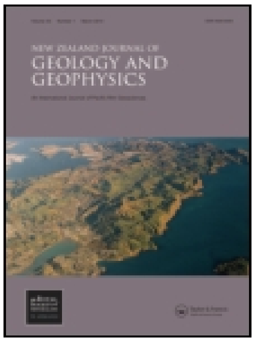

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Marine terraces of the Conway coast, South Island, New Zealand

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Abstract Three interglacial-glacial cycles of marine cliffing, marine aggradation, regression of the sea, followed by erosion and fan accumulation can be recognised on the Conway coast, Central Canterbury, New Zealand. The times of formation of the marine Tarapuhi, Kemps Hill, and Amuri Bluff Terraces are tentatively assigned to the Waiwheran, Terangian, and Oturian interglacial stages, respectively. In the last glacial stage, alluvial fans represented by the Claverley Terrace surfaces were much more extensively developed than those in the preceding glacial stages, following rapid uplift of the Hawkswood Range and consequent development of the fluvial drainage.

Conway Flat Surface 1 was developed by postglacial transgression. Since then, beach ridges have been built, advancing the shoreline to its present position. Three periods of minor uplift have brought about the cutting of Conway Flat Surfaces 2 and 3.

The Conway coast shows uplift and northward tilting concordant with the variation of height of the Hawkswood Range, with the area south of the Conway River showing greater uplift than the area to the north. If we accept the age correlations of the terraces, the coast was most actively uplifted and tilted in the period between the Terangian and Oturian interglacial stages, and the mean uplift rate was much higher in the early Holocene than in the late Pleistocene. The uncertainties of correlation and uncertainties of uplift rates prevent conclusive interpretation.

Keywords late Quaternary; tectonics; marine terraces; raised shorelines; alluvial fans; beach ridges; interglacial/glacial sequences; postglacial transgression; buried forests; uplift rates; radiocarbon dating

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INTRODUCTION

In the northeastern part of the South Island, the Conway coast (Fig. 1) is one of the areas where various marine terraces are well developed (cf. Jobberns 1928; Suggate 1965). Although detailed mapping of terraces was not carried out, the lower marine terraces on the coast which are overlain by fan deposits represent at least two interglacial–glacial cycles of marine cliffing, marine aggradation, recession of the sea with erosion, and finally fan accumulation (Suggate 1965). The Conway coast, therefore, can be expected to be a favourable area to establish a late Quaternary chronology. The purpose of this investigation of the Conway coast was to elucidate its geomorphic development and tectonic activity during the late Quaternary.

Fieldwork, supplemented by airphoto interpretation, was carried out from 17 November to 5 December 1977, chiefly in the Conway area, but also in the Hurunui River mouth and Motunau areas, and in the drainage basins of the Hurunui and Waiau Rivers. In the Conway area, the fieldwork was limited to the coastal zone between Amuri Bluff in the north and Dawn Creek in the south.

Exposed sections of terrace deposits were observed, geomorphic relationships investigated, and heights of marine deposits, underlying rocks, and terrace surfaces were measured by two Paulin aneroid altimeters. Heights measured by altimeters

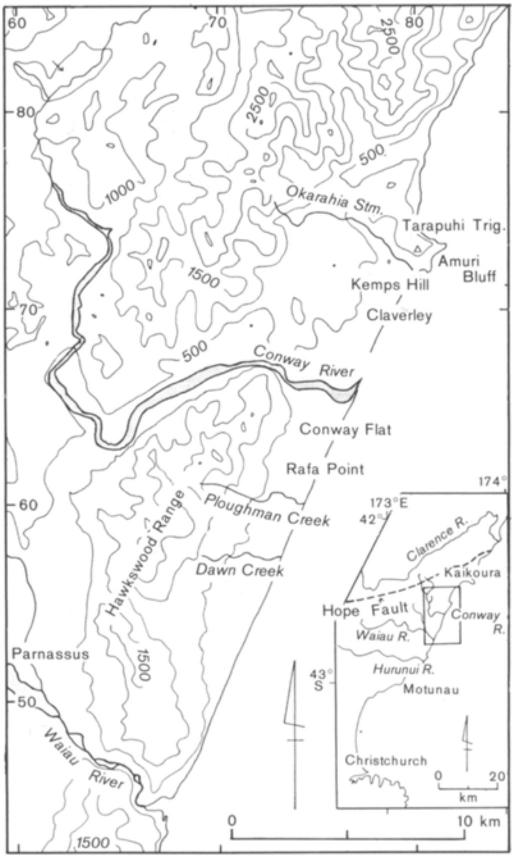

Fig. 1 Generalised topography of the Conway-Parnassus district. Contour intervals are 500 ft. Contour lines are drawn from 1:63 360 topographic maps by deleting valleys less than 500 m (c. 1460 ft) wide. Stippled areas show the present river floor of the Conway and Waiau Rivers.

were corrected by reading those at sea level about every 2 h for low-level terraces, while for high-level terraces calibration to sea level was at longer intervals. This results in an accuracy of measurement of less than ± 3 m for low-level terraces and less accuracy for high-level ones, but less than ± 5 m. Profiles of Holocene terraces were drawn based on pace and hand-level surveys. Radiometric ages of wood samples were measured by the geochemical laboratories of Gakushuin University and Japan Isotope Association. Two radiocarbon dates obtained in New Zealand (Suggate pers. comm.) are also referred to.

GENERAL DESCRIPTION

The Conway coast lies in the compressional zone south of the shear zone whose southern boundary is marked by the Hope Fault (Lensen 1975).

South of Conway River, the Hawkswood Range, gently concave to the straight shoreline, separates the Conway coast from the inland Parnassus Basin (Fig. 1). The range, composed mainly of Jurassic greywacke of the Torlesse Group, rises to 700 m and gradually descends to the north and south. North of Conway River, the extension of the Hawkswood Range, which there consists mainly of upper Cretaceous–Miocene sediments, is less than 300 m high. The north–south-trending Parnassus Basin west of the Hawkswood Range is a downwarped depression containing a folded Plio-Pleistocene sequence (Gregg 1964). The east-flowing Waiau and Conway Rivers and the Okarahia Stream traverse the coastal range through narrow gorges.

On the eastern slopes of the range, various terrace levels are developed south from Amuri Bluff to north of the Waiau River mouth, and are bordered by former sea cliffs. To the north and south of the Conway River mouth, a bow-shaped narrow coastal plain lies behind the shoreline. The terraces are cut into upper Cretaceous–Miocene sediments in the north and the Plio-Pleistocene sequence in the south. In spite of variable coastal features, the shoreline is strikingly straight, except for the projection of Amuri Bluff at its northern end.

Terraces on the Conway coast were first recorded by Jobberns (1928) who described marine terraces at eight levels and young raised beach ridges at three levels on the coastal plain. He concluded that uplift of the area was uniform, judged by the similar heights of correlated marine terraces.

Gregg (1964) mapped marine deposits underlying fan deposits at three levels, and correlated the marine and nonmarine deposits to successive interglacial and glacial periods, respectively. His mapping relied on the work of Fleming & Suggate (1964) and Suggate (1964, 1965). The first work described in detail the deposits of a terrace about 170 m above sea level west of Amuri Bluff, and concluded that because they contain a cool-climate fauna, they were deposited when the sea had begun to retreat significantly from the maximum transgression in the Terangian Stage.

Suggate (1964, 1965) briefly described marine gravel beds of at least two levels and fan deposits unconformably overlying them. He recognised two interglacial–glacial cycles and postglacial raised beaches up to 12 m above sea level. He also suggested a northward tilting of the area. According to his description, the Amuri Bluff fossiliferous bed was deposited before the two interglacial–glacial cycles.

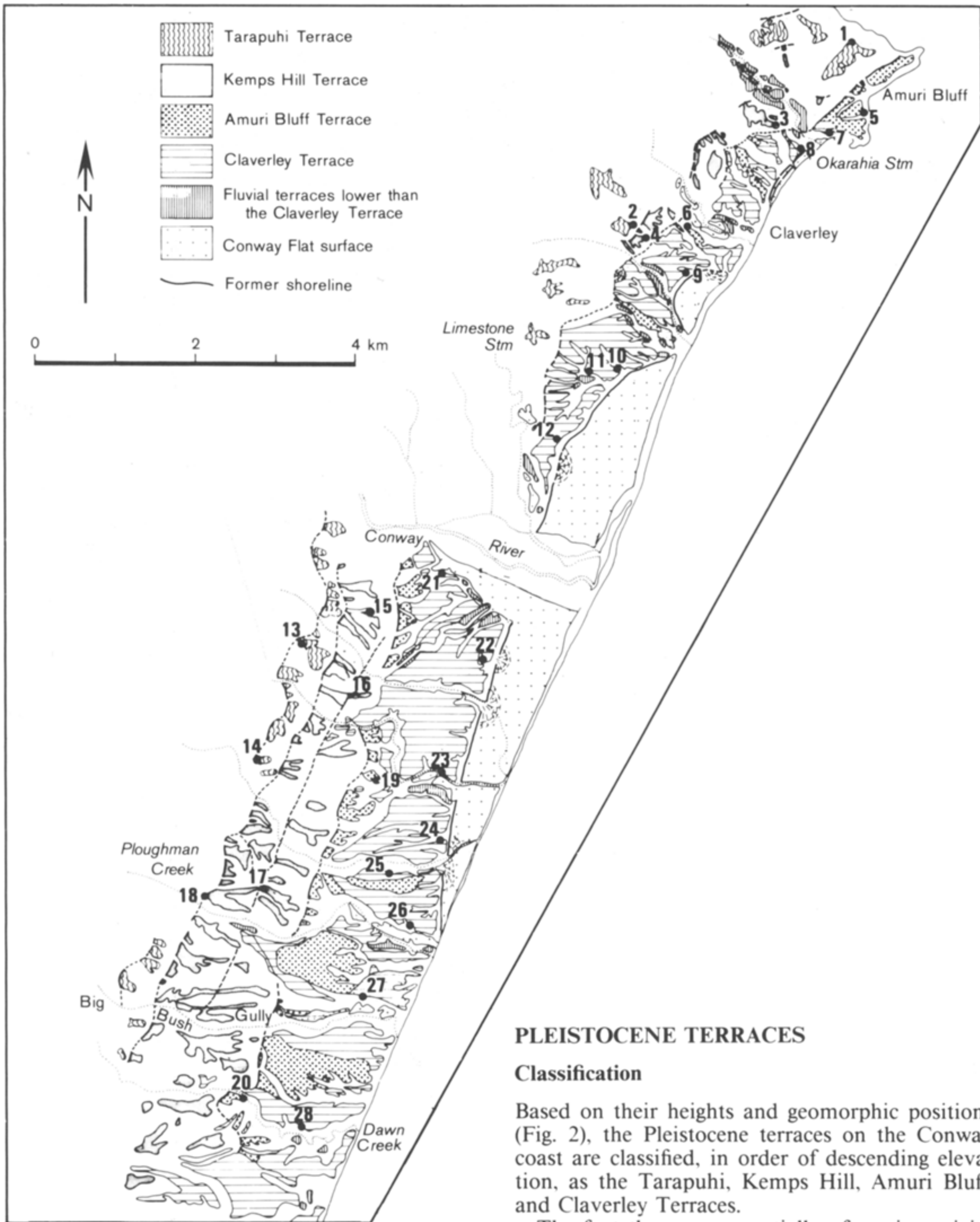

Fig. 2 Distribution of terraces on the Conway coast. Dots and numbers indicate the location and numbers of exposures, respectively, drawn in Fig. 3A–D.

PLEISTOCENE TERRACES

Classification

Based on their heights and geomorphic positions (Fig. 2), the Pleistocene terraces on the Conway coast are classified, in order of descending elevation, as the Tarapuhi, Kemps Hill, Amuri Bluff, and Claverley Terraces.

The first three are essentially of marine origin, although they are locally overlain by fan deposits which are covered by loess. The Claverley Terrace is, however, almost everywhere underlain by thick fan deposits overlain by loess, and marine deposits are exposed only locally below the fan deposits.

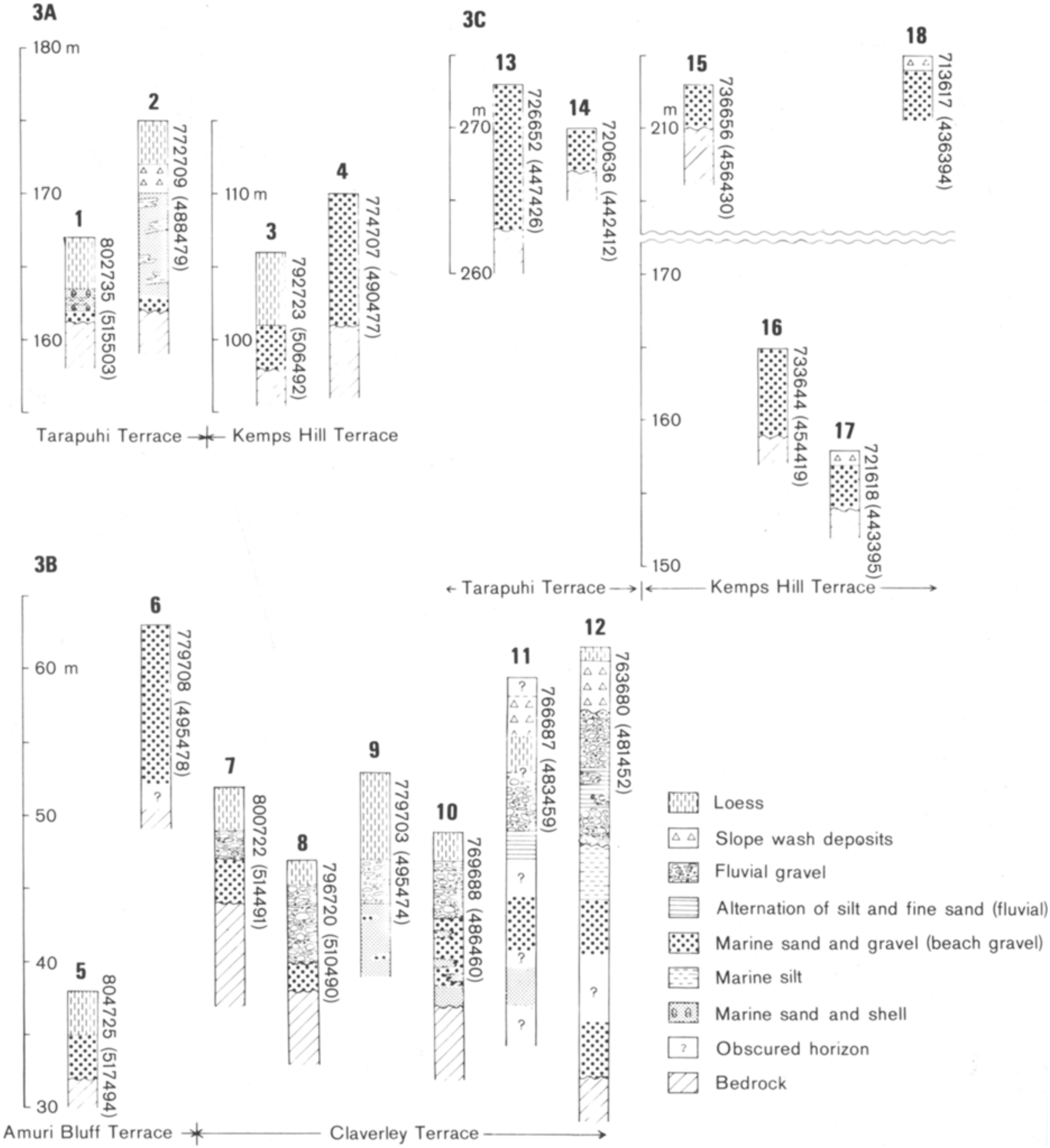

Fig. 3 *(above and opposite page)* Columnar sections of representative exposures of Pleistocene terrace deposits. Location of exposures is shown in Fig. 2. **A** Sections of Tarapuhi (1, 2) and Kemps Hill (3, 4) Terraces in the area north of the Conway River. **B** Sections of Amuri Bluff (5, 6) and Claverley (7–12) Terraces in the area north of the Conway River. **C** Sections of Tarapuhi (13, 14) and Kemps Hill (15–18) Terraces in the area south of the Conway River. **D** Sections of Amuri Bluff (19, 20) and Claverley (21–28) Terraces in the area south of the Conway River. Small figures on the right-hand side of each section indicate grid reference (NZMS 1 sheet S55 & 56, and NZMS 260 sheet O32 in brackets).

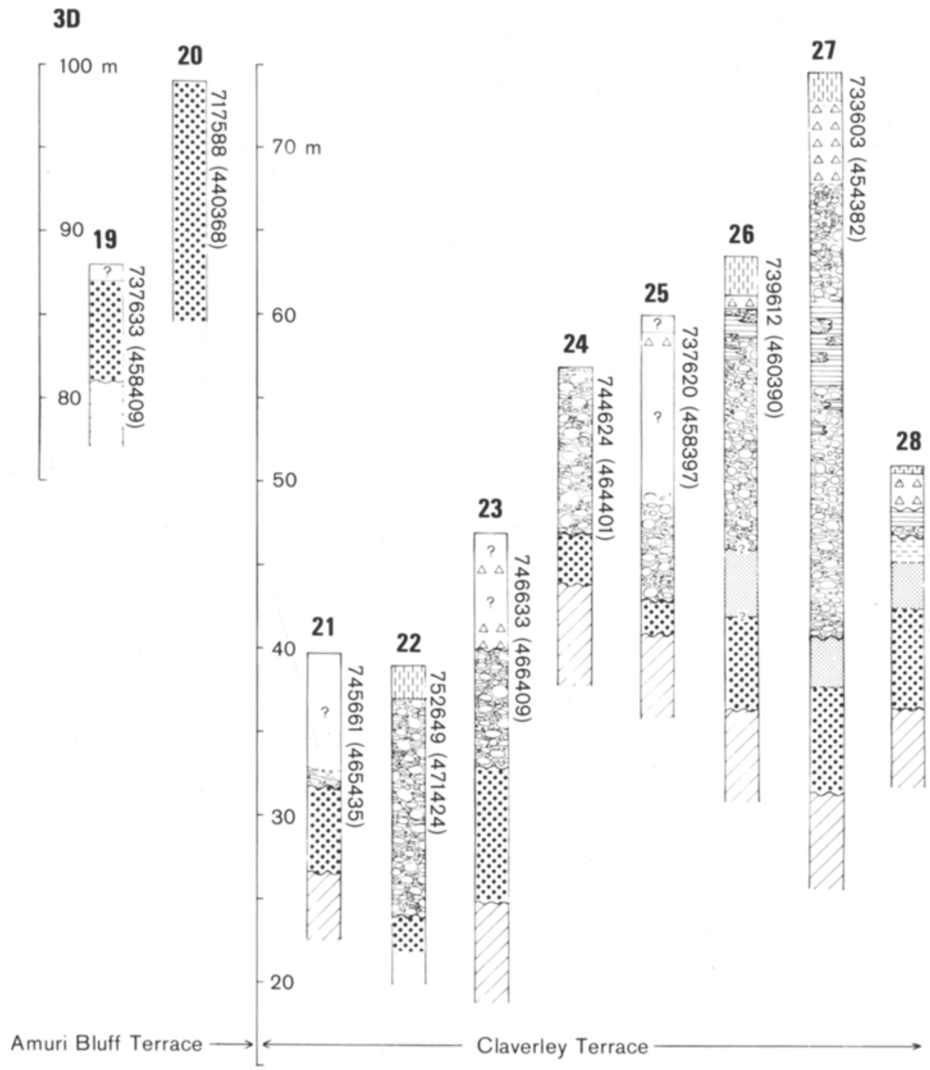

Fig. 3 *(continued).*

Tarapuhi Terrace, the highest marine terrace preserved on the coast, has a type locality on a terrace about 170 m a.s.l., northwest of Amuri Bluff, at Tarapuhi Trig (grid ref. S55 & 56/802735 [O32/515503]*; Fig. 3A-1). Terrace deposits at this locality were described by Fleming & Suggate (1964). The terrace fragments have a scattered distribution on the eastern slopes of the Hawkswood Range. Former shorelines are well preserved south of the Conway River, but poorly preserved north of the river.

The type locality for Kemps Hill Terrace is about 115 m a.s.l., 0.5 km southeast of Kemps Hill, on the right bank of the Okarahia Stream (792723 [506492]; Fig. 3A-3). This terrace, also of marine origin, is extensively preserved south of the Conway River, and is subdivided into two levels at a few localities as shown in Fig. 2.

Amuri Bluff Terrace is the distinctive marine terrace bordering the seaward side of Amuri Bluff, where the former shoreline is about 50 m a.s.l. Sec-

*Grid references are based on the national thousand-yard grid of the 1:63 360 topographical map series NZMS 1, followed by the equivalent grid reference of the metric 1:50 000 topographical map series NZMS 260.

tions of the terrace are continuously observed along the sea cliff (e.g., 804725 [517494]; Fig. 3B-5). This terrace is poorly preserved to the north of Conway River, but to the south it increases in width.

Claverley Terrace is composed mainly of fan deposits. Its height at the type locality, west of the Claverley Station, is less than 50 m a.s.l., slightly lower than Amuri Bluff Terrace at this locality. In general, the Claverley Terrace deposits fill valleys dissecting the Amuri Bluff Terrace surface, but they also partly cover the inner part of the latter at many places (e.g., 779703 [495474]; Fig. 3B-9). It is, therefore, hard to distinguish between these two terrace surfaces on topographic evidence alone. Narrow younger fluvial terraces are also found at a few levels in valleys dissecting the Claverley Terrace surfaces.

Description

Amuri Bluff area (Fig. 4): Tarapuhi Terrace is preserved best in this area. The terrace surface is moderately dissected and gently rolling, but steep slopes which are considered to represent former sea cliffs are found at its northern margin. Beneath the terrace surface, fossiliferous marine deposits (Fleming & Suggate 1964) about 2.5 m thick, capped by loess about 3.5 m thick, unconformably overlie Tertiary siltstone (Fig. 3A-1). The top of the marine deposits is about 170 m a.s.l. near the former shoreline.

Kemps Hill Terrace at about 90 m a.s.l. is very narrow in this area; no terrace deposits were observed.

Amuri Bluff Terrace is well developed and bordered by distinctive sea cliffs. The terrace surface is underlain by well-rounded marine gravel about 3 m thick, unconformably overlying a horizontal abrasion platform in Tertiary limestone (Fig. 3B-5). The original terrace surface formed by marine abrasion and deposition is well preserved, although the surface is now partly covered by secondary deposits of loess and slope wash. The altitude of the marine gravels ranges from about 45 to 35 m near the former shoreline, suggesting slight northward tilting. Near the mouth of the Okarahia Stream, Amuri Bluff Terrace is overlain by 2 m of fluvial gravels (Fig. 3B-7) that are probably of similar age to the Claverley Terrace deposits to the south.

Okarahia Stream to Conway River: Tarapuhi Terrace is poorly preserved in this area. The well-dissected undulating terrace surface ranges from 160 to 190 m a.s.l. About 1.5 km west of Claverley, the terrace is underlain by 9 m of marine gravels with a cover of loess and slope wash (Fig. 3A-2).

Kemps Hill Terrace, ranging from 100 to 120 m a.s.l., is present in the north. The terrace surface is underlain by marine gravel which is 3–10 m thick up to 105 m a.s.l. (Fig. 3A-3) and is overlain by a few metres of loess or angular gravel of slope wash origin. However, on the south bank of the Okarahia Stream at the inner margin of the terrace, 10 m of fluvial gravel overlies marine deposits.

Amuri Bluff Terrace is found only discontinuously in the northern part of this area and is bordered by gentle slopes up to about 10 m in height which descend to the Claverley Terrace surfaces. A typical outcrop of the Amuri Bluff Terrace to the south of the Old Claverley Creek shows 10 m of well-sorted and stratified beach gravels unconformably overlying Tertiary bedrock (Fig. 3B-6). The upper surface of marine deposits near the former shoreline is about 60 m a.s.l. with no overlying sediments.

Claverley Terrace is well developed in the south, whereas in the north it is mostly preserved in valleys dissecting the Amuri Bluff Terrace. Its surface is underlain by 2–3 m of loess or slope wash resting on subangular fan deposits, 5–10 m thick, that unconformably overlie marine gravels of Amuri Bluff Terrace (Fig. 3B-7–12). The terrace surface ranges from 85 to 70 m a.s.l. near its inner margin, and slopes seaward down to less than 40 m a.s.l., its gradient being steeper than that of Amuri Bluff Terrace. This results in divergence of both terrace surfaces downstream.

The area south of Conway River (Fig. 5): On the eastern slopes of the Hawkswood Range, Tarapuhi Terrace is bordered at its inner margin by conspicuous former sea cliffs. The terrace surface is well dissected and undulating with only some flat remnants. It is underlain by well-sorted and slightly weathered marine gravel, 2–10 m thick, but no angular gravel or loess is present (Fig. 3C-13,-14). The former shoreline on the terrace is well preserved in the range from 260 to 275 m a.s.l.

Kemps Hill Terrace, which is extensive and undulating, is separated from the Tarapuhi Terrace remnant by distinct risers that are apparently old sea cliffs. At a few places it is subdivided into two levels of low risers. The marine terrace deposits are well-sorted gravels, 3–6 m thick, very similar to those of the marine gravels of Tarapuhi Terrace. They are locally overlain by 1–2 m of angular gravel, but no loess is apparent (Fig. 3C-15–18). The heights of former shorelines at the backs of the terraces range from 220 to 240 m a.s.l. at the higher level and from 150 to 170 m a.s.l. at the lower level.

Amuri Bluff Terrace is very narrow in the north, and is overlain by the Claverley Terrace deposits.

Fig. 4 Terraces in the Amuri Bluff and Claverley areas are in the foreground with Amuri Bluff Terrace well developed to the right. Kemps Hill Terrace is in the middle background and Tarapuhi Terrace in the background.

Fig. 5 Terraces from Te Maria to Ngaroma south of Conway River. Tarapuhi and Kemps Hill Terraces extend in front of the Hawkswood Range, and Amuri Bluff and Claverley Terraces are in the middleground. The foreground is the Conway Flat Surface 1 bordered by low cliffs.

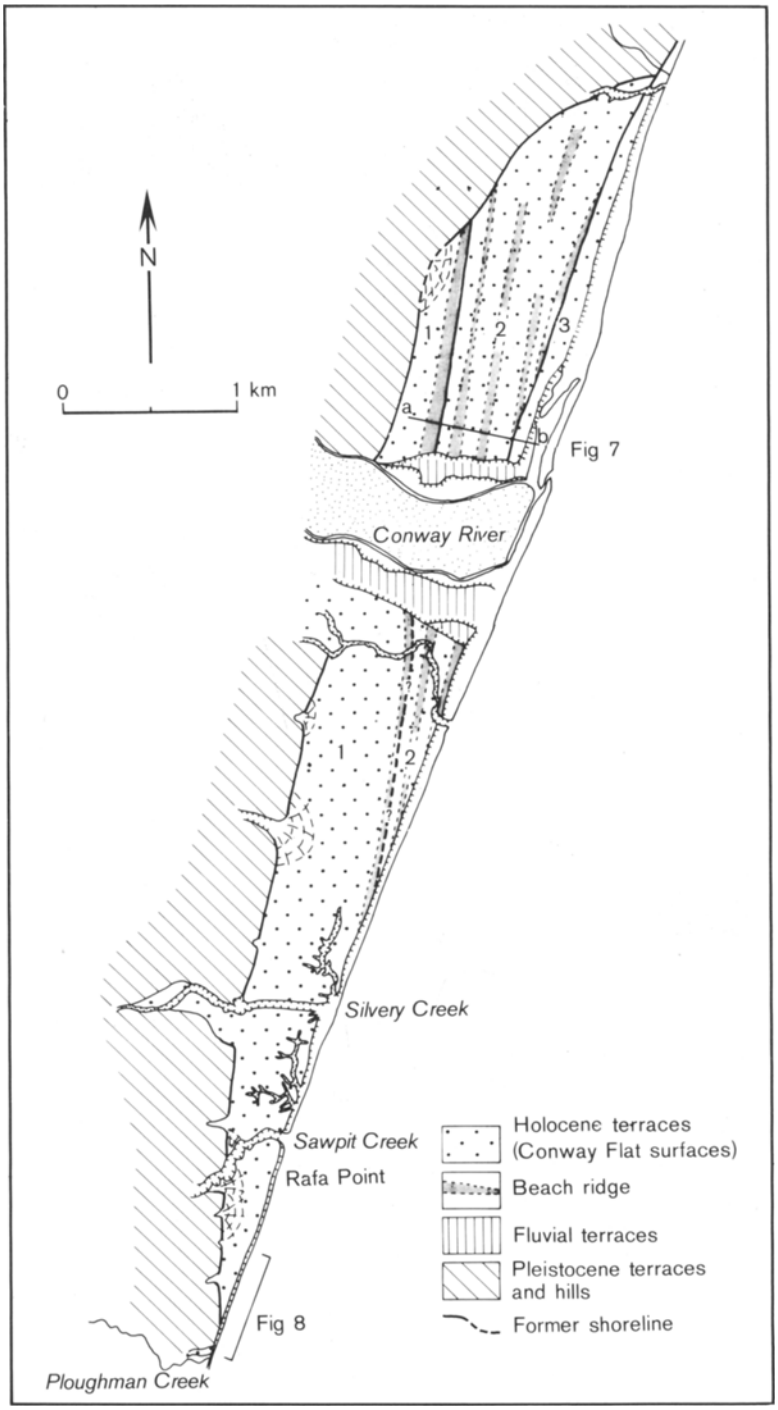

Fig. 6 Geomorphic map of the Conway Flat Surface. The locations of Fig. 7 and 8 are shown.

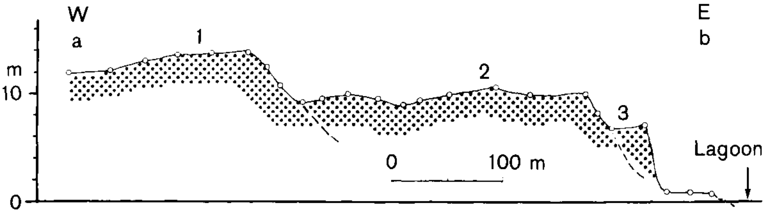

Fig. 7 Cross section of the Conway Flat Surface. The locality for this section is shown in Fig. 6. Data points on the profile are height above lagoon level (approx. 0.7 m below mean sea level).

It is more extensive south of Rafa Point (Fig. 1) where it is usually bordered by gentle slopes which descend about 10 m to Claverley Terrace. A typical outcrop of this terrace is shown in Fig. 3D-19 and 3D-20, where well-sorted rounded marine gravels are exposed without any overlying fluvial deposits. The top of the marine deposits along the inner margin ranges from about 100 m a.s.l. in the south to about 80 m in the north, showing a gentle northward tilt.

Claverley Terrace is made up of former alluvial fans and is well developed in the northern part of the area. In the south it occurs in valleys dissecting the Amuri Bluff Terrace surfaces. The terrace deposits consist of angular–subangular fan gravel, 20–30 m thick, unconformably overlying the marine deposits of Amuri Bluff Terrace, and are covered by less than 3 m of loess or slope wash deposits (Fig. 3D-21–28). The basal surfaces of the fan deposits are lower at the mouths of streams draining the Hawkswood Range, especially on the right bank of the Conway River, than in interfluve areas. Narrow fluvial terraces are distributed at a few levels in valleys dissecting the Claverley Terrace surfaces, and the fluvial deposits are generally thinner than the Claverley Terrace deposits.

Geomorphic relations between marine terraces and fan terraces

The Amuri Bluff and Claverley Terraces best exemplify the complex relationships between marine and nonmarine depositional surfaces. While the Amuri Bluff Terrace has very little seaward gradient owing to its marine origin, the Claverley Terrace of alluvial fan origin slopes eastwards more steeply than the Amuri Bluff Terrace. This results in an intersection of profiles of these two terrace surfaces: for instance, their height is similar near the inner margin of the Amuri Bluff Terrace, or the Claverley Terrace is higher than the Amuri Bluff Terrace in the places where the latter is overlain by the Claverley Terrace deposits. However, the height difference between the Amuri Bluff and Claverley Terraces gradually increases seawards. A pattern of distribution of these two terraces is different from that of high-level terraces which are preserved parallel to the shoreline. Because of a strong dissection and deposition by streams graded to the lower sea level than at the time of the Amuri Bluff Terrace formation, preservation of the Amuri Bluff Terrace is limited only to interfluve areas of subsequent streams, in contrast to the wide preservation of the Claverley Terrace (Fig. 2).

Because only minor remnants of the high terraces are preserved, the details of the relationships between the older marine and nonmarine deposits are not clear, but they may have been similar to that of the Amuri Bluff and Claverley Terraces. The high marine deposits are locally overlain unconformably by thick fluvial gravel beds beneath the upper terraces north of the Conway River. However, these old alluvial fans may not have been very extensive, and during the early periods dissection may have been sufficient only to form narrow valleys in which the nonmarine deposits were confined. This probably resulted from the Hawkswood Range having a lower relief than later, with correspondingly smaller streams draining the range.

HOLOCENE TERRACES

A narrow bow-shaped coastal plain tapers northwards and southwards from the Conway River mouth. Its inner margin is bordered by distinct former sea cliffs which fringe the Pleistocene terraces and run concave to the present straight shoreline. Small low-angle alluvial fans are formed at the foot of the cliffs. The coastal plain is divided into two parts by Conway River, along which narrow fluvial terraces are recognised at two levels (Fig. 6).

North of Conway River: Conway Flat Surface 1, about 12 m a.s.l., extends along the southern half of the former sea cliff, and a broad beach ridge about 2 m above the surface runs a little oblique to the shoreline along its outer margin, terminating in the north at the foot of the cliff. The landward side of the beach ridge is flat, and the seaward side is bordered by a gentle scarp, about 5 m high, descending to Conway Flat Surface 2 (Fig. 7).

Conway Flat Surface 2, about 9 m a.s.l., is the most extensive surface in this area. Four beach ridges about 1 m above the surface are developed on it. While the inner three beach ridges run a little oblique to the present shoreline, the outermost ridge trends nearly parallel to the shoreline. Its seaward margin, together with the southern terminus of the ridge immediately behind, is bordered by a scarp about 3 m high, which descends to Conway Flat Surface 3 (Fig. 7).

Conway Flat Surface 3, about 7 m a.s.l., is very narrow with its outer margin cut by a 6 m scarp descending to the present beach.

South of Conway River: Conway Flat Surface 1 is the most extensive. The inner three beach ridges prominent on Conway Flat Surfaces 1 and 2 north of Conway River extend southwards across the river into the north of this area (Fig. 6). The gentle scarp between Conway Flat Surfaces 1 and 2 is not apparent here, probably because of the proximity of the two inner ridges. The coastal plain, therefore, is generally flat at one level and is bordered only at its outer margin by a low scarp descending to the present shoreline, which obliquely truncates the southward-extending beach ridges. In the southern part of this area, only Conway Flat Surface 1 is preserved and is partly dissected by small streams.

South of Rafa Point and at the mouth of Ploughman Creek, trees, in growth position and buried by deposits of the Conway Flat Surface 1, are exposed by erosion on the modern beach. Radiocarbon ages and stratigraphic positions are shown in Table 1 and Fig. 8 and 9. The ages of forests are c. 7600–8400 years old. At the Ploughman Creek mouth, a silt bed of brackish or lagoonal origin is unconformably overlain by a fluvial gravel from the base of which wood has been dated at 3050 ± 85 years B.P. (N-3266, Table 1). South of Rafa Point, the silt bed burying the forest is again covered by a fluvial gravel bed which contains wood in the upper part dated at 3550 ± 110 years B.P. (GaK-7923, Table 1).

It is inferred that these forests were buried by brackish to littoral silt beds deposited during transgression c. 8000 years ago, and that prior to about 3000–3500 years ago, the sea had retreated causing some erosion of the silt beds followed by deposition of the dated gravels.

DISCUSSION

Ages and geomorphic development of Pleistocene terraces

There is no evidence to determine the ages of terraces on the Conway coast, except the Conway Flat Surface which is Holocene. Postglacial transgression which resulted in the formation of the Conway Flat Surface definitely ended prior to c. 3500 years ago. A precise age of the culmination of the transgression is, however, not known. Three levels of marine terraces, Tarapuhi, Kemps Hill, and Amuri Bluff Terraces, record successive former sea levels, and the Claverley Terrace records a relatively low sea level between the Amuri Bluff Terrace and Conway Flat Surface in the Holocene. By correlating terraces in the Conway coast with those in the Hurunui River mouth area, we can attempt a relationship to the Pleistocene glacial terraces in the upper drainage basins of the Hurunui and Waiau Rivers (cf. Suggate 1965; Carr 1970).

The marine terraces in the Hurunui River mouth area were classified by Carr (1970), in order of descending elevation, into Mt Seddon, Manuka Bay, and Port Robinson Terraces. The height, geomorphic position, and thick marine deposits

Table 1 ^{14}C ages of wood collected on the Conway coast. The decay constant of ^{14}C is 5570 years. Sample horizons are shown in Fig. 8.

Sample number	Lab. code number	Material	Height (m)*	Age (years B.P.)	Grid reference (NSMS1 S55&56)	(NZMS260)
A-1	N-3266	wood	7	3050 ± 85	S55/744612	O32/464390
A-2	N-3267	wood	5	7350 ± 105	744612	464390
A-3	N-3268	wood; standing tree	2	7670 ± 90	744612	464390
A-4	N-3269	wood	1	7730 ± 120	744612	464390
B-1	GaK-7923	wood	10	3550 ± 110	745615	465393
B-2	GaK-7924	wood	2	8300 ± 200	745615	465393
B-3	GaK-7925	wood; standing tree	2	8400 ± 170	745615	465393
577	NZ-533†	wood	H.T.L.‡	7360 ± 110	747623	467400
578	NZ-546†	wood; standing tree	H.T.L.‡	7750 ± 90	748625	467402

*Approximately above mean sea level.
†R. P. Suggate (pers. comm.).
‡High tide level.

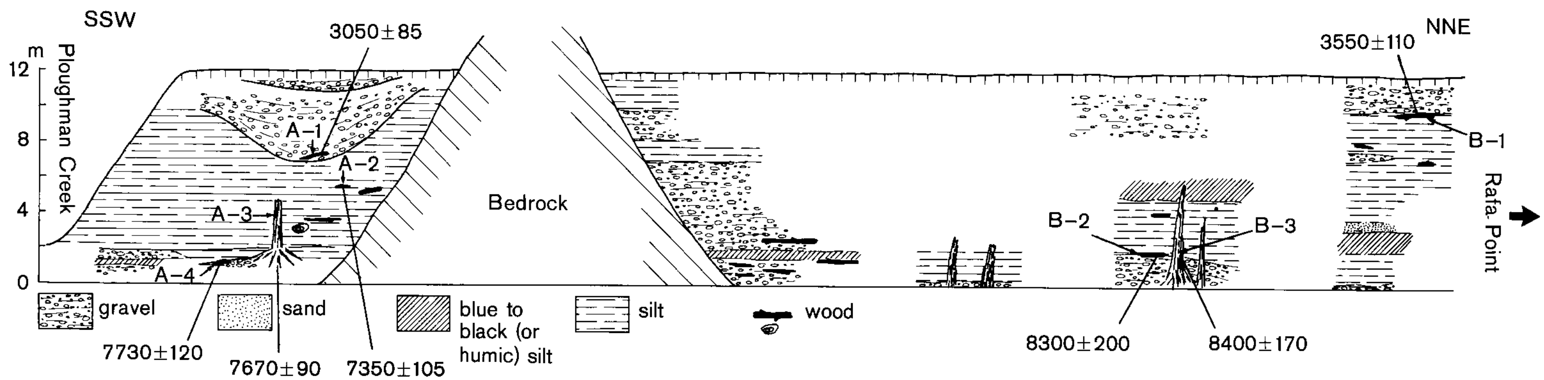

Fig. 8 Geological section of the Conway Flat Surface 1 south of Rafa Point. The location of the section is shown in Fig. 6. Heights are approximately above mean sea level, and the horizontal distance is not to scale. Radiocarbon ages for years before AD1950 are shown.

Fig. 9 Exposure of sea cliff at the mouth of Ploughman Creek. The tree stump at the base of the cliff is sample A-3 and wood protruding from the cliff on the right-hand side is sample A-1 in Fig. 8.

underlying these terraces indicate the Amuri Bluff Terrace on the Conway coast is a likely correlative of the Port Robinson Terrace in the Hurunui River mouth area. Furthermore, the Tormore fluvial terrace along the Hurunui River (Carr 1970) is a little lower than the Port Robinson Terrace at the river mouth and can be traced geomorphologically upstream to Hitchin Hills Terrace in the Cathill Gorge. Suggate (1965) correlated the Hitchin Hills Terrace older than the Main Surface of Culverden Basin with the Otarama advance of Otiran glaciation. From this tentative correlation, the Tormore Terrace is inferred to be of the early stage of Otiran glaciation. It is therefore concluded that the Amuri Bluff Terrace is probably of the last (Oturian) interglacial stage, and that the alluvial fans represented by the Claverley Terrace are products supplied from the Hawkswood Range in the last (Otiran) glacial stage. Major Pleistocene marine terraces in uplifted areas can represent high sea levels in successive interglacial stages. By analogy with the Amuri Bluff Terrace, the Kemps Hill and Tarapuhi Terraces are probably of the penultimate (Terangian) and antepenultimate (Waiwheran) interglacial stages, respectively.

Nevertheless, alluvial fans of Claverley Terrace surfaces were more extensively developed than those in the intervals between Amuri Bluff and Kemps Hill Terraces and between the Kemps Hill and Tarapuhi Terraces. This may be because the Hawkswood Range had not attained its present altitude, and drainage from the range prior to the last (Otiran) glaciation had not been able to supply such great amounts of debris from the eastern slopes.

Late Pleistocene deformation deduced from former shoreline heights

Figure 10 shows the former shorelines on Pleistocene marine terraces projected to the general trend of the present shoreline of the Conway coast.

The former shorelines on Tarapuhi, Kemps Hill, and Amuri Bluff Terraces are about 270, 220, and 100 m a.s.l. in the south and about 180, 120, and 40 m a.s.l. in the north, respectively. The northward decrease of the heights of the former shorelines is comparable to the summit height pattern of the Hawkswood Range, and progressive northward tilting during the Quaternary is apparent (cf. Suggate 1964).

In the area south of the Conway River, the former shorelines tend to gradually descend both south and north, except the lower Kemps Hill Terrace. A distinctive height difference is also apparent north and south of the Conway River. It is uncertain whether the height difference is due to faulting, as no former shorelines are preserved near the river.

If we compare the former shoreline heights between the southernmost and northernmost parts of the studied area to know the general tendency of tilting, the higher two terraces have approximately the same gradient towards the north. The Amuri Bluff Terrace, however, shows a more gentle slope than the higher two. If the correlation and ages suggested are correct, the time intervals between the ages of the successive shorelines are about the same, that is, 100–120 thousand years. The greater heights and steeper gradients of former shorelines would then suggest that uplift with northward downtilting of the Hawkswood Range has been most active during the period from the age of the Kemps Hill Terrace to that of the Amuri Bluff Terrace. The uplift appears to have been so rapid that the Kemps Hill Terrace can be subdivided into two levels in the area south of the Conway River. The maximum uplift rate and gradient of the last interglacial shoreline (Amuri Bluff Terrace) are about 1 m/1000 years and 0.3%, respectively.

Holocene sedimentation and uplift

The early phase of the postglacial transgression is not represented in outcrops on the Conway coast. However, geologic development after about 8000 years ago can be inferred. Two interpretations are possible for the formation of the buried forests. One is that the forests stood on the gravel beds, which had been deposited at a time of minor relative regression prior to about 8000 years ago, briefly interrupting the postglacial sea-level rise. They were then buried by deposition of silt caused by renewed transgression. Alternatively, the forests stood on fluvial terraces, graded to a lower sea level during the last glacial age, and were buried by rising sea level c. 8000 years ago. Since it is considered improbable that significant fluvial terraces were formed in the narrow valley of Ploughman Creek in the last glacial age, the former interpretation seems to be more likely. An assumed regression of c. 8000 years ago fits with a eustatic sea-level lowering of c. 8400 years B.P., proposed by Gibb (1979, fig. 6-3). No direct evidence to support this regression was obtained from this study. Therefore, two possibilities still remain to interpret the Holocene sedimentation sequence shown in Fig. 6.

The gravels on which standing trees were grown were probably deposited near or slightly above sea level, as they interfinger with brackish to littoral silt beds which were identified from a diatom analysis. If so, the coast is estimated to have been uplifted about 26 m since 8400 years B.P., based on the estimated height of paleo sea level (about 24 m below present sea level) at c. 8400 years B.P.

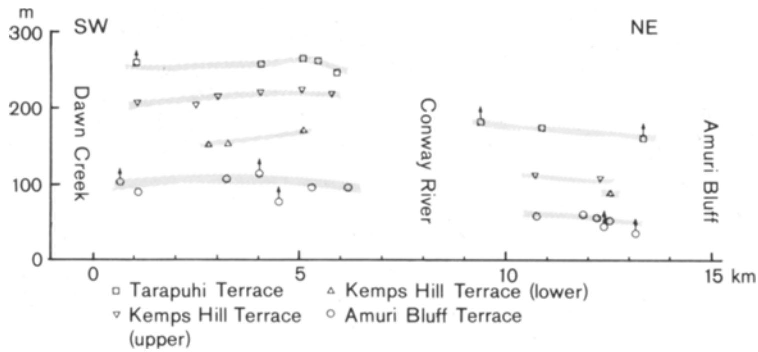

Fig. 10 Projection of Pleistocene shorelines on the Conway coast parallel to the general trend of the present shoreline. Arrows show the height of marine terrace surfaces located a little seaward from former shorelines.

The maximum mean uplift rate of the coast since that time is thus about 3 m/1000 years. The Conway Flat Surface 1, composed of silt beds in part unconformably overlain by fluvial gravels about 3000 years old, may represent the stage when sea level attained its present height about 6500 years B.P. (Gibb 1979). Present height of 12 m a.s.l. derives a mean uplift of about 1.8 m/1000 years. The same uplift rate is also estimated north of the Conway River, judging from the terrace correlation and height (Fig. 6 and 7). Overlying gravels observed south of the Conway River were probably deposited as a response to a minor relative sea-level lowering since about 3500 years ago.

Conway Flat Surfaces 2 and 3, at 9 m and 7 m a.s.l., respectively, were formed by intermittent uplift, as eustatic sea-level lowering has been less than 1 m since 6500 years ago (Gibb 1979).

The average rate of uplift in late Holocene time is about 2 m/1000 years. If this average rate had been maintained throughout the period of formation of the marine terraces, the highest Tarapuhi Terrace would have been formed 125 000 years ago, the last interglacial sea level maximum. The possibility that all terraces younger than Tarapuhi Terrace were formed at high sea levels since the last interglacial maximum must also be considered. This speculation has at present nothing to support it but would require revision of the suggested terrace correlation.

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