CHAPTER FIVE. GENESIS OF THE BLACKBUTT AND FLOODED GUM SOILS

5.1 THE EFFECT OF RELIEF AS A SOIL FORMING FACTOR

Wilde (1958) stated that;

> "No matter how strong is the soil forming influence of forest vegetation it may be offset by the more powerful effects of climate, topography and parent rock" (p.118)

In the terms of general soil genesis theory, this is the problem of distinguishing soil properties which are determined by the independent external state factors (climate, parent material, relief, organisms and time; Jenny 1941, 1958, 1961) from those soils properties dependent upon the present or past vegetation.

The common occurrence of blackbutt and flooded gum communities in vegetational toposequences in the Coffs Harbour region suggests that these eucalypt species are both part of the external, independent, biotic state factor for this region (Jenny, 1941: Crocker, 1952). Comparing the two study sites shows that the biotic and climatic state factors can be considered as being relatively constant while the relief factor varies and the status of the time and parent material factors is questionable. So from the Jenny fundamental equation of soil development the general differences between the soils of the Bruxner Park and McNamaras Road sites can be considered as some function of relief with reservations concerning the status of the parent material and time independent variables.

Florence (1964, 1968) and McColl (1969) have both established toposequential gradients of certain soil properties under eucalypt forest and similar results were found in this study between the upper slope blackbutt site and the lower slope flooded gum site.

Total soil N and P increases from the blackbutt to the flooded gum soils while C:N ratios decrease. Properties such as exchangeable Al, pH, CEC and bulk density are variable within each site in relation to the individual trees but generally the variability is greater in the blackbutt soils.

In comparison with the results of McColl (1969), exchangeable Al has its highest values in the upper slope, blackbutt soils but these values are found in soil adjacent to the blackbutt boles while away from the same trees the lowest values of the two sites occur. The flooded gum exchangeable Al values are also variable in relation to the position of the tree but the variability is within the range found at the blackbutt site. The pH, CEC and bulk density results are similar in variability within and between sites to exchangeable Al so caution is needed before generalized, vegetation - soil property toposequence relationships are postulated because the individual tree can induce variability in soil properties within a forest community greater than that found between forest communities on a toposequence.

Soil morphological properties are also dependent upon relief and therefore vary between the flooded gum and blackbutt sites. Depth of solum increases and profile stoniness decreases downslope but one of the major differences between the blackbutt and flooded gum sites is the effect of the flooded gum sites' lower slope position on the origin of the Bruxner Park site soil materials. While the blackbutt soils are forming in situ from the weathering mudstone of the ridge-line the flooded gum soils have possible inputs of colluvial or alluvial material because of the Bruxner Park sites' lower slope position.

(a) Polygenesis of the Bruxner Park Site Soils

A proposed outline for the formation of the Bruxner Park site soils is presented below, based upon the general morphological features and soil properties of the 7 described profiles and the spatial change of these properties within the soil pits of the site.

Basic assumptions of this model are that, i) the B32 horizon was formed from in situ weathering of the greywacke parent material, ii) the lower slope situation of the flooded gum site near Bucca Creek and the local relief of approximately 200m increases the probability that layers of colluvium and/or alluvium may have been deposited upon the weathering parent material of the site, and iii) the thickness of the geological beds of greywacke described by Korsch (1978) for this region indicate that the colluvium and even the alluvial material would originate from similar parent materials to that at the site.

The circumstances which produced the coarse red and white mottles of the B32 horizon of the Bruxner Park soils are unknown but are assumed to be related to the weathering of the greywacke. Such mottled subsoils occur on the mid and lower slopes of the undulating foothills in the Coffs Harbour region. Profile UNE 6 described in Stace el al.(1968) (Appendix II) from Pine Creek State Forest, south of Coffs Harbour has a similar coarsely mottled subsoil horizon to the B32 of the Bruxner Park site.

Figure 5.1 outlines the possible genetic pathways of soil formation for the Bruxner Park site. A hypothetical initial soil body is proposed for which the only known horizon is the B32, weathering from the greywacke parent material. The first problem is the origin of the B31 horizon which is paler in colour, with fewer coarse mottles than the B32 horizon. The horizon's morphology could be a result of the presence of past and present tree boles, alternatively, the B31 could be related to the B32 horizon with some agent destroying its morphology away from the flooded gum bole. The latter proposal is the more acceptable in consideration of the soil properties of the B31 horizon such as texture, extractable Fe and coarse to fine sand fraction ratios, which indicate stronger affiliation with the B32 horizon than to the B2 horizons.

If the B31 horizon is considered to have formed from the B32 horizon then the second morphogenetic problem encountered with these forest soils is whether the horizons above the B3 horizons have developed from further <u>in situ</u> soil formation, or, alternatively, do they constitute a secondary pedogenetic layer formed from colluvial or alluvial deposition. Ignoring profile 1D for the moment, there is no evidence to suggest an alluvial origin to the upper horizon layers but undoubtedly there has been some colluvial downslope movement, influencing at least the nature of the A horizons.

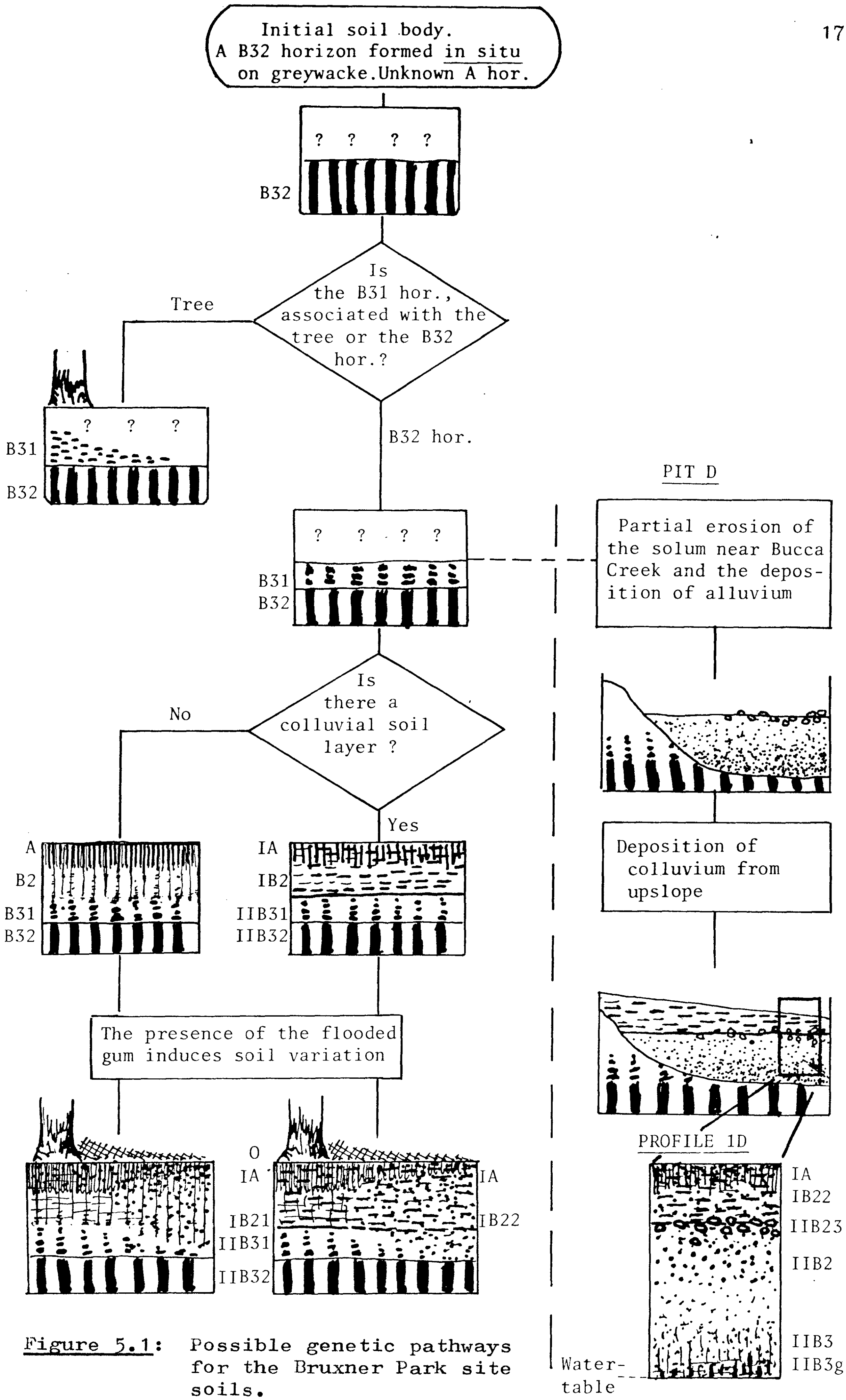

Figure 5.1: Possible genetic pathways for the Bruxner Park site soils.

Whether this could be extended to colluvial deposition of all the soil layers above the B31 horizon is conjectural.

Some of the features that suggest a polygenetic origin to the Bruxner Park site soils could be interpreted as due to pedoturbation of the upper soil horizons by tree roots or soil fauna (this alternative interpretation is also relevant to the morphology of Profile UNE 6, Appendix II, which R. Brewer proposed as polygenetic upon the evidence of the profile's micromorphology). The soil morphology of Pits C and B indicate that earthworm mixing could be the mechanism destroying the morphology of the B31 horizon away from the tree. If this is the case then the B31 horizon and the overlying colluvium have been partly intermixed by the earthworms, destroying any distinct depositional boundaries.

It is the distinctive morphology of profile 1D that offers the main evidence for polygenicity of the Bruxner Park site soils.

(1) Profile 1D:

The characteristic features of profile 1D have already been partly discussed, so in summary, the evidence from particle size analysis and certain chemical properties indicate that there are at least two pedogenetic layers constituting profile 1D.

A diagrammatic illustration of the proposed genesis of this profile is presented in Figure 5.1. It is assumed that the initial soil body consisting of B31 and B32 horizons over parent material was partly eroded by Bucca Creek (profile 1D is the closest of the Bruxner Park soils to Bucca Creek). Alluvium, rich in coarse sand and of low clay content was then deposited. Towards the top of this alluvial layer pieces of gravel were also deposited. This alluvium now comprises the parent material of the lower morphological layer of profile 1D. At some stage after the deposition of the lower alluvial layer, colluvium started to cover the surface soil. Whether this occurred as a single event or gradually over time is unknown but the properties of this upper 90cm of profile 1D are similar to the horizons above the B31 horizons for all the other Bruxner Park site soils.

Therefore either this upper layer is colluvium which covers the whole site or, if the soils other than 1D are monogenetic, the colluvial layer of profile 1D is derived from downslope movement of surface soil material of the other flooded gum soils.

Whatever the case may be, soil processes influenced by the individual trees of the flooded gum community (such as organic matter accumulation, root and faunal pedoturbation) affect the morphology of the Bruxner Park site soils to at least a depth of 1m (if not deeper for profile 1D), obliterating any sedimentary structures and partially mixing alluvial and colluvial layers in profile 1D.

Topographical relief has influenced the origin and development of the Bruxner Park site soil materials but biological factors have superimposed a disturbed morphology upon these possibly polygenetic soils, diminishing the effects of relief as a soil-forming factor.

Only for profile 1D can a polygenetic origin for the features of the soil be substantiated morphologically. So for this reason and those present above only the horizon designation of profile 1D implies any layering of contrasting soil materials (see Appendix III).

5.2 SOIL FORMATION NEAR LARGE BLACKBUTT AND FLOODED GUM TREES

(a) Soil Properties Influenced by the Eucalypts

(1) Flooded Gum:

The spatial pattern of soil properties in the pits radial to the large flooded gum at the Bruxner Park Site indicate that:-

i. The morphology of Pits A, B and C vary both laterally and vertically. Mottling is more pronounced near the bole in the subsoil horizons and tapers out away from the tree. Soil faunal activity in the subsoil increases away from the bole. The surface organic horizons increase in thickness towards the bole where high bark concentrations and thick O2 horizons occur.

ii. Horizon boundaries are diffuse in pedons showing increased mesofaunal activity.

iii. Bulk density is higher and pH values lower adjacent to the tree bole. Pit C field soil moisture contents indicate higher water contents of soil adjacent to the tree after a period of rain but this spatial pattern disappears with dry weather, as found in Pit A. Soil organic matter is concentrated in the surface soil next to the tree and shows relatively high values in the subsoil both near and at distance from the tree in Pit C.

iv. The profiles adjacent to the tree are relatively higher in total contents of exchangeable Ca, Mg and Al, having a higher CEC, which is related to the organic matter content, than the profiles away from the tree.

v. The profiles in the wind-throw pit and next to the old stump in Pit A still have residual high bulk density, low pH and high subsoil exchangeable Al indicative of the past presence of large trees, though their profile morphology shows signs of disturbance and features different to the profiles next to the flooded gum.

(2) Blackbutt:

The spatial pattern of soil properties in the pits radial to the large blackbutts indicate that:-

i. The greater the concentration of major roots in the soil adjacent to the trees the more disturbed and complex the horizon morphology of the soils.

ii. O horizons are discontinuous over the blackbutt site but generally adjacent to the trees are the thickest O1 and O2 layers. There is greater development of B horizons or thickness and differentiation of BC and C horizons next to the trees. Discontinuous and intermittent horizons are associated with major roots, infilled root channels and the root stock of the trees. A horizons are more developed away from the blackbutt boles. Mottling and pale soil aureoles around roots occur in patches in the subsoil adjacent to the root stock of the blackbutt.

iii. The pedons adjacent to the blackbutts had a marked increase in acidity : lower pH, lower base saturation and higher exchangeable Al values were found in the subsoils next to the blackbutts. Soil organic matter and consequently the CEC were higher in the surface soil adjacent to the boles.

(b) Factors Influencing the Soil Adjacent to the Eucalypts

(1) Stemflow:

No attempt was made to measure the quantity and composition of stemflow for the large eucalypts so the relative difference in water and solute input to the soils adjacent to the tree compared with the soils under the canopy is unknown.

Stemflow was observed during rain periods at both sites and the high soil moistures contents for the soil adjacent to the flooded gum in Pit C Bruxner Park site were from sampling which occurred after a period of heavy rain.

Indirect evidence of the importance of stemflow for these forest soils comes from the greater acidity and the morphology of pedons next to the eucalypts. A more humid soil water regime near the tree and the consequent greater leaching and weathering potentials would explain the lower pH and higher exchangeable Al values of these soils (Pedro, Jamagne and Begon, 1978). Organic acid leachates from stemflow or added to stemflow when passing through the forest floor could contribute to the lower pH values. Kodama and Schnitzer (1973) provided data showing that fulvic acids can dissolve chlorite, releasing large amounts of aluminium to the exchange sites. Organic acids can also mobilize Al and Fe which would produce the pale, Fe-poor, soil aureoles around the roots in the subsoils next to the tree boles.

The acid, mottled B23* horizon associated with the blackbutt root-stocks has the highest contents of exchangeable Al which dominates the CEC of this horizon.

Diffractograms of this horizon's clay fraction shows the partial distribution of the 14Å, chlorite-vermiculite intergrade peak. Campbell (1964) proposed that increased acid leaching of Al-intergrade clays in the surface soils in New Zealand next to Nothofagus fusca caused "dealumination" of the Al-intergrade and the eventual formation of montmorillonite. No evidence of montmorillionite was found in the forest soils studied though the results are evidence for the increased rates of dealumination of the chlorite-vermiculite intergrade in soil adjacent to the eucalypts.

(2) Organic matter and forest floors:

The O horizons of the forest soils were always thicker at the base of the eucalypts (although the distribution around the blackbutt boles was discontinuous). The principal component of this litter was bark which formed thick O1 and porous, crumb-like O2 horizons especially at the Bruxner Park site. Similar results were found by Smith (1973) for Eucalyptus saligna in a wet sclerophyll forest.

The concentration of bark with its high C:N ratio in the forest litter causes slower decomposition and the development of duff mull or moder (in one case mor) forest humus adjacent to the eucalypts boles. Duchaufour and Souchier (1978) have suggested that such forest humus reduces the formation of immobile clay-iron-humus complexes characteristic of the brunification pedogenetic process and instead promotes the development of organic acids and the mobile organic acid-metallic ion chelates; an integral part of the podzolization process. The translocation of Fe from near roots, mottling and alumination of the exchange complex could therefore be purely related to increased organic acid concentration of water passing through the thick O1 and O2 horizons next to the trees and not to stemflow per se. There are however few signs of illuviation of clay, Fe, Al or organic matter in these soils next to the trees so whether podzolization processes predominate in these pedons is questionable.

The thick O horizons affect the development of A horizons. This is an important morphological feature in the classification of these soils using the Soil Taxonomy.

The nutrient status of these forest soils is intimately related to organic matter. The CEC was found to be strongly correlated to soil organic carbon in concentration and distribution. Similarly, the highest base saturation and concentrations of total N, total P, exchangeable Ca and Mg occur in the A horizons and diminish with profile depth.

(3) Tree roots:

In the deeper Bruxner Park soils major roots are only encountered in the A horizon. They appeared to spread out from the buttresses just under the surface soil (see Plate 3.1). Contrasting conditions exist at the McNamaras site where the shallowness of these soils concentrate the blackbutt roots throughout profiles, especially adjacent to the tree where roots penetrated the C and R horizons.

Tree roots are a very important cause of disturbance to the soil morphology of the blackbutt soils. Infilled and partly infilled root channels exist at both sites but for the blackbutt soils the following quote from Lutz and Griswold (1939) is most applicable:-

> "..frequently the soil horizons were very irregular and occasionally long tongues from the upper layers penetrated deeply into the layers below. In some instances horizons were discontinuous and masses of soil material were found translocated to positions above or below those normally occupied. Occasionally, material from upper and lower horizons was rather intimately mixed... some agency, or agencies, had disturbed the soil body. Evidence accumulated that tree roots were responsible."

under conditions as those described above traditional methods for describing soil profiles as successive horizontal soil layers with an implied anisotropic genesis and morphology, (i.e. A horizons by definition are organic enriched surface soils above B horizons) are inadequate in conveying the disturbed morphology of the soil. For instance, if A horizons are formed by surface accession of decaying litter or organic matter, what designation should be used for a subsoil layer enriched in organic matter derived from root sloughing or decay? Such a discontinuous horizon associated with roots in the blackbutt soils was arbitarily designated A3*, and in the case of an infilled root channel in profile 3G; AB*. The interrelationship between tree roots and pedogenesis in shallow forest soils requires further investigation.

(4) Forest soil organisms:

While major soil disturbance can be attributed to tree roots at the blackbutt site, soil faunal activity, especially that due to large earthworms is believed to cause the greater degree of pedoturbation at the flooded gum site.

The Bruxner Park soils have the maximum earthworm disturbance of the B horizons away from the flooded gum bole. The mixing of soil material through earthworm casting influences profile horizonation, soil structure, aggregate stability, consistence and fabric of the flooded gum soils. The stable structure and earthy fabric promotes well aerated soil conditions and the whole-coloured nature of the B22 horizon. The mixing of A1 and B2 horizon derived materials creates the transitional A3 and B1 horizons, effectively redistributes organic matter through the upper profile and increases the chroma of the A horizon. These A horizons are often classified as ochric epipedons in the Soil Taxonomy even though they are high in organic matter content.

The general effect of earthworm casting and faunal pedoturbation is to create "haploidized" profiles (Buol, Hole and McCracken, 1973) and these profiles are most clearly represented away from the influence of past or present tree boles at the Bruxner Park site.

In the blackbutt soils termites are the soil fauna with the most obvious influence of soil properties.

The effects of termites are however less pronounced than the features attributed to the Bruxner Park earthworms. Termites, or possibly ant channels are common in the blackbutt subsoils but a more unusual feature is believed to be the indirect influence of termites on the formation of soil concretions; some of which resemble parts of termite mounds and others which look like a "breccia" of soil and gravelly aggregates cemented by an organic agent. This cementing agent and the reddish organic stain of the discontinuous A3* horizons near major roots maybe related to the "mudguts" of termite-infested eucalypt trees.

(5) The tree:

Evidence for the direct influence of the actual trees on soil morphology comes through two contrasting processes from the Bruxner Park and McNamaras Road Sites.

The high soil bulk density next to the flooded gum may indicate that a pressure "bulge" has formed as a consequence of the mass of the tree. Residual "bulges" occur associated with the windthrow pit and the old stump. Earthworm activity could be restricted from such areas of high bulk densities.

Alternatively, earthworm pedoturbation may decrease bulk density and this activity could have been inhibited adjacent to the tree by poor aeration, or by incompatibility with organic leachates derived from the tree. When such a tree is removed or dies the size of the high bulk density bulges is slowly reduced.

For Pit E of the McNamaras Road site the soil property isograms and the horizon morphology of the pit face and profile 1E suggest that the soil adjacent to the blackbutt BB2 (which contains very few major roots) has been upwelled through growth pressures of the tree and eroded. The soil remaining next to the bole (profile 1E) would then be subsoil material of lower pH, soil organic carbon content and CEC while having high gravel contents and minimal signs of horizon development.

The accumulation of tree litter over the eroded surface soil creates the mor-type morphology of the forest floor and the pale ochric epipedon of profile 1E next to the tree. Where there are more major roots abutting the trunk of the blackbutts than at 1E, upwelled material is partially protected between the root stock and the accumulation of organic matter restricts major erosion but it does not allow the development and differentiation of thick A horizons as found at the Bruxner Park site. This process, proposed to explain the morphology of profiles 1E, 1G and 1F, is illustrated diagrammatically in Figure 5.2.

Another form of "floral pedoturbation" investigated at the Bruxner Park site was that associated with uprooting of a tree and the creation of a windthrow pit. Profile 2A situated in this pit has some of the features peculiar to the soils adjacent to the flooded gum; that of high bulk density and exchangeable Al, and low pH, although windthrow disturbance has created distinctive profile morphology.

One possible clue to the eventual morphology of such disturbed soils comes from profile 2G at the McNamaras Road site. Disturbed subsoil horizons, bands of charcoal with assocated increases in soil organic carbon and CEC values in profile 2G indicate that this soil has undergone some form of disturbance in the past. The relative deep, brown, organic-rich soil seems to have formed from material infilling an old depression (plate 3.6b). Of particular interest is the nature of the soil clays for this profile for they show stronger kaolinite peaks and 14Å peaks than any other of the forest soils. This could be explained by the greater weathering experienced by the transported material which infilled a natural depression, possibly a very old windthrow pit.

(c) Conclusions

The special pedogenetic factors reviewed in Chapter 1, *viz*, organic matter, tree roots, specific forest organisms

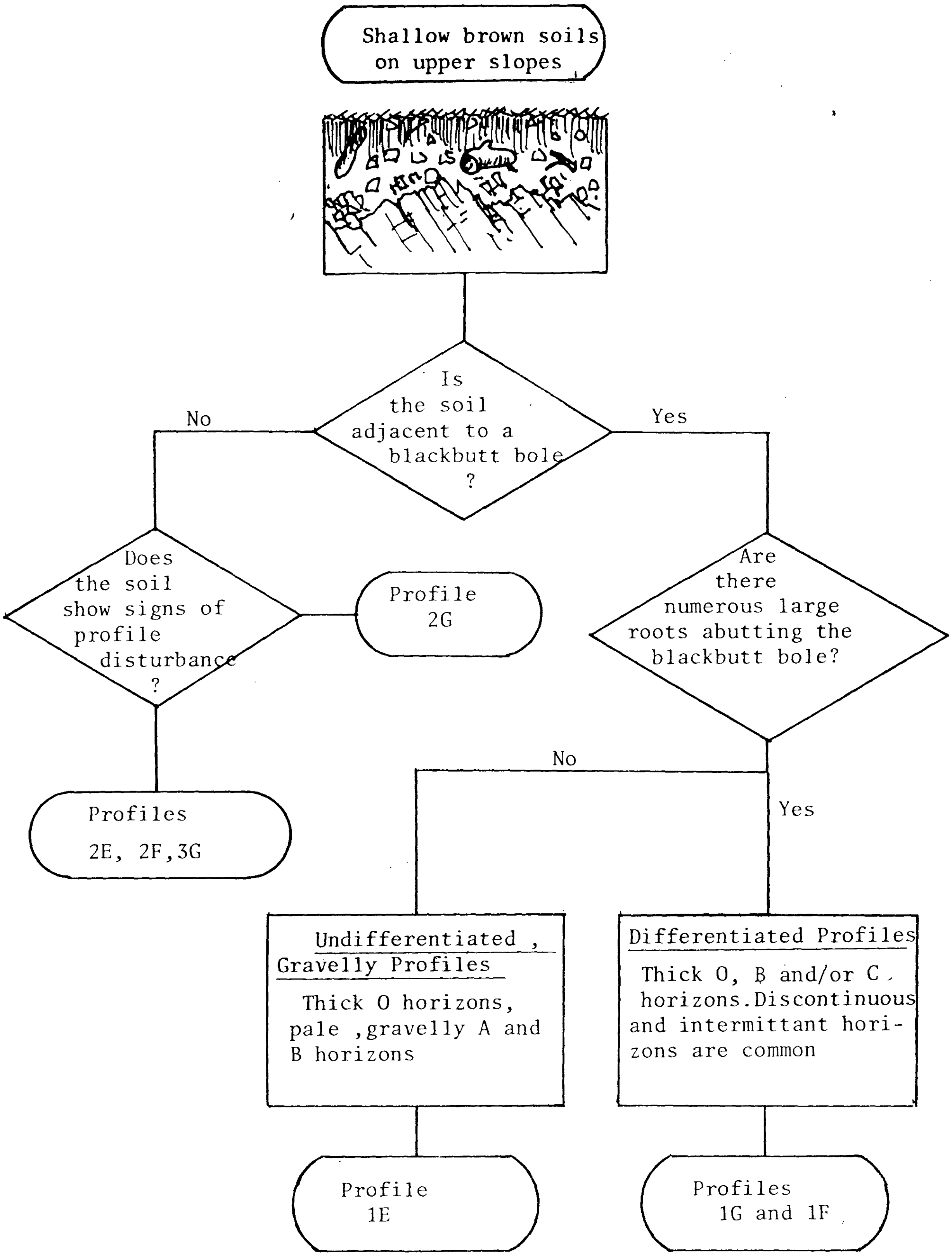

Figure 5.2 : Possible genetic pathways for the McNamaras Road site soils.

and the individual tree, are all operating to some degree at both the flooded gum and blackbutt sites.

While all the factors are present at both sites, the blackbutt and flooded gum sites vary in what particular pedogenetic factor contributes the greatest influence and how the effects of each pedogenetic factor are spatially distributed in the forest soils. For instance, while soil fauna are important for their preferential soil mixing away from the flooded gum at the Bruxner Park site, tree roots cause the greater degree of profile disturbance in the vicinity of the blackbutts at the McNamaras Road site.

The intensity of the soil properties produced by the pedogenetic factors varies between the blackbutt and flooded gum trees. This could be related to physiological properties of the eucalypts or differential soil weathering and leaching relationships due to topographic position.

These biological pedogenetic factors are particularly important in contributing to the spatial heterogeneity of soil morphology and processes of soil formation associated with the individual large eucalypts.

5.3 GENERAL DISCUSSION AND CONCLUSIONS

Simonson (1959) argued that soil genesis could be considered as two basic steps; firstly the accumulation of parent material and secondly, horizon differentiation. This latter process is affected by changes in soil properties through, additions, removals, transfers or transformation of soil material. In forest soils, pedogenetic factors which are considered important in affecting horizon differentiation are organic matter, tree roots, specific organisms, and the individual tree. All of these factors have influenced soil properties to some degree at the Bruxner Park and McNamaras sites.

Of the above pedogenetic factors the individual tree has special significance because it can directly or indirectly induce spatial heterogeneity both in the accumulation of parent materials and horizon differentiation of the forest soils studied. The tree intercepts precipitation containing solutes and redirects flow through the canopy where more dissolved and particulate matter are gained. If the dissolved or suspended components of through-fall and stemflow are considered as "parent material" then the tree concentrates these compounds in stemflow and so maximum accumulation of this parent material occurs at the base of the tree bole. Similarly if organic matter is considered as a parent material for forest soils then the individual blackbutt and flooded gum can cause increased accumulation of certain forest litter components about the base of the tree.

The individual blackbutt and flooded gum can also cause spatial variability in the degree of horizon differentiation in their forest soils. For instance, earthworms can create haploidized profiles away from the flooded gum while the blackbutt and its roots can disturb and mix soil profiles near the boles. The individual eucalypt affects chemical transformations in soil adjacent to its bole through a combination of increased leaching by acidic stemflow water and the presence of thick O horizons which creates an environment favouring the formation of mobile organic acid-metallic ion complexes rather than immobile clay-humus-iron complexes.

Therefore the processes of soil formation operating over these forest sites can vary in the vicinity of the individual tree bole because the tree induces spatial heterogeneity in the accumulation of parent materials and horizon differentiation of the soil adjacent to the boles. The hypothesis of Simonson (1959) that, "..shifts in balance among combinations of processes are responsible for soil difference rather than the operation of markedly different genetic processes", provides for a gradational change in the nature of soil genesis away from the boles of the flooded gum and blackbutts.

The soils of a forest community can therefore be viewed as a complex mosaic of soil types forming under differing pedogenetic regimes induced by the individual trees and replicated, in varying degree, for each tree of the forest community. The basic difference in this tree-induce soil patterning to other forms of soil patterns, such as gilgais, is that gilgais are a relatively constant, cyclic, microtopographical pattern whereas tree-induced soil variability is dependent upon the tree and so very dynamic over pedological times in spatial position and degree of development.

(a) Implications for the Classification of Forest Soils

None of the three soil classification schemes used gave a general differentiation between the soils of the blackbutt and flooded gum communities. However the soils adjacent to the individual trees within each forest community have properties formed under a differing equilibrium of pedogenetic processes to that which exists away from the tree boles. Soil classification schemes should be able to separate soils forming under differing genetic regimes at some appropriate taxonomic level if there are discernible differences in soil morphology. The separation of profiles adjacent to the eucalypt boles as seen in the Northcote Key and the Soil Taxonomy is therefore considered pedologically meaningful.

The emphasis in the Soil Taxonomy on distinctive epipedons defined on A and B horizon relationships stresses the importance of organic matter in these forest soils and also has implied, many associated chemical and physical properties. This appears to be more usefully related to the modes of forest soil formation than the more restricted morphological properties of the mottling and colour of the B horizon which separates these soils in the Northcote Key. The Soil Taxonomy therefore is the preferred classification for the previously termed brown forest soils.

(b) Implications for Forest Management

Wilde (1958) observed that as a consequence of agricultural selection, forest soils are naturally found in rugged terrain which has inherent soil variability. The complication of spatial patterning induced by trees produces formidable problem in sampling strategies in forest communities. Bevege (1978) defines the problem:

> "Consideration of these patterns is essential in biomass studies in natural vegetation; ideally, sampling for litterfall, precipitation throughfall, standing litter, mineralization and soil nutrient status should be efficient enough to account for this variation by using sufficiently intensive sampling schemes. Logistically however this is virtually impossible.."

even so, it is essential to recognise that such variability exists and make suitable provision for it when planning data collection programs.

A second important feature about the forest soils studied is the importance of organic matter as a pedogenetic factor influencing the morphology and classification of both the blackbutt and flooded gum soils. Forest managers should be mindful of how their practices affect the soil organic regime if they are to retain the morphology and nutrient status of these soils.

Third and finally, the forest soil morphology of both the blackbutt and flooded gum sites indicate that major natural, biological disturbance is occurring continually in these soils through various agents. The impact of modern-day forest management upon soils can cause abrupt, and in some cases profound soil disturbance. Yet with greater knowledge of the natural processes of forest pedoturbation the severe impact of these management practices maybe alleviated.

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