mudstones were interbedded. The sandstones examined at Mount Berryman and Mount Sugarloaf landslide sites were found to be labile to sublabile with the feldspar content of all samples always less than three per cent. Quartz was generally more abundant at Mt Sugarloaf which is west of the study area. Sandstones were also generally found to be weathered with high contents of iron oxide.

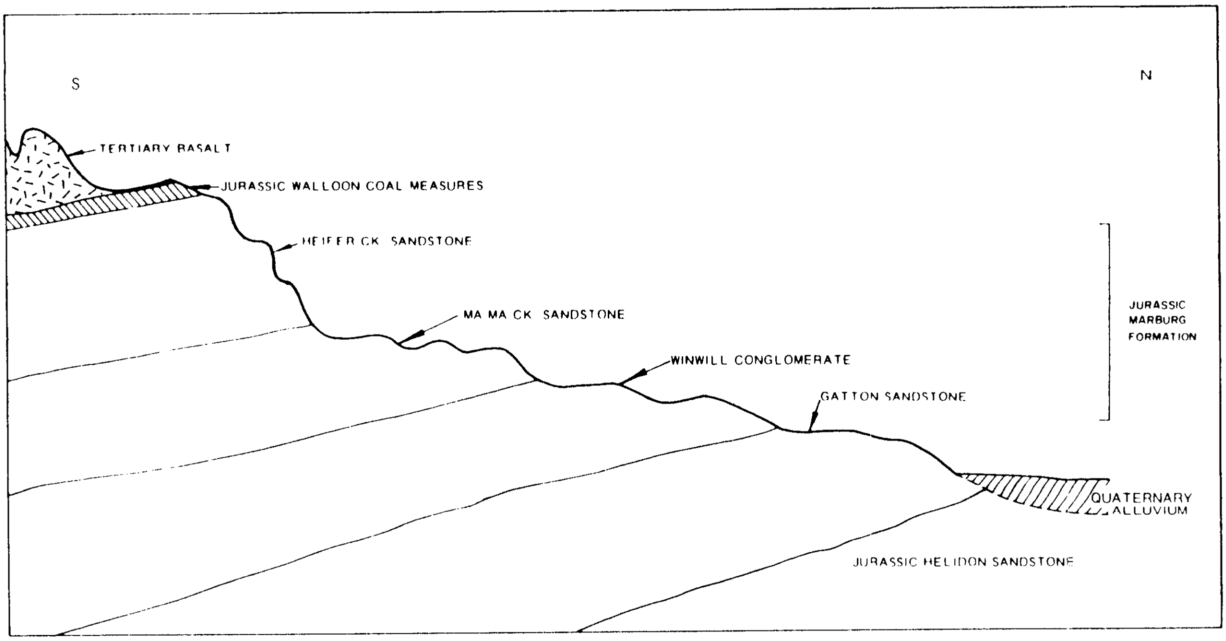


Fig. 6.1. Idealised cross-section of the geology of the study area.

Table 6.1. Source materials in Tenthill Creek catchment.

Source material	Thickness (m)	Lithology	Areal extent ha	%
Basalt	200-450	olivine basalt, minor rhyolite, trachyte, and interbasaltic tuff	28496	54
Walloon Coal Measures	<30*	shales, siltstones, lithic sandstones, coalseams and limestone	2094	4
Heifer Creek Sandstone	200-300	coarse, ferruginous, quartzose sandstone, mudstone and flaggy sandstone	11396	22
Ma Ma Creek Sandstone	80	flaggy lithic sandstone, shale, siltstone, minor fossilwood conglomerate	2512	5
Winmill Conglomerate	30-50	flaggy sandstone and fossilwood conglomerate	726	1
Gatton Sandstone	30-40	caliche and lithic sandstone	553	1
Alluvia	10-30	clay, silt, sand and gravel	6730	13

* In the catchment area, Walloon Coal Measures, some 200 m thick, were stripped prior to burial by the Tertiary basalt.

6.2. Weathering and erosion of source materials

Miocene

The higher basalts in the western edge of the Lockyer Valley were thought to have been deeply weathered during the Miocene. Stevens (1969) reported that lateritising conditions existed before and between basalt flows of Late Oligocene - Early Miocene age. Watkins (1967) believes that occurrences of lateritic weathering in elevated positions are the dissected remnants of an upper erosion surface which was widespread in south-east Queensland during the Eocene - Oligocene. However, Beckmann and Stevens (1978) suggest that lateritisation occurred in the Miocene and may not have extended very far to the east. Field observations in the study area revealed the presence of lateritic materials (ferruginous zones, silcrete) on the stripped remnants of Walloon Coal Measures but not on Tertiary basalt (K.K. Hughes, unpublished report). Understanding of the relationships between elevated weathering features from different locations in south-east Queensland is far from complete.

Late Miocene - Early Pliocene

In this time, Tenthill Creek and its tributaries cut narrow valleys back into the basalt plateau, leaving ranges in the interfluves. As dissection proceeded, and valleys widened, structural trends influenced valley form and stream direction (Beckmann and Stevens 1978).

Eventually base level became stable enough for a distinct erosion surface to develop in some localities. This erosion surface has been termed the Woodford Surface by Beckmann and Stevens (1978) and was named the Middle Erosion Surface by Watkins (1967). The gently undulating lower beds of the Marburg Formation streams are considered by Watkins (1967) to be dissected peneplain remnants of the Woodford Surface.

Late Pliocene - Early Pleistocene

During this period there was minor tectonic activity and the highlands were steadily reduced (Beckmann and Stevens 1978). By the Early Pleistocene, the landscape of the study area is thought to have reached its present form (Fig. 4.2) and apart from active headward cutting, later changes have been mainly within the valley floors (Beckmann and Stevens 1978).

At present, bare rock scree slopes can be observed in places on the steepest scarps of basalt. The basalt scarps give way to low rolling plateaux and ridges of the stripped Walloon Coal Measures or the steeper ridges of Heifer Creek Sandstone beds. The interbedded nature of the Heifer Creek Sandstone member has led to benches forming on the softer, readily decomposible sediments, and the accumulation of weathering debris on steep slopes (Willmott 1984). Such materials on slopes are extremely susceptible to mass movement. As a result a series of benches separated by low cliffs were produced.

Below the exposures of Heifer Creek Sandstone are low hills of Ma Ma Creek Sandstone and gently undulating rises of Winmill Conglomerate and Gatton Sandstone. These become more predominant in the downstream reaches of Tenthill Creek and Lockyer Creek.

Hillwash deposits and alluvial fans occur over small areas in the tributaries of the major drainage lines. The major streams are surrounded by river terraces in their upper reaches and broad alluvial plains downstream (see Section 4.2.3 for more detail).

The main source materials as deduced from geomorphological evidence are the elevated basalt and Heifer Creek Sandstone. Walloon Coal Measures, Ma Ma Creek Sandstone, Winwill Conglomerate and Gatton Sandstone appear to be of minor importance as source materials.

6.3. Mineralogical studies

To elucidate further the nature of source materials and their relationship to valley floor alluvia, the particle size distribution, clay and fine sand mineralogy of a range of potential source material were estimated. Soil, sediment and saprolite samples were collected from five upland regions at 23 sites which were positioned either on distinct lithologies or landform elements, or in sequence along a transect (soils map, and Table 6.2).

Table 6.2. Sampling details for source materials.

Location	Site No. (on soil map)	Source material	Comments
Woodbine	18	basalt	saprolite beneath shallow chocolate soil on 20% midslope
	19	basalt	prairie soil (Dd4.12) profile on basaltic knoll
	20	Walloon Coal Measures	grey clay (Ug5.22) profile on plateau landscape
	21	Heifer Creek Sandstone	red podzolic soil (Dr4.41) on 25% midslope
Lower Tenthill landslide	9	Mix of Heifer Creek Sandstone and Ma Ma Creek Sandstone	sandy outwash at base of landslide
	9	Mix of Heifer Creek Sandstone and Ma Ma Creek Sandstone	loamy outwash at base of landslide
Lower Tenthill	4	Ma Ma Creek Sandstone	saprolite beneath shallow yellow brown gradational soil
Mt Vale borehole	17	shale bed in Heifer Creek Sandstone	weathered grey shale saprolite from 6 m below surface
Mt Sylvia	12	Heifer Creek Sandstone	surface horizon of shallow soil on Heifer Creek Sandstone

Soil profiles were examined and sampled from exposures or from 0.15 m diameter cores. Field descriptions of each profile are presented in Appendix 4.

6.3.1. Clay mineralogy

Results of particle size and clay mineralogical analyses are shown in Table 6.3.

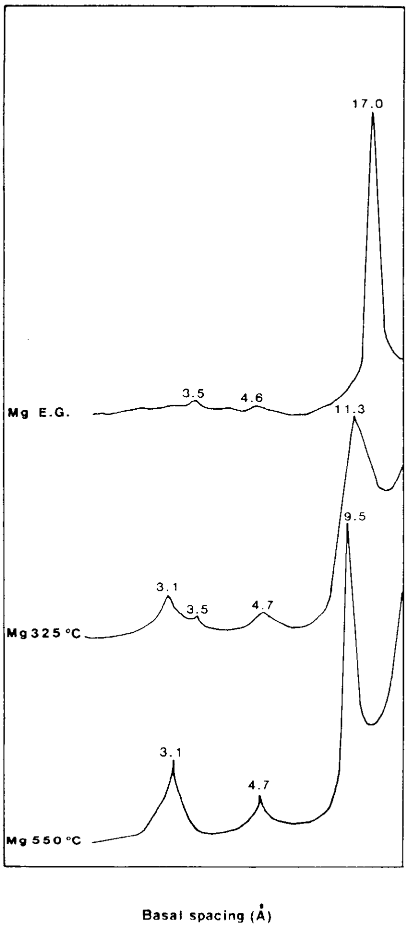
Table 6.3. Particle size and clay mineralogy of source materials.

Source materials	Site no.	Particle size (%) *				Clay minerals							
		CS	FS	Si	C	S	SI	RIM	K	I	Q	V	C
Chocolate soil	18	20	39	22	20		++++		+	tr			
saprolite (basaltic)													
Prairie soil	19												
(basaltic)													
0.0 - 0.15 m		18	27	25	20	++++		+	tr				
0.3 - 0.5 m		14	20	28	38	++++			tr				
0.8 - 1.0 m		23	23	28	23	++++							
1.2 - 1.5 m		13	29	27	31	++++		+					
Walloon	20												
grey clay													
0.0 - 0.13 m		13	22	32	33			+++	+++	+	tr		
0.13- 0.44 m		4	10	22	62			+++	+++	+	tr		
0.44- 0.56 m		4	10	27	59			+++	+++	+	tr		
0.56- 0.71 m		3	16	32	49			+++	+++	+	tr		
0.71- 0.90 m		3	30	31	36		tr	+++	+++	+	tr		
Heifer Ck. Sandstone	21												
red podzolic soil													
0.0 - 0.03 m		36	33	24	7			+++	++++	+	tr		
0.1 - 0.3 m		28	33	15	24			+++	++++	++	tr		
0.6 - 0.7 m		16	35	13	36			+++	+++	+	tr		
1.0 - 1.2 m		10	30	14	46			+++	++++	++	tr		
1.4 - 1.5 m		8	29	15	48				++++	+	tr		++
Landslide - loamy outwash	9	13	58	12	17	+++			+++	+	tr		
- sandy outwash	9	59	29	12	8	+++			+++	+	tr		
Ma Ma Ck.Sandstone	4												
saprolite		15	55	17	14				++++	+	tr	+++	
Heifer Ck. Sandstone	17												
upper mudstone bed (3 m)		1	9	37	53	++++			++	+	tr	+	
lower mudstone bed (6 m)		2	24	30	44	+++			+++	+	tr		
Heifer Ck. Sandstone	12												
colluvium		33	21	16	30			++	+++	++			

* International system size classes

Basalt

Soil and saprolite clay samples derived from Tertiary basalt were found to be dominated by smectitic clay (Table 6.3, Fig. 6.2). Very little kaolinite was present. The strongly dissected, high-positioned basalt has been subjected to considerable erosion, forming a landscape of steeply sloping ranges (15-40% slopes). The basalt flow sequences were thick enough for erosion of unstable slopes to periodically expose the less weathered basaltic saprolite in which smectites are forming.



Mg = magnesium saturated
E.G. = ethylene glycol
325 ° C = heated to 325 ° C
550 ° C = heated to 550 ° C

Fig. 6.2. Smoothed x-ray diffractogram of clay in a prairie soil (0.3-0.5 m) developed on Tertiary basalt (site 19).

The weathering of minerals like augite and olivine in the basalt would have resulted in a high concentration of magnesium in weathering solutions, thereby favouring the persistance of smectite.

Heifer Creek Sandstone - sandstone beds

Table 6.3 shows that a red podzolic soil (site 21) and colluvium (site 12) formed on Heifer Creek Sandstone, contains kaolinite (dominant), randomly interstratified mineral and minor illite (Fig. 6.3). Zahawi and Trezise (1978) found deep core samples of the sandstone beds of Heifer Creek Sandstone to vary in clay compositions from one site to another. At one site illite-smectite mixed layer clays were the important matrix-forming component where as illite and kaolinite were the dominant clays at another. Differences in deep core samples were attributed to inherent differences in sandstone composition as well as weathering, whereas clay mineral composition in the red podzolic soil is believed to be mainly the result of weathering. Zahawi and Trezise (1978) suggested that fluid movement and cation exchange proceeded unhindered in the buried sandstones resulting in the formation of mixed-layer clays.

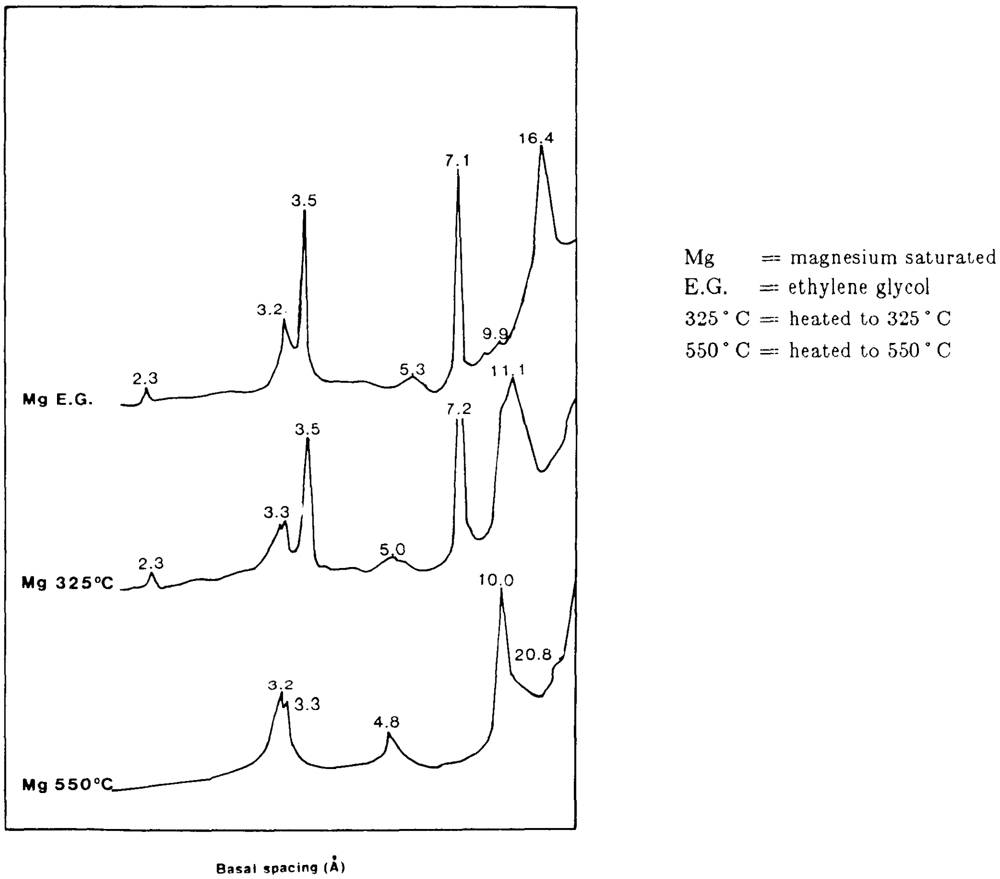
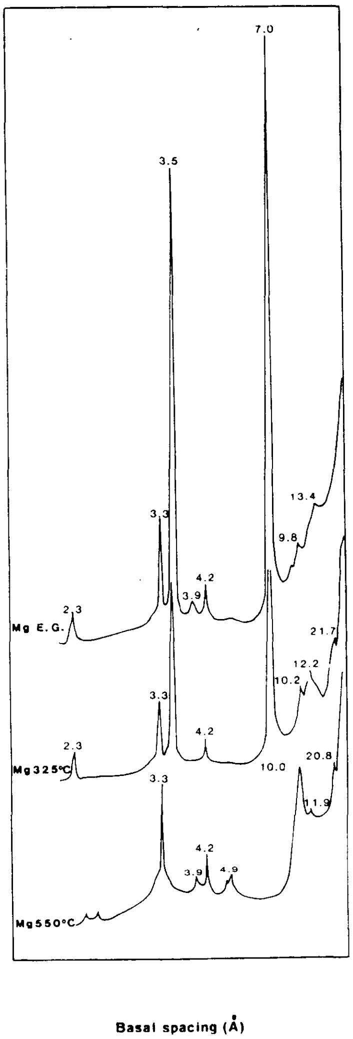


Fig. 6.3. Smoothed x-ray diffractogram of clay in a red podzolic soil (0.1-0.3 m) developed on Heifer Creek Sandstone (site 20).

The red podzolic soil at site 21 was positioned on a steep midslope which would be in transit to the valley below by soil creep. Movement of this material would occur at a very low rate unless vegetation cover was removed during episodes of aridity or by clearing, whereby rill and gully erosion would rapidly transport soil materials downslope.

Argillaceous sediments

In deep core samples at site 17, interbedded mudstones in Heifer Creek Sandstone were found to contain smectite or interlayered smectite and kaolinite with minor illite (Table 6.3). Zahawi and Trezise (1978) also found buried mudstones in the Heifer Creek Sandstone to be largely composed of smectite; they attributed the lack of mixed layer clays (interstratified clay minerals) to the absence of available K-feldspar and restriction of fluid movement during the compaction phase.



Mg = magnesium saturated
E.G. = ethylene glycol
325 °C = heated to 325 °C
550 °C = heated to 550 °C

Fig. 6.4. Smoothed x-ray diffractogram of clay in landslide outwash from upper Marburg beds (site 9).

Zahawi and Trezise (1978) also observed that the rupture zones of landslides occurred within the smectite rich mudstone beds. Analysis of landslide debris (site 9) in Table 6.3 indicate the presence of co-dominant smectite and kaolinite (Fig. 6.4). These appear to be clay minerals derived from a mixing of mudstone and sandstone materials.

In samples of *in situ* soils derived from argillacieous sediments, clay composition differs from buried samples (Table 6.3). A grey clay developed from a mudstone bed of the Walloon Coal Measures (site 20) is mainly composed of randomly interstratified mineral and kaolinite with minor illite. Clay below 1.0 m depth at site 21 is a weathered argillaceous sediment also and shows similar composition.

Clay minerals in soils derived from the Walloon Coal Measures are likely to vary since calcareous sandstones have a smectite matrix whereas in mudstone and siltstone members, kaolinite is the dominant clay mineral (Cranfield *et al.* 1976).

Ma Ma Creek Sandstone

Saprolite weathered from Ma Ma Creek Sandstone was found to be dominated by kaolinite and vermiculite. However, because of their lower position on the landscape (Fig. 6.1) and their minor extent (5%) such materials are unlikely to have contributed significantly to the alluvia in the valley floors. In some areas however, they may be locally important.

Conclusions

Regolith positioned high in the landscape and derived from weathering basalt and the upper Marburg materials associated with landslides (Fig. 6.1) are both important potential sources of smectitic minerals (Table 6.3). Because basalt is the major rock in the catchment (54%) it is likely to be the main source of smectitic clays in the alluvia. The association of mudstones with landslide activity, and their ready weathering to easily transportable fine particle sizes, suggest that at times of active mass movement, mudstones were significant source materials. This would be particularly apparent in landslip prone parts of the catchment. Relict landslides have been observed in the Lockyer Valley (Ceisiolka 1974, Shaw 1979, Zahawi and Tresize 1981) and these were possibly active during episodes of rapid and extensive alluvial deposition on the valley floors of the study area.

It is concluded that parent material, topography and geomorphic processes have played major roles in determining the composition of clay minerals of the upland regolith. This in turn has influenced the composition of clay minerals in the alluvium deposited in the valleys below and the soils formed from them.

6.3.2. Fine sand mineralogy

Table 6.4 indicates that basaltic saprolite is a major source of augite and plagioclase (as estimated from CaO content) in the fine sand fraction. If it is assumed that all the calcium with a CaO content of 12% in the light mineral component of the fine soil fraction is in the feldspar labradorite (Ab4 An6), then the estimated labradorite content is 9%. This would be a minimum value as calcium is one of the first minerals to be removed on weathering (Creasey *et al.* 1986). Much of the measured calcium is likely to be adsorbed to the surface of beidellite pseudomorphs formed on weathering of plagioclase (Glassman and Simonson 1985). In contrast to basaltic saprolite other source materials analysed have little augite and for calcium oxide contents in the fine sand light fraction.

In comparison to the basaltic saprolite the prairie soil profile sample developed on basalt (site 19) has little augite in the fine sand fraction, probably due to weathering and leaching.

All source materials derived from the Jurassic sediments are consistently low in augite and high in opaques. Apart from the shallow sandy surface horizon of the red podzolic soil derived from Heifer Creek Sandstone which has 12% zircon, the other fine sand minerals identified, occur in minor amounts only.

Light/heavy ratios of the fine sand fraction suggest trends but give no clear separation between potential source materials (Table 6.4). Low values (<10) characterise materials of basaltic origin, landslide debris and buried mudstones. Extremely high values (>100) are linked to regolith associated with Walloon Coal Measures or sandy surface horizons of soils developed on Heifer Creek Sandstone.

Table 6.4. Mineral composition of the 53-106μm sand fraction of source materials.

Source material	Site no.	Light/heavy ratio	Light fraction % CaO	Augite	Opaques	Zircon	Tourmaline	Rutile	Other	Augite/ Opaque ratio
				Heavy fraction percentage						
Chocolate soil saprolite	18									
(basaltic)		6.2	2.29	58	42	-	-	-	tr	1.41
Prairie soil	19									
(basaltic) (0.8-1.0 m)		10.2		1	91	-	-	3	4	0.04
Walloon grey	20									
clay (0.45-0.65 m)		117	0.05	1	85	2	2	tr	10	0.01
Heifer Ck. Sandstone	21									
red podzolic soil										
(0.1-0.3 m)		229		3	77	12	3	2	2	0.03
(1.0-1.2 m)		15	0.41	3	87	2	tr	2	5	0.02
Ma Ma Ck. Sandstone	4									
saprolite		13	0.23	tr	96	1	tr	tr	2	<0.01
Landslide	9									
loamy outwash		9.3		1	83	2	2	tr	11	<0.01
Heifer Ck. Sandstone	17									
mudstone (6 m)										
saprolite		7.8	0.09	tr	96	-	tr	tr	3	0.03

Note: tr = trace

6.4. Conclusions

The mineralogical data provide some guidelines for identifying the source materials from which the valley floor alluvium was derived. Alluvia derived from basaltic saprolite are likely to have:

(i) high smectite/kaolinite ratios (interlayered smectite included on smectite components)

(ii) no randomly interstratified minerals in the clay fraction

(iii) illite in trace amounts only

(iv) high augite/opaque ratios in the heavy fine sand fraction

(v) high calcium oxide values in the light fine sand fraction

In contrast, alluvia derived from Jurassic sediments will have:

(i) either lower smectite/kaolinite ratios if derived from little weathered mudstones in landslip prone catchments or no smectite at all if derived from surface weathered regolith.

(ii) randomly interstratified minerals in the clay fraction

(iii) illite present in more than trace amounts

(iv) low augite/opaque ratios in the heavy fine sand fraction

(v) low calcium oxide values in the light fine sand fraction.