RIVER TERRACES AND OTHER GEOMORPHIC FEATURES
OF
CASTLE HILL BASIN, CANTERBURY, NEW ZEALAND

by

William J. Breed

A Thesis Submitted to the Faculty of the

DEPARTMENT OF GEOLOGY

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 6 0

STATEMENT BY THE AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made. Requests of permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in their judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: William J. Breed

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

John F. Lance — May 11, 1960

JOHN F. LANCE
Professor of Geology

Date

RIVER TERRACES AND OTHER GEOMORPHIC FEATURES OF CASTLE HILL BASIN, CANTERBURY, NEW ZEALAND

ABSTRACT

Extensive systems of terraces in Castle Hill Basin are evidence for widespread cycles of aggradation and degradation of the rivers. The surfaces formed during periods of aggradation have been named as follows: Bridge Hill surface, Long Spur surface, Enys surface, Cheeseman surfaces and Post-Cheeseman surfaces. Evidence from moraines indicates that these aggradational surfaces were created during periods of glaciation when the streams of the valley were overloaded. Degradation and valley deepening ensued during non-glacial conditions, leaving the former river floodplains preserved as glacial terraces. The terraces of Castle Hill Basin have been correlated with similar surfaces in the Waimakariri Valley described by Dr. Maxwell Gage.

TABLE OF CONTENTS

LIST OF FIGURES

Figure

Figure

LIST OF PLATES

ACKNOWLEDGMENTS

The author is indebted to numerous people, both in the United States and in New Zealand, who have contributed their time to helping me complete this investigation. I am especially grateful to Dr. Maxwell Gage, Canterbury University, Christchurch, New Zealand, who originally suggested this problem and under whose direction the field work was completed. I am also indebted to Dr. Robin S. Allan and to Mr. J. D. Campbell, Canterbury University, and Dr. Richard P. Goldthwaite, Ohio State University, for their many useful suggestions. I also want to thank the members of the Canterbury Winter Sports Club who generously gave me permission to use their ski huts as field headquarters for this investigation.

I would especially like to thank the members of my thesis committee at the University of Arizona, Tucson -- Dr. John F. Lance, Dr. Joseph Schreiber, and Dr. John Harshbarger for critically reading and reviewing this report. Much aid in this respect was also given by Maurice E. Cooley.

Finally, I am deeply grateful to the U. S. Government for the Fulbright Grant which made my journey to New Zealand, as well as the present study possible.

INTRODUCTION

Within recent years an ever increasing understanding of the effects of Pleistocene glaciation has solved many problems that used to be considered too complex for comprehension. During this period extensive investigations in New Zealand have revealed valuable information concerning glaciation in this part of the world and a glacial chronology has been established. In the wake of this attainment, the author has attempted to interpret the late Pleistocene history of a small intermontane basin of the Southern Alps. The field work for this study was completed during the summer (January and February) of 1958 while the author was associated with Canterbury University, Christchurch, on a Fulbright Scholarship.

Location

Castle Hill Basin, in the South Island of New Zealand, is sixty miles west of Christchurch along the main road to Arthurs Pass and the West Coast (figure 1). This area, also referred to as Trelissick Basin, is included in the western half of the Broken River Sheet (S66, unpublished) of the New Zealand Map Series. Roughly triangular in outline, the basin is bordered on the south by the Red Hills and the Torlesse Range whose peaks range up to 6500 feet high; on the west by the Craigieburn Range over 7200 feet; and on the northeast by the Broken Hill Range, the least imposing of the three, with its highest peak slightly more than 5100 feet. These mountains form a barrier around the basin which is interrupted in only four places: (1) by the low saddle at the head of Cave Creek Valley; (2) by Coleridge Pass; (3) by the low gap between Spring Creek and Lake Lyndon; and (4) by the narrow gorge through which Broken River leaves the basin and ultimately joins the Waimakariri River.

Previous Work

Although Haast (1879, p. 392) did extensive studies of glacial effects in other areas of Canterbury, he disregarded Castle Hill Basin, other than to remark that the Rakaia and Waimakariri glaciers joined during their greatest extent through Lake Lyndon. McKay (1881, p. 57) was concerned mainly with the stratigraphy and paleontology of the area but was aware of the terraces to the extent that he postulated that Castle Hill Basin was once a lake with its origin due to ice action. Hutton (1887, p. 395) likewise studied the stratigraphy and paleontology but omitted the river gravels and terraces from consideration. He considered that during the last great glacial epoch the basin was a snowfield; thus he did not expect or see any marks of glacial action.

The moraines of the basin were first reported by Speight (1935, p. 308), but his interpretation of the glacial history of the region was hindered because he did not believe that New Zealand had experienced multiple glaciation. This paper along with a later work on the whole Waimakariri Valley (Speight, 1938) are of more value to the present study than his earlier papers on the basin (Speight, 1914, 1917, 1919, and 1920), which were more concerned with pre-Pleistocene stratigraphy, paleontology, and tectonics.

The most recent paper on the whole Waimakariri Valley is by Gage (1958). In his paper the glacial and glaciofluvial deposits were studied in order to determine the advances and retreats of the glacier. However, the evidences from Castle Hill Basin were not investigated in detail.

Purpose and Methods

Since the study by Gage (1958) of late Pleistocene glaciation in the Waimakariri River Valley, it has become desirable to study the river terraces and other evidences of glacial action in Castle Hill Basin. The present study was undertaken at Dr. Gage's suggestion in order to integrate these features more closely with those of the

Waimakariri River system. This investigation may be useful for future work in the Rakaia drainage basin since Castle Hill Basin is a connecting link between the two river systems (figure 2).

In order to interpret the glacial history of Castle Hill Basin, the author made use of the methods already employed by Gage (1958) in his study of the Waimakariri Valley. The numerous river terraces were first studied intensively near the junction of Broken River and Cave Creek and their relative heights were established by means of an aneroid barometer. This sequence was then correlated with surfaces of similar elevation and gradient throughout the basin by visual field observation and where possible the terraces were traced to moraines in order to establish their glaciofluvial origin. With this information river and terrace profiles were constructed which enabled correlation with the regional chronology of the Waimakariri Valley, thus enabling the glacial history of Castle Hill Basin to be compared with the glacial events of other parts of New Zealand (Plates 1, 2, and 3).

Much frustration was encountered in the field in attempting to obtain accurate results with the aneroid barometer. During storms from the northwest this temperamental instrument would fluctuate as much as twenty feet with the various gusts of wind and there would be changes of elevation from morning to evening at the same station ranging from 30 to 250 feet. As much as possible these errors were corrected by visiting the elevation points several times. The altitudes recorded on the map (Plate 4) are accurate relative to each other; any inaccuracies that may exist would have little or no effect on the correlations and the river and terrace profiles.

Aerial photographs were utilized in the field to record elevations and terrace locations. As topographic maps of the area were not available, this data was then transferred to a base map obtained from the Land and Survey Office in Christchurch.

GEOMORPHIC AND GEOLOGIC SETTING

Pre-Pleistocene Stratigraphy

The mountains that encircle the basin are composed mainly of folded and faulted geosynclinal greywacke and argillite of Triassic age. These rocks were subjected to intense deformation during the early part of the Cretaceous period, followed by erosion which ultimately resulted in their peneplanation. Westward transgressing seas reached the area in the Late Cretaceous. Thereafter, the area was below sea level during a considerable part of Tertiary time and the following sequence of beds was deposited (Speight, 1914, p. 341; ages modified from information from Gage, Personal communication, 1960) with unconformities marking local movements during the lower Oligocene and again at the end of the Oligocene:

Pareora - Southland - Wanganui Series (?) (Miocene to L. Pliocene (?)	Brown sands, conglomerate lenses Cross-bedded estuarine sands with lignite up to 2 ft. Fine gray sands, with concretionary shell beds
- - - - - - - - (unconformity) - - - - - - - - - - - - - -	
Landon Series (Oligocene)	Alternating limestones and basaltic tuff; basaltic sills, dikes and lava pillows. Argillaceous limestone Quartz sands
- - - - - - - - (local unconformity) - - - - - - - - - - -	

Mata-Arnold Series (Upper Cretaceous-Eocene)	Glauconitic sands with concretary bands, rarely fossiliferous. Gray-green fine glauconitic sands and greensands Sandstones with <u>Inoceramus</u> and <u>Concothyra parasitica</u> in concretionary bands. Carbonaceous sandstones with lignite locally up to 6 ft.

- - - - - - - - - (Regional unconformity) - - - - - - - - - - - -

During the emergence and uplift which followed, the Cretaceous and Tertiary rocks were strongly folded and faulted during the Pliocene-lower Pleistocene (Kaikoura) movements, greatly reduced in extent by erosion from the summits of the tectonic "highs" and subsequently preserved in the structural depression that is called Castle Hill Basin, only one of a number of such intermontaine basins floored by outliers of the originally extensive Cretaceous and Tertiary cover.

Through the combined actions of subaerial and glacial erosion the basin has been sculptured to its present form with the limestones of the Landon Series forming prominent escarpments and hills; the weaker beds of the Pareora Series forming slumps and hummocky landscape; and the tuff beds forming typical badland topography. Aside from the tuffs, the only other volcanic rocks are in the vicinity of Prebble Hill where they form a series of dikes which have been mapped and discussed by Hutton (1887, p. 403).

The pre-Pleistocene rocks of Castle Hill Basin have been mapped recently by Gage as part of the New Zealand

Geological Survey map series. This map will be at a scale of 1:63660 and will include a marginal outline of the geology. This should result in a more precise understanding of the structural and stratigraphic relationships of the area.

Physiographic Setting

In Castle Hill Basin, the river terraces are a striking feature of the landscape (Figure 4). They are composed mainly of gravel deposits topped by a flat surface. An abundant source of gravels for these terraces is found in the mountains which encircle the basin. Here frost action splits the excessively jointed greywacke into rectangular prismatic blocks (Speight, 1907, p. 17) and the scree thus formed is readily available for transportation downstream to the floor of the basin.

The drainage pattern of the basin is divided into two unequal sections by the main stream consisting of the Porter River plus the lower part of Broken River (Figure 3). In the northwest portion of the drainage basin, the streams originate on the slopes of the Craigieburn Range and consist of six major tributaries - Cave Creek, Broken River, Waterfall Creek, Hogback Creek, Thomas River and Whitewater River. These streams receive the greater part of the runoff and have a greater volume than the other streams of the basin. The main river terraces of the basin were also found along their flanks. In contrast, the streams in the southeast portion of the drainage receive most of their runoff from the Torlesse Range and have a very low volume. These streams are so insignificant that only three of them have been named; Camp Creek, Dry Creek and Spring Creek. The latter drains the valley between Red Hills and the Torlesse Range and receives most of its flow from Lake Lyndon by underground seepage. These streams normally have a high gradient and have built huge alluvial cones and fans where they enter the basin.

The reason for this unbalanced distribution of runoff can be explained by an examination of the rainfall pattern. In Castle Hill Basin, the rainfall is much greater on the slopes of the Craigieburn Range than on the Torlesse Range for three main reasons: (1) greater height, (2) proximity to the main divide of the Southern Alps and (3) favorable location in regard to the storm pattern which brings the majority of rainfall from a westerly direction. In the winter, more snow would accumulate on the Craigieburn Range as its eastern slopes are protected from the afternoon sun and the prevailing westerly winds would carry snow from its western to its eastern slopes. The melting rate and evaporation rate on the northwest slopes of the Torlesse Range would be much greater as they are exposed to the direct rays of the sun for most of the day.

During the Pleistocene this same situation existed in Castle Hill Basin for today evidences of glaciation in the form of cirques, moraines, and tarns can be discerned in the Craigieburn Range (Figure 10), whereas such evidence is lacking in the Torlesse Range, the Red Hills, and the Broken Hill Range. The typical U-shaped profile usually associated with glaciated areas is not present in the Craigieburn Range; however this is due to the masking effect of the scree.

GLACIAL CHRONOLOGY OF NEW ZEALAND AND THE WAIMAKARIRI VALLEY

From his study of the Waimakariri Valley, Gage (1958, p. 126) has established a glacial chronology consisting of two main periods of glaciation divided by a long interglacial interval as follows:

	(post-glacial)
Waimakariri Glaciation	Poulter Advance (Short interglacial interval) Blackwater-II Advance (Brief recession) Blackwater-I Advance (Interglacial interval) Otarama Advance (Rel. long interglacial interval) Woodstock Advance
	(Prolonged interglacial interval)
Avoca Glaciation (possibly multiple)	

This local terminology is part of the basis for a glacial chronology of New Zealand as proposed by Gage and Suggate (1958, p. 593), in which the Avoca and Waimakariri Glaciations are correlated respectively with the Waimaungan and Otiran Glacial Stages. This standard chronology for New Zealand has been established from studies in Westland, Nelson and Canterbury.

Gage and Suggate (1958, p. 597) have not attempted any correlation between the above glacial chronology and that of North America other than to suggest that the Blackwater and Poulter Advances represent a span of time similar to the Wisconsin, even though the whole Otiran Glacial Stage can not be considered equivalent. They also indicate that the correlation of Waimaungan to Illinoian is possible, but speculative.

LATE PLEISTOCENE TERRACES AND MORAINES

This thesis will be concerned mainly with a description of the various terraces and terrace deposits of Castle Hill Basin. A cross section (Figure 5) reveals the terraces are composed of gravel deposits topped by a flat surface which is usually the vestige of a former river floodplain. Terraces formed while the river is building up its valley floor are termed aggradational. Those formed when the river is eroding its former deposits are indicative of nothing more than a temporary halt in downcutting and may be termed degradational. Although superficially degradational and aggradational terraces resemble each other, the difference is important in working out the regimen of a stream.

Many of the aggradational terraces when traced upstream were found to originate in moraines. This would indicate that the streams of the basin under periglacial conditions would be overloaded with glacial debris and building up their channels. Downcutting would ensue during nonglacial conditions and the former floodplains would be preserved as river terraces.

Climatic fluctuations alone would then be sufficient to account for the terraces. Fluctuations in sea level would have little effect for the basin is 100 miles from the ocean and the hingeline separating climatic from thalossostatic surfaces lies somewhere in the Canterbury Plains east of the basin (Gage, 1958, p. 154).

Bridge Hill Surface

The highest terrace remnants that have been found in Castle Hill Basin are present on top of Bridge Hill at an elevation of over 3400 feet and along the flanks of Broken Hill at elevations from 2850 to 3020 feet. All of these deposits which are approximately 1000 feet above the present level of the streams are considered to belong to the same surface, which will be referred to as the Bridge Hill surface.

The gravel deposits of this surface are not exceptionally thick, varying from approximately 20 feet at Bridge Hill to about 40 feet near the triangulation station "Trig. K". The deposits are intensely weathered with only an occasional medium-sized, rounded, greywacke boulder protruding through the tussock-grass cover.

Long Spur Surface

Approximately 500 feet below the deposits at Bridge Hill, another set of terraces has been mapped throughout the basin as the Long Spur surface. This surface was named for one of the landmarks of the basin, a prominent flat-topped ridge which extends from the lower flanks of Mt. Cloudesley between Hogback Creek and the Thomas River, known as Long Spur. Most of the terrace remnants which can be correlated with this surface are approximately 500 feet above the present river level.

The slightly dissected, flat surface of Long Spur is a remnant of a floodplain and underlain by approximately 90 feet of fluvial gravels. The gravels are larger and more angular near the Craigieburn Range. One isolated segment of Long Spur above Timm's Creek contains angular boulders up to four feet in diameter. As Long Spur surface was formed from glacial outwash, this would indicate that the terminus was very near. Similar boulders are found in the remnant of the Long Spur Surface between Broken River and Waterfall Creek.

Enys Surface

In the divide between the Thomas River and Broken River another flat-topped terrace has been preserved. Upon this level surface at the base of Long Spur one of the first homesteads of Castle Hill Basin was built by J. D. Enys. So the name "Enys surface" will be given to terrace remnants of comparable elevation and age throughout the basin.

The remnants of the Enys surface are very restricted throughout the basin. In all cases they are 150 to 200 feet above the present river levels and more deeply dissected than the surface immediately below. Aside from the terrace between Broken River and the Thomas River, the Enys surface is present in only three other localities in the basin: (1) along the east bank of Cave Creek and an isolated portion farther upstream, (2) on the divide between the Porter River and Whitewater Creek and (3) in the lower part of the basin across from the junction of Flock Creek and Broken River.

Moraines

Speight (1935, p. 308) has pointed out that on the south side of Tim's Creek, at a point where it leaves the greywacke slopes and enters the floor of the basin, there is an area covered with morainic dumps. These morainic dumps consist of rounded hills with several large angular boulders sitting on their summits and sides (Figure 11). They are much too low in elevation to be moraines for the Long Spur surface and the terraces below the Enys surface have their origin farther up the mountain; therefore, if they are moraines, they could only be moraines of the glacier which formed the Enys surface. However, there is much doubt of this for close investigation reveals the presence of large boulders at higher elevations related to the Long Spur surface. Several large boulders farther down the slope have obviously rolled to their present position, but are now stabilized. There is also a fault between the boulder accumulation and the morainic dumps which is partly responsible for recent land slides. For these reasons, the author prefers to interpret this "moraine" as a rock slide which possibly occurred during a later glacial advance.

A similar hill of rounded boulders near the entrance of Arizona Creek into Cave Creek valley was examined by the author in company with Dr. Gage. We concluded that this hill was not a moraine in situ because of the presence among the debris of "Coal Measures" a relatively unconsolidated formation which could not have been carried very far intact. There were other factors present corresponding to the preceeding case which prompted us to hesitate before calling the debris a moraine: (1) the presence of other rock slides along the same hill, (2) indications of the presence of a fault between the hill and the rock slide and (3) accumulations of boulders higher up the slope.

North of this hill, there is an isolated terrace remnant in the center of Cave Creek Valley. Since this hill is covered with glaciofluvial gravels, it is certainly a river terrace, but it is difficult to account for its preservation in such an unlikely location. This remnant of the Enys Surface was probably caught between two channels of a braided stream and not destroyed by later degradation. A similar situation now exists at the junction of the Hanmer River and the Waiau River south of Hanmer Springs.

Cheeseman Surfaces

The most extensive and widespread system of terraces in Castle Hill Basin lies below the Enys surface. Although these terraces consist of more than one level, they are related as all are underlain by a continuous layer of glaciofluvial material. These terraces will be referred to as the Cheeseman surfaces and the three main components have been mapped as Cheeseman-A, Cheeseman-B, and Cheeseman-C. These surfaces have been named for Mt. Cheeseman (6652 feet), one of the prominent peaks of the Craigieburn Range.

The Cheeseman-A surface is very extensive with its most noticeable remnant the flat terrace upon which the Castle Hill Station is located. In Cave Creek Valley (Figure 8), it is the higher of the two prominent terrace levels and it can be traced as almost a continuous surface to within one mile of Craigieburn Saddle. This terrace is also widespread in the areas between the other main rivers.

Immediately below the Cheeseman-A surface, particularly along the Porter River, numerous degradational terraces have been formed as a result of downcutting during glacial retreat. The most prominent of these are indicated on the map, but they have not been studied in detail for the author considers them unimportant for the present study.

Underlying the Cheeseman-A surface, particularly in the northern area of the basin, is a surface which the author has mapped as the Cheeseman-B surface. Since this terrace was originally used as a surface of reference, it was at first considered important and mapped throughout the basin. However, since the completion of mapping, it has been decided that this surface is nothing more than a widespread degradation terrace.

The Cheeseman-C surface forms the main terrace to the west of Broken River and the terrace immediately below the Cheeseman-A surface near Cave Creek, as well as numerous other small remnants throughout the basin. In Cave Creek Valley, this surface is the lowest surface that can be traced to Craigieburn Pass, thus indicating that after the formation of this surface, no more outwash from the Waimakariri Glacier entered.

Since all the Cheeseman surfaces are underlain by gravels it is exceedingly difficult to separate degradational from aggradational terraces. The only indication that the gravels underlying the Cheeseman-C surface are different from those under the Cheeseman-A surface is in Cave Creek Valley where in a period following a heavy rain it was noticed that the upper four feet of gravels were more porous than the lower six feet. If the upper four feet of gravel were deposited at a much later date on an erosion surface, this would indicate that the Cheeseman-C surface is aggradational.

On the divide between Spring Creek and Porter River, indications of recent faulting was observed on the Cheeseman-C surface. The surface in that area has been crossed by two faults perpendicular to the stream forming a small graben with a displacement of three or four feet.

Moraines

As indicated on the map (Plate 4) several of the Cheeseman surfaces have their origin in moraines formed where the rivers emerge from the mountains. However, moraines are not found in all river valleys as many have either been removed by erosion or buried by the unstable scree. The best preserved moraines seem to be at Hogback Creek (Figure 13). They have been preserved possibly because the valley terminates at a high elevation and the moraines were formed outside of the steep valley walls. These moraines are formed on the Cheeseman-A and Cheeseman-C surfaces and both are at approximately the same position, thus indicating that the two glacial advances were of almost equal extent. The Cheeseman surfaces in the upper part of the Porter River also originate from moraines.

Post-Cheeseman Surfaces

River terrace surfaces lower than the Cheeseman surfaces are present in both Broken River and Porter River, but no attempt has been made to trace them for any great distance as they are insignificant in area compared to the previous surfaces and would thus be very difficult to map. However, at Broken River Bridge and below the Broken River Gorge two terrace levels have been observed which are 60 to 80 feet above the river and 50 feet lower than the Cheeseman surfaces. Each of these terraces consists of about five feet of gravel on a bedrock base. More definite evidence for a period of glaciation after the deposition of the Cheeseman surfaces has been found in the upper reaches of Broken River where a post-Cheeseman terrace contains several kettle lakes. Although this indicates that the terrace was near a glacier, no actual moraines were found. However, a moraine of post-Cheeseman age was found in one of the south branches of Broken River.

If there was glaciation in the upper reaches of Broken River, it is also probable that small glaciers were present in the upper reaches of the other main rivers, but evidence for this has been obscured by the great quantities of scree completely covering the upper reaches of the Craigieburn Range. The presence of a small tarn at the head of Hogback Creek may also be evidence for late glaciation.

INTERGLACIAL INTERVALS

Following the deposition of each aggradational surface in the basin, periods of active downcutting reduced the level of the river valleys before the next surface was deposited. This erosion was of approximately the following extent: (1) after the Bridge Hill surface - 350 feet, (2) after the Long Spur surface - 200 feet, (3) after the Enys surface - 250 feet, (4) after the Cheeseman surfaces - 50 to 100 feet and (5) after the Post-Cheeseman surfaces - 40 to 50 feet. This period of downcutting can most readily be explained as an interglacial interval when the streams, no longer overloaded with glacial outwash, could scour their channels and remove the gravels deposited during glaciation. There have been no deposits observed from any of these interglacial intervals.

Evidence that downcutting after the deposition of the Cheeseman-C surface was extremely rapid is indicated by the fact that several streams that were adjusted to Broken River at the Cheeseman-C level were not able to erode as fast as the main stream and their valleys were left hanging. One example of this is the small unnamed tributary that enters Broken River immediately south of its upper gorge.

CORRELATION

The Pleistocene surfaces in Castle Hill Basin have been tentatively correlated with the glacial advances in the Waimakariri Valley (Plates 1, 2 & 3). This correlation has been accomplished mainly by comparing the relative heights of the terraces and where possible extending the terrace profiles of the Castle Hill deposits downstream to their point of intersection with terraces in the Waimakariri Valley.

The Bridge Hill Surface at Trig. K has already been referred to by Gage as a deposit of Avoca Glaciation, so these two can be considered equivalents. The correlation between the Cheeseman surfaces and the Chimney and Vagabond surfaces of the Blackwater Advance (Gage, 1958, fig. 2 and 12) has been determined mainly by extending the surfaces downstream approximately three miles to Winding Creek. This correlation is relatively secure for the Blackwater surfaces in Castle Hill Basin and the Waimakariri Valley are the most extensive and prominent of all the terrace deposits. The correlation of the remaining surfaces is based entirely on their position above or below the Cheeseman or Blackwater surfaces.

Correlation Between Glacial Stages in the Waimakariri Valley and Castle Hill Basin

Gage, 1958	Breed, 1960
(post-glacial)	(post-glacial)
WAIMAKARIRI GLACIATION	CASTLE HILL GLACIATION
Poulter Advance	Post-Cheeseman surfaces
Blackwater II Advance (Vagabond Surface)	Cheeseman-C surface
Blackwater I Advance	Cheeseman-A surface
Otarama Advance	Enys surface
Woodstock Advance (Long Interglacial Interval)	Long Spur surface
AVOCA GLACIATION	BRIDGE HILL SURFACE

PLEISTOCENE GEOLOGIC HISTORY

Avoca Glaciation in Castle Hill Basin

Both Haast (1879, p. 392) and Speight (1935, p. 309) have suggested that during the glacial maximum Castle Hill Basin acted as a snowfield and connecting link between the Rakaia and Waimakariri Glaciers. Hence, during the Avoca Glaciation, which is considered the glacial maximum, Castle Hill Basin was probably an extensive cirque supplying névé and ice through the lower extremeties of the basin to the existing Waimakariri Glacier. At the same time, distributaries of the Rakaia Glacier were also supplying the Basin with ice through Coleridge and Lake Lyndon Passes.

Under these conditions, there would be no glacial deposits in the upper parts of the basin. Likewise, the thickness of any deposits found in the lower reaches of the basin would be considerably less than the 1400 feet accumulation formed during the Avoca Glaciation in the Waimakariri Valley (Gage, 1958, p. 130). This is substantiated by the scarcity of Bridge Hill deposits and their restricted distribution to areas in the vicinity of Bridge Hill and Broken Hill. Furthermore possible erosional remnants of the original Avoca cirque are found as benches carved into the mountain spurs. This is illustrated by the flat bench north of

Waterfall Creek near the Canterbury Winter Sports Club Middle Hut. This bench can best be described as the relict of an ice-carved surface.

Woodstock Advance in Castle Hill Basin

In the Waimakariri Valley, there are scant survivals of the Woodstock Advance as the next advance (Otarama) was almost as extensive (Gage, 1958, p. 136). Since the floor of Castle Hill Basin was not glaciated by either advance, there is a greater possibility that the glaciofluvial deposits of the earlier advance would be preserved. This has been verified as Long Spur surface is more extensive throughout the basin than the products of the Otarama Advance.

During the deposition of the Long Spur surface, Castle Hill Basin must have contained numerous, large, braided streams which flowed from the termini of the glaciers approximately at the base of the present mountains. Distributaries of the Rakaia Glacier were feeding debris into the basin through Coleridge Pass, as indicated by its U-shaped cross section and striations. Lake Lyndon Pass was also low enough to contain distributaries from the Rakaia Glacier. It cannot be known how far these distributaries penetrated, but it is possible that they could have terminated where the present rivers emerge into the floor of the basin.

At the head of Cave Creek Valley, a lobe of the Waimakariri Glacier was pouring glaciofluvial material into the basin, but there is no indication that the ice ever entered.

During the deposition of the Long Spur surface, the tops of Flock Hill and Castle Hill were prominent features of the landscape as they are today. The upper half of Flock Hill that was not covered by the Woodstock deposits has been weathered into rounded forms which have the appearance of sheep. These shapes do not exist below the level of the Long Spur surface, so it is obvious that the limestone had to be exposed before and during the Woodstock Advance in order to develop into these weird forms.

Otarama Advance in Castle Hill Basin

The sparsity of the Enys surface makes it exceedingly difficult to determine the history of Castle Hill Basin during the Otarama Advance. In the Waimakariri Valley, the Otarama Advance was practically as extensive as the Woodstock Advance (Gage, 1958, p. 136), so there is reason to believe that the glacial advances which deposited the Enys surface and the Long Spur surface were similar.

Thus we can assume that during the Otarama Advance, Castle Hill Basin looked much as it did during the Woodstock Advance except that the rivers were lower in elevation and numerous remnants of the Long Spur surface were notable features on the landscape. As during the Woodstock Advance, distributaries of the Rakaia Glacier entered the basin through Coleridge Pass and Lake Lyndon Pass and the Waimakariri

Glacier was pouring outwash into the basin through Cave Creek Valley.

During the Woodstock and Otarama Advances, even though the floor of Castle Hill Basin was not glaciated, its outlet into the Waimakariri Valley was blocked by glaciers (Gage, 1958, Fig. 7, p. 135). Thus the base level of the basin would be determined by the height of the existing glacier in the Waimakariri Valley. In this situation, widespread aggradation would result during a glacial advance and rapid downcutting during glacial recession. A similar situation to this exists in New Zealand where the outwash and meltwater of the Murchison Glacier is blocked by the Tasman Glacier (Figure 6). If the Tasman Glacier ever retreats enough to free this outlet, there will undoubtedly be rapid downcutting of the existing glaciofluvial deposits.

Blackwater Glaciation in Castle Hill Basin

During the Blackwater Advances, many of the main physiographic features of Castle Hill Basin were formed. Outwash filled the eroded valleys of the basin to the level of the Cheeseman-A terraces. Moraines indicated the advance of glaciers to the foot of the mountains. During the slight recession which followed, the rivers started downcutting the Cheeseman-A surface and formed the numerous degradational terraces which are so numerous throughout the basin. The valley glaciers then readvanced to within 100 feet of their previous position as shown by the glacial moraines at the head of Hogback Creek. This advance did not contribute quite as much glaciofluvial material to the basin; thus the Cheeseman-C surface was not as widespread as the Cheeseman-A.

At the junction of the Porter River and Whitewater River an interesting feature was observed. During the deposition of the Cheeseman-C surface, the quantity of material brought down by the Whitewater River was more abundant than that brought into the basin by the Porter River. Therefore, there are indications that the Whitewater built an alluvial fan which blocked the Porter and formed a small lake. The evidences for this are as follows: (1) The Cheeseman-C terrace as it leaves the Whitewater River forms a curve as it enters the Porter Valley and is actually at a lower elevation; (2) a bed of lacustrine silts and clays in the gravels along the Porter River; (3) terraces on the spur between the Porter River and Spring Creek, which may have been formed by the lowering of the lake.

The relation of Lake Lyndon to the basin during the Blackwater Advance is not clear. Lake Lyndon is on a level comparable to the Cheeseman-C surface, but the direct connection between the lake and the basin is blocked by numerous alluvial fans. These alluvial fans merge into the Cheeseman-C surface so they must have formed during that advance. A remnant of a higher alluvial fan at approximately the Cheeseman-A level is present where Spring Creek leaves the

Red Hills (Figure 12). There is the possibility as Dr. Gage has suggested that this fan was built against stagnant ice for the eastern part of the fan is missing with no streams present in that vicinity to erode the section away (Gage, personal communication, 1958). This would indicate that a stagnant lobe of ice was still present in this area as late as the first Blackwater Advance.

The Cheeseman surfaces in the upper part of the Porter River do not reach Coleridge Pass, but originate from moraines at a lower elevation. At this time the glacier in the Rakaia must not have been high enough to overflow into Castle Hill Basin.

Poulter Glaciation in Castle Hill Basin

The last phase of major ice activity in the Waimakariri Valley, the Poulter Advance, was multiple, but not extensive as it never threatened the previous deposits either by burial or erosion (Gage, 1958, pp. 148-150). Similiarly in Castle Hill Basin, the post-Cheeseman surfaces are a minor feature of the landscape and the glacial effects of this period were not very great.

OTHER GEOMORPHIC FEATURES

Numerous other geomorphic features of interest are also present throughout the basin. An excellent example of subterranean cutoff is present in the lower reaches of Cave Creek where the stream has abandoned its former channel and now reaches Broken River through a tunnel in the limestone under the spur between the two rivers (Figure 15). The age when this change occurred cannot be determined exactly, but it is evident that both the tunnel exit and the abandoned channel are at a level much lower than any of the terraces that are considered to be of Poulter Age. Therefore, it is evident that Cave Creek has been diverted from its former channel sometime in the period since the last ice advance during a period of degradation.

There are also a large number of alluvial fans and cones throughout the basin; many of them formed along the Torlesse Range where the gradient of the streams is quite steep (Figure 14). Several of the fans have been enlarged during the past decade, such as the one east of the Porter River Bridge which was greatly enlarged during a torrential rainstorm. Several fans which were formed on the Cheeseman surfaces are now covered with vegetation and no longer active. These were probably built under the periglacial conditions which accompanied the deposition of the glacio-fluvial gravels of the terraces. Many of the fans formed since the Pleistocene are still being enlarged and some that are graded to different levels have evidently been active as the river level was being lowered.

Patterned ground is also present in the basin at an elevation of over 4520 feet at the top of Leith Hill. The rock stripes observed were formed in an area of slight slope and the patterns formed are small (Figure 18). This is consistent with the fact that they were formed under diurnal rather than seasonal changes in temperature.

At the point where Arizona Creek enters Cave Creek Valley there has been a river capture. When it flowed on the Cheeseman-A surface, Arizona Creek flowed diagonally along the course shown in Figure 7, but during later degradation as Cave Creek was widening its banks it cut through the divide so that Arizona Creek is now drained by a more direct route.

The Cheeseman-B surface north of Hogback Creek seems to have been formed by drainage from Waterfall Creek flowing into Trout Creek. Since Waterfall Creek no longer flows in this direction, and since there is a Cheeseman-C terrace along its present route, it is obvious that sometime before the formation of the Cheeseman-C surface, the drainage of Waterfall Creek was diverted into its present course to Broken River.

<u>REFERENCES CITED</u>

Gage, Maxwell, 1958, Late Pleistocene Glaciations of the Waimakariri Valley, Canterbury, New Zealand: New Zealand Journal of Geology and Geophysics, v. 1, no. 1, p. 123-155.

Gage, Maxwell and Suggste, R. P., 1958, Glacial Chronology of the New Zealand Pleistocene: Geol. Soc. America Bull., v. 69, p. 589-598.

Haast, Julius von, 1879, Geology of Canterbury and Westland: "Times" Office, Christchurch, N.Z.

Hutton, F. W., 1887, Geology of the Trelissick or Broken River Basin: Trans. N. Z. Inst., v. 19, p. 392-403.

McKay, Alexander, 1881, On the Trelissic Basin, Selwyn County (with map and sections by J. Hector): Rep. Geol. Explor. during 1879-80., p. 53.

Relph, D. H., 1857, The Vegetation of Castle Hill Basin: New Zealand Geographer, v. 9, no. 1, p. 41-55.

Speight, R., 1908, Some Aspects of the Terrace Development in the Valleys of the Canterbury River: Trans. N.Z. Inst., v. 40, p. 16-43.

__________, 1915, The Intermontane Basins of Canterbury: Trans. N.Z. Inst., v. 47, p. 336-353.

__________, 1917, The Stratigraphy of the Tertiary Beds of the Trelissick or Castle Hill Basin: Trans. N.Z. Inst., v. 49, p. 321-356.

__________, 1919, Further Notes on theGeology of the Trelissick or Castle Hill Basin: Trans. N.Z. Inst., v. 51, p. 157-160.

__________, 1920, The Geological Features of the Broken River Coal Area: N.Z. Journal of Science and Technology, v. III, no. 2 and 3, pp. 93-104 and 148-156.

Speight, R., 1928, Geological Features of the Waimakariri Basin: Records Canterbury Museum, v. 3, pt. 3, p. 199-229.

__________, 1935, Further Notes on the Geology of the Trelissick or Castle Hill Basin, No. II: Transactions of the Royal Society of New Zealand, v. 64, pp. 303-314.

__________, 1938, Morainic Deposits of the Waimakariri Valley: Transactions of the Royal Society of New Zealand, v. 68, p. 143-160.

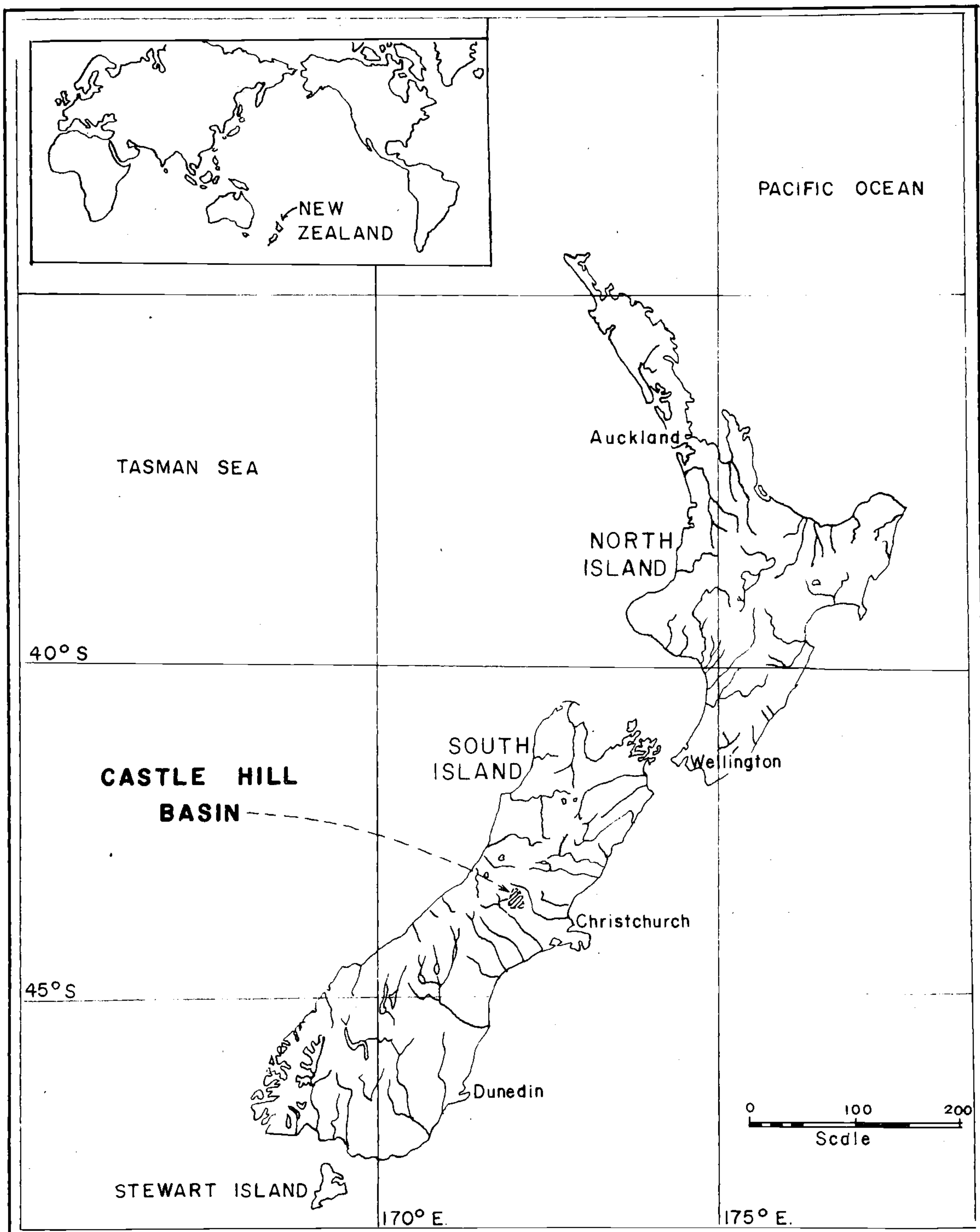


Figure 1.— Index Map of New Zealand showing location of Castle Hill Basin.

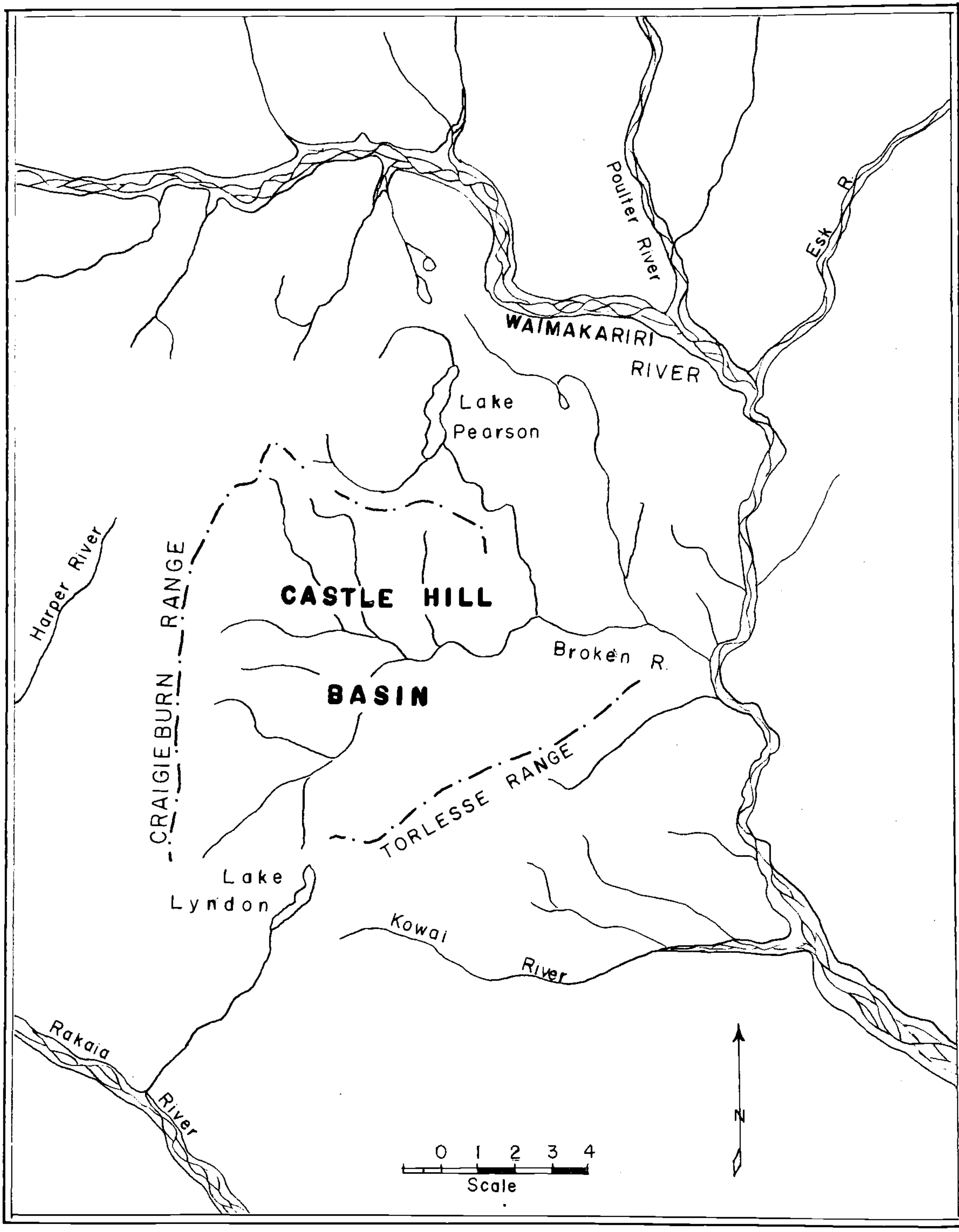
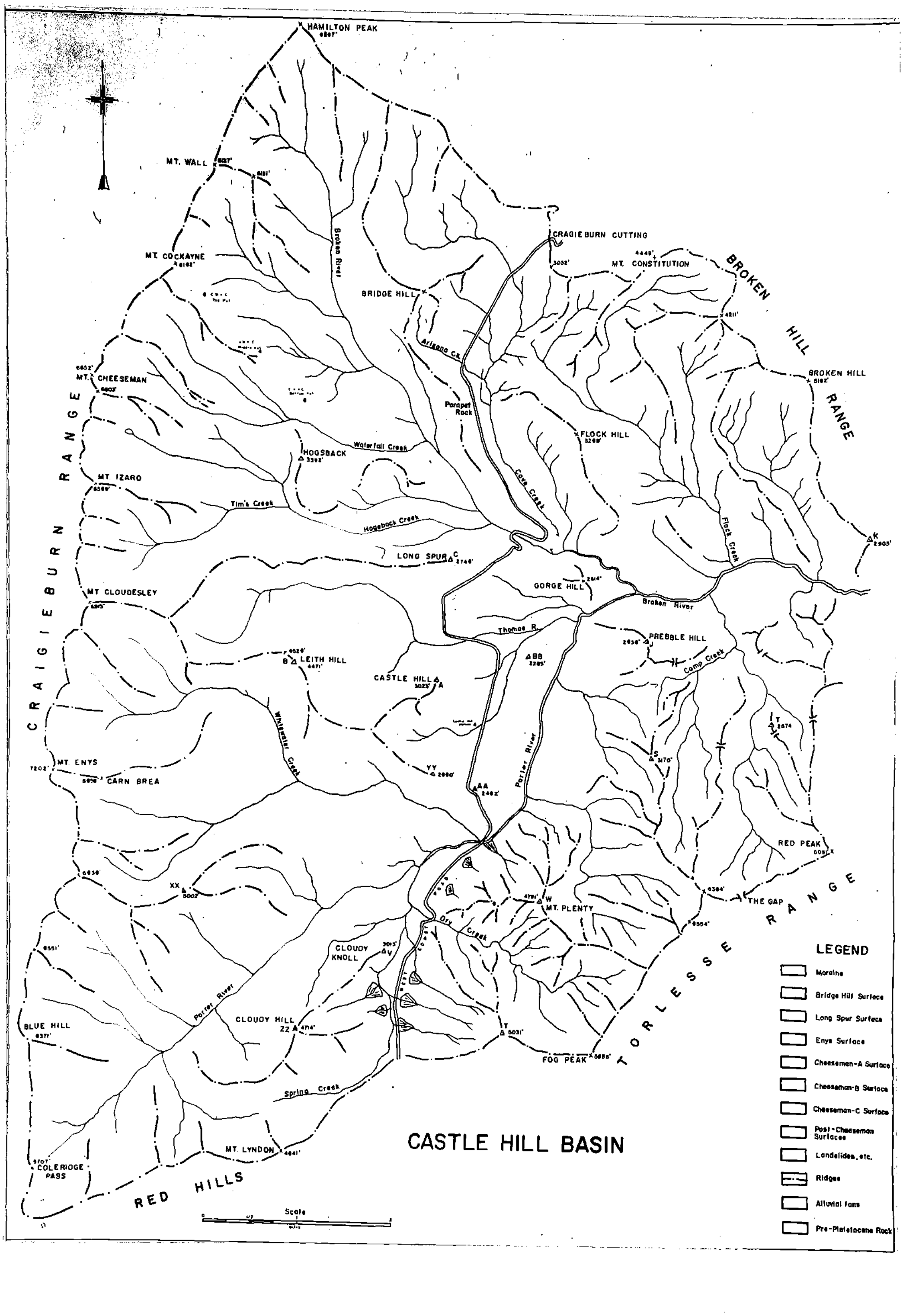


Figure 2.— Index Map showing the drainage relationship between Castle Hill Basin and the Waimakariri Valley.

Figure 3. Castle Hill Basin: Showing Principal Drainage and Mountain Ranges.



CASTLE HILL BASIN
HAMILTON PEAK
MT. WALL
MT. COCKAYNE
BRIDGE HILL
CRAIGIEBURN CUTTING
MT. CONSTITUTION
BROKEN HILL RANGE
BROKEN HILL
MT. CHEESEMAN
CRAIGIEBURN RANGE
Broken River
Arizona Ck.
Parapet Rock
FLOCK HILL
Waterfall Creek
HOGSBACK
MT. IZARO
Tim's Creek
Hogsback Creek
Cave Creek
Flock Creek
LONG SPUR
GORGE HILL
MT. CLOUDESLEY
Thomas R.
PREBBLE HILL
Camp Creek
LEITH HILL
CASTLE HILL
Whitewater Creek
MT. ENYS
CARN BREA
Porter River
RED PEAK
MT. PLENTY
THE GAP
Dry Creek
CLOUDY KNOLL
CLOUDY HILL
BLUE HILL
FOG PEAK
TORLESSE RANGE
Spring Creek
MT. LYNDON
COLERIDGE PASS
RED HILLS
Scale
LEGEND
Moraine
Bridge Hill Surface
Long Spur Surface
Enys Surface
Cheeseman-A Surface
Cheeseman-B Surface
Cheeseman-C Surface
Post-Cheeseman Surfaces
Landslides, etc.
Ridges
Alluvial fans
Pre-Pleistocene Rock

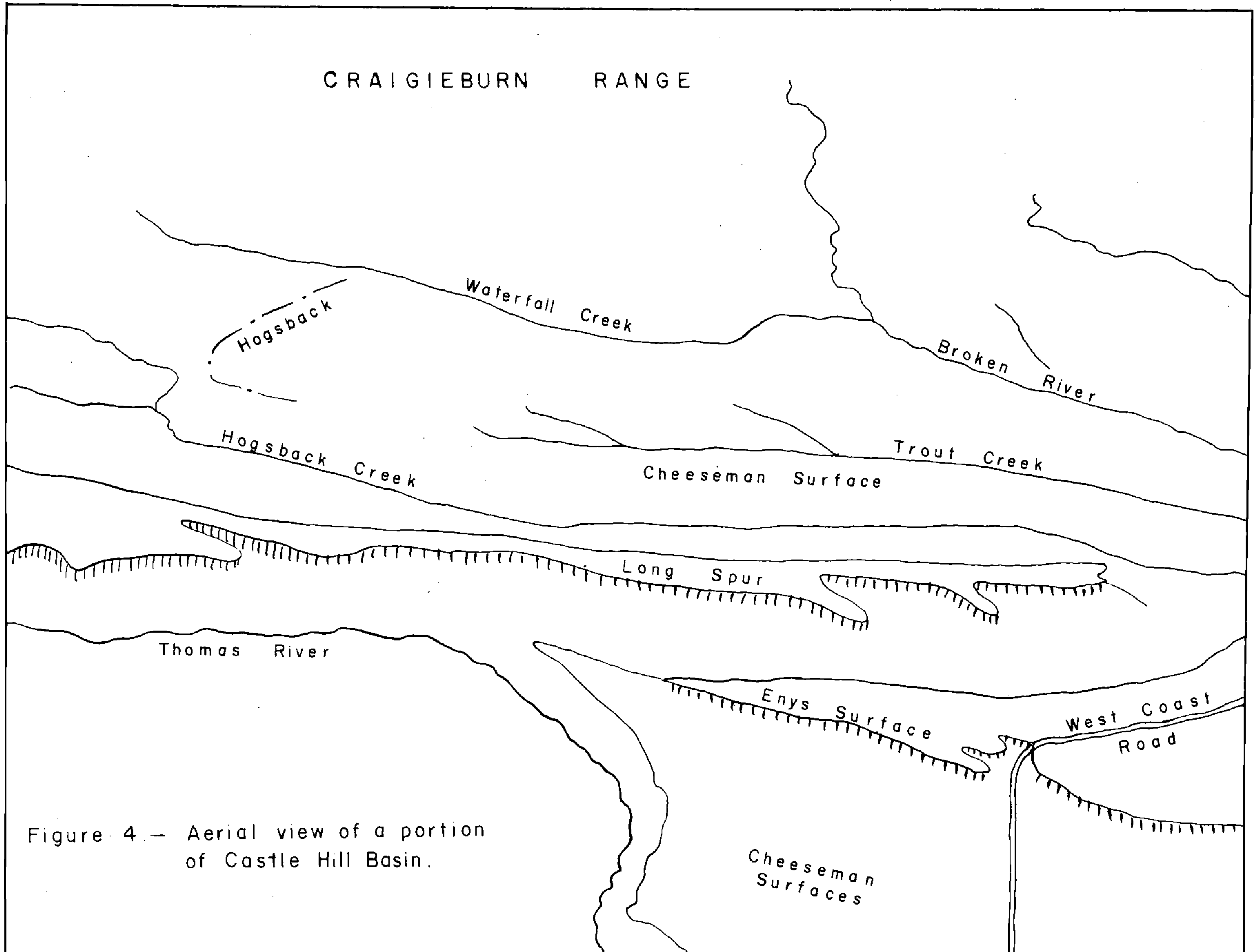


Figure 4.— Aerial view of a portion of Castle Hill Basin.

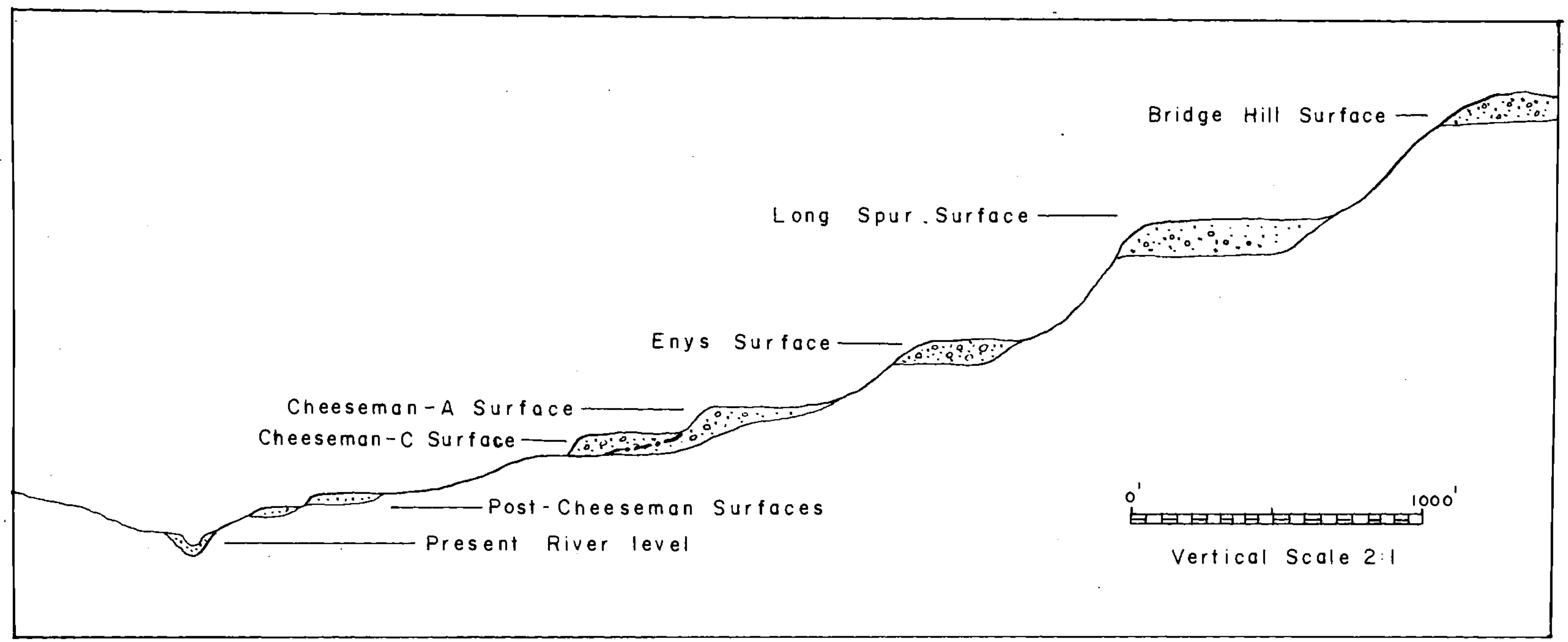


Figure 5.— Generalized Terrace Cross Section.

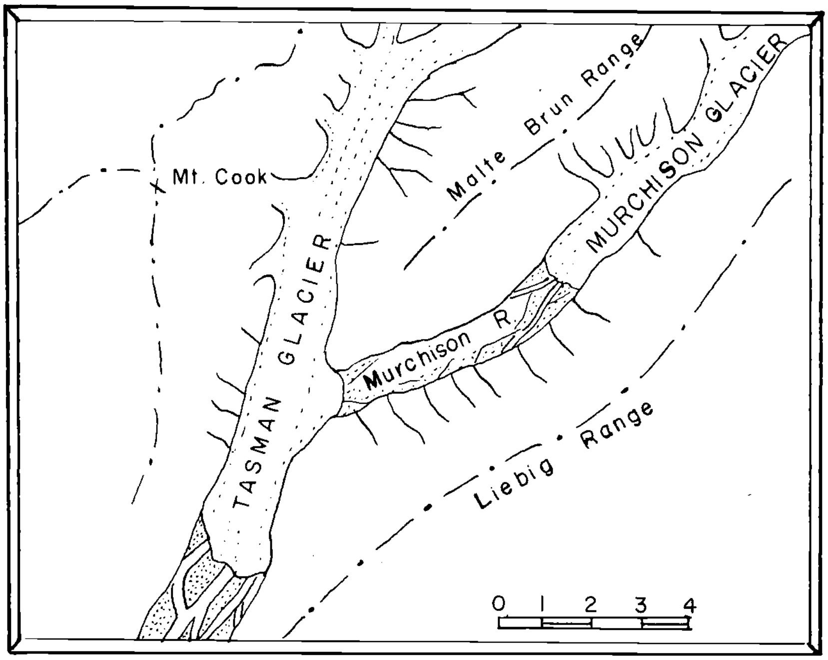


Figure 6.— Map showing Tasman Glacier and Vicinity.

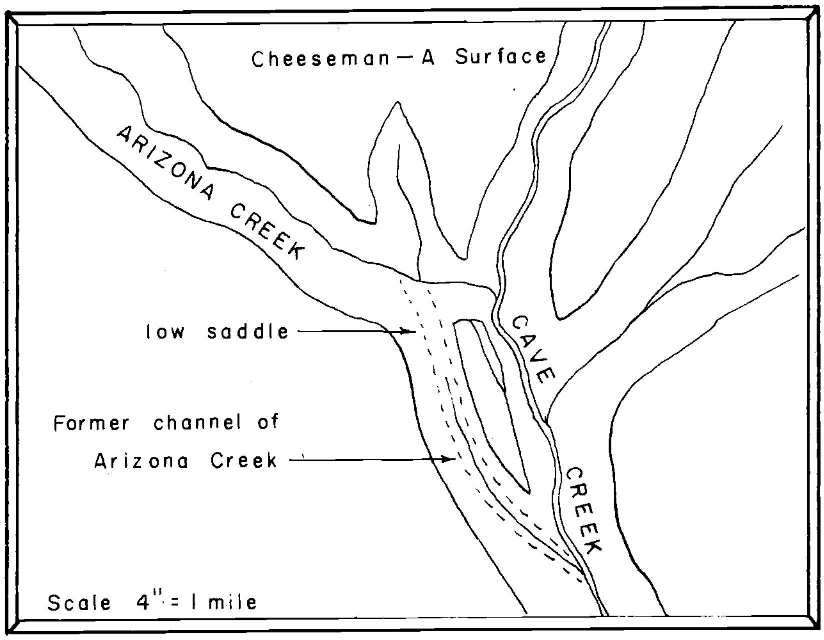


Figure 7.— Map showing course of Arizona Creek before and after capture.

Figure 8. Cave Creek: looking downstream from Parapet Rock. Cheeseman-A and -C terraces on left. Slight remnants of Enys Surface above Cheeseman -A terrace, but it is mainly destroyed by erosion. Torlesse Range in background.

Figure 9. Cheeseman terraces along Hogsback Creek. Craigieburn Range in background. Speight's "moraine" to left of center.

Figure 10. Craigieburn Range showing cirques at heads of Hogsback and Tim's Creek. In this area the most prominent moraines are found.

Figure 11. Speight's "moraine" at center above tree line. Note erosional and landslide features on hill.

Figure 12. Lake Lyndon in foreground. Hill to left of center may be alluvial surface built against stagnant glacier.

Figure 13. Moraines at head of Hogsback Creek.

Figure 14. Talus Cone near Porter River Bridge.

Figure 15. Natural tunnel formed by Cave Creek near its junction with Broken River.

Figure 16. Porter River near junction with the Thomas. Note braided pattern and wide valley floor.

Figure 17. Broken River flowing through gorge in limestone below junction with Cave Creek. Typical of gorges throughout the Basin.

Figure 18. Patterned ground on top of Leith Hill (4471')

Figure 19. Sheep trails on hill east of Hogsback.

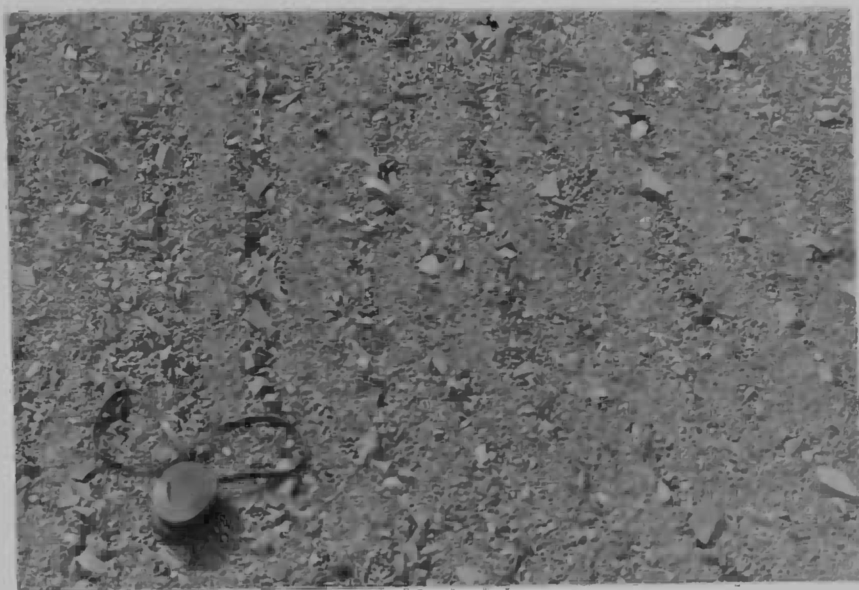


Plate 1.— Terrace Profile along Cave Creek.

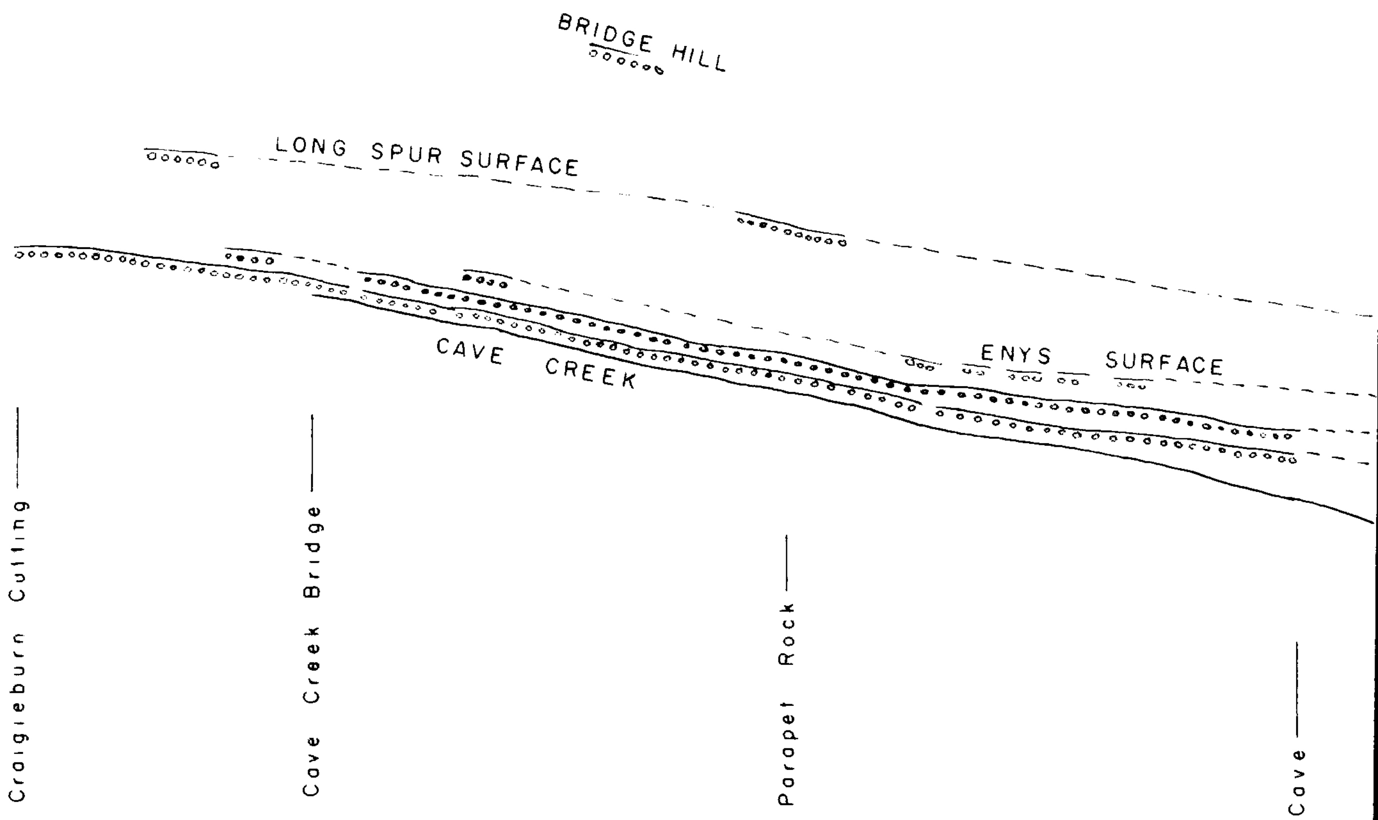


Plate 2.— Terrace Profile along Hogsback Creek and Broken River.

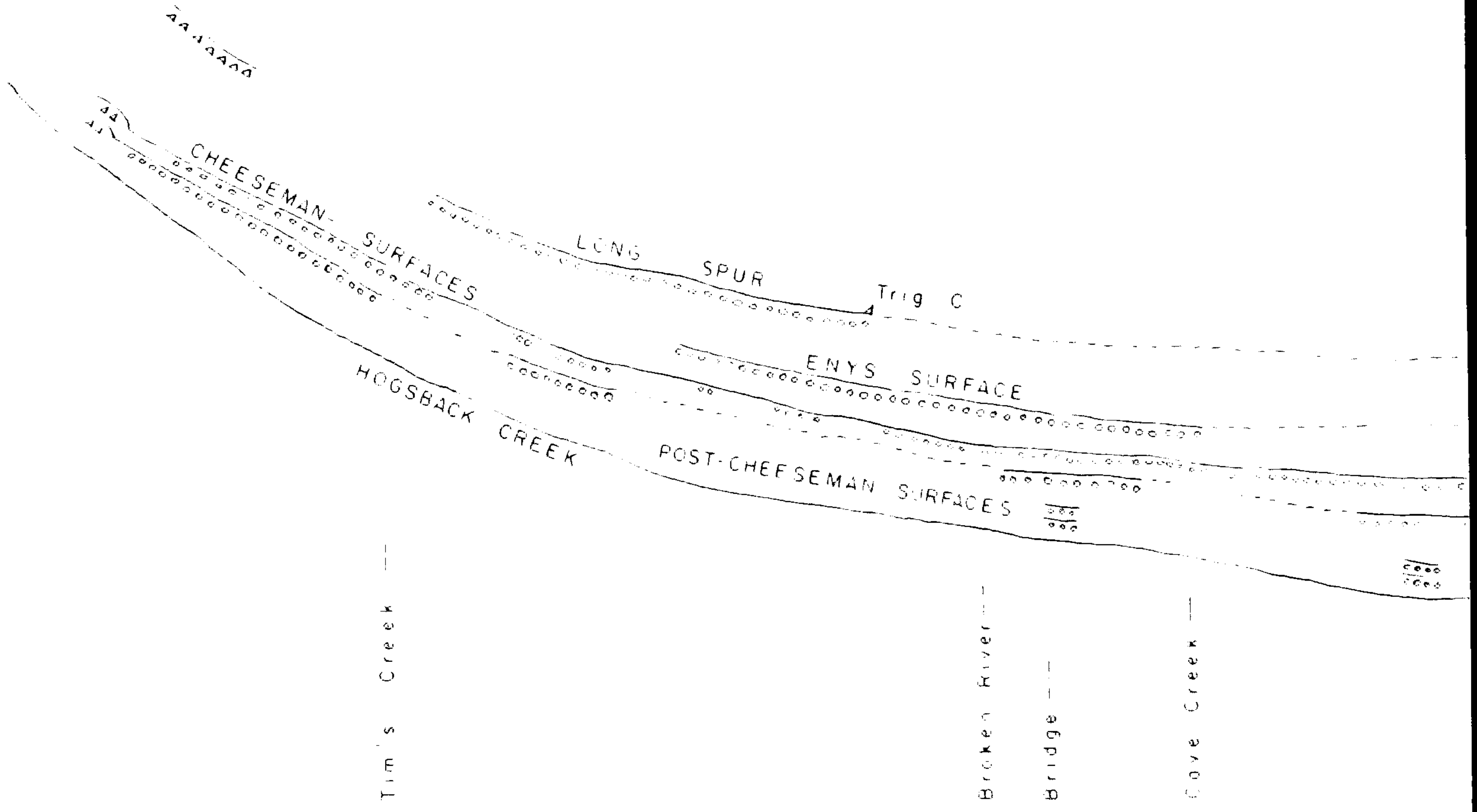
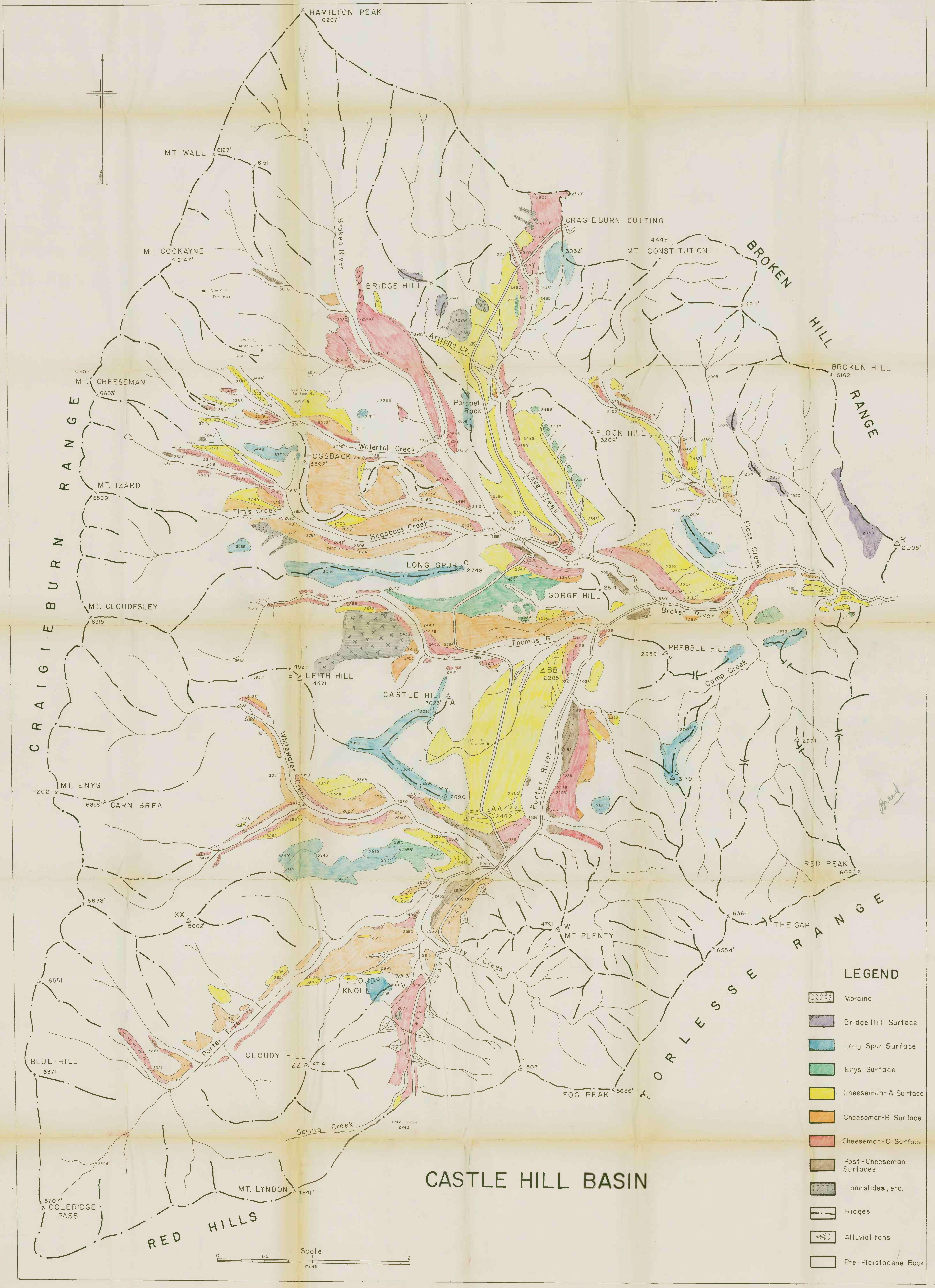


Plate 3.— River and Terrace Profile from
Coleridge Pass to Sloven's Creek.
Surface underlain by glacio-fluvial deposits
Surface underlain by moraine
0
1
2 miles
vertical Scale X5
LONG SPUR SURFACE
ENYS SURFACE
PORTER RIVER
CHEESEMAN-A SURFACE
CHEESEMAN-C SURFACE
Trig. K
Avoca deposits
(Gage, 1958)
BLACKWATER I
BLACKWATER II
BROKEN RIVER
Coleridge Pass
Spring Creek
Porter River Bridge
Thomas R.
Broken R.
Sloven's Creek

PLATE 4


CASTLE HILL BASIN
LEGEND
Moraine
Bridge Hill Surface
Long Spur Surface
Enys Surface
Cheeseman-A Surface
Cheeseman-B Surface
Cheeseman-C Surface
Post-Cheeseman Surfaces
Landslides, etc.
Ridges
Alluvial fans
Pre-Pleistocene Rock
Scale
0
1/2
1
2
miles
HAMILTON PEAK 6297'
MT. WALL 6127'
6151'
MT. COCKAYNE 6147'
MT. CHEESEMAN 6652'
6603'
MT. IZARD 6599'
MT. CLOUDESLEY 6915'
MT. ENYS 7202'
CARN BREA 6858'
6638'
6551'
BLUE HILL 6371'
COLERIDGE PASS 5707'
MT. LYNDON 4841'
RED HILLS
CRAIGIEBURN RANGE
CRAIGIEBURN CUTTING
MT. CONSTITUTION 4449'
BROKEN HILL RANGE
BROKEN HILL 5162'
4211'
FLOCK HILL 3269'
BRIDGE HILL
Broken River
Arizona Ck.
Parapet Rock
Cave Creek
Flock Creek
Waterfall Creek
HOGSBACK 3392'
Tim's Creek
Hogsback Creek
LONG SPUR C 2748'
GORGE HILL 2614'
Broken River
Thomas R.
PREBBLE HILL 2959' J
Camp Creek
LEITH HILL 4471' B
4529'
CASTLE HILL 3023' A
BB 2285'
Porter River
Whitewater Creek
YY 2890'
AA 2462'
S 3170'
T 2874
K 2905'
RED PEAK 6081'
THE GAP
6364'
6554'
TORLESSE RANGE
MT. PLENTY 4791' W
XX 5002
Dry Creek
COAST ROAD
CLOUDY KNOLL 3013' V
CLOUDY HILL ZZ 4714'
Porter River
T 5031'
FOG PEAK 5686'
Spring Creek
Lake Lyndon 2743'
C.W.S.C. Top Hut
C.W.S.C. Middle Hut
C.W.S.C. Bottom Hut
Castle Hill Station