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The Width of Shore Platforms in Britain, Canada, and Japan

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ABSTRACT

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Variations in the width of shore platforms were investigated within southern Wales, Gaspé in eastern Canada, and southern Japan. The strong, positive linear relationship between platform gradient and tidal range implies that platform width may be largely independent of tidal range, although regional negative correlations between platform gradient and width suggest that platforms become narrower with increasing tidal range. Platform width increases with wave intensity, and the widest platforms are oriented toward the dominant waves. The width of the platforms also decreases with increasing rock dip. A structural classification, based upon combinations of rock dip and strike, relative to the orientation of the cliff face, helped to explain variations in platform width in Canada and Japan. Changes in structural class induced by variations in coastal orientation may partially account for differences in the width of platforms on headlands and in embayments. Platform width is also influenced by the presence and type of cliff-foot deposits.

ADDITIONAL INDEX WORDS: *Rock coasts, geomorphology, Canada, Wales, Japan.*

INTRODUCTION

The morphology of quasi-linear shore platforms is controlled by platform gradient and width, and the height of the cliff-platform junction. Platform gradient is largely determined by the tidal range, and the cliff-platform junction by the elevation of the high tide, although they are also sensitive to a variety of geological influences (TRENHAILE, 1987, 1997). Platform width is an expression of the difference in the amount of erosion accomplished at the high and low tidal levels over a period of time. Mathematical modelling suggests that platform width increases with the size of the waves and decreases with the strength of the rocks (TRENHAILE and LAYZELL, 1981; TRENHAILE, 1983; SUNAMURA, 1992). Wave attenuation across wide, gently sloping platforms must eventually produce a state of equilibrium, however, when recession rates at the high and low tidal levels become equal (EDWARDS, 1941; BIRD, 1968; TRENHAILE and LAYZELL, 1981; SUNAMURA, 1992). Because little is known of the factors that determine platform width, the intent of this research was to identify some of the reasons for variations in the width of the shore platforms between and within three study areas, the Vale of Glamorgan in Wales, southwestern Britain, Gaspé in Québec, eastern Canada, and the southern Kii Peninsula in southern Japan (Fig. 1).

THE STUDY AREAS

The Vale of Glamorgan is a macrotidal (spring tidal range 9 to 12 m), storm wave environment. Tidal range increases eastwards across the area, but wave intensity decreases because of changes in coastal orientation and fetch. There are shore platforms along about 68 percent of this coast in quasi-horizontal Liassic limestones and shales in the west, and in Triassic conglomerates, limestones, and marls in the east. Wave quarrying is the most significant erosional process, although some solution and corrasion also occur. The platforms are generally between 100 m and 250 m in width, and they slope seawards with gradients of two to three degrees, passing below low tidal level without a marked break of slope (TRENHAILE, 1972).

Gaspé is a mesotidal (2.25 to 3.5 m spring tidal range), storm wave environment. There are platforms along about 87 percent of this coast, in steeply dipping Ordovician flysch consisting of shales, argillites, and greywackes. Mechanical wave erosion is dominant, but coastal ice and frost weathering are also important on the cliffs and platforms in this region (TRENHAILE and RUDAKAS, 1981; GUILCHER, 1981; DIONNE and BRODEUR, 1988). The platforms are quasi-horizontal (zero to one degree) and they have developed at elevations close to the mid-tidal level. They are usually between 30 and 150 m in width, and they generally terminate abruptly seawards in a low tide cliff or ramp (TRENHAILE, 1978).

Most of the southern Kii Peninsula is a micro- to mesotidal (tidal range 0.2 to 2.6 m), swell wave environment. Mean wave height is 1.7 m for swell waves and 1.11 m for wind waves. There are platforms in Miocene conglomerates, sandstones, siltstones, and mudstones along about 30 percent of this coast. Wave quarrying and corrasion are significant erosional processes, and subaerial weathering may also be important. Although there are several types of platform, most

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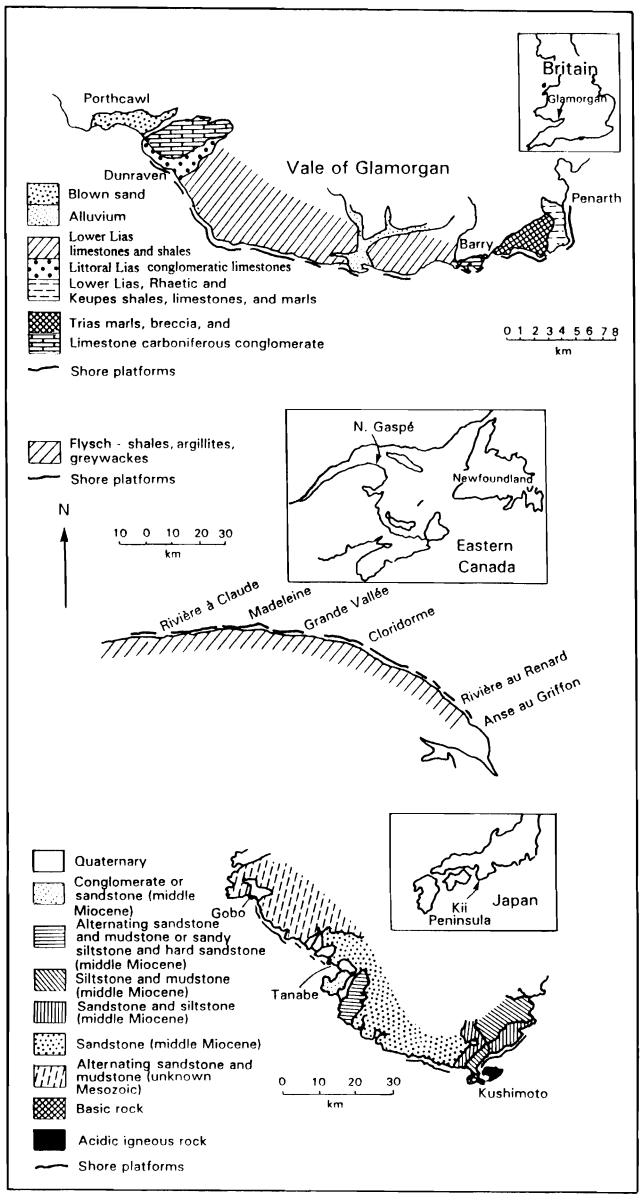

Figure 1. The study areas. The map of the Kii Peninsula was modified from TAKAHASHI (1977).

have very low gradients (0 to 18′) and they terminate abruptly seawards in low tide cliffs. Shore platforms are rarely more than 125 to 150 m wide in southern Japan, and they are generally from 40 to 100 m in the Kii Peninsula. They are at a variety of elevations relative to mean sea level, although this may be related to the tectonic instability of the Japanese islands, rather than to any genetic factors (TAKAHASHI, 1977).

DATA AND METHODS

Platform width was defined as the shore-normal distance between the cliff foot and either the mean low spring tidal level, or, where present, the top of the low tide cliff. The width of the platforms was determined in a number of ways. Surveyed profiles in the Vale of Glamorgan were supplemented by air photographs of scale 1:10,560. A total of 175 measurements were made at 200 m intervals in platform areas along about 40 km of the coast between Dunraven and Penarth (Figure 1). Three hundred measurements of platform width were also obtained by field survey at nineteen sites in Gaspé. Data from areas which were not surveyed were obtained from air photographs of scale 1:10,000. A total of 660 measurements were made at 200 m intervals along about 135 m of the coast from Riviére à Claude to Anse au Griffon (Figure 1). Data from test sites obtained by field survey and air photographs were compared and found to be statistically similar. TAKAHASHI (1977) made 103 measurements of platform width, which were surveyed at irregular intervals along 120 km of the southern Kii Peninsula in Japan.

Data were collected in the field on cliff height, cliff-foot deposits, and rock type, dip, and strike in Glamorgan and Gaspé. Platform gradient was determined from surveyed profiles in Glamorgan, and from surveyed profiles and Abney level measurements in Gaspé (TRENHAILE, 1972, 1978). These data were supplemented by additional information on rock strike, cliff height, and platform-cliff orientation obtained from air photographs and topographic and geologic maps. Wave data for Gaspé were acquired from Environment Canada, and tidal data for Glamorgan and Gaspé from tidal tables published by the Hydrographer of the Navy and the Canadian Hydrographic Service, respectively. TAKAHASHI (1977) tabulated similar platform statistics from southern Japan. Platform data from the southern Kii Peninsula, including width, orientation, and gradient, as well as rock type, dip, and strike, were particularly useful in the present study, although additional information from other areas in Japan was included where appropriate. Data pertaining to each variable were not always available or relevant for each area, however, and some analysis was restricted to one or two of the study areas. The scale of this study precluded consideration of the effect of variations in bed thickness, joint density, and rock hardness in relation to the erosive processes, although they are undoubtedly of great significance.

TIDAL RANGE AND PLATFORM GRADIENT

One of the most fundamental characteristics of shore platforms is the strong positive relationship that exists between regional mean platform gradient (β) and spring tidal range (T_r), a relationship which plays an important role in accounting for global differences in platform morphology (TRENHAILE, 1987, 1997). The regression equation between regional mean spring tidal range and platform gradient suggests that:

$$\beta = 0.26\ T_r$$

where β is in degrees and T_r is in metres (Figure 2). Therefore, for a linear platform extending below the low tidal level without a low tide cliff, or other major break of slope:

$$W = T_r \cot \beta = T_r \cot 0.26\ T_r$$

where W is platform width. This equation suggests that, as

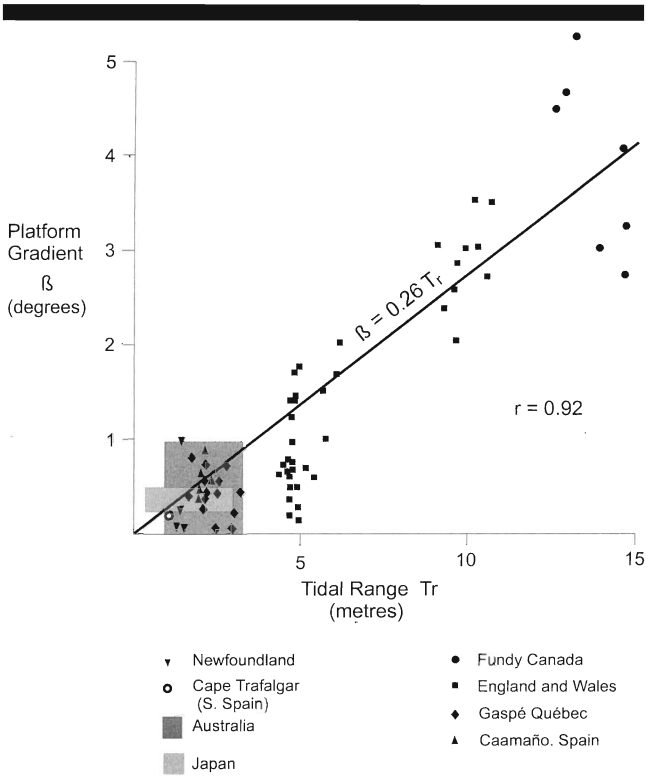

Figure 2. The relationship between shore platform gradient (β) and tidal range (T_r). Each point represents the regional mean of a large number of platform profiles. The data for Japan and Australasia were not included in the regression equation (modified from TRENHAILE, 1997).

there is a linear relationship between platform gradient and tidal range, maximum platform width must be a constant, equal to about 220 m. This is consistent with the equilibrium concept, although maximum width would be expected to vary to some degree according to deep water wave energy and the nature of the rock. Furthermore, whereas the maximum width of platforms in macrotidal environments is often between about 200 m and 250 m, the calculation of maximum width is based on geometrical assumptions that are inappropriate for micro- and mesotidal platforms which terminate abruptly seawards. The relationship between gradient and tidal range is based upon the regional averages of large numbers of individual profiles. Because of the influence of other factors, however, including rock hardness, the strike and dip of the rocks, cliff height, wave intensity, and the mobility of the cliff-foot deposits, there are considerable variations in platform morphology within local areas, and to a much lesser extent between regional means.

It is possible, geometrically, for platform width to increase, decrease, or to remain constant as platforms steepen in response to increasing tidal range, and there is evidence to support each of these scenarios. Several workers have suggested that platform width increases with tidal range (EDWARDS, 1941; FLEMMING, 1965; WRIGHT, 1969), but although there was a high positive correlation (r = 0.83) between these variables for the combined data for the three study areas, the lack of tidal ranges between 3.5 m and 9 m made it impossible to normalise the data. When the data were normalised by incorporating additional information from southern Japan and southeastern and northeastern England (SO, 1965; TAKAHASHI, 1977; ROBINSON, 1977), the correlation was low and insignificant.

Support for a negative relationship between platform width and tidal range is provided by the correlation between platform gradient and width within local areas. There was a significant negative correlation between these latter variables in alternations of sandstones, siltstones, and mudstones in the southern Kii Peninsula (r = −0.38), although the relationship was not significant in three other rock types. Significant correlations between platform gradient and width ranged between r = −0.27 and r = −0.59 in other parts of southern Japan, and it was r = −0.38 when all the Japanese data, irrespective of rock type or area, were combined. A similar significant negative correlation (r = −0.37) was obtained in Gaspé, but correlations were much higher in Glamorgan, where they ranged from r = −0.76 to r = −0.83 for the four main rock types. As platform gradient increases with tidal range, these correlations suggest that platform width and tidal range are negatively correlated. This conclusion is only valid, however, if platform profiles are rectilinear. This is approximately true in macrotidal environments, but in southern Japan and Gaspé, where the tidal ranges are much lower, correlation coefficients decline as low tide cliffs and high and low tide ramps become prominent elements of platform profiles (TRENHAILE, 1987). Because of the abrupt truncation of profiles by low tide cliffs, it is even possible that a decrease in platform gradient could be accompanied by a decrease in platform width, thereby producing a positive correlation between platform width and gradient.

WAVE ENERGY

Shore platforms are the product of cliff recession, and there is often a direct relationship between platform width and the exposure of the coast to strong wave action. In southern Japan, for example, mean platform width is about 40 m on the sheltered Inland Sea, 50 m on the more exposed Japan Sea, and 60 m on the exposed Pacific coast (TAKAHASHI, 1977). Nevertheless, there are also many examples of wide platforms on fairly sheltered coasts, where they are protected from the most powerful waves (JOHNSON, 1933; BARTRUM, 1935; HILLS, 1949).The complex relationship between platform width and the wave environment may be partly related to wave saturation in the inner surf zone, where wave height becomes locally depth controlled and largely independent of the height outside the breaker zone (THORNTON and KIM, 1993).

In Glamorgan, the widest platforms (mean width about 170 m) are along the exposed westerly-facing coastline which experiences prevailing and dominant winds from the southwest, blowing over fetches which extend into the Atlantic Ocean (TRENHAILE, 1972). These platforms are much wider than those formed on similar rocks on the less exposed southern coast (mean width about 120 m), and especially, despite weaker rocks, on the easterly facing coast, where the pre-

Table 1. *Relationship between wave power and platform width and occurrence, Gaspé, Québec.*

Cliff Orientation (degrees)	Wave Power	Number Platform Profiles	Platform Width (m)						
			0–50	50–100	100–150	150–200	200–250	250–300	300–350
180–194	5.9	0							
195–209	8.8	0							
210–224	19	0							
210–224	19	0							
225–239	230	0							
240–254	80	0							
255–269	34	0							
270–284	79	3		1	1	1			
285–299	22	0							
300–314	13	12	3	6	3				
315–329	24	2							
330–344	24	44		13	28	3			
345–359	9.3	144	13	78	50	3			
0–14	12	165		108	50	5	2		
15–29	11	96	1	48	42	5			
30–44	3.2	109	1	79	23	5	1		
45–59	25	35	1	18	14	2			
60–74	48	14	2	7	5				
75–89	60	12	1	6	3	2			1
90–104	34	7		4	1		1		
105–119	21	0							
120–134	2.2	0							

* Wave power is given in N M yr $^{-1}$ per m of wave crest $\times 10^8$.

vailing winds are offshore and fetch distances are short. Platform width also generally increases with wave height and energy in southern Japan, although my analysis of TAKAHASHI's (1977) tabulated data produced insignificant correlations between platform width and mean swell and wave wind heights.

Hourly wave and wind conditions are recorded at an Environment Canada buoy (C45138) anchored in water 335 m deep off Mont Louis, Gaspé, approximately 10 km east of Rivière à Claude. The Gaspésian coast is dominated by waves generated by westerly winds blowing along the axis of the St. Lawrence Estuary, and to a lesser extent by northeasterly and easterly waves propagating across the estuary or entering it from the Gulf of St. Lawrence. Waves approach this coast from directions between 225° and 285° for about 40 percent of the time, and between 45° and 105° for about 23 percent of the time. Peak periods for the wave spectra are generally less than 8s, and significant wave height is usually between about 0.15 and 1 m. The mean annual total and directional wave power or energy flux (P) were calculated from the daily significant wave height (H_s) and the peak period of the wave spectrum (T) recorded at 12.45 p.m. from 1991 to 1996:

$$P = ECn$$

where E, the wave energy, = $1/8(\rho g H^2)$; Cn, the wave group celerity, = 0.78T in deepwater; ρ is the density of sea water; and g is the acceleration due to gravity. Approximately 52 percent of the annual wave power is associated with southwesterly to westerly waves, and about 21 percent with northeasterly to easterly waves (Table 1). Furthermore, as there must be a minimum wave height capable of causing erosion on the Gaspésian coast, it is significant that the highest and most erosive waves also come from the southwest and west, and about half as frequently from the northeast and east.

The Rayleigh Test (CURRAY, 1956) was used to determine the relationship between platform width and orientation in the three study areas (Table 2). Platforms were classified as either wide or narrow according to their width, relative to the mean width for each study area and the general shape of the frequency-width distributions. Preferred orientations were found in all areas, and in most cases they were different for the wide and narrow platform categories. The wider platforms in the *bucklandi* and *angulata* limestones and shales of Glamorgan are oriented toward the dominant southwesterly waves and long fetches, whereas narrower platforms are associated with weaker and less frequent wave attack and much shorter fetch distances. About one-third of the world's tropical cyclones (on average about twenty-two per year) originate in the area to the south of Japan (WMO, 1976). Many of these cyclones, or typhoons, move northwards, approaching southern Japan from the southwest or south-southwest (CHIN, 1972). Although they are infrequent and occur at irregular intervals, they generate very high waves (DAVIES, 1972). In the Kii Peninsula, the widest platforms in alternating siltstones, sandstones, and mudstones have a preferred orientation towards the southwest, coinciding with the approach direction of these powerful waves. Narrower platforms, oriented toward the south–southeast, generally experience the much weaker waves of the east coast swell environment. There is little variation in coastal orientation on the siltstone and mudstone section of the Kii Peninsula, however, and both wide and narrow platforms face south to southeast (Figure 1). Because of the general orientation of the coast, Gaspésian cliffs and platforms generally face north-northwest to north-northeast (330° to 60°). Nevertheless, although

Table 2. *Platform width and orientation—the Rayleigh test.*

Location	Rock Type	Platform Width (m)	Azimuth of Resultant (%)	Mean Angular Deviation (%)	Is Difference in Azimuth Significant at 0.05 Level?
Gaspé (all data)	flysch	narrow (0–99)	14.07*	9.17	Yes
		wide (100–250)	11.48*	9.17	
Rivière à Claude	flysch	narrow (0–99)	357.94*	16.27	No
		wide (100–250)	357.04*	8.37	
Grande Vallée	flysch	narrow (0–99)	5.57*	3.78	Yes
		wide (100–250)	8.88*	7.45	
Rivière au Renard	flysch	narrow (0–99)	30.29*	6.19	No
		wide (100–250)	28.52*	8.71	
Glamorgan	*bucklandi*	narrow (0–149)	175.00*	7.16	Yes
		wide (150–275)	200.42*	5.16	
	angulata	narrow (0–249)	195.02*	6.07	Yes
		wide (250–675)	238.19*	5.84	
Southern Kii Peninsula	alternating sandstone, siltstone, mudstone	narrow (0–49)	167.43*	17.30	Yes
		wide (50–150)	209.15*	27.04	
	siltstone, mudstone	narrow (0–74)	161.82*	46.41	No
		wide (75–350)	174.77*	14.68	

* Significant at the 0.05 level.

the preferred orientation of the wide platforms is only slightly more northerly than that of the narrow platforms, the difference is significant. This may partly reflect the importance and varying degree of exposure of cliffs and platforms to the strong and persistent southwesterly waves which are refracted onto this coast.

GEOLOGY

The resistance of rocks to erosion is related to their hardness, dip, strike, and joint density, as well as to the degree of weathering. Although it is logical to assume that wide platforms develop in weak, rapidly eroding rock types, the relationship between platform width and rock hardness may be quite complex. There are narrow and wide platforms on weak rocks around the English coast, for example, and rapid erosion of low tide cliffs may limit the width of platforms in weak rocks in Australia (EDWARDS, 1941; AGAR, 1960; EVERARD *et al.*, 1964; SO, 1965; ROBINSON, 1977). In many cases, physical hardness is not the main measure of a rock's resistance to erosion, especially if the rock is bedded and well jointed. In southern Japan, for example, water absorption and swelling causes mudstones to be eroded more quickly than interbedded tuff, although the abrasion hardness and the compressive and impact strength of the mudstones are much greater than those of the tuff (SUZUKI *et al.*, 1970).

Platforms have developed in flysch throughout Gaspé, and the effect of different rock types is therefore negligible. In Glamorgan, platforms are formed in variable combinations of Liassic limestone and shale. A series of t-tests showed that although mean platform width is significantly greater in the *angulata* than in the thicker limestones and thinner shales of the lower *bucklandi,* even wider platforms occur on the more resistant conglomerates and limestones of the Littoral Triassic (Table 3). The widest platforms in southern Japan are on conglomerate and tuff, and in alternations of sandstone, siltstone, and mudstone, and they are narrow or ab-

Table 3. *Platform width and rock type.*

Area	Rock Type	Number	Mean Width (m)	Standard Deviation (m)	Significant Difference in Width at 0.05 Level (*) 1	2	3	4	5
Glamorgan	1 *angulata*	34	154.1	22.2					
	2 *bucklandi*	76	136.0	26.1	*				
	3 Triassic red	20	136.0	27.9		*			
	4 Triassic–littoral	26	174.3	26.6	*	*	*		
	5 Carboniferous limestone	26	140.4	79.8					
S. Kii	A Alternating	32	70.0	40.3					
	B Siltstone	35	96.0	62.6	*				
	C Conglomerate	20	104.0	80.6					
	D Sandstone	9	59.0	23.1		*	*		

The significance of differences in mean platform width were tested using the t-test for two independent samples when neither population variance is known.

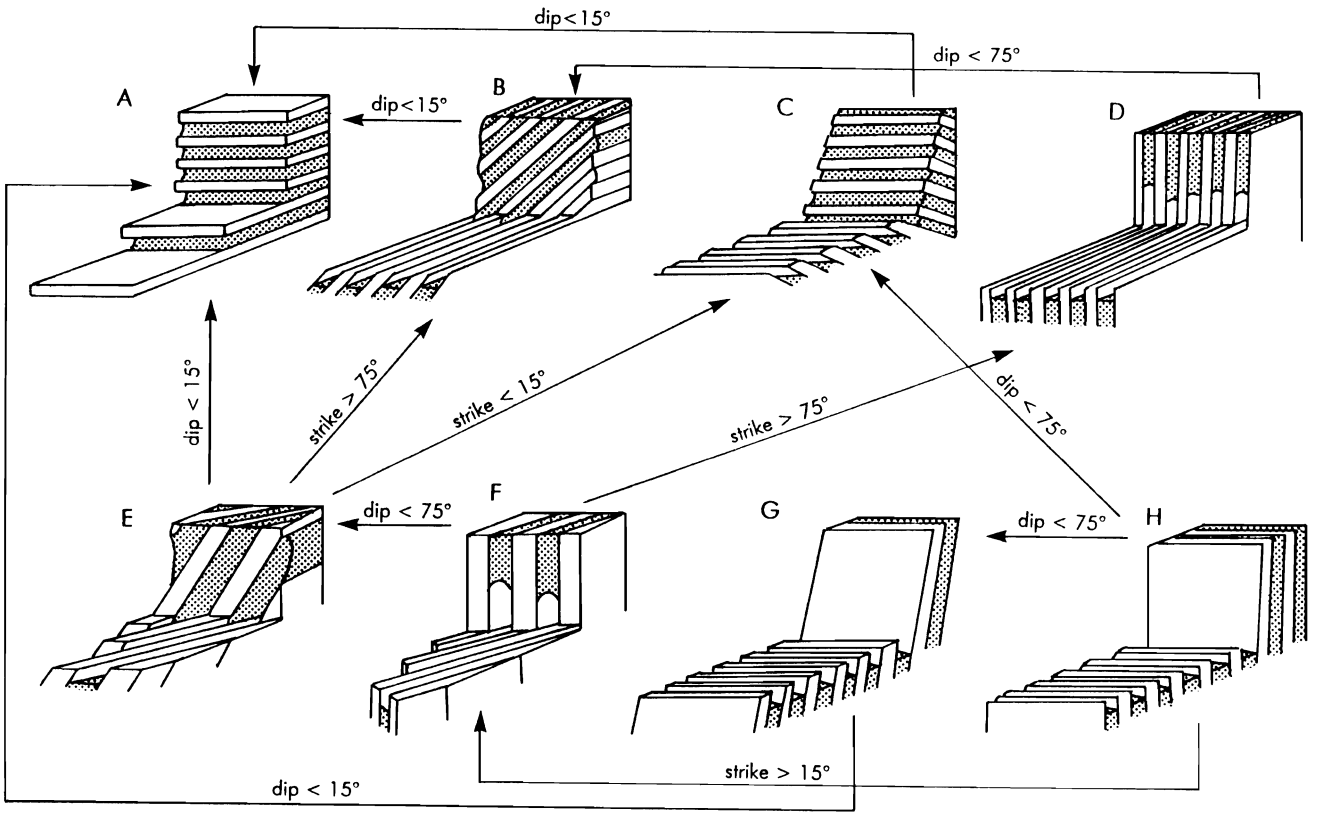

Figure 3. Structural classes according to rock dip and strike relative to the cliff face. Arrows signify changes in structural class as dips and included angles approach class boundary values: all changes in class are reversible (TRENHAILE, 1987).

sent on igneous rocks. On the southern Kii Peninsula, the narrowest platforms have developed in sandstones and in alternating sandstones, siltstones, and mudstones, which are resistant in this area (TAKAHASHI, 1977) (Table 3).

Rock Dip and Strike

Differential erosion of steeply dipping strata may produce irregular corrugated or washboard relief, with the more resistant beds forming ridges that protect the weaker beds from wave attack. Resistant strata in the cliff face may also protect the weaker beds behind, retarding cliff recession. Rock dip therefore determines the degree of protection afforded by resistant strata to weaker beds. The strata are essentially horizontal in Glamorgan and the effect of rock dip on platform width is negligible. Although there is a significant negative correlation between platform width and the maximum rock dip, irrespective of its direction, in alternations of sandstones, siltstones, and mudstones in the Kii Peninsula ($r = -0.48$), and in the flysch of Gaspé ($r = -0.24$), the dip encountered by the incoming waves is of greater relevance. Assuming that waves are perfectly refracted, correlations between platform width and the rock dip perpendicular to the cliff in the alternating, seaward dipping strata of the southern Kii Peninsula ($r = -0.70$) and in landward dipping rocks in Gaspé ($r = -0.35$) suggest that platform width decreases as rock dip increases. These relationships are logically consistent with the protection afforded to the cliff and platform by resistant, dipping beds, which is greatest when the dip is seawards.

EVERARD *et al.* (1964) suggested that shore platforms are widest in steeply dipping rocks when the strike is perpendicular to the cliff, and in gently dipping strata when the strike is parallel to the cliff. TRENHAILE (1987) distinguished eight combinations of rock strike and dip in alternations of beds of variable resistance to erosion. The structural classes are ranked in descending order according to their predicted susceptibility to mechanical wave erosion (Figure 3):

Type A. In horizontal rock, the weaker beds are accessible to wave attack, which undermines the more resistant strata (TRENHAILE, 1972). Cliff recession is the result of rock falls caused by deep undercutting along single beds. Platforms consist of the exposed bedding planes of resistant strata, separated by landward retreating scarps. Fairly smooth platform profiles allow large waves to attack the cliff base. This category experiences the most rapid rates of cliff recession.

Type B. Cliff erosion is almost as rapid when strata dip in a direction parallel to the cliff face. Weaker beds in the cliff are accessible to wave attack, although the discontinuity of these beds in the horizontal plane may retard cliff retreat. Upstanding ridges of resistant strata in the platform may afford some protection to troughs of weaker rock.

Table 4. *Platform width and structural class.*

Area	Rock Type	Number	Mean Platform (m) for each Structural Class								Significant Difference at 0.05 Level (Mann-Whitney U-test)
			A	B	C	D	E	F	G	H	
S. Kii	Alternating	32	134.3	99.0	42.7		58.2	32.5	58.0	60.8	B>H, E>F
	Siltstone	34	142.8	96.8	101.8		79.1	89.0	109.0	45.0	
	Conglomerate	20	76.0	89.0		62.0	159.1	58.5			A>E
	Sandstone	9	65.0				69.3	31.5			
	All rock types	95	102.8	96.1	76.5	62.0	86.1	52.9	88.6	57.6	A≥E, B>C, C>E, E>F, A>F, B>F, C>H
Gaspé	Flysch	422		115.7	96.4		105.4	92.1	106.3	91.3	B>C, B>F, C>E, E>F, F>G, B>E, B>H, C>G, E>H, G>H

Type C. In landward dipping strata striking parallel to the cliff, erosion makes the weaker beds increasingly inaccessible to wave attack. Continued erosion therefore depends upon removal of the resistant strata. Rock slides in the cliff are inhibited by the dip of the beds.

Type D. Vertical strata striking perpendicularly to the cliff provide easy access to wave attack, so that the weaker strata may be quickly eroded. Eventually, however, continued removal of weak strata must be accompanied by erosion of the columns of resistant rock on either side. Washboard relief on the platform retards cliff recession by reducing the wave energy reaching the cliff foot.

Type E. When dipping rocks strike obliquely to the cliff, erosion of the weaker beds in the cliff and platform is retarded, because of the protection afforded by the resistant strata. D and E are considered to be equally suitable for cliff recession.

Type F. Vertical strata striking obliquely to the cliff initially provide easy access to the weaker strata, although as recession continues, they are increasingly protected by the resistant beds on either side. Irregular washboard relief is prominent on the platform.

Type G. Seaward dipping beds in the cliff face may form a resistant wall to incoming waves, although if the dip is low, the exposure of beds of variable resistance to erosion may permit some undercutting and slippage. Ridges of resistant strata in the platform effectively protect the weaker beds behind, and platform and cliff erosion is very slow.

Type H. The erosion of cliffs cut in vertical strata, striking parallel to the cliff face, eventually produces a frontal wall consisting of particularly resistant beds. Further cliff recession depends upon the destruction of these resistant rocks, but well developed washboard relief on the platform reduces wave energy, resulting in the slowest rates of cliff recession.

To test this model, rock structures in the study areas were classified according to their strike and dip. TAKAHASHI's (1977) structural data were used for the Kii Peninsula, and field and air photographic data for Glamorgan and Gaspé. Dips of less than 15° were considered to be horizontal, while dips greater than 75° were considered to be vertical. Similarly, if the strata run into the cliff at an angle (the included angle) that is less than 15°, the strike was considered to be parallel to the cliff, whereas if the angle is greater than 75°, the strike was considered to be perpendicular to the cliff. Because discrete classes were used to represent a continuous spectrum of forms, the classification is sensitive to slight changes in the rock dip or the included angle about the 15° or 75° boundaries. The greatest promotion within the width-class hierarchy occurs when classes G and E become class A, when rock dip falls below 15° (Figure 3). Despite these extreme cases, however, the classification is essentially robust, and changes in dip or included angle about the class boundaries generally result in only a one or two place change in rank.

In most parts of Gaspé and Glamorgan, the rock strike is parallel to the cliff, or it intercepts it at a small angle, but there is a wider range of included angles on the Kii Peninsula. Rock structure in the Vale of Glamorgan falls almost exclusively within class A, and was not considered in the analysis. It may be noted, however, that this area has the widest platforms in the study, although this may be the result of a number of other factors. In Gaspé, most rocks are steeply dipping, usually in a landward direction: classes C, H, E, and F are therefore particularly numerous, whereas classes A and D are absent. In the southern Kii Peninsula, classes A and E are most common, and only one platform profile was classified as D.

To assess the model's ability to explain variations in platform width, the Mann-Whitney U-test was used to compare pairs of structural classes, for each rock type. Some differences in width were not significant, probably because of insufficient sample size, but general agreement was found between model predictions and variations in platform width in Gaspé and the Kii Peninsula. The widest platforms in these areas were associated with classes A and B, and the narrowest platforms with classes F and H (Table 4). The position of some intermediate classes in the hierarchy was slightly different from model predictions, but this was not surprising considering the sample size and the many other factors which

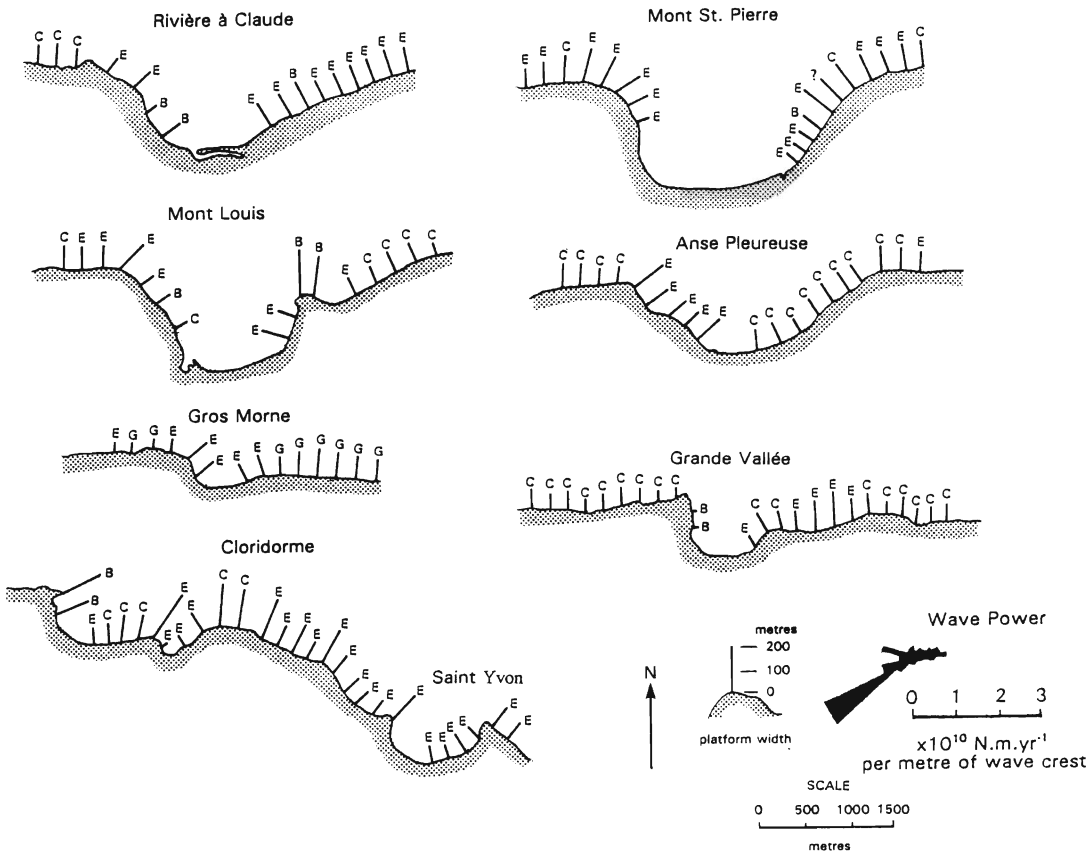

Figure 4. Platform width along the embayments of Gaspé, Québec in relation to rock structural class and wave power.

influence platform width, including bed thickness, joint density, and variations in the direction of wave attack.

Rock strike and dip, relative to the cliff face, can also vary along crenulated coasts because of changes in cliff orientation (TRENHAILE, 1987). The most important indentations along the Gaspé coast are located at the mouth of stream valleys, where there are broad, quasi-log spiral embayments (Figure 4). Variations in platform width along the flanks of these bays could be the result of variations in exposure to wave action, or changes in rock dip and strike, relative to the cliff. Many of the widest platforms along this coast are on the northwestern flanks of the bays, in rocks that dip between 15° and 75°, and strike between 15° and 75° to the cliff. If wave energy were constant in all directions, and the wave fronts approached parallel to the cliff face, then the rock structure at these sites would be classified as type E, which is not conducive to the formation of wide platforms. The Gaspésian coast, however, is dominated by westerly and southwesterly waves that attack the northwestern extremities of the embayments at high angles to the cliffs, as they are refracted into the bays. Reclassification of rock strike and dip according to their relationship to the approximate direction of the waves, rather than to the orientation of the cliff, would place most of these sites within structural type C, which is more consistent with the occurrence of the wide platforms that are generally found in these areas.

CLIFF-FOOT DEPOSITS

The mobility of the cliff-foot deposits determines the degree of protection afforded to the cliff foot and the amount of abrasion that can occur. It has been suggested that variations in platform width in northeastern England are largely the result of differences in the degree of protection afforded to the cliff-foot by accumulating material. ROBINSON (1977) found that sandy beaches at the cliff base are most favourable for the development of wide platforms, followed in decreasing order by a bare cliff foot, a boulder beach, and a talus cone. To test this hypothesis, data were analysed from Glamorgan and the Kii Peninsula: the almost continuous occurrence of talus at the base of the cliffs in Gaspé made it impossible to consider the effect of different cliff-foot deposits in this area. The Mann-Whitney and Kruskal-Wallis tests were used to compare variations in platform width between groups which were classified according to their cliff-foot deposits (Table 5). Direct comparison with Robinson's results was difficult, however, partly because some deposits, including talus, are absent in Glamorgan and the Kii Peninsula, whereas pebble beaches,

Table 5. *Platform width and cliff-foot deposits.*

Area	Rock Type	Cliff-Foot Type	Mean Platform Width (m)	Differences Significant at 0.05 Level
Glamorgan	lower *bucklandi*	pebble beach	181	pebble > bare > boulder
		bare	163	
		boulder beach	133	
	angulata	bare	293	bare > sand-debris
		boulder beach	186	and boulder > pebble
		sand-debris beach	185	
		pebble beach	146	
	upper *bucklandi*	pebble beach	354	pebble > boulder
		boulder beach	94	
	Keuper marls	boulder beach	138	sand-debris > boulder
		sand-debris beach	180	
	Littoral Triassic	bare	165	
		boulder beach	143	
S. Kii	siltstone and mudstone	bare	141	
		sand beach	111	
	alternating	sand beach	76	
		bare	7	

Differences in width were tested with the Mann-Whitney and Kruskal-Wallis tests.

which Robinson did not consider, are common in the lower *bucklandi* of Glamorgan.

In Glamorgan, a bare cliff foot, which permits effective wave quarrying, and possibly a pebble beach, which may allow some abrasion, appear to be more favourable than a boulder beach for the development of wide platforms. Narrow platforms in the Keuper marls and in the shaly *angulata* are backed by a sandy cliff foot, however, and there was no relationship between platform width and cliff-foot deposits in the Japanese data. Although the Glamorgan results generally suggest that the type of cliff-foot deposit is partly responsible for variations in platform width, full evaluation of this factor would have to include the amount, size, and mobility of the deposits, which are determined by the wave energy reaching the cliff foot and the structural and lithological characteristics of the cliff.

CLIFF HEIGHT

Rock-fall debris effectively protects the cliff foot. The amount of debris produced by a rockfall, and the time that is needed to remove it, increase with cliff height. This suggests that there is an inverse relationship between cliff height and platform width, although the relationship may be obscured by the effect of other factors (EDWARDS, 1941). There is a slight negative correlation between platform width and cliff height in Gaspé (TRENHAILE, 1978), and platform width decreases with cliff height for most rock types in the Vale of Glamorgan (TRENHAILE, 1972). Lack of data on cliff height, however, prevented consideration of this factor on the Kii Peninsula.

CONCLUSIONS

The width of shore platforms is determined by the intensity of the erosional processes, the resistance of the rocks, and the length of time that the processes have operated. The present study has identified a number of morphogenic and geological factors which may partly account for variations in platform width, but the list is far from exhaustive. Although erosion rates are determined by the interaction of numerous geologic and morphogenic factors, the availability and form of the data generally necessitated the use of bivariate analysis in the present study. Furthermore, platform width may be partly dependent upon the degree of inheritance that has occurred from interglacial stages and other periods when sea level was similar to today (BROOKE *et al.*, 1994; STONE *et al.*, 1996; TRENHAILE, in press). Understanding the factors that determine the width of shore platforms will explain their absence along some coasts, and it will help us to assess the degree to which platforms are inherited or contemporary. The width of emerged Pleistocene platforms in tectonically active regions could also provide important clues to palaeo sea-levels and morphogenic environments during interglacial stages.

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