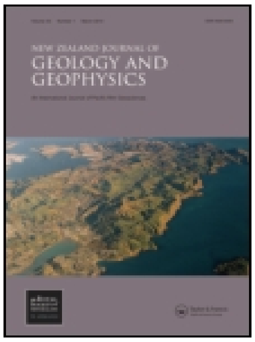

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LATE QUATERNARY SHORE LINES NEAR LAKE ELLESMERE, CANTERBURY, NEW ZEALAND

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ABSTRACT

Detailed study of the Kaitorete barrier enclosing Lake Ellesmere suggests that barrier formation took place 6 000–7 000 years ago when sea level was still rising in this area. Relic cliffs and shore platforms west of Birdlings Flat date from the last interglacial or earlier. Barrier development has now ceased and shore-line erosion is extending eastwards across the barrier.

INTRODUCTION

The barrier separating Lake Ellesmere from the sea, south of Banks Peninsula, was studied geomorphologically in 1970.

It forms part of the "ninety miles beach" fronting the Canterbury Bight (Fig. 1). The Bight cuts into the fluvio-glacial outwash gravels of the Burnham formation (22 000 years B.P., Soons 1968) and fluvial gravels of the Springston formation (less than 10 000 years B.P., Cox reported in Suggate 1963). South of the Rakaia River the gravels are cliffed and separated from the sea by a steep, narrow, mixed sand shingle beach (Kirk 1969). For the 38 km north-eastwards to Banks Peninsula the beach becomes broader and flatter, curving away from the alluvial fan margins and enclosing Lake Ellesmere and the poorly drained low-lying areas landwards of Kaitorete Spit. This area's main characteristics are shown in Fig. 2. Most evidence of former shore lines is on Kaitorete Spit* which can be more accurately described as "barrier" rather than "spit" (American Geological Institute 1962, p. 275; Zenkovich 1967, p. 384). Other evidence is from the cliffed spur-ends of Banks Peninsula west of Birdlings Flat.

Early writers accepted that the Kaitorete barrier was a marine feature formed by beach drifting from the eroding gravel cliffs south of the Rakaia River (Carruthers 1877; Speight 1910; Jobberns 1927). Speight (1930) first gave evidence that the barrier could not have formed from Banks Peninsula, indicating differences in composition between the volcanic rocks of the Peninsula and the sedimentary rocks of the barrier. Suggate (1968) proposed a shore-line sequence in the Lake Ellesmere area related to the post-glacial rise in sea level. He suggested that the sea advanced into the area occupied by Lake Ellesmere and extended eastwards to the spur-ends of

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*New Zealand Geographic Board name on NZMS 1, Sheets 93 & 94.

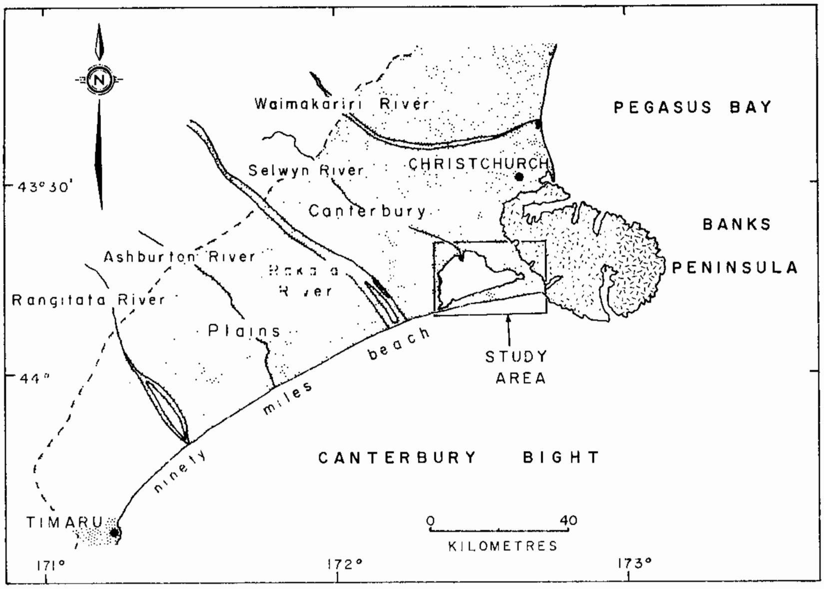

Fig. 1—Location of the study area.

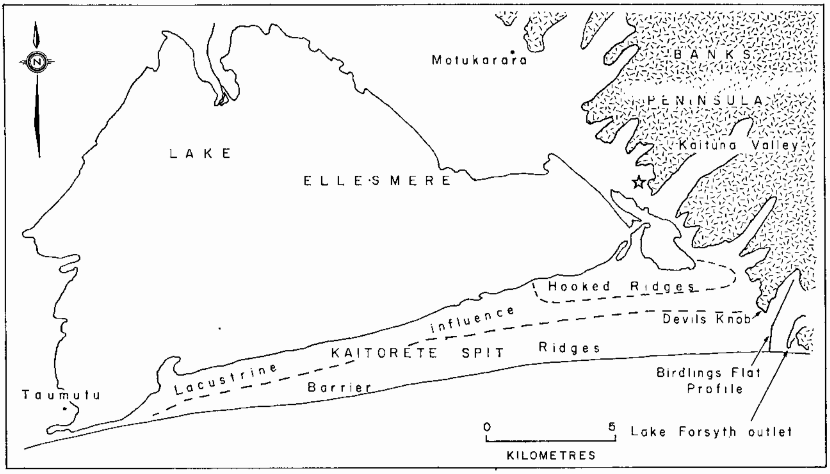

Fig. 2—Study area: Kaitorete Spit and the main groups of landforms. The star marks the location of the section illustrated in Fig. 5.

Banks Peninsula. Suggate thought that at this time, with sea level higher than at present, the relic shore platforms and sea cliffs on the Peninsula's south-western spurs were cut, or at least re-exposed (R. P. Suggate pers. comm. 1970). The sea was then excluded by formation of the Kaitorete barrier at some period within the last 5 000 years.

BEACH RIDGES ON KAITORETE BARRIER

The Kaitorete barrier is a low marine-formed feature 58 km^2 in area, lying mostly between 3 and 8 m above mean sea level. In Fig. 2 it can be seen to increase in width towards Banks Peninsula from 200 m at Taumutu to more than 2 000 m at Birdlings Flat. Dunes between 4 and 8 m high are present along most of the barrier's coastline. Lake silts cover the barrier's lakeward margins and the extension of barrier deposits into Lake Ellesmere is uncertain.

Two groups of beach ridges can be distinguished: the Hooked Ridges of the eastern inner barrier and the Barrier Ridges on the seaward portion of the barrier (Fig. 2). Figure 3 traces the ridge axes of both groups. The Hooked Ridges occupy an area extending 6·5 km east–west, and 1 km wide. Their ridge axes indicate a series of east–west oriented ridges from which curved ridges branch, trending northward towards a north–south alignment. The Barrier Ridges decrease in width from 2 000 m in the east to less than 100 m in the west. The ridge sequences west of the Hooked Ridges have been destroyed by waves generated on Lake Ellesmere and ridges formed by such waves comprise the northern margin of the Barrier Ridge sequence: Bayleys, Speight, Railway Cutting, and Birdlings Valley Ridges.

Hooked Ridges

The alignment of the Hooked Ridges was determined from the lakeside vegetation pattern. *Scirpus americanus* (three-ribbed arrow sedge) grows on the lake silts that overlie a shingle base up to 3 m beneath the surface. Five transects were made in this area using a 3.4 m probe, and the presence or absence of vegetation was compared with the depth of shingle beneath the lake silts. It was concluded that the sedge's growth is clearly related to shingle depth and that the trace of vegetation does reflect an underlying ridge pattern (Armon 1970, p. 64.).

Ridge Axes

The plan of these ridges suggests they formed at the distal end of a spit developing eastwards, before the presence of the main barrier. The linear ridges indicate a beach on the seaward face of a spit and the "hooks" suggest recurves formed by waves refracting around the end of the spit. Wave conditions related to the formation of ridge hooks would vary, often cutting off or modifying earlier ridges.

An alternative hypothesis, that of formation of these ridges within the present Lake Ellesmere by waves on the lake, cannot be accepted because

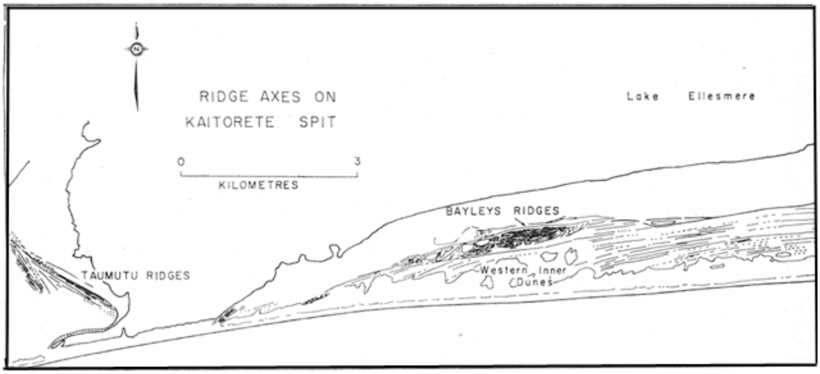

Fig. 3—Ridges-axes on Kaitorete Spit (drawn from aerial photographs—1952 Aerial Survey, approximate scale 1: 15 900, runs 2116 to 2118).

of the projection of the ridges into the lake. The hooks proceed into the lake at angles that would often oppose the direction of approaching waves. Moreover, their curvature cannot be explained in terms of filling a re-entrant angle of the lakeshore because the hooks are more than 2 km from the opposite spurs at the sequence's western end. The marine hypothesis satisfactorily explains the plan-form of the ridges and is supported by their position landwards of the rest of the barrier. An eastern shore line is thus indicated at the time a spit was present. To the west, the barrier's inner margin provides a general idea of the early western shore line, in the absence of any other evidence. It suggests this shore line curved seawards of Taumutu at the barrier's western end.

Sea Level During Spit Development

The Hooked Ridges are between 0 and 1·5 m above present mean sea level. Estimates of the sea level at the time of their formation can be made by comparison with present-day beach and sea levels, and modern ridge heights. A lower sea level would account for the Hooked Ridges. There are two possible relationships.

(1) Ridge heights above sea level may have been similar to that of the latest-formed ridge at Birdlings Flat, which is 8 m above present sea level.

(2) Ridge heights might have been 5 m above sea level, the height of the present barrier beaches at the outlets of Lakes Ellesmere and Forsyth.

The possibility that there was no difference between sea level and ridge tops is discounted because of the high-energy wave environment of this coast and the definite ridge and swale form that is present. It is therefore suggested that sea level during the presence of the spit was at least 5 m lower than the ridge tops, and thus at least 3.5 m below present mean sea level, when the sea was excluded from the Ellesmere area by the linking of the spit to Banks Peninsula.

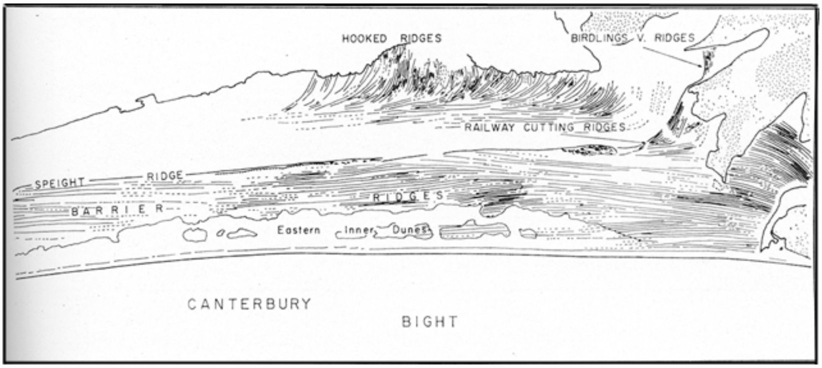

Fig. 3—(*Continued from opposite page*).

These levels allow some estimation of the time of spit formation by comparison with a chronology of land-sea relationships established for the Christchurch area (Suggate 1958, 1968). This curve is used, rather than absolute curves of sea-level rise, because of the uncertainty of absolute land-sea relationships in the past 7 000 years. No evidence of recent tectonism is known in this area (Suggate 1968). Two radiocarbon ages between 6 000 and 7 000 years B.P. (S76/505 and S84/523) indicate a sea level 3–5 m below the present level in the Christchurch area. Sea levels older than 7 500 years B.P. are 15 m or more below the present level, while levels dated as more recent than 5 500 years B.P. approximate that of the present. The sea level which formed the Hooked Ridges probably lay between 4 and 8 m below the present sea level which suggests an age of at least 6 000–7 000 years B.P. for the spit.

The evidence so far cited suggests barrier formation before the sea reached its present level, earlier than Suggate (1968) estimated. A study of the Barrier Ridges supports this contention.

Barrier Ridges

Ridge Axes

Axes of the Barrier Ridges show a systematic variation along the Kaitorete barrier (Fig. 3) and indicate shore lines in the northern Canterbury Bight after the formation of the barrier. Ridge axes parallel the sea coast for the eastern 16 km, but for the westernmost 8 km projections of the axial trends cross the coast at increasing angles up to 18°. Their truncation by the present coast indicates former shorelines west of the barrier were seaward of the present coast, confirming that present coastal recession (Speight 1950; Kirk 1969) has continued for a long time. The similarity between ridge axes and the present coast at the eastern end of the Kaitorete barrier shows that progradation has been the most recent trend there.

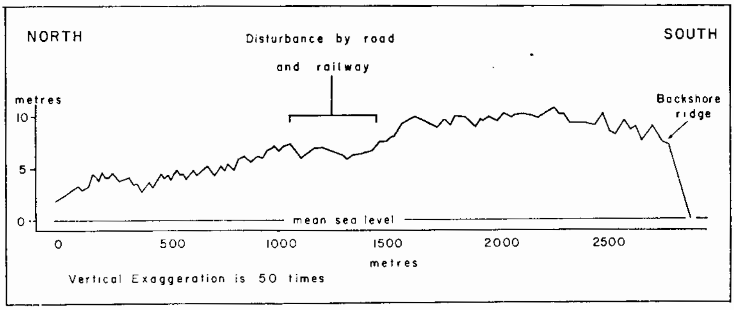

Fig. 4—Profile of ridge levels across the Barrier Ridges at Birdlings Flat.

Ridge-Level Trends

One of the five profiles surveyed across the Kaitorete barrier traversed the complete beach ridge sequence present at Birdlings Flat. This profile (Fig. 4; for location of profile see Fig. 2) allows inferences to be drawn of sea-level trends during barrier development. Figure 4 shows an increase in ridge levels from 3 m above present sea level at the northern end of the profile to 9 m over a distance of 1 500 m. The ridge levels then vary between 7 and 9 m for the subsequent 1 200 m to the beach.

The major factor, other than sea-level variations, likely to have influenced ridge levels is the greater exposure near the present coast; the earliest ridges in this sequence were formed in a former coastal indentation. Ridge-axes are a response to the waves forming them: straight ridges indicate an even distribution of wave energy along the shore. Lateral dispersion of wave energy means less energy at any one place and this could conceivably result in lower ridges. The straightness of the ridges crossing the profile seawards of the inner 750 m is evident in Fig. 3. Ridges curve over the landward 750 m and indicate a spreading wave energy within the former bay, marking a possible decrease in exposure.

The effects of variations in sediment composition, storm intensity, and sediment supply on changes in ridge levels are believed to be minor. Firstly, there is little observed change in sediments across the ridges. Secondly, changes in intensity of storm waves on this coast are unlikely because of its unlimited fetch to the south-east and its latitudinal position north of the major storm belt. Thirdly, the effects of variations in sediment supply would be removed by the frequent occurrence of large storms. At present, storms which occur two or more times a year work sediments 5 to 6 m above sea level; more violent storms, occurring less frequently, would have a greater effect. If progradation occurred at such a rate that storms could not act on the sediments, there would be no ridge and swale pattern. Ridges are well formed across Birdlings Flat, however, indicating the full action of storms.

It is concluded that the 4 m increase in level from 5 to 9 m recorded over the ridges seawards of 750 m traces an equivalent rise in sea level. It indicates progradation occurring on a rising sea level which was initially lower than that of the present. This conclusion confirms the presence of the spit at a sea level below that of the present. The ridge levels across the Barrier Ridges reflect a 4 m sea-level rise during subsequent barrier development. The outer 1 200 m of these ridges may represent a sea level close to the present level or 1–1·5 m higher, depending on the relationship between the backshore ridge at Birdlings Flat and sea level. If this ridge is fully developed, then a former higher sea level is indicated.

The inferred sea-level increase during barrier development allows the approximate dating of the shore line when the present land-sea relationship was attained—about 5 000 years ago according to the curve of relative sea-level rise. The shore line at this time appears to have been at a position level with Devils Knob, where ridges between 8 and 9 m above mean sea level are first reached.

These conclusions conflict with Suggate's hypothesis that the spit and barrier formed after the sea reached a level equal to the present level. Relic shore platforms and sea cliffs on the spurs of Banks Peninsula indicate formation on a higher sea level than the present and must be considered when establishing recent shore lines in the area.

RELIC SHORE PLATFORMS OF BANKS PENINSULA

Former shore platforms, cliffs, and sea stacks occur near the spur ends of Banks Peninsula for 19 km west (inland) of the present sea cliffs at Birdlings Flat. Platforms are sometimes backed by cliffs in basalt, but more often cliffs are absent and the relationship of the platforms to the associated loess covering the spurs is uncertain. The shore platforms occur between 2 and 8 m above mean sea level and may have been formed by a postglacial sea at a level higher than the present.

The relationship between loess and shore platforms is crucial in considering the age of the shore platforms. Speight (1908) wrote that loess overlies these platforms. Figure 5 illustrates a section located on a spur one valley west of Kaituna valley (see Fig. 2) where the shore platform continues beneath the loess. Its continuation is partly obscured by claywash but vertical cracks in the loess stop at the loess-basalt contact. Horizontal bedding, with concretions in some layers, is present in the loess covering the platform, indicating the loess is a primary deposit. The possibility of re-deposition from higher on the spur can be ignored.

This was the only section giving a clear view of the bedding in loess overlying a shore platform. Two other sections clearly showing loess overlying platforms had vegetation obscuring the nature of the loess deposit, leaving some uncertainty whether the loess is a primary deposit or has been reworked.

Mr J. K. Hill (Senior Lecturer in Engineering Geology, University of Canterbury) reports the unsubstantiated results of undergraduate field work (pers. comm. 1970) on a spur north of Motukarara (grid ref. S84/946339).

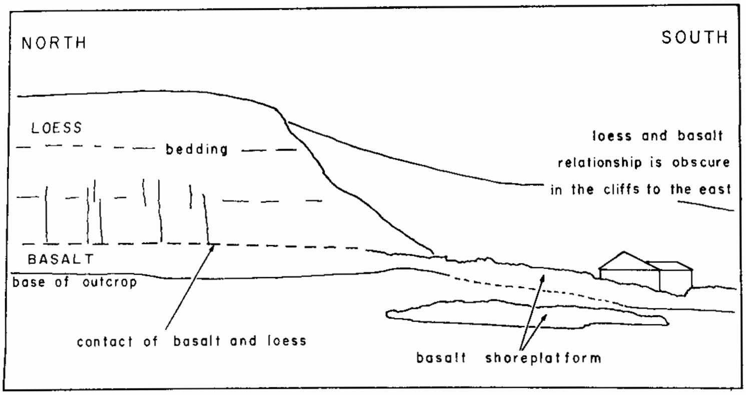

Fig. 5—Stratigraphy of shore platform and loess on a spur one valley west of Kaituna valley (indicated by star on Fig. 2). View eastwards. House on right indicates scale.

Transects of the spur, using a method of seismic refraction, indicate that a basalt surface conformable with the exposed platform is present beneath the loess. This "surface" rises away from the end of the spur beneath thicknesses of loess of up to 20 m until, several hundred metres from the spur end, it slopes steeply towards the surface. This surface form suggests that the platform continues beneath the loess to a former cliff, also buried by loess. Bedding indicates the loess in this situation is a primary deposit.

The relationships of loess and shore platform in two instances indicate that the formation of the platforms predates that of the loess. The loess was derived in Canterbury by wind erosion of glacial outwash and possibly the exposed continental shelf during lower sea levels in glacial periods (Raeside 1964). Sequences of six loess layers in South Canterbury and North Otago have been tentatively related to Gage's (1961) Otira and Waimaunga Glaciations. (Suggate's (1965) revision divides these into three glaciations.) Over the relic shore platforms layered exposures show at least four beds and the lower loess could possibly be pre-Otiran.

It thus appears likely that at least some of the shore-line features on the spur ends are pre-Holocene in age and one could extend this to include all platforms and cliffs present. The exposure of this early shore line could have taken place along recent lake shores on a former higher Lake Ellesmere. Lake-formed ridges on Kaitorete barrier, in Birdlings valley, and on the western shore of Lake Ellesmere (including the Taumutu Ridges, Fig. 2) relate to uncontrolled lake levels and occur up to 7 m above mean sea level. Theoretical wave dimensions for the larger and deeper lake indicate wave heights up to 0·9 m and periods up to 4·5 s (Armon 1970, p. 103); such waves would be of sufficient magnitude to erode the loess. It is thus suggested that formation and exposure of these features can be explained without the presence in the area of a postglacial sea higher than the present level.

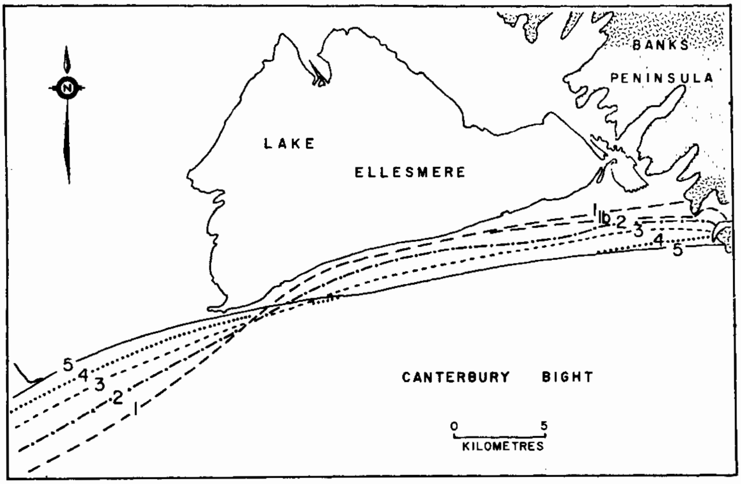

Fig. 6—Probable shore lines after the joining of the spit to Banks Peninsula. 1–5 represent successive barrier shore lines and their tentative western extensions.

SHORELINE CHANGES IN THE LAKE ELLESMERE AREA

Evidence presented in this paper suggests that lower sea levels initiated spit and barrier development in the Lake Ellesmere area in postglacial times. The spit grew at an angle to the shoreline in the south, across an embayment between the alluvial fan margins and Banks Peninsula. Changes in the position of the spit were probably related to adjustment of the coastline between Timaru and Banks Peninsula to form a curving shore line facing the dominant direction of wave approach (the south-east). Kirk (1969) shows the present shore line of the Canterbury Bight is close to equilibrium in plan except that the central portion is too "flat" for equal energy distribution.

A barrier linked the spit to Banks Peninsula, possibly as long as 6 000 years ago. Progradation occurred along the full length of the barrier although retrogradation continued in the west as the sea level stabilised at approximately its present position. Subsequent progradation of the eastern barrier was restricted. Figure 6 illustrates the probable shore-line sequence in the northern Canterbury Bight during the last several thousand years.

The westward decrease in width along Kaitorete barrier can be attributed to: (1) the presence of the fulcrum between the prograding and eroding sectors near the barrier's western end allowing only minor progradation there; (2) the extension of the eroding coastal sector onto the western barrier, removing the barrier's seaward portion; opposite Taumutu there has been complete removal with only a beach barrier present now.

CONCLUSIONS

Beach ridges on the Kaitorete barrier indicate that, as the sea level along the northern shore line of the Canterbury Bight rose towards that of the present, a spit and then a barrier formed. Sub-equilibrium conditions appear to have existed with considerable input of sediment from the eroding coast to the south-west.

The barrier contained Lake Ellesmere, which was larger, and at a higher level than at present; waves on the lake formed ridges on the barrier and western lake shore and exposed relic shore-line features on the south-western spurs of Banks Peninsula. The succeeding pattern of progradation and retrogradation along the barrier occurred in response to continued recession of the central portion of the "ninety miles beach".

ACKNOWLEDGMENTS

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