STRATIGRAPHY AND RESERVES OF PUMICEOUS SAND DEPOSITS IN PERRY'S 'ASPARAGUS BLOCK' AT HOROTIU

Informal report prepared for

Perry Aggregates Limited

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The University of Waikato
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This report mainly summarises information from a Diploma in Applied Sciences dissertation at the University of Waikato by A. Lootsma. While we have attempted to interpret and present this information in as factual a manner as possible, we disclaim responsibility for any unintentional errors that may occur in the report, or that may arise as a consequence of future on-site investigations or exploration. However, we remain very prepared to consider assistance in helping address any such queries.

CONTENTS

SUMMARY

The stratigraphic relationships between the deposits of the Hinuera Formation and the Taupo Pumice Alluvium are described over a 16 ha plot of land known as the 'Asparagus Block' at Horotiu. The Hinuera Formation is exposed at the surface at the southern end of this block, and is overlain by a wedge of Taupo Pumice Alluvium which increases in thickness from 0 to 8 m northwards across the block. Lithofacies in the Hinuera Formation are dominated by trough cross-bedded gravelly sands (lithofacies A1), with common cross-laminated sands (lithofacies B) and massive to horizontally laminated silts (lithofacies D). The pumice content of these deposits is mainly <10%, but in lithofacies B and D can locally reach >70%. Lithofacies in the Taupo Pumice Alluvium are dominated by horizontally to inclined (tabular cross-) bedded slightly gravelly sands and sands (lithofacies G1/2), with common occurrences of horizontally bedded to massive sandy silts (lithofacies D). The pumice content of these Taupo deposits is high, typically >80%. Cross-sections are presented showing an interpreted subsurface distribution of these lithofacies from south to north through the 'Asparagus Block'. The estimated reserve of extractable pumice sand from the block is of the order of about 400,000 to 450,000 m^3.

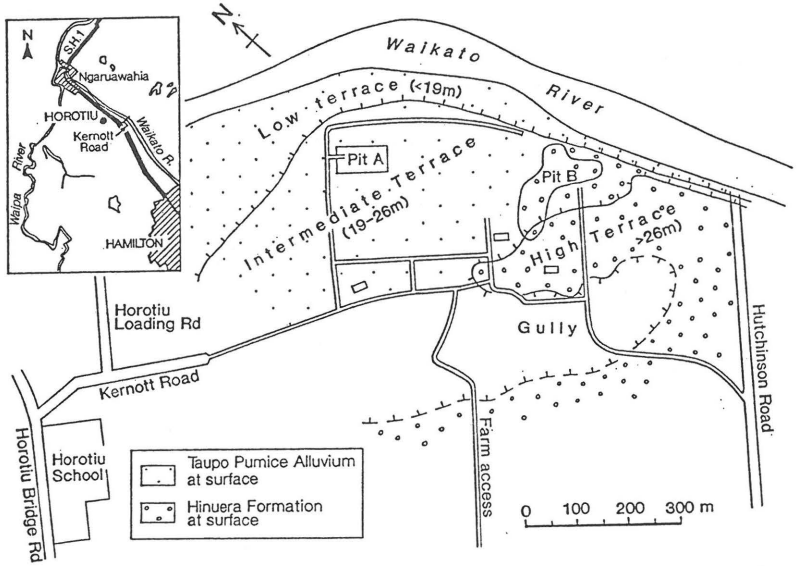


Figure 1 - Locality and simplified geomorphic map for the 'Asparagus Block' contained within the area including Pits A and B and bounded by the "rectangle" of unnamed tracks. Note the occurrence of three general terrace levels and the "at surface" distribution of Taupo Pumice Alluvium and Hinuera Formation deposits.

INTRODUCTION

In 1996 Perry Aggregates Ltd approached the Department of Earth Sciences to engage a student in a study of the pumice sand resource in a 16 ha (40 acre) area of land known as the 'Asparagus Block' lying between the west bank of the Waikato River and State Highway 1, just south of Horotiu Rd (Fig. 1). The study was undertaken by Anneke Lootsma who has compiled her results in a dissertation titled "Distribution and Nature of Pumiceous Sand Resources, Perry's 'Asparagus Block', Horotiu" (Lootsma 1997). Here we adapt and summarise some of the information contained in that report, emphasising matters most relevant to an assessment of the pumice sand resources in the 'Asparagus Block'.

The land surface forming the 'Asparagus Block' comprises three main terraces (Fig. 1). The highest terrace at 26-30 m a.s.l. elevation corresponds to the Hinuera Surface of Schofield (1965) and represents the level of maximum sediment aggradation by an ancient braided Waikato River system at the time of the Last Glaciation, especially between about 22,000 and 15,000 years ago (McCraw 1967; Hume et al. 1975; Hogg et al. 1987). The coarse volcaniclastic sediments beneath the Hinuera Surface are known as the Hinuera Formation (Schofield 1965). The lowest terrace at 12-19 m elevation, closest to the modern river, comprises highly pumiceous sediments of the Taupo Pumice Alluvium deposited about the margins of the Waikato River following the major Taupo volcanic eruption centred in northeastern Lake Taupo about 1850 years ago (Kear and Schofield 1978). The intermediate level terrace, at about 19-26 m elevation, comprises the majority of the 'Asparagus Block' and consists of both Hinuera Formation and Taupo Pumice Alluvium. The main intention of the present study was to determine the distribution and thickness of the Taupo Pumice Alluvium over this intermediate terrace.

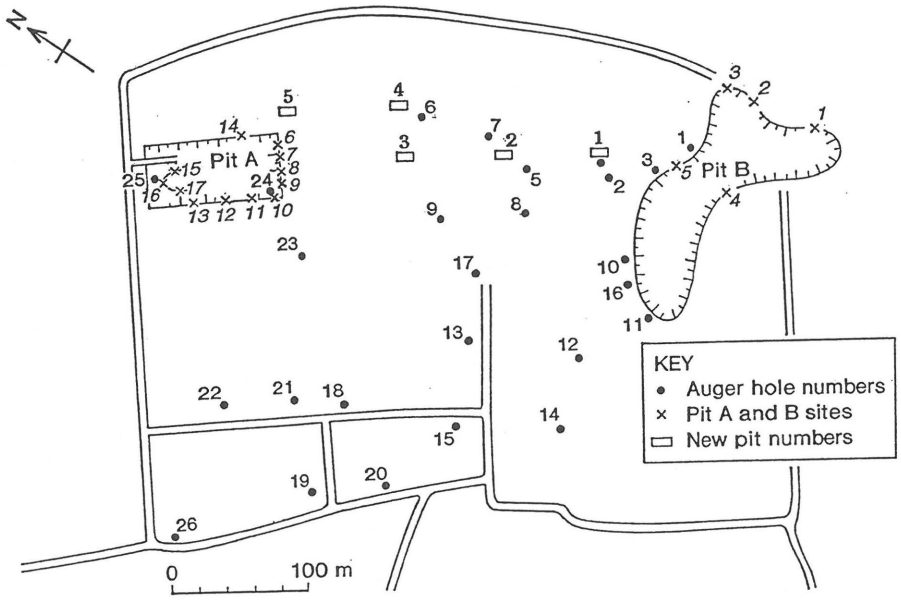


Figure 2 - Location of stratigraphic columns (Appendices I-III) based on pit section and auger hole descriptions across the 'Asparagus Block'.

FIELD SITES

Three main kinds of sample sites have been used to determine the nature of the Hinuera Formation and Taupo Pumice Alluvium over the 'Asparagus Block' (Fig. 2).

(1) Two large extraction pits are excavated in the block. Pit A, at the northern end of the area, is in Taupo Pumice Alluvium and was being actively worked at the time of examination in summer 1996/97. Pit B, in the southeastern corner, exposes mainly Hinuera Formation deposits and was not being worked during the field study; however, at the time of preparing this report the Pit B area had been considerably modified by subsequent quarry development. A number of sediment columns (numbers 1-17 marked by crosses in Fig. 2) were described and measured on the walls of both Pits A and B, providing typical sections through the Taupo Pumice Alluvium and Hinuera Formation, respectively. These sections are reproduced from Lootsma (1997) in Appendix I.

(2) A Dutch auger was used at 26 sites (numbers 1-26 marked by solid dots in Fig. 2) to determine the shallow subsurface stratigraphy across the area, and particularly to determine the boundary between the Hinuera Formation and Taupo Pumice Alluvium, and hence derive the thickness of the latter. Logs of the augered sites are reproduced from Lootsma (1997) in Appendix II.

(3) A series of five new small pits were excavated on our request by the site bulldozer at the time of the study (numbers 1-5 marked by small rectangles in Fig. 2). Pit wall descriptions of the stratigraphy are reproduced from Lootsma (1997) in Appendix III.

HINUERA FORMATION

The Hinuera Formation is an unconsolidated alluvial deposit formed in a braided river system during the Last Glaciation (Schofield 1965). Three properties especially characterise the field appearance of these deposits: (1) they comprise coarse-grained sands and gravels (mainly gravelly sands); (2) they contain an abundance of acid volcanic minerals and rock fragments (e.g., volcanic quartz, sodic plagioclase feldspar, rhyolitic and ignimbrite fragments, and pumice); and (3) they exhibit a wide variety of cross-bedded sedimentary structures (dominantly trough cross-bedding) that represent deposition within dunes and bars in the paleoriver channels of the time.

A

Lithofacies	Occurrence	Dominant Composition	Dominant Texture	Sedimentary Structures	Flow Regime	Bed Forms	Depositional Environment	Stratigraphic Position
A1	Extremely common	Quartz-feldspar-rhyolitic rock fragments-pumice	Gravelly sand	Rho cross-stratification	Upper part of lower to lower part of upper	Dunes on longitudinal bars or longitudinal bar migration	Active braided channel	Channel
A2	Rare		Gravelly sand	Epsilon cross-stratification	Upper or lower			
B	Fairly common	Quartz-feldspar-pumice	Sand	Nu cross-stratification	Lower part of lower	Ripples on transverse bars		
C1	Uncommon	Quartz-feldspar-rhyolitic rock fragments	Sandy gravel	Type 1 horizontal stratification or massive	Upper	Plane-bed on longitudinal bars		
C2	Rare	Quartz-feldspar-pumice	Gravelly sand	Type 2a horizontal stratification	Transitional			
D	Moderately common	Glass shards-pumice	Silt	Type 2b horizontal stratification or massive	Suspension deposits	-	Abandoned braided channel	Overbank
E	Uncommon	Carbonaceous material-glass shards-pumice	Silt	Type 2b horizontal stratification	*In situ* and suspension deposits	-	Floodbasin	

B

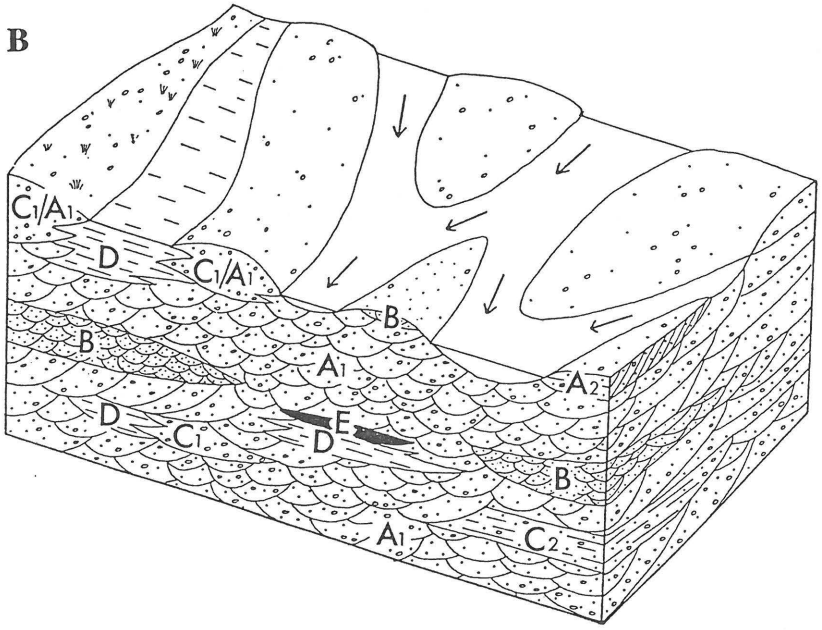


Figure 3 - (A) Lithofacies codes, characteristics, and interpreted paleoenvironments for the Hinuera Formation; and (B) Physiographic model showing schematic relationship of lithofacies in the Hinuera Formation. Both diagrams from Hume et al. (1975).

Hume et al. (1975) devised a scheme for classifying the sediments of the Hinuera Formation into five main lithofacies, A to E, with some subdivisions. The scheme is reproduced as Fig. 3A, and visualisation of the lithofacies within their original braided river setting is depicted in Fig. 3B. Descriptions of the Hinuera Formation sediments at the various sampling sites in this study (Fig. 2) were made in relation to this scheme, and the relevant lithofacies letter is shown alongside the lithologic sections including Hinuera sediments in Appendices I-III.

Modern soils developed on the Hinuera deposits in the vicinity of the 'Asparagus Block' are well drained and well developed soils of the Horotiu series (McCraw 1967; Bruce 1979), classified as Typic Orthic Allophanic Soils in the New Zealand Soil Classification of Hewitt (1992).

TAUPO PUMICE ALLUVIUM

The Taupo Pumice Alluvium formed about 1850 years ago and was associated with the catastrophic release into the entrenched Waikato River of huge volumes of pumiceous gravel, sand and silt derived from the products of the Taupo Tephra eruption from Taupo volcano at Lake Taupo (Froggatt and Lowe 1990). The Taupo Pumice Alluvium in Hamilton Basin typically consists of horizontally-bedded to large-scale inclined or tabular cross-bedded pumice sands and gravels with scattered charcoal fragments (Kear and Schofield 1978). These deposits are generally thickest in the "low terraces" bordering the margins of the modern Waikato River, but can also extend into, and variably infill, gullies that were cut back into the Hinuera Formation during the entrenchment of the Waikato River after about 15,000 years ago through to the time of the Taupo eruption.

A scheme for classifying the various sediment types within the Taupo Pumice Alluvium has been suggested by Lootsma (1997), and for convenience this approach is accepted here. The scheme builds on that already available for the Hinuera Formation deposits (Fig. 3A) where lithofacies D (or pumice silt) is common to both formations, while lithofacies F and G are new and restricted to the Taupo Pumice Alluvium. Both of these facies can be horizontally- or cross-bedded and both comprise variable admixtures of mainly sands and gravels, but lithofacies F includes conspicuous amounts of non-pumice material (e.g., rock fragments and feldspars) whereas lithofacies G is pumice-dominated. Lootsma (1997) subdivided lithofacies F and G into a number of subfacies on the basis of contrasts in

Table 1 - Lithofacies characteristics of the Hinuera Formation and Taupo Pumice Alluvium. Scheme extended from Fig. 3A (Hume et al. 1975). Important lithofacies in the 'Asparagus Block' are shaded (see Tables 3 and 4).

Lithofacies symbol	Formation	Dominant composition[1]	Colour	Dominant texture	Sedimentary structures
A1	Hinuera	Q-F-RRF-P	Yellow-brown, cream, varied, (iron-stained)	Gravelly sand	Medium-scale trough cross-bedded
A2	Hinuera	Q-F-RRF-P	Yellow-brown, cream, varied, (iron-stained)	Gravelly sand	Medium-scale trough cross-bedded
B	Hinuera	Q-F-P	Grey (iron-stained)	Sand	Small-scale cross-bedded/laminated
C1	Hinuera	Q-F-RRF	Yellow-brown, cream, varied, (iron-stained)	Sandy gravel	Horizontally bedded or massive
C2	Hinuera	Q-F-P	Cream (iron-stained)	Gravelly sand	Horizontally laminated
D	Hinuera	GS-P	Light grey (iron-stained)	Silt	Horizontally laminated or massive
	Taupo	GS-P	Light brown to grey	Sandy silt	Horizontally bedded, laminated or massive
E	Hinuera	CM-GS-P	Light grey to black	Silt	Horizontally laminated
F1	Taupo	GS-F-RRF-P	Grey to light brown	Sandy silt	Horizontally or inclined or
F2	Taupo		Grey	Sand	tabular cross-bedded
F3	Taupo		Brown/grey	Sandy gravel	
G1	Taupo	P(-GS-F-RRF)	Light grey	Sand	Horizontally
G2	Taupo		Light grey	Sand	or inclined or
G3	Taupo		Light grey (staining)	Sandy gravel	tabular cross-bedded
G4	Taupo		Light grey (staining)	Gravelly sand	

[1] Q, quartz; F, feldspar; RRF, rhyolitic rock fragments; P, pumice; GS, glass shards; CM, carbonaceous matter; ( ), subordinate

texture. A complete classification scheme for the various facies and subfacies in both the Hinuera and Taupo Pumice deposits is summarised in Table 1. Descriptions of the Taupo Pumice Alluvium sediments at the various sampling sites in this study (Fig. 2) were made in relation to this scheme, and the relevant lithofacies letter is shown alongside the lithologic sections including Taupo Pumice sediments in Appendices I-III.

Modern soils developed on the Taupo Pumice Alluvium deposits in the 'Asparagus Block' are, because of their young age, considerably less well developed than those on the Hinuera Formation, and have at most a thin 'weathered B' subsoil horizon (i.e., Bw or BC horizon; Clayden and Hewitt 1989). They belong in the Waikato series (McCraw 1967; Bruce 1979) and classify as either Immature Orthic Pumice Soils or Typic Sandy Recent Soils in the New Zealand Soil Classification of Hewitt (1992).

Some distinguishing features between the Taupo Pumice Alluvium and Hinuera Formation deposits are summarised in Table 2.

Table 2 - Some distinguishing features between deposits of the Hinuera Formation and Taupo Pumice Alluvium in the Hamilton Basin.

Identifying features	Hinuera Formation	Taupo Pumice Alluvium
Terrace position	On high or intermediate	On intermediate or low
Soils	Horotiu series - well developed B horizon	Waikato series - weakly developed B horizon
Age	c. 15,000-22,000+ years	c. 1,850 years
Pumice content	Low (usually < 10%)	High (usually > 80%)
Charcoal	None	Present
Colour	Typically yellow-brown, but variable, often iron-stained	Usually pale grey, locally iron-stained
Texture	Gravelly sands dominate Pure silts (often weathered)	Slightly gravelly sands and sands tend to dominate Sandy silts
Sedimentary structures	Small- to medium-scale trough cross-bedding	Horizontal bedding to large-scale inclined or tabular cross-bedding
Consistence	Typically compact, coherent	Typically loose, forms free-running grains when disturbed

Table 3 - Approximate frequency abundance of lithofacies in the Hinuera Formation deposits in the 'Asparagus Block'.

Hinuera lithofacies	Total thickness (m) in pits B and 'new'	% Occurrence
A1	8.9	40
B	5.0	22
C1	2.0	9
D	6.4	29

Table 4 - Approximate frequency abundance of lithofacies in the Taupo Pumice Alluvium deposits in the 'Asparagus Block'.

Taupo lithofacies	Total thickness (m) in pits A and 'new'	% Occurrence	Total thickness (m) in augers plus pits A and 'new'	% Occurrence
D	6.8	15	19.0	23
F1/2	3.5	8	6.9	8
G1/2	32.5	74	55.2	66
G3	0.6	1.5	1.8	2
G4	0.5	1.5	0.5	1

SUBSURFACE DISTRIBUTION OF DEPOSITS

The individual columns and sections in Appendices I-III show the stratigraphy and lithofacies of the Hinuera Formation and the Taupo Pumice Alluvium at the various sample sites over the 'Asparagus Block'. The percentage occurrence of the different lithofacies in the subsurface can be roughly estimated by comparing their recorded thicknesses against the total cumulative thickness for each of the two formations. Results are summarised in Tables 3 and 4.

The Hinuera Formation in the 'Asparagus Block' is dominated by cross-bedded gravelly sands of lithofacies A1 (typically 40-50%), with significant amounts of cross-laminated sands of lithofacies B (about 20%) and massive to horizontally laminated silts of lithofacies D (about 30%) (Table 3). This lithofacies frequency distribution is very similar to that for the Hinuera Formation more widely in the Hamilton Basin (Fig. 3A).

The Taupo Pumice Alluvium in the 'Asparagus Block' is completely dominated by horizontal to inclined (or tabular cross) beds of light grey pumiceous sands assigned to lithofacies G1/2 (about 70%), with moderately common occurrences of pure to impure pumiceous mixed silt-sand deposits of lithofacies D and F1/2 (about 20% and10% occurrence, respectively) (Table 4). Lithofacies F3, G3, and G4 are rare.

To gauge some idea of the lateral distribution of lithofacies in the subsurface over the 'Asparagus Block' a series of three roughly north-south oriented cross-sections have been interpreted from the available sample site information. The cross-sections are presented as Fig. 4 and, because the Hinuera Formation in this study effectively forms the "undermass basement" deposits, distinguish principally the lithofacies variations within the Taupo Pumice Alluvium across the area. Note the suggested presence of a subsurface terrace escarpment cut into Hinuera Formation in the southern part of the 'Asparagus Block' and buried by deposits of Taupo Pumice Alluvium.

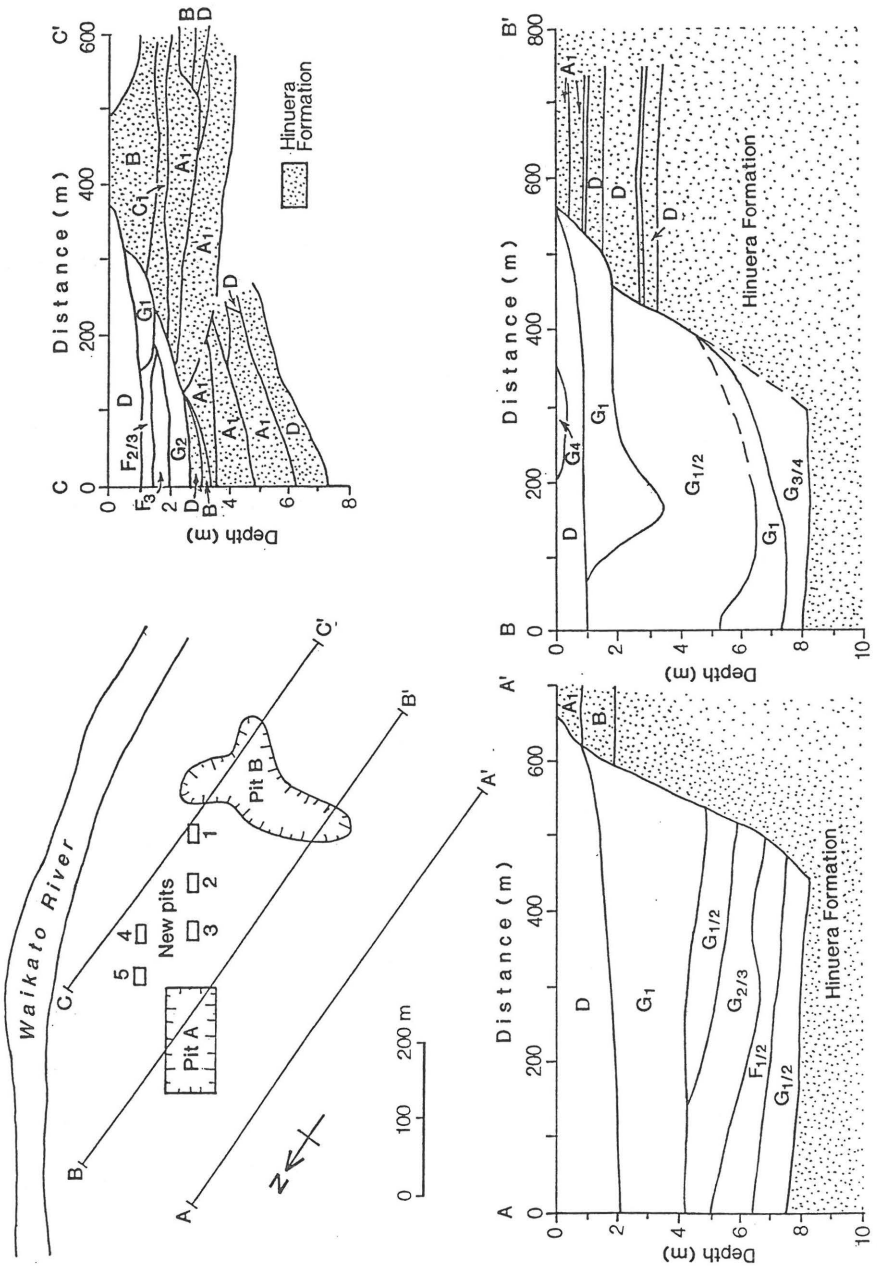


Figure 4 (Opposite) - Schematic cross-sections through the 'Asparagus Block' showing the subsurface distribution of Hinuera Formation (stippled) and Taupo Pumice Alluvium (clear) lithofacies (see Table 1 for definition of codes) as interpreted from auger and pit descriptions.

TEXTURE OF DEPOSITS

Information about the texture of the Hinuera Formation deposits in the Hamilton Basin has been compiled by Hume et al. (1975), and several particle-size analyses for the Taupo Pumice Alluvium in the Hamilton Basin are contained in a study by Tilly (1987). Based on these sources, a summary of the main textural classes of sediment in the two formations are compared on a slightly modified version of Folk's (1968) triangular gravel-sand-mud diagram in Fig. 5. Note that the 'mud' apex of the triangle (i.e., sediment finer than 0.063

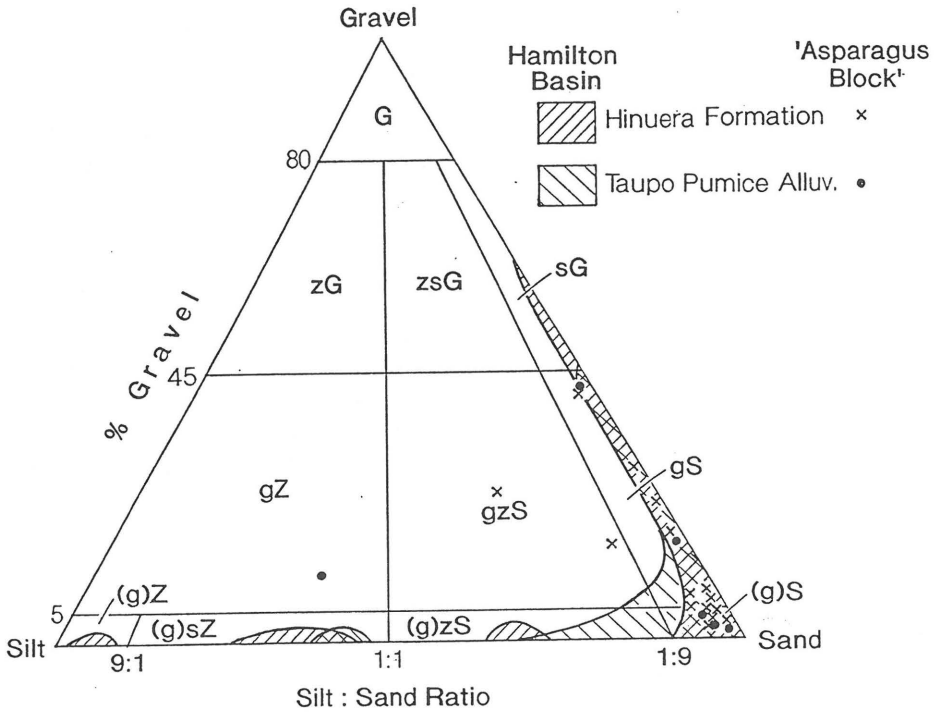


Figure 5 - Textural triangle showing the main fields for samples of Hinuera Formation and Taupo Pumice Alluvium from the Hamilton Basin (based on Hume et al. (1975) and Tilly (1987)) with some superimposed analyses of samples from the 'Asparagus Block'. G, gravel; g, gravelly; S, sand; s, sandy; Z, silt; z, silty; ( ), slightly. See text for discussion.

mm or 63 μm) is substituted by the more specific textural name 'silt' (i.e., size range 0.004 mm or 4 μm to 0.063 mm or 63 μm) because both Hume et al. (1975) and Tilly (1987) found genuine clay-sized material (i.e., <0.004 mm or <4 μm) was virtually absent in these formations. Also note that not every analysed sample of Hinuera Formation and Taupo Pumice Alluvium is accounted for within the textural fields depicted in Fig. 5, but at least 95% of them are, so that the fields outline the dominant textural types represented in the two formations.

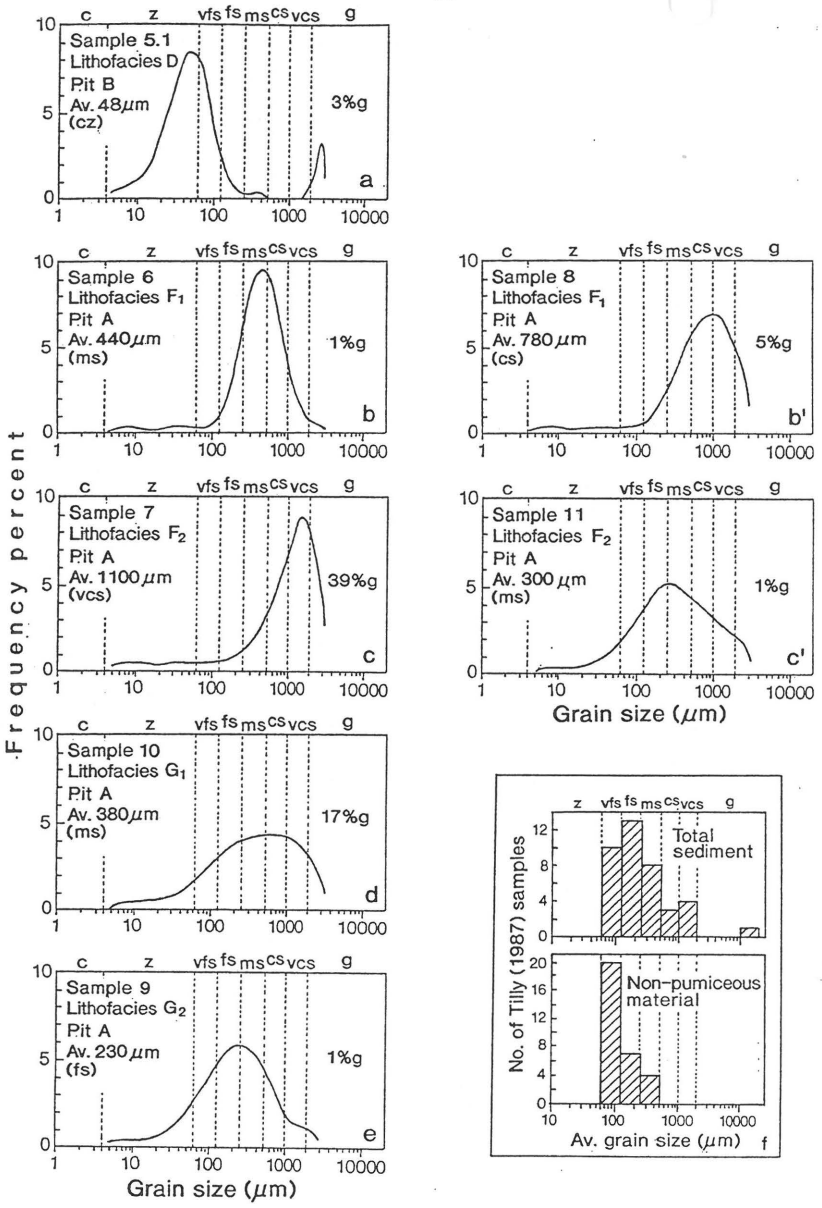
The textural triangle (Fig. 5) shows:

(1) The Hinuera deposits are mainly mixtures of sand and gravel, and cluster closely inside the fields for sandy gravels, gravelly sands and slightly gravelly sands. Occasional sand-silt combinations occur, more-or-less gravel-free, and silts are common as lithofacies D (Table 1).

(2) The Taupo Pumice Alluvium is also dominated by mixtures of sand and gravel, but (a) the content of gravel is usually not so high as in the Hinuera Formation, so that deposits are typically gravelly or slightly gravelly sands, not sandy gravels, and (b) sand-silt mixtures are much more prevalent than in the Hinuera Formation, comprising both silty sand and sandy silt members. Unlike the Hinuera Formation, it appears that no 'pure' silts are recorded in the Taupo deposits.

Some textural analyses made by Lootsma (1997) have been plotted on the textural triangle to compare the 'Asparagus Block' results with the above generalisations for the Hinuera Formation and Taupo Pumice Alluvium in the wider Hamilton Basin. All except two of the Hinuera samples, which are gravelly silty sands, fall within the gravelly to slightly gravelly sand fields that dominate the formation in general (Fig. 3A; Hume et al. 1975). Only a few Taupo samples are available for plotting, but again these lie within the gravelly and slightly gravelly sandy fields typical of the Taupo Pumice Alluvium elsewhere, while one of the finer samples plots very near the 'established' sandy silt field for the formation. Consequently, both the Hinuera and Taupo sediments in the 'Asparagus Block' are texturally comparable to those elsewhere in the Hamilton Basin.

Lootsma (1997) presents grain size distribution curves and statistical analyses for several samples of both Hinuera Formation and Taupo Pumice Alluvium from the 'Asparagus



Block'. We reproduce in Fig. 6 examples of frequency distribution curves for samples from the various lithofacies of Taupo Pumice Alluvium only. Note that the laser sizer instrument used for these analyses cannot handle gravel-sized material (>2000 μm or >2 mm), and so any gravel in samples has first been sieved out and is not represented within these distribution curves. However, the content of gravel-sized material in the samples is noted on the diagrams, with values ranging from a few to almost 40%. Significantly, while the Taupo Pumice Alluvium is usually dominated by sand-sized sediment (Fig. 5), these curves demonstrate that the actual grade of the sand (i.e., very fine, fine, medium, coarse, or very coarse) ranges widely. In these cases the average grain size varies from fine to very coarse sand, and in most samples the spread (or sorting) of sizes spans several sand grades (Fig. 6). For the silt sample of lithofacies D the average grade is coarse silt (about 30-60 μm).

The spectrum of pumice sand sizes in the Taupo Pumice Alluvium can be further shown by the grain-size data of Tilly (1987). The 'inset' histogram in Fig. 6 illustrates the average sizes for about 40 samples that he collected from (now disused) pumice quarries between Ngaruawahia and Horotiu. These range from very coarse to very fine sand, with most samples being fine sands. For one sample the average size was in the gravel grade. Also shown in the 'inset' is the dominant size grade of the non-pumiceous material in these otherwise pumice-dominated sediment samples, which clearly lies principally in the fine to very fine sand size range.

Figure 6 (Opposite) - Examples (a to e) of grain-size frequency distributions for the gravel-free fraction of samples from different lithofacies of the Taupo Pumice Alluvium from the 'Asparagus Block'. Data adapted from Lootsma (1997). The content of gravel-sized sediment in each sample is shown at right side of each figure (e.g., 3%g). The average (median) size is recorded at left for each sample. c, clay (<4 μm); z, silt (4-63 μm); vfs, very fine sand (63-125 μm); fs, fine sand (125-250 μm); ms, medium sand (250-500 μm); cs, coarse sand (500-1000 μm); vcs, very coarse sand (1000-2000 μm); g, gravel (>2000 μm). The inset (f) shows in the upper diagram the average grain size (mean) of Taupo Pumice Alluvium samples analysed by Tilly (1987) from now disused pumice quarries between Horotiu and Ngaruawahia, while the lower diagram shows the same information for the non-pumiceous components in those samples.

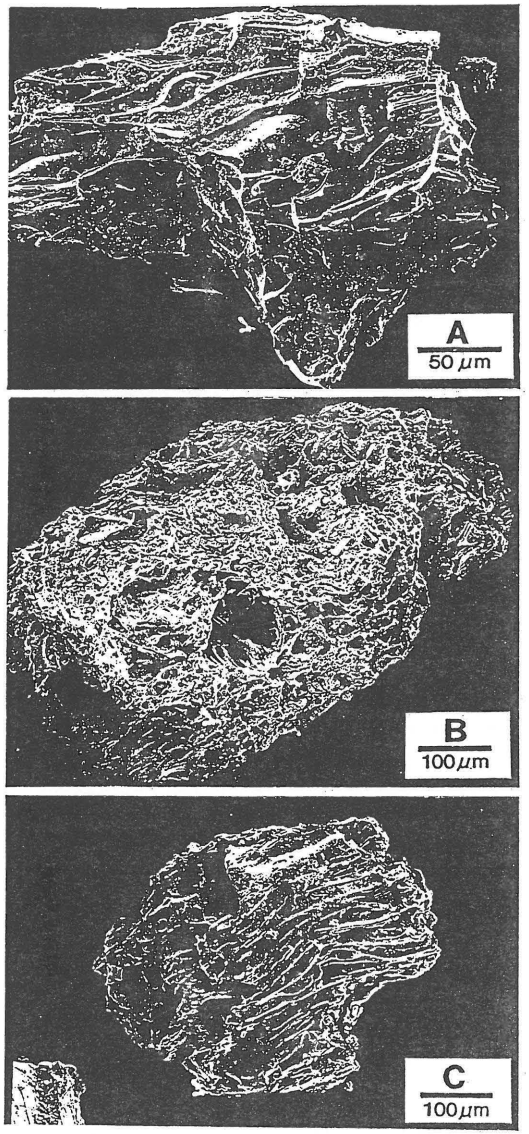


Figure 7 - Scanning electron microscope images of examples of vesicular pumice particles. (A) From sample 4.1 (Column 4, Pit B, Hinuera Formation) showing elongate and stretched vesicles. (B) From sample 7 (Column 5, Pit A, Taupo Pumice Alluvium) showing fine irregular to subspherical vesicles. (C) From sample 8 (Column 5, Pit A, Taupo Pumice Alluvium) showing elongate vesicles.

PUMICE CONTENT OF DEPOSITS

Pumice is a light coloured, vesicular, glassy rock having a high silica composition. It is the major component of many of the primary pyroclastic deposits, such as ignimbrites, resulting from explosive silicic eruptions in the Taupo Volcanic Zone during the Quaternary (Froggatt and Lowe 1990). Erosion of these volcanic deposits produces alluvial pumice fragments which can exhibit unusual behaviour in water because of their vesicularity. Large fragments with many vesicles will float until they become waterlogged, while smaller pumice fragments tend to contain fewer vesicles and have a greater chance of being transported as part of the river bedload, along with other mineral grains. Even then, a particle density of just over 1.0 g cm^{-3} means that pumice grains can become sorted from other minerals of comparable size but having different composition, such as quartz and feldspar grains. Moreover, the softness of pumice particles means they become quickly abraded and rounded during surface jostling while floating or by grain impact during bottom transport. Glass shards are formed either from the abrasion of pumice particles or they can represent the finest of ash particles discharged during an explosive volcanic eruption.

Scanning electron micrographs show that pumice particles in samples from the 'Asparagus Block' are irregular to rounded in shape, support few sharp edges, and contain abundant vesicles having both spherical and tubular outlines (e.g., Fig. 7).

Hinuera Formation

Compositionally, the Hinuera Formation consists mainly of quartz, plagioclase feldspar and volcanic rock fragments (Table 1). The volcanic rock fragments are dominated by rhyolitic breccias, with common rhyolites, ignimbrites and pumice (Hume et al. 1975). Overall, the content of pumice in the dominant gravelly sand lithofacies A1 is typically <10%. However, the silts of lithofacies D are completely dominated by attrited pumice, or glass shards. Hume et al. (1975) showed that the distribution of pumice in the Hinuera Formation samples tends to be bimodal, occurring preferentially in the fine gravel sizes (2-4 mm) and (as pumice and/or glass shards) especially in the very fine sand and coarse silt sizes (0.03-0.125 mm). Between these size intervals smaller amounts of pumice persist.

Table 5 - Examples of pumice content in Hinuera Formation and Taupo Pumice Alluvium lithofacies in the 'Asparagus Block'. Data are from Lootsma (1997).

Lithofacies[1]	Hinuera Formation		Taupo Pumice Alluvium	
	Pumice content[2]	Example %	Pumice content[2]	Example %
A	Rare	15		
B	Common	70		
C1	Rare	<5		
C2	Rare	10-15		
D	Rare (to Abundant)	<5	Abundant	85
F1			Common	65
F2			Abundant	80
G1			Abundant	75
G2			Abundant	80

[1] See Table 1 for symbol definition

[2] Rare, <20%; Common, 20-70%; Abundant, >70%

Lootsma (1997) presents some analyses of the pumice content of a few Hinuera samples from the 'Asparagus Block'. The deposits contain <15% pumice, except for the sands of lithofacies B where a content of 70% is registered (Table 5). The apparently low content of pumice she records in the silts of Hinuera lithofacies D reflects the fact that only the sand and gravel fractions were analysed, when in fact the dominant silt fraction in these samples undoubtedly consists mainly of glass shards derived from the abrasion and breakdown of larger pumice fragments.

Taupo Pumice Alluvium

The Taupo Pumice Alluvium is characterised by a high pumice content. Based on the analysis of about 40 samples collected mainly from (now abandoned) quarries between Ngaruawahia and Horotiu, Tilly (1987) showed that the pumice abundance in samples of the formation ranges between about 63-99%, with an average for this dataset of about 92%.

Based on a small number of analyses from the 'Asparagus Block', Lootsma (1997) recorded the Taupo Pumice Alluvium as containing between about 65-85% pumice, with a weighted average in the vicinity of 80% (Table 5). The non-pumiceous content of these samples comprises plagioclase feldspar and heavy minerals (e.g., hypersthene, magnetite) liberated from the Taupo pumice particles themselves by abrasion, and/or a variety of volcanic rock fragments, quartz, plagioclase feldspar and heavy minerals mixed into the pumice alluvium from erosion of the Hinuera Formation forming the banks of Waikato River at the time of deposition of the Taupo Pumice Alluvium. Note that in places these "pumice-depleted" Taupo deposits appear very similar to the older Hinuera Formation sediments and are distinguished from them mainly by the presence of occasional charcoal fragments (Nelson and Lowe 1997). Kear and Schofield (1978) coined the name Hopuhopu Sand Member for this Hinuera-like facies within the Taupo Pumice Alluvium, and used the name Melville Pumice Member for the more typical pumice-rich sediments. Reconstructed subsurface cross-sections through the 'Asparagus Block' show the presence of a bounding bank of Hinuera deposits during accumulation of Taupo Pumice Alluvium (Fig. 4), so that the opportunity for reworking Hinuera sediments into more marginal parts of the Taupo alluvium clearly existed at the site.

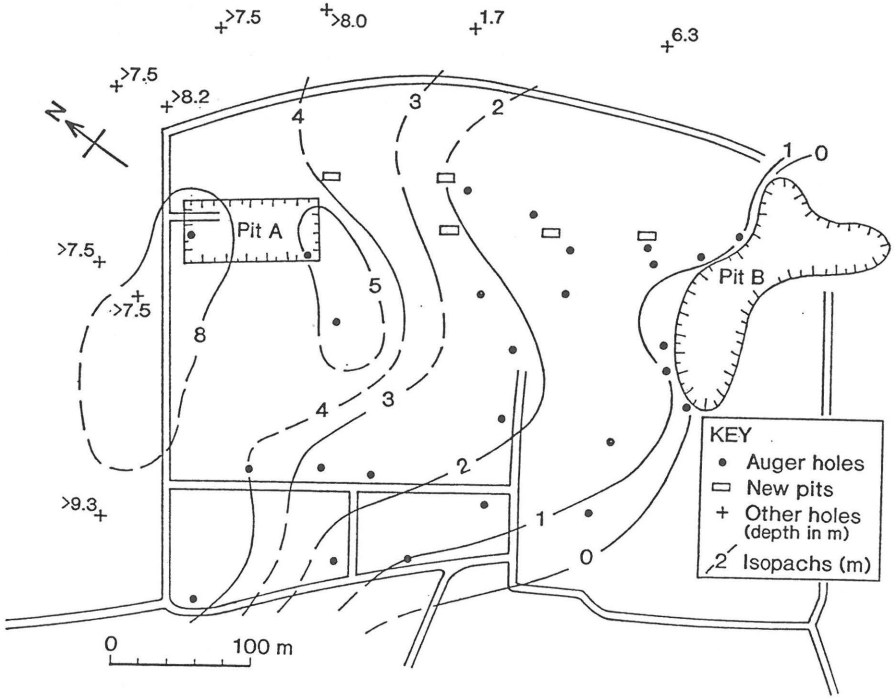


Figure 8 - Isopach (or thickness) map (in m) for the Taupo Pumice Alluvium at the 'Asparagus Block'. Note that the thickness of pumice-rich deposits generally increases from south to north across the area from about 0-8 m and, from the depth information in Mitchell (1996) shown by the crosses, continues to exceed about 8 m thickness immediately beyond the northern boundary of the 'Block'.

ESTIMATES OF PUMICE RESERVES

Ignoring the mainly pumice-poor Hinuera Formation deposits, it is possible to roughly estimate the reserves of pumice contained within the Taupo Pumice Alluvium in the 'Asparagus Block'. First, from the thickness data for the formation obtained from the different sample sites over the block (Fig. 2), including data from a separate study by Mitchell (199X), an isopach (or thickness) map for the Taupo Pumice Alluvium has been compiled (Fig. 8). Like the cross-sections (Fig. 4), this shows the thickness increases in a wedge-like manner from zero in the southern portion of the block to about 8 m along the northern edge. Immediately beyond the northern edge thicknesses exceed 7.5 m, and locally 9.3 m (Fig. 8).

The volume of Taupo Pumice Alluvium in the 'Asparagus Block' can be represented in simplified form by a 400 m-wide x 450 m-long wedge increasing stepwise in thickness from 0 to 8 m as depicted in Fig. 9. This translates into a volume of about 535,000 m^3 of Taupo Pumice Alluvium. Assuming an overall average pumice content of about 80% in these Taupo deposits (Table 5), this yields a pumice reserve of about 428,000 m^3 within the confines of the 'Asparagus Block'.

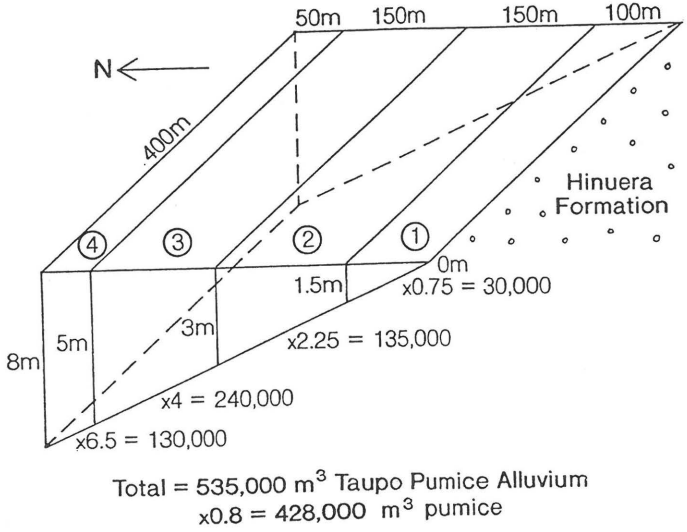


Figure 9 - Schematic diagram of the dimensions of the wedge of Taupo Pumice Alluvium overlying Hinuera Formation at the 'Asparagus Block' showing the figures used to establish a rough estimate of the volume of extractable pumice sand reserves at the site, possibly of the order of 400,000 to 450,000 m^3.

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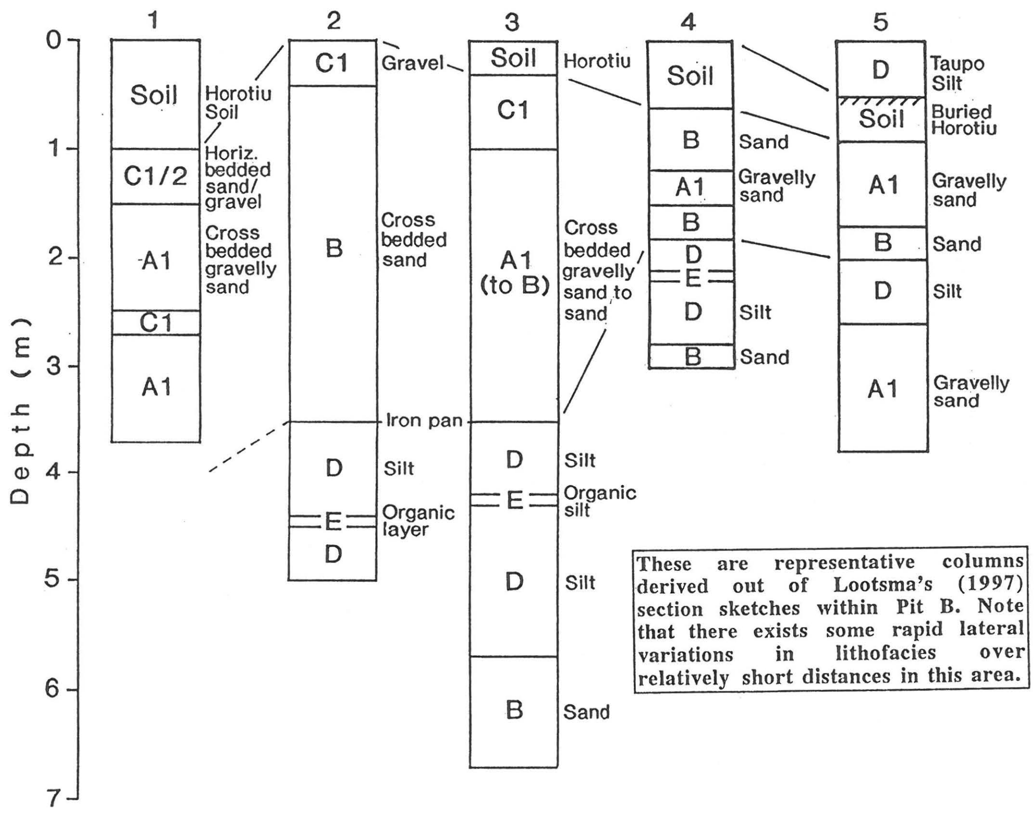
APPENDICES

The columns on the following pages are taken more or less directly from Lootsma (1997) and depict her interpretations of the field lithofacies present in the Hinuera Formation and Taupo Pumice Alluvium at the 'Asparagus Block' at Horotiu. Site locations are shown in Fig. 2.

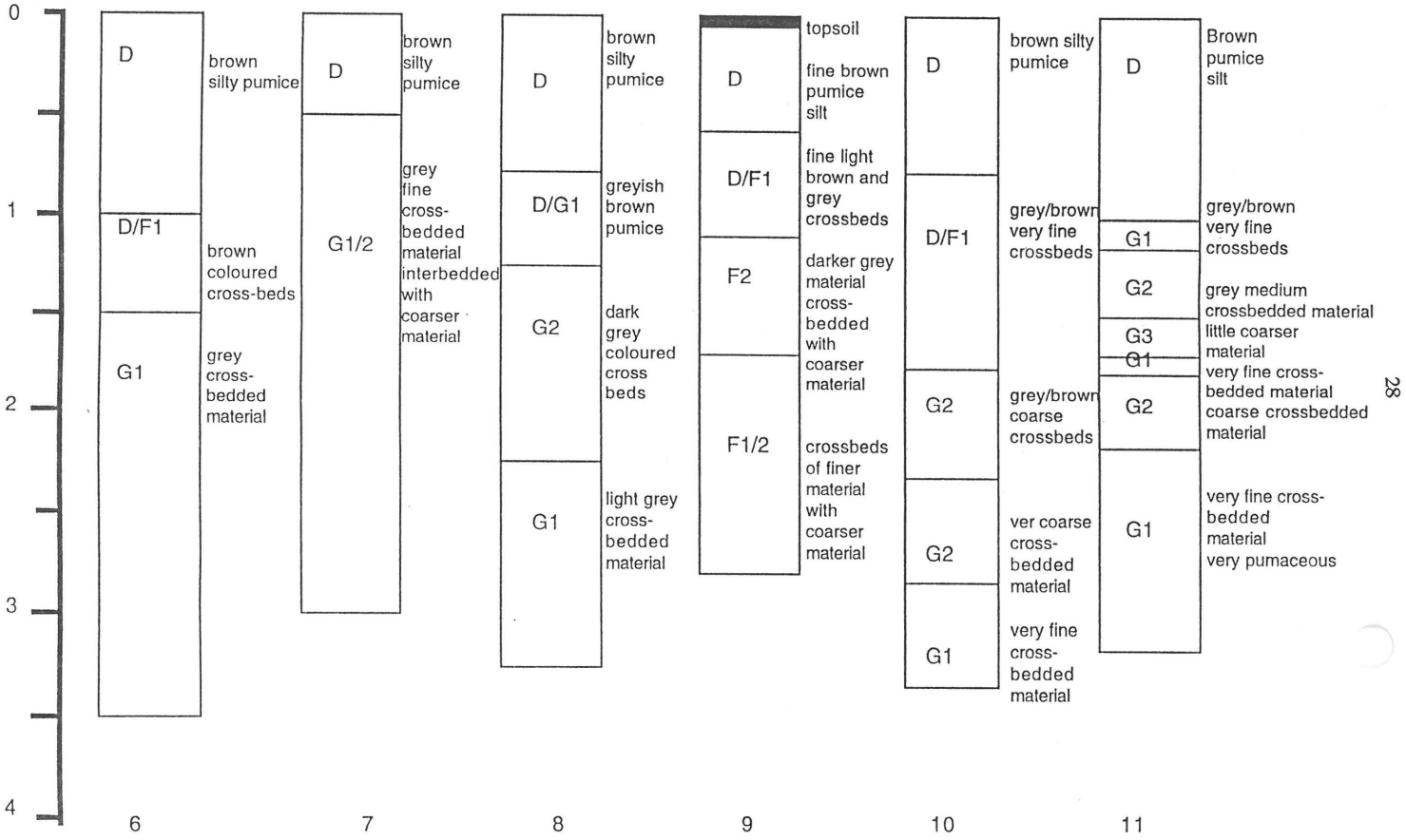
Appendix I

Pit B sections in Hinuera Formation, wall sites 1 - 5



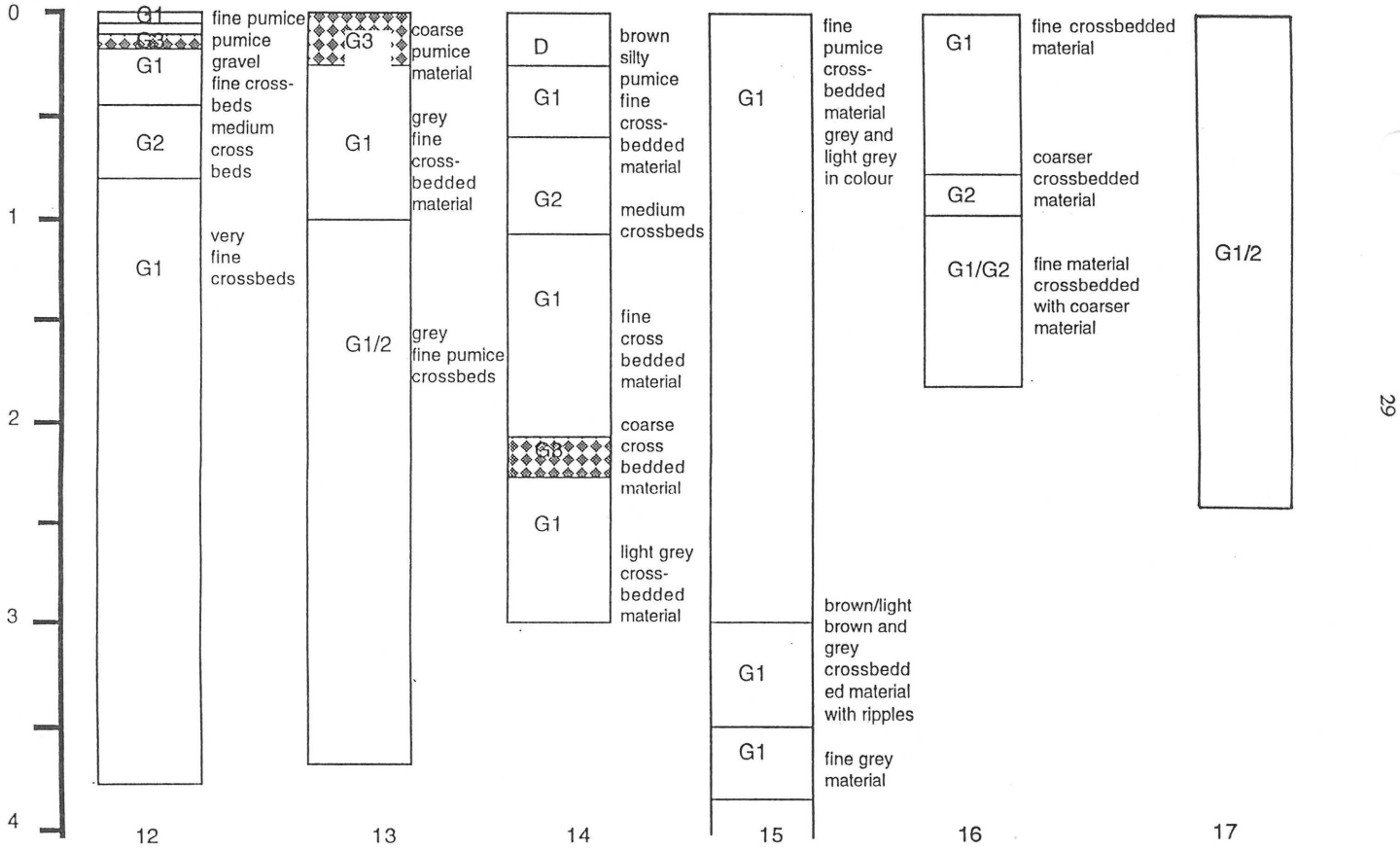
These are representative columns derived out of Lootsma's (1997) section sketches within Pit B. Note that there exists some rapid lateral variations in lithofacies over relatively short distances in this area.

Pit A sections in Taupo Pumice Alluvium, wall sites 6 - 11



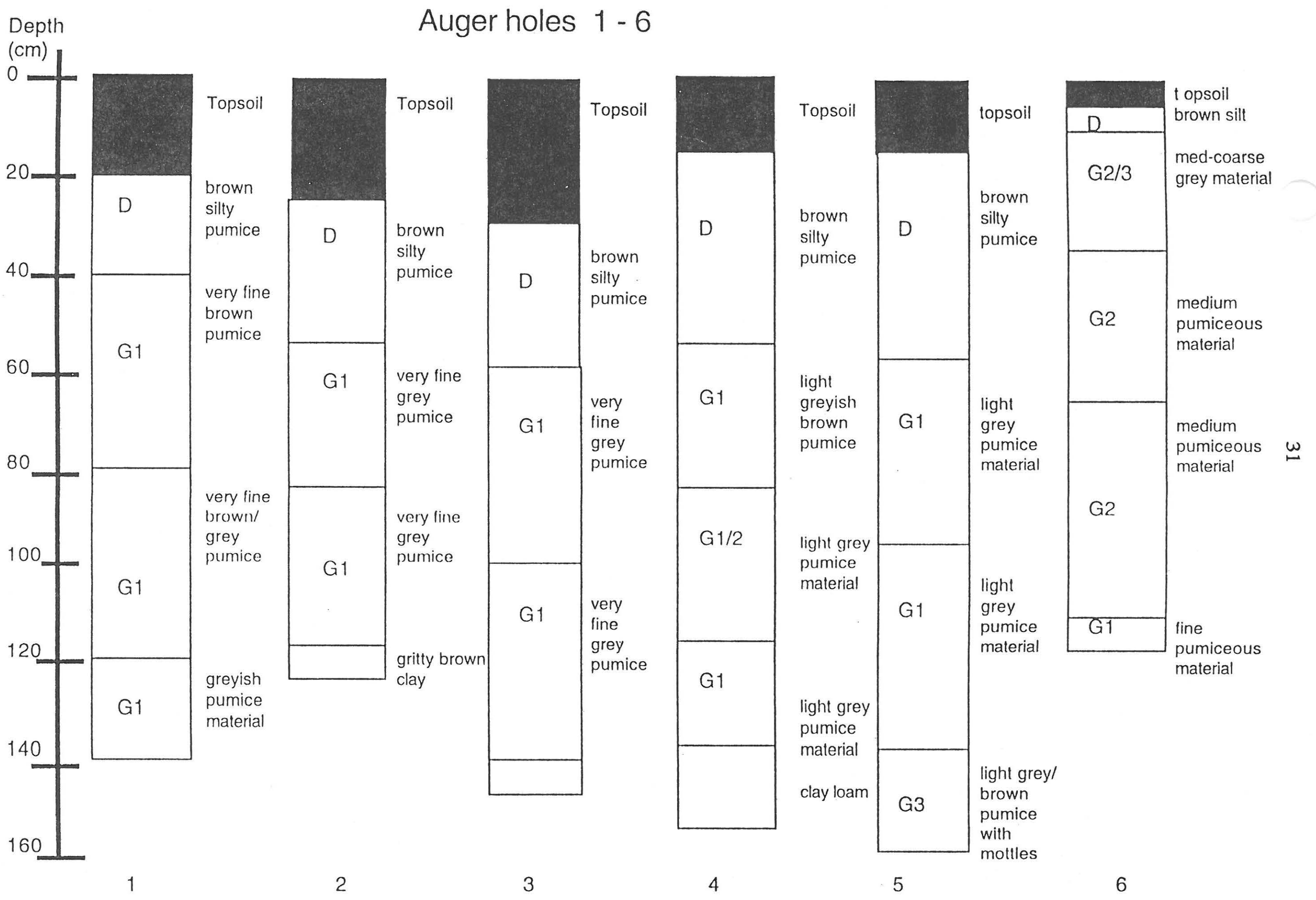
28

Pit A sections in Taupo Pumice Alluvium, wall sites 12 - 17

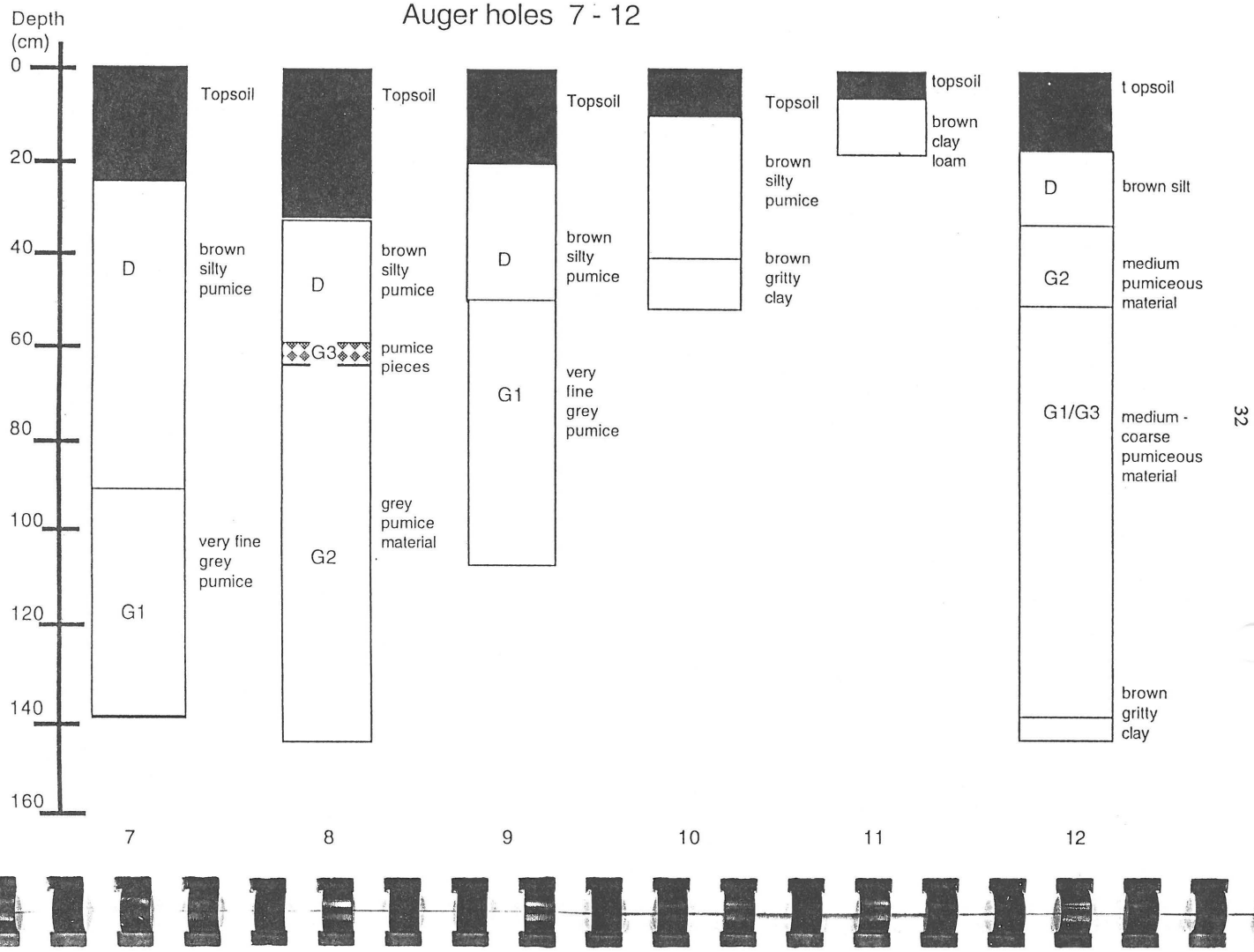


29

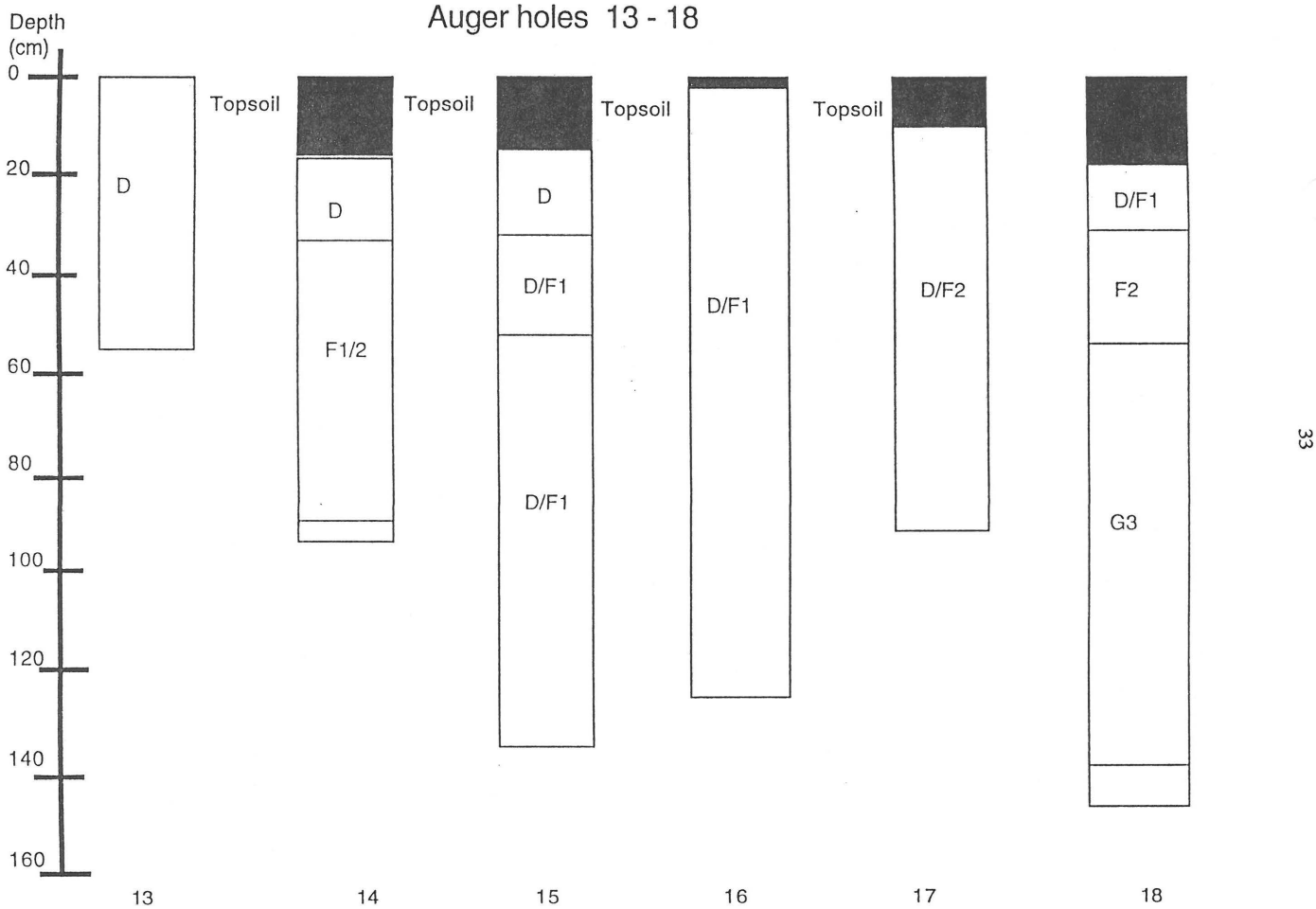
Appendix II


Auger holes 1 - 6
Depth (cm)
0
20
40
60
80
100
120
140
160
Topsoil
D
brown silty pumice
G1
very fine brown pumice
G1
very fine brown/ grey pumice
G1
greyish pumice material
1
Topsoil
D
brown silty pumice
G1
very fine grey pumice
G1
very fine grey pumice
gritty brown clay
2
Topsoil
D
brown silty pumice
G1
very fine grey pumice
G1
very fine grey pumice
3
Topsoil
D
brown silty pumice
G1
light greyish brown pumice
G1/2
light grey pumice material
G1
light grey pumice material
clay loam
4
topsoil
D
brown silty pumice
G1
light grey pumice material
G1
light grey pumice material
G3
light grey/ brown pumice with mottles
5
t opsoil
D
brown silt
G2/3
med-coarse grey material
G2
medium pumiceous material
G2
medium pumiceous material
G1
fine pumiceous material
6

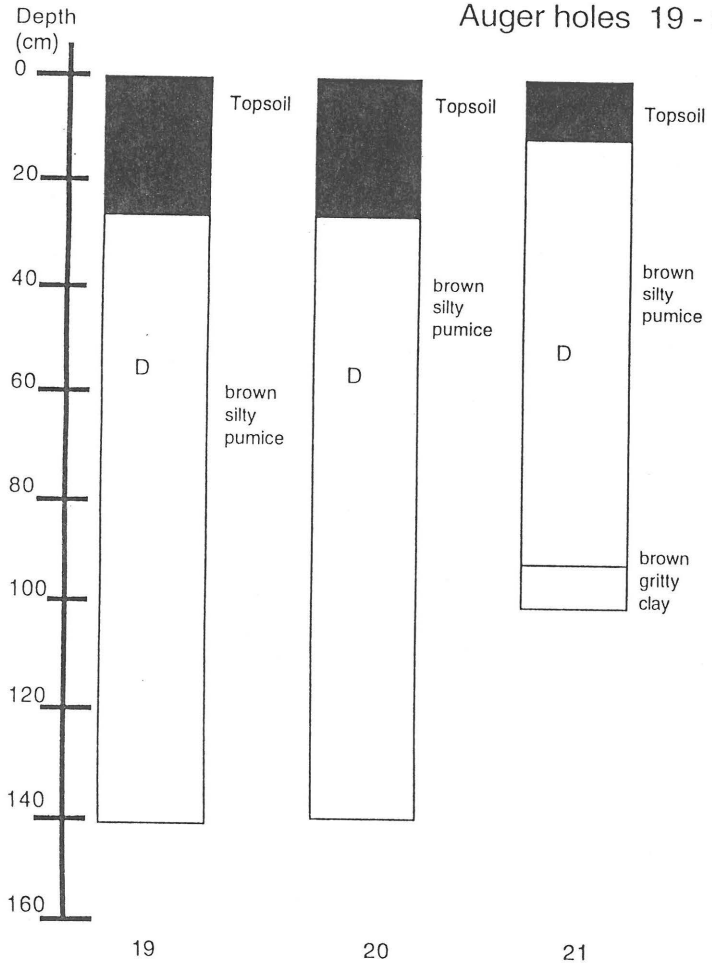
Auger holes 7 - 12



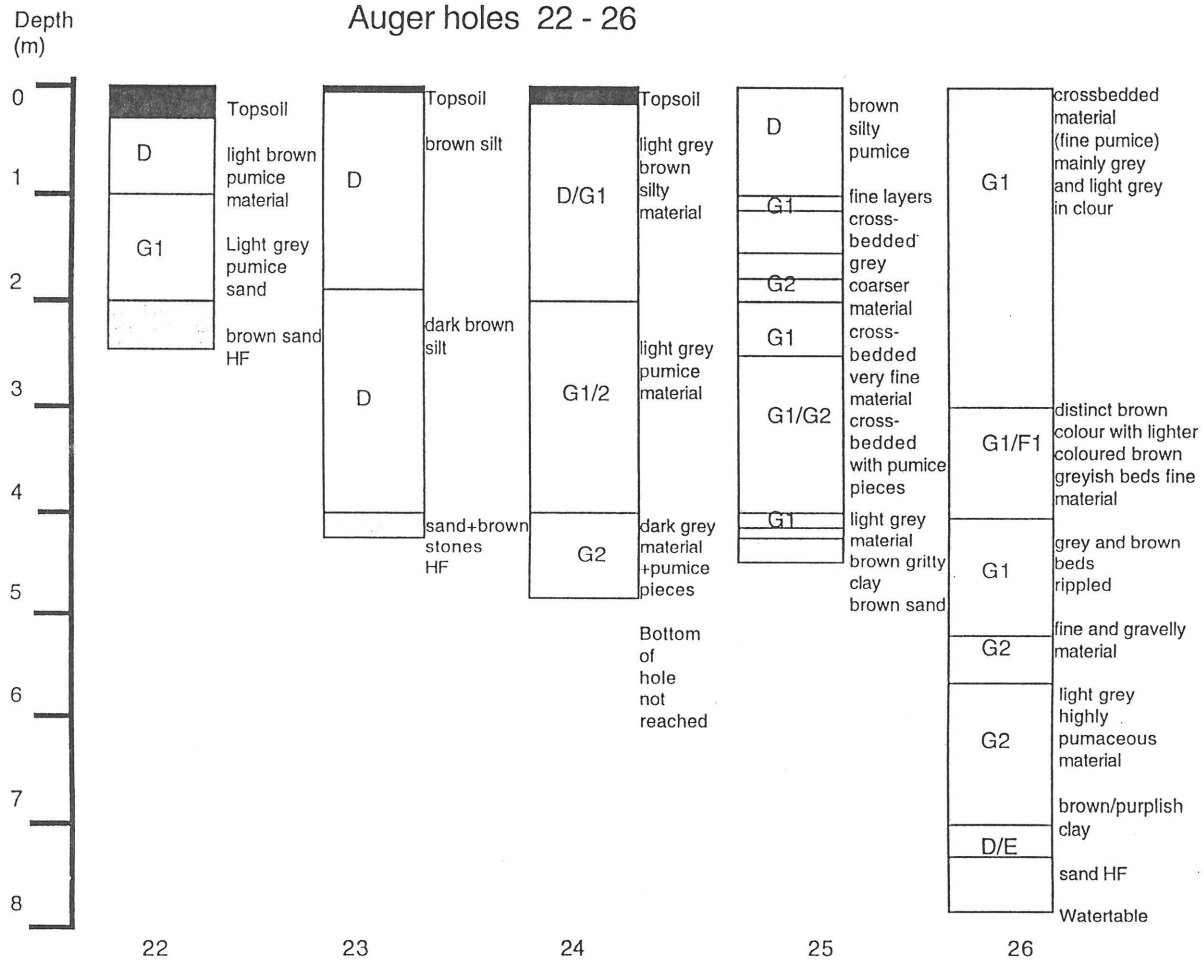
Auger holes 13 - 18



Auger holes 19 - 21



Auger holes 22 - 26



Appendix III

New pit wall sections 1 - 5