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CHRONOLOGY OF FANS AND TERRACES IN THE GALATEA BASIN

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Abstract

Air-borne volcanic ash beds are used to date fans and terraces in the Galatea Basin and to outline the depositional history of this part of the Rangitaiki Valley. The basin is interpreted as a fault-angle depression formed by a downwarped sheet of ignimbrite and an upthrusted block of greywacke which forms the Ikawhenua Range. It is from this range that much of the detritus has been derived to fill the basin, deposited mainly in the form of fans and terraces. The larger fans cover a wide area and their surfaces are older than the Rotoma eruption of *c.* 8000 years B.P. The widespread occurrence of these fans indicates a major erosion interval between *c.* 11,000 and *c.* 8,000 years ago. The younger fans are distributed in a particular order with fans of the Pre-Taupo surface north of the Horomanga Stream and those of the Pre- and Post-Kaharoa surfaces south of the same stream. This ordered distribution of the younger fans suggests a climatic control of fan building.

Aggradation and degradation phases in the Rangitaiki and Whirinaki Rivers have formed a pronounced meander trough containing terraces of the Pre-Taupo, Pre-Kaharoa, and Post-Kaharoa surfaces. The terrace of the Pre-Kaharoa surface, largely of Taupo Pumice alluvium, is the most common. Degradation, however, is controlled by a local base level at the ignimbrite rapids on the Rangitaiki River just north of the Galatea Basin.

INTRODUCTION

This report is similar to that prepared for the lower Whakatane River Valley (Pullar, Pain and Johns, 1968) in that it applies the same principles of using air-borne volcanic ash beds to date the surfaces of terraces and fans. It also extends the work of Vucetich *et al.*, (1960, pp. 12 - 16) in the identification of ash beds in the Galatea Basin.

Location and Description of the Area

The basin (Figure 1) has been described by Vucetich *et al.* (1960, p. 11), and by Grange and Taylor (1935). It lies in the Rangitaiki Valley about 30 miles south of the Bay of Plenty coast (Figure 2c). It is 13 miles long and five miles wide and is bounded on the west by the Kaingaroa Plateau and Rangitaiki River, on the north by rolling hills and Kopuriki Stream, on the east by the Ikawhenua Range, and on the south by both the Kaingaroa Plateau and the Ikawhenua Range, a little south of the Whirinaki River (Figure 1).

The position of the Rangitaiki River on the western side of the basin gives rise to a main terrace with a series of coalescing fans which extend up to two miles from the eastern side bounded by the Ikawhenua Range. The basin lies between the levels of 500 and 750 ft above mean sea level with the main terrace between 500 and 600 ft. The principal fans, the Horomanga and Mangamate, slope at

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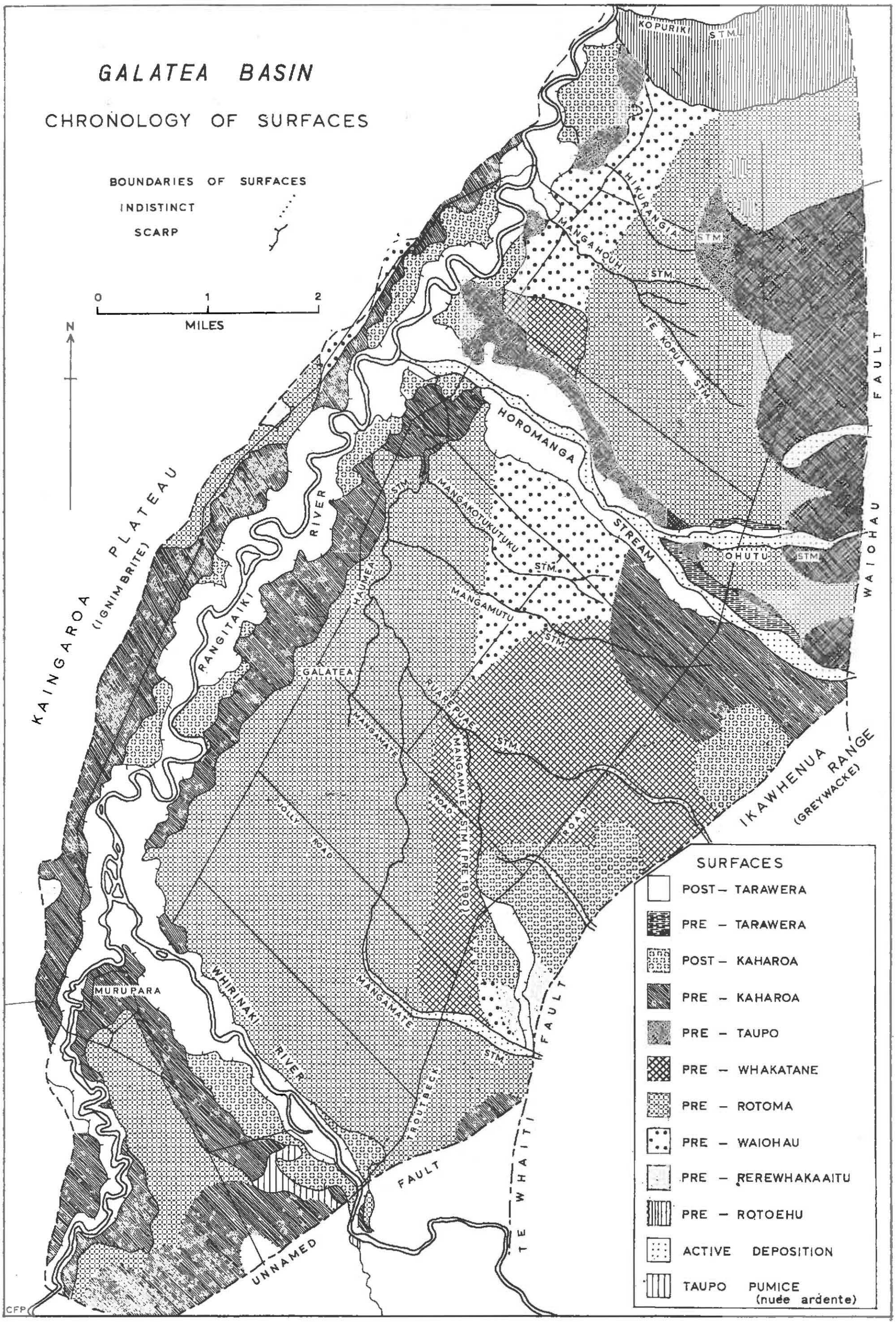

Figure 1. Map showing the distribution of surfaces in the Galatea Basin.

100 ft per mile (Figure 2b). The Kaingaroa Plateau rises slowly from 600 ft to 1800 ft and the Ikawhenua Range rises steeply as high as 3000 ft.

The principal rivers and streams are the Rangitaiki River, and the Whirinaki River and Horomanga, Kopuriki and Mangamate Streams which flow westwards to join the Rangitaiki River. This river enters the basin by a narrow channel and leaves it as a large, fast-flowing river. The Horomanga Stream and the Whirinaki and Rangitaiki Rivers flow in meander troughs with terraced sides. Other smaller streams flow from the Ikawhenua Range and quickly disappear underground to emerge as springs near the foot of the fans (Grange and Taylor, 1935). The streams flowing from these springs are entrenched in the ash beds that cover the greater part of the basin.

Geology

The Galatea Basin is interpreted as a fault-angle depression formed by the downwarping of sheets of Rangitaiki and Matahina Ignimbrites against an upthrust block of Jurassic greywacke along the major Te Whaiti and Waiohau Faults (Healy *et al.*, 1964). It is enclosed by ignimbrite in the west and north, by greywacke in the east, and by both ignimbrite and greywacke in the south. The depression is filled with sedimentary deposits including fluviatile greywacke gravels (h3, op. cit.), old and new fans of greywacke colluvium (hf, ff), Taupo Pumice alluvium (fp), and undifferentiated greywacke and pumice alluvium (fa) on the present flood plains of rivers and streams; apart from the pumice alluvium (fa), all these deposits are mantled with air-borne volcanic ash (Vucetich *et al.*, 1960, pp. 12 - 15).

Rapids and waterfalls in the Rangitaiki River at Aniwhenua, just north of the basin, indicate that basin infilling was subject to local base level control.

At the southern end of the basin is an unusual (nuée ardente) deposit of Taupo Pumice comprising (in thickness) about 30 ft of Upper Taupo Pumice, 18 in. Taupo Lapilli, 2 in. Rotongaio Ash, $\frac{1}{2}$ in. "putty" ash, and $\frac{1}{4}$ in. Hatepe Lapilli. According to Healy (1967, p. 841), thick layers of Upper Taupo Pumice were derived from " . . . huge pumice-laden clouds at high temperature [that] rolled over the region, uprooting and charring forests and other vegetation not already destroyed by the preceding outbursts, and laying down thick deposits of pumice in the hollows and valleys, but leaving only thin and finer deposits on the ridges. This pumice completely choked valleys and gullies . . . " In the present paper, the term "nuée ardente" is used for convenience.

MAPPING

Scarps of terraces and fans, road cuttings, and deep drains were examined and the identity of the lower-most ash bed resting on the alluvium or colluvium was noted at each section. Observations were then plotted on the N.Z.M.S. 1, N 86 (1962) of the scale one inch to one mile. From this map was compiled Table 1, which gives details of marker beds and associated surfaces and landforms, and Figure 1, which shows the distribution of these surfaces. The surface boundaries were mapped from vertical aerial photographs.

The surface is given the name of the ash lying immediately above it but since there is likely to have been a lapse of time between the deposition of the alluvium or colluvium and the deposition of the ash, the surface is properly designated by adding "Pre-" to the name of the ash (Pullar, Pain and Johns, 1968). Exceptions to this rule are the Post-Kaharoa Surface which lies immediately above the Kaharoa Ash and the Post-Tarawera Surface which is the surface of present-day flood deposits. The ash beds used in this nomenclature have been described by Vucetich and Pullar (1964, and in press).

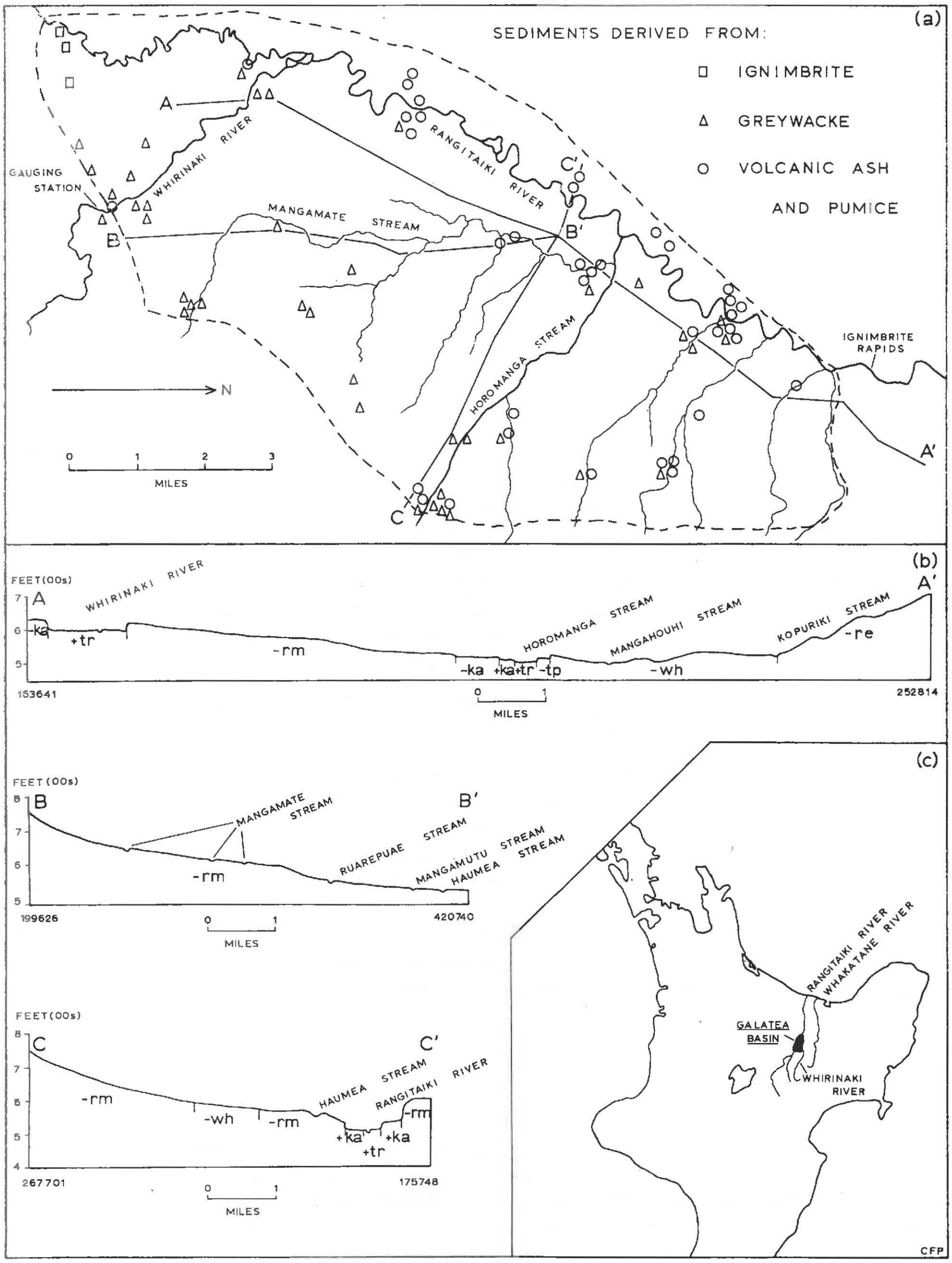

Figure 2 (a) Map showing the occurrence of the three classes of sediments as plotted during fieldwork.

(b) Cross sections showing slope of main terrace, and surfaces of different ages. (For key to symbols see Table 1.)

(c) Location map.

THE SURFACES

The Pre-Rotoehu Surface (undated, *c.* 36,000 years B.P.) at the northern end of the basin, where Rotoehu Ash rests on ignimbrite, is the oldest mapped in this paper. As it is an erosional surface it is not further discussed; but, more important for the history of deposition in the basin, is the Pre-Rerewhakaaitu Surface (*c.* 14,700 yrs B.P., N.Z. 14C 716). This is the oldest depositional surface in the Galatea Basin that can be dated by air-borne ash, and consequently sets an important age limit to the depositional surfaces in the basin. Deposits with the Pre-Rerewhakaaitu Surface are limited on the map to the Mangamate fan, as the base of Rerewhakaaitu Ash was not found west of the Rangitaiki River.

The Pre-Waiohau Surface (*c.* 11,250 yrs B.P., N.Z. 14C 568) is confined to a remnant of the Horomanga fan, where the base of Waiohau Ash was not found during field work, and to remnants of a Rangitaiki River terrace north of the Horomanga Stream. The Horomanga fan surface has since been covered by greywacke gravels of the Pre-Rotoma Surface. The Pre-Waiohau Surface associated with the Rangitaiki River is interpreted as the surface of a terrace rather than of a fan because of the existence of a remnant at the same elevation on the western side of the river.

The Pre-Rotoma Surface (between *c.* 8050 [N.Z. 14C 719] and *c.* 11,250 [N.Z. 14C 568] years B.P.) is the largest in the basin. Most of the deposits associated with this surface are from greywacke and come from the Ikawhenua Range, especially by way of the Whirinaki River and the Horomanga and Mangamate Streams (Figure 2a). Again, from the distribution of this surface, it is interpreted as the surface of a terrace of both the Whirinaki and Rangitaiki Rivers. Parts of it belong, however, to fans of the Mangamate Stream in the south, and of the Horomanga and Ohutu Streams in the north, as well as to a fan of an unnamed stream adjacent to the northern boundary of the basin.

The Pre-Whakatane Surface (undated, *c.* 5000 years B.P.) occurs on three major fans that have coalesced. These fans stem from the Horomanga, Ruarepuae, and Mangamate Streams. A terrace remnant of Pre-Whakatane age is also present in the Horomanga meander trough, and another in the Whirinaki Valley where it was covered by the Taupo nuée ardente.

The smaller streams flowing across the Pre-Whakatane, Pre-Rotoma and Pre-Waiohau Surfaces have seldom eroded their beds to the greywacke gravels that lie beneath the ash, but rather are incised in the ash itself; the Pre-Rotoma Surface, for example, has an average thickness of 15 ft of ash resting on it, and its streams are rarely incised more than 10 ft. The beds of the streams, and narrow alluvial benches associated with them, consist of re-worked older ash alluvium, the maximum age of the benches being Pre-Kaharoa (not mapped).

The Pre-Taupo Surface (*c.* 1819 years B.P.) occurs almost wholly north of the Horomanga Stream, and occurs on large greywacke gravel fans debouching across the Waiohau Fault, and on small ash alluvial fans formed where the streams leave the Pre-Waiohau terrace. A Pre-Taupo terrace is present in the Horomanga meander trough.

The Pre-Kaharoa Surface (*c.* 930 years B.P.) is represented on terraces in the Rangitaiki and Whirinaki meander troughs and on fans of the Horomanga Stream and south of the Mangamate Stream. The deposits under this surface are, in the Rangitaiki meander trough, almost entirely Taupo Pumice alluvium (Figure 2a). In the Whirinaki meander trough, greywacke gravels and pumice gravels of the Pre-Kaharoa Surface are commonly mixed. The deposits below the Pre-Kaharoa Surface in the fan of the Horomanga Stream are predominantly pumice with minor amounts of greywacke gravels, while those in the corresponding fans south of the Mangamate Stream are predominantly greywacke (Figure 2a).

The surfaces of low terraces in the Rangitaiki and Whirinaki meander troughs, and of fans along the Te Whaiti Fault belong to the Post-Kaharoa Surface (*c.* 300 years B.P.). On both fans and terraces are found soil profiles very similar to the Opouriao soil occurring on the Post-Kaharoa Surface of the lower Whakatane River Valley (Pullar, Pain, and Johns, 1968).

The Pre-Tarawera Surface (A.D. 1886) is limited to a small terrace in the Horomanga meander trough. The Post-Tarawera Surface is more extensive, its main expression being in the flood plains of the Horomanga Stream and Whirinaki and Rangitaiki Rivers. A small but important area of Post-Tarawera Surface (A.D. 1950+) occurs on the Mangamate fan (see below), and another area on a small fan south of the Whirinaki River on the Rotorua-Wairoa main highway. The latter may be artificial and the result of road building.

DEPOSITIONAL HISTORY

An important factor in the depositional history of any area is the changes that have occurred in the base levels of streams in the area. In the Galatea Basin base level is locally controlled, since the Rangitaiki River flows over ignimbrite rapids as it leaves the basin. The present elevation of the upper end of the rapids (460 ft above sea level) puts an effective limit on downcutting by streams in the basin. In this paper the base level is assumed to have remained little changed during the period of deposition discussed. On this assumption, changes in the relative height of the terraces along the main stream are interpreted as being due to changes in the rate of debris supply.

As indicated above, deposits below the Pre-Rerewhakaaitu Surface are the oldest dated in the Galatea Basin. The location of these deposits at the head of the Mangamate fan indicate that this fan has been active for at least 20,000 years. Between *c.* 20,000 years and *c.* 11,250 years B.P., the Horomanga fan was active, and at the same time, the Rangitaiki River aggraded to an elevation of 508 ft above sea level just north of the Horomanga Stream (Figure 2b).

The most important period of deposition in the Galatea Basin was that before the Rotoma eruptions, between *c.* 11,250 and *c.* 8050 years ago. Fan building from the Ikawhenua Range filled up a large part of the basin, and the Whirinaki River and Horomanga Stream contributed large amounts of greywacke gravels. These gravels were reworked by both the Rangitaiki and Whirinaki Rivers giving rise to broad flood plains. The Pre-Rotoma Surface on these flood plains was about 15 ft higher than the Post-Tarawera Surface of the present flood plain, and subsequent air-borne ash deposits on the Pre-Rotoma Surface have raised it to a height of 30 ft above the present river level.

Between the Rotoma and Whakatane eruptions (between *c.* 8050 and *c.* 5000 years B.P.) fan building took place along the Te Whaiti Fault from three streams — the Mangamate, Ruarepuae, and Horomanga Streams. At this time also, the Horomanga Stream was degrading in its lower reaches, as evidenced by a Pre-Whakatane Surface on a small terrace in the Horomanga meander trough near the Rangitaiki River.

Before the Taupo Pumice eruptions *c.* 1819 years ago, important fan building took place along the Waiohau Fault. Gravels poured from the Ikawhenua Range as far as one mile into the basin. Simultaneously the Rangitaiki River was downcutting allowing the formation of small fans (Pre-Taupo Surface) at points along the terrace scarp (Pre-Waiohau Surface) north of the Horomanga Stream (Figure 1). At this time the Rangitaiki River may have cut down to its present level. As a result of the considerable supply of material to the Ohutu and Horomanga Streams, small terraces (Pre-Taupo Surface also) were built in their meander troughs.

The next depositional phase began with the onset of the Taupo eruptions, *c.* 1819 years ago. The small nuée ardente deposit in the Whirinaki Valley has already been noted. In addition, Taupo Pumice alluvium was quickly carried down the Whirinaki and the Rangitaiki Rivers building up the meander troughs of these rivers to a level 15 ft above the present flood plain. At the same time a fan deposit (of Pre-Kaharoa Surface) consisting mainly of pumice and reworked ash alluvium was built on the southern side of the Horomanga fan, covering Pre-Whakatane and Pre-Waiohau Surfaces. Between *c.* 1819 and *c.* 930 years ago, probably later than the period of main deposition of the Taupo Pumice alluvium, a series of small greywacke fans was extended from the unnamed fault that marks the south-eastern boundary of the basin.

The Whirinaki and Rangitaiki Rivers entrenched themselves once more following the Taupo Pumice eruptions, but this entrenchment was later interrupted as indicated by low terraces with the Post-Kaharoa Surface in their meander troughs. Grant (1963), working in the Huiarau Range which contains the headwaters of the Whirinaki River, reported low terraces that were about 300 years old (according to tree-ring counts). He concluded that they were due to an erosion interval at or before A.D. 1650. Pullar, Pain, and Johns (1968) accepted this date for their Post-Kaharoa Surface in the lower Whakatane River Valley, and reviewed the occurrence of this surface elsewhere in the Bay of Plenty, in Gisborne, and in Hawke's Bay. The Opouriao soil found on this surface is noted above and again in Table 1. For this paper, then, the terraces with the Post-Kaharoa Surface in the meander troughs of the Whirinaki and Rangitaiki Rivers, and fans of the same age along the Te Whaiti Fault, are considered to be a probable consequence of an erosion interval that took place about A.D. 1650. The location of terraces having the Post-Kaharoa Surface north of but not south of the confluence of the Whirinaki and Rangitaiki Rivers and that these terraces are formed from material mainly of greywacke origin, support this date for the interval by indicating that the Whirinaki River transported the material from its source in the Huiarau and Ikawhenua Ranges, and consequently the terraces are genetically linked with those in the Huiarau Range (Grant, 1963).

During the last 300 years the Rangitaiki and Whirinaki Rivers and the Horomanga Stream have degraded in their meander troughs. However, during this period the Horomanga Stream formed a small terrace prior to the Tarawera eruption (A.D. 1886) indicating a small erosion interval in either the Ohutu or Horomanga catchments, and the Whirinaki and Rangitaiki Rivers appear to have been relatively stable.

Fans along the base of the Ikawhenua Range have continued to be active with coarse greywacke gravels frequently being deposited on farm properties and disrupting communications. Of particular interest is the Mangamate fan, the stream of which once flowed almost due north on the Post-Tarawera Surface that is shown in Figure 1. In order to 'combat dryness' in the area west of the Mangamate fan, one of the settlers in the 1890's diverted a tributary of the Mangamate; " . . . today his four-foot trench is a gully 35 feet deep with a huge gravel wash sprawling beyond and overwhelming in its course the Kahuwaea [Troutbeck], the Taranui [Jolly] and the Mangamate roads." (Fox and Lister, 1949, p. 36; see also Grange and Taylor, 1935).

DEPOSITS IN THE GALATEA BASIN

There are three main classes of material making up the alluvial and colluvial deposits in the Galatea Basin. These are the materials derived from greywacke, ignimbrite, and air-borne volcanic ash and pumice respectively. Figure 2a gives some indication of the extent of each of these three classes. The least extensive class is the ignimbrite gravels which occur solely along the Rangitaiki River and

Table 1. Surfaces of different ages and associated landforms.

Surface Designation and Reference Symbol	Landform	Marker bed (and date of formation or radiometric age in years before 1950).	Event: age of surface in years	Notes
Post-Tarawera (+tr)	Flood plains of Rangitaiki and Whirinaki Rivers, and Horomanga Stream. Fan south of Whirinaki River.	Recently deposited alluvium A.D. 1950+	Present-day flood deposits.	Active deposition in Mangamate, Ruarepuae and Horomanga Streams. Note previous course of Mangamate Stream at time of first European settlement. Tarawera Ash seldom seen in present-day flood deposits within depth of 24 in. from surface.
Pre-Tarawera (—tr)	Low terrace (second bottom) in meander trough of Horomanga Stream.	Tarawera Ash (1886). The 3-in. isopach (Vucetich *et al.*, 1960) could be extended south to Murupara	Local stream degradation prior to 1886.	Small area limited to Horomanga and Ohutu meander troughs.
Post-Kaharoa (+ka)	Low terraces in Rangitaiki and Whirinaki meander troughs. Fans along Te Whaiti Fault south of Horomanga Stream.	Soils similar to Opouriao soil which is on surface that has been dated *c.* 300 B.P. by tree-ring counts	Fan building during last 1000 years. Rivers and streams degrading after A.D. 1650.	Adjacent to flood plains, similar to Lower Whakatane Valley where Opouriao soils have been mapped. Accumulation now ceased. Kaharoa Ash not always present.
Pre-Kaharoa (—ka)	Highest terraces in Rangitaiki, Whirinaki and Horomanga meander troughs. Horomanga fan; fans south of Mangamate Stream.	Kaharoa Ash (930 ± 70; N.Z. 14C 10†)	Vigorous aggradation after Taupo Pumice eruptions; then down-cutting and terrace formation before Kaharoa eruption. Fan building between the two eruptions.	Vucetich *et al.* (1960; p. 16, Fig. 7) shows more extensive area but limited to soil-forming materials.
Pre-Taupo (—tp)	Fans along Waiohau fault north of Horomanga Stream; small fans fronting main terrace near Rangitaiki River and north of Horomanga Stream; north bank of Horomanga Stream.	Taupo Pumice (1819 ± 17; see Healy, 1964, p. 33)	Fan building between 3000 and 2000 years ago.	Small fans, result of stream entrenchment in main terrace. Thick deposit of upper Taupo Pumice mapped separately at point of debouchure of Whirinaki River from hills.

Pre-Whakatane (—wk)	Main Mangamate fan; Ruarepuae fan. Old Horomanga flood plain.	Whakatane Ash (undated; *c.* 5000)	Fan building between 8000 and 5000 years ago.	Whakatane Ash clearly identified on Mangamate and Ruarepuae fans.
Pre-Rotoma (—rm)	Main Rangitaiki and Whirinaki terrace. Mangamate fan; old fans and flood plains of Horomanga, Ohutu, Te Kopua and other streams at northern end of basin.	Rotoma Ash (undated; more than 8050 (N.Z. 14C 719) and less than 11,250)	Main Whirinaki infilling between 11,000 and 8000 years ago. Fan building during same interval.	Base of ash section not found west of Rangitaiki River.
Pre-Waiohau (—wh)	Horomanga fan. Rangitaiki terrace north of Horomanga Stream.	Waiohau Ash (11,250 ± 200; N.Z. 14C 568)	Horomanga fan building between 15,000 and 11,000 years ago. Possibly fan building by Mangahouhi and Te Kopua Streams. Rangitaiki infilling during same interval. Stage in Mangamate fan building.	Base of ash section not found south of Horomanga Stream. On rusty greywacke gravels at Mangahouhi Stream.
Pre-Rerewhakaaitu (—rk)	Mangamate fan. Mantling ignimbrite spurs of Kaingaroa Plateau (?).	Rerewhakaaitu Ash (14,700 ± 200; N.Z. 14C 716)	Stage in Mangamate fan building 20,000 to 15,000 years ago.	Base of ash section not found west of Rangitaiki River.
Pre-Rotoehu (—re)	Ignimbrite plateau at northern end of basin characterised by rolling hills and thick ash mantle.	Rotoehu Ash* (undated, *c.* 36,000)	At Kopuriki dam site (now abandoned) Rotoehu Ash rests on undifferentiated ash on Hamilton Ash; at Kopuriki Stream, Rotoehu Ash rests on ignimbrite. Thus an erosion interval before Rotoehu eruption.	Rotoehu Ash not observed in this part of the basin, but noted in road cuttings through rolling hills just north of Kopuriki Stream. Ignimbrite marks the edge of the basin.

* Provisional name by Vucetich and Pullar (in press).

† Radiocarbon numbers from Grant-Taylor and Rafter (1963).

are confined to the southern end of the basin. The most important class in terms of basin-infilling is the greywacke gravels from the Ikawhenua Range which underlie most of the surfaces in the basin. Since the Rangitaiki River (which has ignimbrite in its headwaters) has, at present, a larger average flow than the Whirinaki River (Table 2) (which has greywacke in its headwaters) the small area of ignimbrite gravels deposited by the Rangitaiki River compared with the area of greywacke gravels indicates that the ignimbrite is considerably more resistant than the greywacke. The third class, alluvial and colluvial material from volcanic ash and pumice, is found in most parts of the basin. It includes most of the material brought down by the Rangitaiki River while significant amounts also come from the Ikawhenua Range and the Kaingaroa Plateau. The ease with which this material is stripped from hill slopes is evidenced by the widespread nature of the deposits.

Of the three major rivers and streams, the Horomanga Stream and the Whirinaki River have between them contributed most of the deposits to the basin, and the Rangitaiki River has contributed minor deposits of Taupo Pumice alluvium and other volcanic ash alluvium but has mainly reworked older deposits within the basin. The Rangitaiki River has also been important in degrading its meander trough to the level of the ignimbrite rapids, 460 ft above sea level, at the northern end of the basin. Hydrological data (Table 2) show that the respective role of each of the rivers in the transportation of detritus appears to be continuing. Thus the Rangitaiki River at Murupara has an average annual flow of 744 cusecs and a maximum flood flow in 1967 of 4400 cusecs, while the Whirinaki River has an average annual mean flow of 513 cusecs but a maximum flood flow in 1967 of 11,900 cusecs. Moreover, the Rangitaiki River at 1600 cusecs has an average sediment load of 1000 tons per day, while the Whirinaki River at 4000 cusecs has 25,000 tons per day. At lower rates of flow (about 1000 cusecs) the difference is not so marked.

From these hydrological data, two important conclusions emerge. (1) The Whirinaki River and streams flowing into the basin from other parts of the Ikawhenua Range have a greater variability of flow and sediment load than the Rangitaiki River and the streams flowing from the Kaingaroa Plateau. (2) As indicated by the distribution of the surfaces of different age, the Ikawhenua Range is the most important source of sediment for the basin. These differences are related to the incidence of erosion which is higher in greywacke than in ignimbrite.

Table 2. Hydrological data for the Galatea Basin.

	cusecs	year	tons/day
Rangitaiki River at Murupara (1948 - 1962)			
Minimum annual mean flow	502	1950	—
Average annual mean flow	744	—	—
Maximum annual mean flow	1,045	1962	—
Maximum flood flow	4,400	1967	—
Sediment	at 1,600	—	1,000
	at 1,200	—	100
Whirinaki River at Troutbeck Road (1953 - 1962)			
Minimum annual mean flow	266	1961	—
Average annual mean flow	513	—	—
Maximum annual mean flow	721	1962	—
Maximum flood flow	11,900	1967	—
	9,900	1965	—
Sediment	at 4,000	—	25,000
	at 1,000	—	100

Source: from information supplied by Mr A. P. Griffiths, Design Engineer, Bay of Plenty Catchment Commission, Whakatane.

CAUSES OF FAN BUILDING

Deposition on alluvial fans has generally been attributed to the sudden decrease in channel bed slope as a stream debouches from a higher area on to a lower-lying area. Cotton (1922) stated that fan building was consequent on such a change in channel slope, and more recently Thornbury (1954) has reiterated this idea. Carryer (1966), working in the South Island, states that fan building is caused by a decrease in the gradient of the stream and hence a decrease in water velocity, and by the loss of water through seepage. However, while an alluvial fan may be initiated in this manner, the fan is quickly built up until the slope of the upper-most segment of the fan is similar to that of the valley floor above the apex of the fan. Bull (1964a, 1964b) points to this similarity of stream gradient and continues "Erosion predominates in the valleys [above the apex] before the fans have attained the same gradients as the valleys. After the same gradient has been attained, aggradation of the upper fan surface and stream valley maintains this common gradient . . . " (Bull, 1964a: pp. 101 - 2). Using an equation applied by Leopold and Maddock (1953) to stream-flow problems, Bull offers an explanation as to why deposition occurs on alluvial fans. The equation is $Q = wdv$, where Q is the discharge per unit time, w is the width, d the mean depth, and v the mean velocity of flow. Assuming Q to be constant, an increase in w, as happens at the apex of an alluvial fan, will result in a decrease in d and v, and thus part of the sediment load is deposited. This deposition is commonly hastened on alluvial fans because of seepage losses of water causing a decrease in Q.

Fans of the Pre-Rotoma Surface

If Bull's, probably correct, explanation for deposition on fans is accepted, the apparently spasmodic nature of fan building in the Galatea Basin has to be explained. The oldest fan surface, Pre-Rotoma, is the most widespread and occurs near all three faults bounding the eastern side of the basin. The widespread distribution of this surface indicates a general causal factor in fan building between *c.* 11,250 and *c.* 8050 years ago. Whether this factor is associated with tectonic movement, or with a change in climate sufficiently great to upset the regimes of the streams in the Ikawhenua Range cannot be decided from the present evidence. As the oldest ash mantling the Waiohau Fault is Rotoehu Ash (undated; *c.* 36,000 years B.P.), major faulting must have taken place more than 36,000 years ago.

Fans Younger than the Pre-Rotoma Surface

Study of Figure 1 shows that the age distribution of fans younger than the Pre-Rotoma Surface along the three faults appears to vary with the fault. Fans of a given age occur, in the main, along one fault line only. Along the unnamed fault to the south the fans all belong to the Pre-Kaharoa Surface, apart from one which belongs to the Post-Tarawera Surface. Along the Te Whaiti Fault, excluding the Mangamate fan (Post-Tarawera Surface) and Horomanga fan (Pre-Kaharoa Surface), the fans belong either to the Pre-Whakatane or Post-Kaharoa Surfaces, while along the Waiohau Fault the fans belong to the Pre-Taupo Surface.

Such a distribution indicates that tectonic movement could be an initiating factor in the formation of the fans. According to Simonett (1967) shallow earthquakes are likely to cause most erosion damage, and this erosion may in fact be the only surface expression of tectonic movement. Simonett further postulates that one shallow earthquake of magnitude 7.0 or more is sufficient to increase erosion intensities well above "normal". He presents evidence for this in the Torricelli Mountains, New Guinea, where erosion near the epicentre of such an earthquake exceeded the "normal" rate by 66-fold. In New Zealand, Eiby (1965) considers that slips do not become general below a modified Mercalli intensity of seven, and that they must be seen to occur in the field to be related definitely to seismic activity. Pullar (1965) reported an example of an earthquake (of MM 6 according to Eiby) causing landslides in the Gisborne district (29 December 1956). He examined the slides five years later and found that the severely disturbed ground had been little eroded.

This particular relation of landslides and seismic activity was questioned by Eiby (1965). Although Dickinson and Adams (1967) indicate that between 1942 and 1961 approximately four shallow earthquakes of magnitude 5.0 or greater were experienced in the Galatea area, the writers were unable to confirm that erosion resulted. There is, moreover, a serious objection to tectonic movement as a causal factor in fan building over such limited areas. Most reports of the effects of earthquakes on landslide occurrence show that the effect of a major earthquake is spread over a much larger area (Simonett, 1967, Plate V). Pohlen *et al.* (1947, pp. 163 - 4) in Hawke's Bay examined many of the slips that occurred in the spectacular erosion of 1938 and concluded that the shallow slips, contrary to popular opinion, were mostly unrelated to the cracking and disturbance of hill slopes during the destructive Napier earthquake of 1931, but were due to normal erosion processes during the high-intensity rain storm of the Anzac Day flood. At the same time, however, they quoted many instances of deep slips associated with faults for distances of "some miles". In the Galatea Basin, fan building along all three faults would surely have resulted from a major earthquake, since the whole basin is only 13 miles long. In light of present evidence, however, the localised influence of tectonic movement cannot be entirely rejected.

The occurrence of localised, high-intensity rainfalls may offer an alternative explanation of the age distribution of fans. Grant (1965) gives a useful summary of the occurrence of such rainfalls, with special reference to the Tukituki River, Hawke's Bay. "High-intensity rain storms severely damaged vegetation, and accelerate the supply of rock waste to channels . . . Such storms are limited in area and therefore damage in various tributaries is on a random basis" (Grant, 1965, p. 21). Selby (1967a, 1967b) has discussed the effects of high-intensity rainfalls in the Lower Waikato Basin. He notes that recent high-intensity rainfalls have caused severe erosion in the greywacke ranges surrounding the Lower Waikato Basin, and is quite explicit on the local effects of such storms. ". . . The precipitation in thunder storms is so variable over short distances as to produce quite different intensities in adjacent catchments." (Selby, 1967b, p. 155).

In the Galatea Basin high-intensity rain storms may be cited in explanation of the localised nature of fans of various ages along the eastern boundary of the basin. Rainfall records for the northern end of the basin show that on 3 February 1967, 4.2 inches of rain fell in 11 hours, with a maximum intensity of 1.5 inches per hour. On 1 March 1966, 4.2 inches fell in 14.5 hours, with a maximum intensity of 1.2 inches per hour for a period of 40 minutes. These figures are lower than those at Pokeno where maximum intensities of 4.2, 3.3, 3.0 and 2.5 inches per hour occurred during short time intervals (Selby, 1967b, p. 154). It is probable that the higher elevation and the orographic effect of the mountain front of the Ikawhenua Range cause higher rainfalls of even greater intensity in the headwaters of the streams supplying debris to the fans than in the basin. Unfortunately, rainfall records from automatic gauges do not go back beyond 1966. However, heavy rainfall on 11 February 1965, when 4.97 inches fell at Galatea, caused mass movement on the slopes of the Ikawhenua Range, and fan building occurred on the Mangamate, Ruarepuae, and Te Kopua fans (shown in Figure 1 as areas of active deposition). In general, run-off from the Ikawhenua Range is 10 times that from the Kaingaroa Plateau (A. P. Griffiths, pers. comm.).

Thus present evidence indicates that fan building, since the Rotoma eruptions between *c.* 11,250 and *c.* 8050 years ago, has depended mainly on the random location of high-intensity rain storms. The ordered age distribution shown in Figure 1 is more likely to be a result of the random occurrence of local major storms in time than of tectonic movement or any other causal factor. Fans of the Post-Kaharoa Surface along the Te Whaiti Fault may be the result of fires on the Ikawhenua Range by Maoris living in the Galatea Basin (Vucetich *et al.*, 1960), but, as noted above, there is evidence elsewhere for a widespread erosion interval about this time (*c.* A.D. 1650).

CONCLUSIONS

Volcanic ash showers have been used to date surfaces of different ages. Fans and terraces of similar ages have been correlated in this way though in many cases they were spatially separated.

Since the Galatea Basin is subject to local base-level control, the fan and terrace surfaces on the basin may be regarded as evidence of erosion intervals. Thus the depositional history of the basin is, by implication, the counterpart of the erosional history of the basin catchment area. The incidence of erosion on the Kaiangaroa Plateau and on the Ikawhenua Range is also of importance, the Ikawhenua Range providing most of the detritus to the basin. Of the three main rivers and streams, the Horomanga Stream and the Whirinaki River, flowing from the Ikawhenua Range, supply much of the debris while the Rangitaiki River is important rather in reworking fluvial deposits in the basin, and in transporting material out of the basin.

The dating of fan surfaces along the foot of the Ikawhenua Range provides some clues on the causes of fan building. The widespread nature of fans of the Pre-Rotoma Surface indicates a widespread cause believed to be tectonic movement. The localised distribution of the fans younger than the Pre-Rotoma Surface indicates a localised cause believed to be high-intensity rain storms.

In the lower Whakatane Valley report (Pullar, Pain, and Johns, 1968) the cutting of a meander trough in the Post-Kaharoa Surface was discussed at length and among the causes advanced was a possible slight lowering of sea level during the 17th century. In the Galatea Basin the Post-Kaharoa Surface also occurs on terraces alongside the modern flood plains of the Rangitaiki and Whirinaki Rivers but, as degrading by the river is controlled by a local base level, and not by the sea, the formation of these terraces is attributed to changes in the rate of supply of detritus.

Where volcanic ash beds occur they are extremely useful tools in geomorphology in that they supply not one but several known dates in favourable areas. In the Galatea Basin, description and interpretation of the geomorphology of the area is facilitated by eight known dates ranging from more than 36,000 years ago to the present.

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