Appendix 19

Other Hypotheses for the Origin of Planation Surfaces

Before Davis's hypothesis became popular, most geologists accepted that planation surfaces were formed by marine planation. Beginning in the 1920s, a few geomorphologists found enough problems with Davis' immensely popular "cycle of erosion" to not only question it, but also to develop competing hypotheses. These hypotheses enjoyed a period of respect by various factions within geomorphology, but were followed by disillusionment. Each of the hypotheses still has a few adherents.

Marine Planation

The earliest explanation or hypothesis to explain the origin of planation surfaces was marine planation.

The Hypothesis

This hypothesis invoked sea level rises that moved shorelines inland, each called a transgression—a moving beach over the land. When sea level falls, it is called a regression—the beach recedes seaward. In a transgression, waves would erode the land, smoothing rough surfaces, resulting in an almost level platform. Turbulence in the surf zone would have rounded the rocks, forming gravel. This idea seemed plausible for areas near sea level, and it may explain the origin of marine terraces and strandflats (see chapter 46). If a transgression continued far inland, either by subsidence of the land or a sea level rise, it could potentially form an extensive planation surface.

This explanation was developed by A. C. Ramsay in the mid 1800s, who noted that folded strata around Wales had been eroded and truncated (see Chapter 45). Since the sea is nearby, he reasoned the transgression of the sea was a solution to the Wales planation problem.[1] Ramsay, as well as Charles Lyell, one of the founders of uniformitarian geology, looked to the sea because they were convinced rivers could not have denuded widespread areas of land creating planation surfaces. I agree that Ramsey and Lyell were correct on this belief.

Problems with the Hypothesis

Other scientists at that time had difficulties with this hypothesis. They pointed out the sea erodes too slowly. This would impede its own destructive work by forming beaches, bars, and sandbars. They should have *remained* on the planation surface,[2] but are not found. Of course, Ramsay claimed the debris left on the planation surface after marine planation would have been quickly removed.

In 1869, Archibald Geikie, using estimated rates of erosion by rivers versus ocean waves, quantitatively demonstrated that before the sea could have eroded more than a marginal strip (between 70 to 80 miles (110 to 130 km) inland), the entire continent would have been washed into the sea through river erosion.[3] Within the uniformitarian framework of millions of years,

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[1] Chorley, R.J., A.J. Dunn, and R.P. Beckinsale, 1964. *The History of the Study of Landforms or the Development of Geomorphology—Volume One: Geomorphology before Davis*, Methuen & Co LTD, London, U.K., pp. 301–313.
[2] Chorley *et al*., Ref. 1, p. 311.
[3] Chorley *et al*., Ref. 1, pp. 327–328.

this erosion is comparatively rapid. So, the idea of marine planation became unfavorable and eventually rejected.

Ramsay eventually retreated from his hypothesis: attributing some surfaces to uninterrupted subaerial (above sea level) erosion. However, he provided few details on this modification. Geikie's powerful argument, which was aimed more at Lyell’s marine dissection theory, failed to convince many scientists because of typical resistance to new ideas:

> If, however, any reader should think that Geikie's argument caused the sudden extinction of Lyell’s marine theory, he seriously under-rates the strength of tradition, especially among older geologists. Lyellian die-hards remained very much alive.[4]

For many years, geologists were divided between the marine planation hypothesis and less clear ideas about subaerial erosion, assumed to be caused by rivers and streams. There was no consistent hypothesis of subaerial erosion at the time. Even after the triumph of William Morris Davis’s cycle of erosion, the marine planation hypothesis did not die. It was kept alive and even introduced again by Barrel and Bascom in the early 1900s.[5] And a few diehards have believed the hypotheses even in the late twentieth century! Marine planation is possibly valid in local, coastal areas during recent times, areas such as those in western England and western Norway, but it cannot explain widespread, inland planation surfaces.[6,7]

Walther Penck's Anti-Davis Reaction

Davis’ hypothesis, while enjoying enormous popularity in North America and much of English-speaking Europe, was not well received in Germany. German scientists better understood the difficulties and special conditions required for Davis’ hypothesis. They were especially concerned with the effect of *tectonics* on the cycle of erosion.

The Hypothesis

In the 1920s, this concern inspired Walther Penck to devise a competing hypothesis in which the interplay between tectonic uplift and erosion was reflected in the shape of valley sides, which retreat over time.[8] As far as uplift and denudation are concerned, Penck’s hypothesis would be the “gradualism” of the cycle of erosion. Whereas Davis invoked rapid uplift with no erosion, followed by a stillstand and erosion, Penck advocated gradual uplift with continuous erosion (Figure A19.1b).

In Penck’s hypothesis, rapid uplift produces side slopes with a convex upward profile as the rivers cut downward. As uplift slows, convex valley sides become concave. Acceleration and deceleration of uplift produces a series of benches or rock terraces (erosion surfaces), each retreating backwards forming a pediment at the base until just thin interfluves remain of the original land. As the interfluves continue to retreat, they disappear into scattered inselbergs surrounded by pediments (see Parts XI and XIV for an analysis of inselbergs and pediments, respectively). The inselbergs finally disappear into a series of low relief concave surfaces similar to Davis’ peneplain. Figure A19.1 compares Davis’ sequence of erosion (Figure A19.1a) with

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[4] Chorley *et al*., Ref. 1, p. 328.

[5] Twidale, C.R., 1998. Antiquity of landforms: an 'extremely unlikely' concept vindicated. *Australian Journal of Earth Sciences* 45:661.

[6] Small, R.J., 1978. *The Study of Landforms: A Textbook of Geomorphology*, second edition, Cambridge University Press, London, U.K., p. 167.

[7] Ahnert, F., 1998. *Introduction to Geomorphology*, Arnold, London, U.K., pp. 220–221.

[8] Penck, W., 1953. *Morphological Analysis of Land Forms—A Contribution to Physical Geology*, translated from the German by H. Czech and K. C. Boswell, MacMillan and Co. London, U.K.

Penck’s idea (Figure A19.1b).

Penck’s hypothesis of multiple episodes of acceleration and deceleration during uplift attempted to account for planation surfaces commonly seen at multiple levels and separated by a scarp. Mountaintop planation surfaces were just the first stage in his hypothesis.

Penck’s hypothesis never became popular in the English-speaking countries because of his obscure writing style and terminology (it was written while he was dying of cancer in his 30s), and because the majority of geomorphologists could not read German. Furthermore, Davis misrepresented Penck’s hypothesis, leading to much confusion over Penck’s beliefs. Many geomorphologists were led to think Penck proposed the parallel retreat of slopes, which is Lester King’s hypothesis (Figure A19.1c), described below.

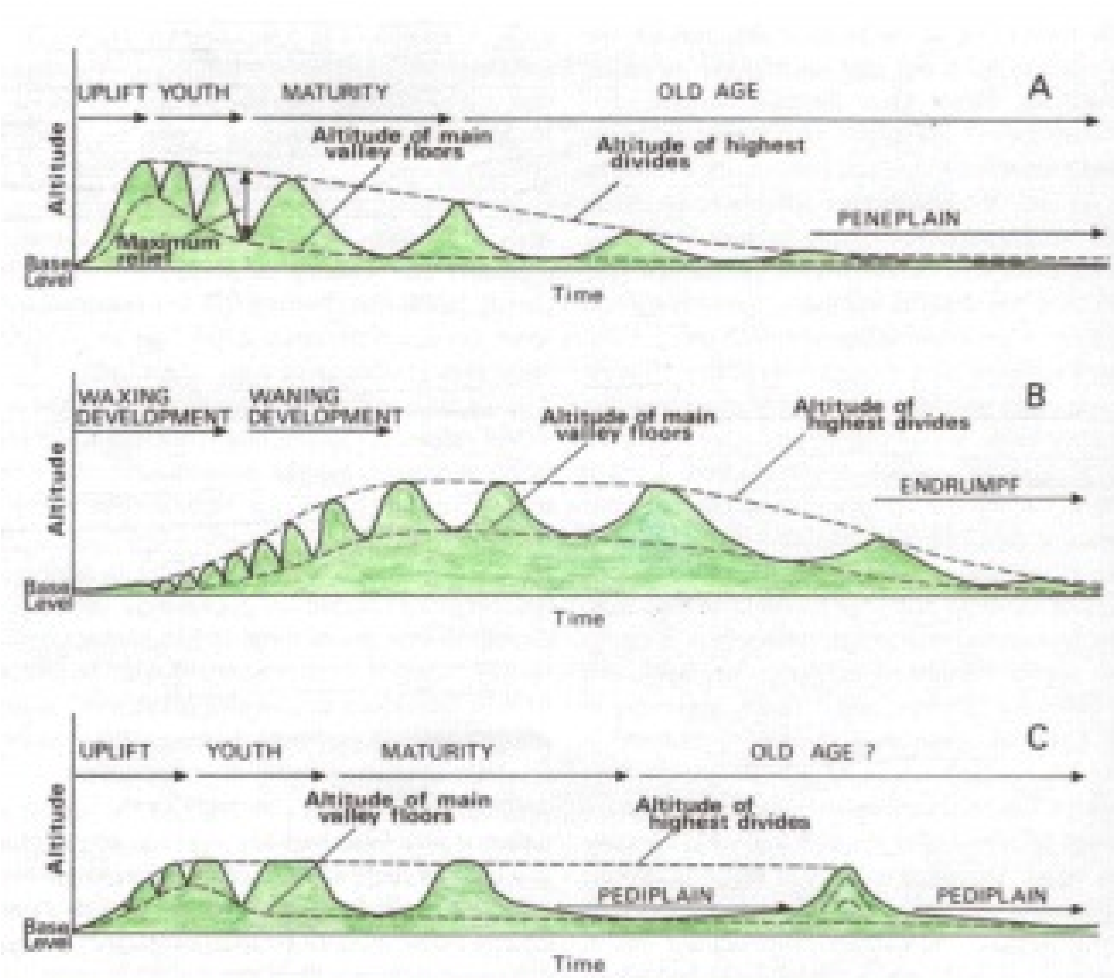

Figure A19.1. (a) Davis’ valley erosional hypothesis in comparison with (b) Penck’s hypothesis and (c) King’s hypothesis. A narrow valley first develops in all the hypotheses, but they differ on the shape of the slope as the slope erodes and the final shape of the land surface.

Problems with the Hypothesis

Unfortunately, as with Davis’ hypothesis, Penck’s explanation is also *simplistic and has a* *number of difficulties*. It too was deductive (imaginative) lacking observational fieldwork.[9] He ignored many erosional variables, such as changes in river discharge due to climate change, and underplayed the effects of variable types of rock.[10] His idea of backwasting, especially, came under criticism.

Penck thought that scarps retreated at constant rates, and each cycle of retreat did not change the slope erosional pattern with time—both are unreasonable assumptions.[11] Crickmay also noted that, according to the uniformitarian paradigm, many scarps have not backwasted at all for many millions of years.[12] Furthermore, it is curious that he would expect a pediment produced by backwasting to remain flat, when the observation of pediment dissection is well documented. Such "old" pediments should have been thoroughly dissected and even destroyed (see Chapter 35). Penck's seemingly-sound idea of side slopes changing from convex to concave upward has been criticized by Ollier,[13] who noted that the shape of the side slope depends mainly on the properties of the rock and the nature of the slope-eroding process. Table A19.1 summarized the problems with Penck's geomorphic hypothesis for producing erosion surfaces.

1. Vague and qualitative
2. Not based on fieldwork
3. Ignored rock type
4. Ignored climate
5. Slopes do not retain the same shape with time
6. Many slopes have not retreated for many supposed millions of years
7. Pediments would not remain flat for millions of years

Table A19.1. Problems with Penck's hypothesis for the origin of planation surfaces.

Lester King's Parallel Retreat of Slopes

The hypotheses of Davis and Penck were subject to intense debate during the second quarter of the twentieth century. Since then, several other hypotheses have been devised, usually as variants or combinations of the two. As stated above, Davis misrepresented Penck's hypothesis as a belief in the parallel retreat of slopes. Lester King, a renowned geomorphologist from the University of Natal in South Africa,[14] *accepted Davis' misinterpretation as Penck's hypothesis*. King then multiplied his error by making that misrepresentation the cornerstone of his own "pediplanation" hypothesis.

The Hypothesis

King's hypothesis is similar to Davis' (Figure A19.1c) in that uplift is episodic and rapid while rates of denudation remain very slow.[10] King, whose model first attempted to explain the landscapes of South Africa, parted company with Davis once the posited uplift was complete. King believed that during stillstand the main agent for denudation is "parallel slope retreat." That

[9] Thorn, C.E. 1988. *An Introduction to Theoretical Geomorphology*, Unwin Hyman, Boston, MA, p. 134.
[10] Summerfield, M.A. 1991. *Global Geomorphology*, Longman Scientific & Technical, New York, NY, p. 461.
[11] Crickmay, C.H., 1974. *The Work of the River: A Critical Study of the Central Aspects of Geomorphology*, American Elsevier Publishing Co., New York, NY, p. 183.
[12] Crickmay, C.H., 1975. The hypothesis of unequal activity. In, Melhorn, W.N. and R.C. Flemel (editors), *Theories of Landform Development*, George Allen and Unwin, London, U.K., pp. 103–109.
[13] Ollier, C., 1991. *Ancient Landforms*, Belhaven Press, New York, NY, pp. 77–78.
[14] Twidale, C.R., 1992. King of the plains: Lester King's contribution to geomorphology. *Geomorphology* 5:491–509.

slope retreat was accompanied by hillslope processes, not fluvial processes, as advocated by Davis.[15] This retreat leaves behind a broad concave-upward pediment. Over time pediments grow, interfluves are worn down, and finally pediments coalesce into what he called a *pediplain* with tiny hills left from the interfluves. The process of landscape development is called pediplanation. The pediplain, the pediments left behind from many retreating slopes, remains little altered until the next cycle of surface uplift or sea level fall, a second cycle, causes the rivers and streams to cut down into the pediplain, forming a new series of pediments at a lower altitude. Then the second cycle goes to completion by parallel slope retreat. There can be third, fourth, fifth, etc. cycles. Meanwhile, the older cycles continue backwearing the slope, shrinking the interfluves even further to the point where the highest erosion surfaces become isolated erosional remnants or inselbergs. King's hypothesis also attempts to explain multiple planation surfaces.

Problems with the Hypothesis

Pediplanation does not differ much from Davis' cycle of erosion for arid regions, and hence it shares many of its problems. Like Davis, King's hypothesis was deductive without detailed empirical observations.[16] King's hypothesis is still somewhat popular in Africa, but has gained only few adherents outside the arid and semiarid regions. This is understandable since pediments are observed in all climatic environments.[15,17]

Since geomorphic cycles have fallen into disfavor, King's hypothesis is viewed in the same way as Davis' hypothesis today.[18] The idea of strictly parallel retreat of a slope has been challenged by evidence that a slope constantly adjusts to rock strength, so the angle of the slope will commonly change with time[19] Furthermore, multiple concave upward plains of great extent, the pediplain, do *not* exist.[20] Besides, the origin of pediments themselves is uncertain, as will be shown in Part XIV. Le Roux points out that a planation surface in southern Africa could not have remained flat for over 20 million years while slopes retreated long distances, because the rocks below the plain are sometimes *soft*.[21] Table A19.2 lists the problems with King's hypothesis of parallel slope retreat and pediment formation.

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[15] Flemal, R.C. 1971. The attack on the Davisian system of geomorphology: a synopsis. *Journal of Geological Education* 19:11.
[16] Le Roux, J.S., 1991. Is the pediplanation cycle a useful model? evaluation in the Orange Free State (and elsewhere) in South Africa. *Zeitschrift für Geomorpholgie N. F.* 35(2):175–185.
[17] Brown, R.W., K. Gallagher, A.J.W. Gleadow, and M.A. Summerfield, 2000. Morphotectonic evolution of the South Atlantic margins of Africa and South America. In, Summerfield, M.A. (editor), *Geomorphology and Global Tectonics*, John Wiley & Sons, New York, NY, pp. 255–281.
[18] Hart, M.G., 1986. *Geomorphology Pure and Applied*. George Allen & Unwin, London, U.K., p. 32.
[19] Partridge, T.C. and R.R. Maud, 1987. Geomorphic evolution of southern Africa since the Mesozoic. *South African Journal of Geology* 90 (2):179–208.
[20] Twidale, C.R., 2003. Canons revisited and reviewed: Lester King's views of landscape evolution considered 50 years later. *GSA Bulletin* 115:1,157.
[21] Le Roux, Ref. 16, p. 179.

1.	Not much different than Davis' model
2.	Seems to apply mainly in dry environments, but pediments are worldwide in many climates
3.	Slopes do not retreat parallel with time
4.	Many slopes have not retreated for many supposed millions of years
5.	Pediments would not remain flat for millions of years
6.	Pediplains do not exist today

Table A19.2. Problems with King's hypothesis.

John Hack's Dynamic Equilibrium Hypothesis

John Hack's dynamic equilibrium model is an outgrowth of some of G.K. Gilbert's ideas of the late nineteenth century. It is quite different from the cyclical hypotheses of Davis, Penck, and King. It is the "punctuated equilibrium" of landform evolution.[22,23] Punctuated equilibrium is the biological evolutionary hypothesis that organisms remain the same (in equilibrium) for a few million years and then rapidly change into new species, leaving *no* fossil evidence. Punctuated equilibrium is an attempt to explain the negative evidence of numerous gaps in the fossil record at the species or genus level.

The Hypothesis

Hack's model states a landscape once perturbed rapidly goes into equilibrium along with its many denudation forces. The landscape then remains in "steady state" or dynamic equilibrium until the next perturbing force. In the ideal case during dynamic equilibrium, the base level and rock type remain constant with time so that the surface profile remains unchanged while the landscape downwastes at a constant rate. Base level (see Chapter 2 and Figure 2.6) is defined as: "The theoretical limit or lowest level toward which erosion of the Earth's surface constantly progresses but seldom, if ever, reaches…"[24] Base level is the level below which a stream cannot erode its bed. Sea level is the ultimate base level, but temporary base levels may exist locally at higher altitudes. According to Hack's hypothesis, mountains remain mountains because of their more resistant rocks. Land of low relief maintains that profile due to their less resistant rocks. All landforms are denuded at the same rate, so that the *same large-scale relief remains*. Since there are no great perturbing forces observed today, the present land surface is in balance or equilibrium with present-day processes.

Problems with the Hypothesis

Hack developed his theory more *in reaction* to Davis' cycle of erosion (geographic cycle) that became unpopular in the mid-twentieth century.[25] Hack also considered Penck's and King's ideas just as inadequate. So, by the 1960s, there was *no* widely accepted geomorphic hypothesis:

> In the last 20 years, however, Davis' ideas have become less popular and the small but ever-present number of geologists who were skeptical of his theories has increased. Though many geologists have been dissatisfied with it, the theory of the geographic cycle

[22] Hack, J.T., 1960. Interpretation of erosional topography in humid temperate regions. *American Journal of Science* 258-A:80–97.
[23] Hack, J.T., 1975. Dynamic equilibrium and landscape evolution. In, Melhorn, W.N. and R.C. Flemal (editors), *Theories of Landform Development*, George Allen and Unwin. London, U.K., pp. 87–102.
[24] Neuendorf, K.K.E., J.P. Mehl, Jr., and J.A. Jackson, 2005. *Glossary of Geology*, Fifth Edition. American Geological Institute, Alexandria, VA, p. 56.
[25] Thorn, Ref. 9, p. 155.

> and its application to the study of landforms has not generally been replaced by any other concept.[26]

Apparently, Hack felt the need for some hypothesis to fill the void!

Hack's hypothesis for landform development also has a number of serious objections. It is doubtful that it can be applied to more than a small area, and denudation processes probably can change in nature and rate through time.[27,28,29]

After rapid tectonic change, Hack's hypothesis demands a rapid adjustment to present denudation forces. Twidale claimed that denudation forces will not come into steady state for a long time after some geological perturbation.[30] Furthermore, during steady downwasting, a surface is likely to erode into rocks of different lithology which would perturb the steady state. Many landforms are considered relict and *not* in equilibrium with the present climate. Ollier maintained:

> ...many of the world's landscapes cannot be fitted into the scheme and dynamic equilibrium cannot be a general theory of landscape evolution. The whole concept of dynamic equilibrium hinges on quite unwarranted assumptions about rates of uplift.[31]

J Harlen Bretz ("J" was his first name), iconoclast of Lake Missoula flood fame,[32] especially took issue with Hack's dynamic equilibrium hypothesis.[33] He noted that significant geomorphic features in the Ozark highlands of southern Missouri and northern Arkansas could not be explained by a constant rate of downwasting from the presently operating drainage (see Chapter 39). These features include: 1) summit flats that bevel rocks of variable resistance, 2) relict hills or monadnocks (defined in Chapter 53) that are no more resistant than the lower flat surfaces, and 3) the failure of escarpments to influence river courses.

So, it appears that Hack's dynamic equilibrium model is simply a reaction against failed past hypotheses and fares no better. Table A19.3 lists the difficulties with Hack's hypothesis.

1. Cannot apply to large areas in the long term
2. Nature and rates of processes through time will change from one climate to another
3. Nature and rates of processes through time will change due to tectonic activity
4. Survival of relict landforms
5. Lacks precision to establish landscapes as truly time independent
6. Changing rock type with downwasting will disturb equilibrium
7. Equilibrium likely cannot be established fast enough after a geological change

Table A19.3. Problems with Hack's equilibrium hypothesis.

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26 Hack, Ref. 22, p. 31.
27 Crickmay, Ref. 11, p. 191.
28 Summerfield, Ref. 10, p. 464.
29 Ollier, Ref. 13, p. 203.
30 Twidale, C.R., 1976. *Analysis of Landforms*, John Wiley & Sons Australasia Pty Ltd, New York, NY, pp. 424–426.
31 Ollier, C. 1981. *Tectonics and Landforms*, Longman, New York, NY, p. 303.
32 Oard, M.J., 2004. *The Missoula Flood Controversy and the Genesis Flood*, Creation Research Society Monograph No. 13, Chino Valley, AZ.
33 Bretz, J.H. 1962. Dynamic equilibrium and the Ozark land forms. *American Journal of Science* 260:427–438.

Crickmay's Lateral Planation and Unequal Erosion Hypotheses

C.H. Crickmay recognized many of the unsolved problems geomorphologists have attempted to explain, such as planation surfaces. He pointed out that any kind of mass wasting roughens a surface and precipitation tends to form rills and coulees on flat land rather than preserve the flat surface.[34] He acknowledged the difficulty of using present processes to explain flat surfaces, especially since the unobserved erosional process planed both hard and soft surfaces equally. In fact, flat surfaces are not being formed today.[35] Crickmay realized that only *water* produces flat land.[36] He summarized his many, sometimes controversial, ideas in the book *The Work of the River*[34] Just the name of the book alone shows that Crickmay understood that water shaped the scenery of the continents (I agree with him), and as a uniformitarian scientists, the water was supplied by rivers (I do not agree). Crickmay developed two hypotheses for explaining flat land: (1) lateral planation by rivers and (2) unequal erosion.[12,34]

The Hypotheses

His first hypothesis, lateral planation, was developed early in the 1930s and states flat land was caused by lateral stream erosion.[37] Assuming sufficient crustal stability, rivers would cut floodplains (erosion surfaces carpeted with a veneer of alluvium) near sea level. The floodplains would then be enlarged by lateral or sideways erosion by the river. After millions of years, floodplains merge and would form one large planation surface separated by interfluves called monadnocks. Crickmay called this a *panplain*. Renewed uplift would cause the process to begin anew, with the former panplain left at a higher altitude as an erosional remnant. This hypothesis is not very different from the others. It differs mainly in the process of erosion by lateral erosion by rivers and not so much by slope processes.

This first hypothesis leads to his second hypothesis, because once a panplain is elevated and isolated, it needs to remain for millions of years with little modification. So the planation surfaces experience little erosion, while great erosion is concentrated near river and stream channels. Crickmay's "hypothesis of unequal activity or unequal erosion" was born. His deduction was based partly on the work of Eleanora Knopf ,[38] who noticed that high level "peneplains" and wind gaps in the Appalachian Mountains have been unaffected by wasting and erosion for millions of years.[39] In fact, Crickmay noted numerous examples of structures that could not exist for very long but boldly dot the landscape. Like other uniformitarians, Crickmay could not conceive that the features were well preserved because they are very young. His irascible personality and writing style kept his ideas from receiving the attention they deserved.[40] Yet, some geomorphologists still advocate Crickmay's two ideas.[40,41,42]

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[34] Crickmay, C.H., 1974. *The Work of the River: A Critical Study of the Central Aspects of Geomorphology*, American Elsevier Publishing Co., New York, NY.

[35] Crickmay, Ref. 34, p. 140.

[36] Crickmay, Ref. 34, p. 217.

[37] Crickmay, C.H., 1933. The later stages of the cycle of erosion: some weaknesses in the theory of the cycle of erosion. *Geological Magazine* 70:337–347.

[38] Knopf, E.B., 1924. Correlation of residual erosion surfaces in the eastern Appalachian highlands. *GSA Bulletin* 35:633–668.

[39] Crickmay, Ref. 37, p. 343.

[40] Twidale, C.R., 1993. C.H. Crickmay, a Canadian rebel. *Geomorphology* 6:357–372

[41] Twidale, C.R., 1998. Antiquity of landforms: an 'extremely unlikely' concept vindicated. *Australian Journal of Earth Sciences* 45:662–663.

[42] Osborn, G. and C. du Toit, 1991. Lateral planation of rivers as a geomorphic agent. *Geomorphology* 4:249–260.

Problems with the Hypotheses

Like its peers, his panplain hypothesis has a number of serious problems. First, present-day features that can be attributed to lateral erosion, such as river terraces and floodplains, are not of any significant extent.[43,44,45] Crickmay himself confessed that his eroded floodplains near sea level would be quite small.[46] His answer to this obvious difficulty is that modern continents have been recently and abnormally disturbed, especially by vertical tectonics.

Second, no large panplain is observed forming today, and so the hypothesis lacks any firm empirical evidence.[40,47] Instead, it is as *deductive* as Davis' geographical cycle because Crickmay based his hypothesis simply on his *observations* of planation surfaces and inselbergs that should not grace the landscape after millions of years of denudation. He simply concluded that weathering and wasting were extremely slow and that only rivers eroded to any appreciable degree, without providing evidence for why erosion is so slow. As a result, his hypothesis is not so much a mechanism as an attempt to explain the observations of awkward features such as planation surfaces. It is similar to the biological evolutionary hypothesis of "punctuated equilibrium," which is simply a deduction based on the observation of small gaps in the fossil record rather than a demonstrated mechanism.

Of course, there is some truth to Crickmay's hypothesis of unequal activity. Areas near rivers should erode faster than dry uplands, but it is doubtful that it can account for the million-to-one difference in erosion (the rivers erode a million times faster than the flat surfaces) that he has postulated for a thinly gravel-capped plateau in South Africa and its adjacent lowlands.[48] Such "unequal erosion" is the basis behind the claims of spectacular inversion of relief over millions of years.

Relief inversion is the hypothetical idea that a valley carpeted with stream alluvium will erode little over millions of years while side ridges erode away below the altitude of the stream making the stream valley the new ridge (see Figure 15.2). Relief inversion is often invoked to explain old, barely-eroded planation surfaces and other geomorphic features that form the higher elevations of an area. Crickmay, a brilliant scientist,[49] saw the serious problems of explaining the features of the earth's surface better than anyone else. However, his solution, although better than many others, has problems of its own. Twidale summarized:

> Crickmay's ideas on lateral planation and unequal activity do not offer a panacaea for geomorphological ills, but both are useful in the interpretation of many landscapes."[50]

Table A19.4 summarizes the problems with Crickmay's two hypotheses for the formation of planation surfaces.

1. Lateral erosion observed to produce small floodplains or terraces
2. No large panplain observed today
3. Deductive and simply based on existence of "old" planation surfaces
4. Cannot account for extreme differences in erosion.

Table A19.4. Problems with Crickmay's two hypotheses.

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43 Small, Ref. 6, p. 165.
44 Ollier, Ref. 31, p. 148.
45 Osborn and du Toit, Ref. 42, p. 259.
46 Crickmay, Ref. 37, p. 345.
47 Ollier, Ref. 31, p. 148.
48 Crickmay, Ref. 12, pp. 108–109.
49 Twidale, Ref. 40, p. 358.
50 Twidale, Ref. 40, p. 367.