Chapter 81

Superimposed Stream Hypothesis—An Act of Desperation

Geologists have commonly switched to the superimposed (sometimes referred to as *superposed*) stream hypothesis after rejecting the antecedent stream hypothesis. (A stream here also refers to a river.) Does this second hypothesis fare any better?

What Is the Superimposed Stream Hypothesis?

A superimposed stream or river is defined as: "A stream that was established on a new surface and that maintained its course despite different lithologies and structures encountered as it eroded downward into the underlying rocks."[1] In this hypothesis, a landscape is buried by renewed sedimentation, usually by a marine transgression. Then the area uplifts and a stream or river is established on the generally flat cover of sediments or sedimentary rocks, called the "covermass." The top of the covermass is sometimes a planation surface. As erosion takes place over millions of years, the stream erodes downward *in the same location* (Figure 81.1). So, after millions of years the stream ends up flowing through structural barriers.

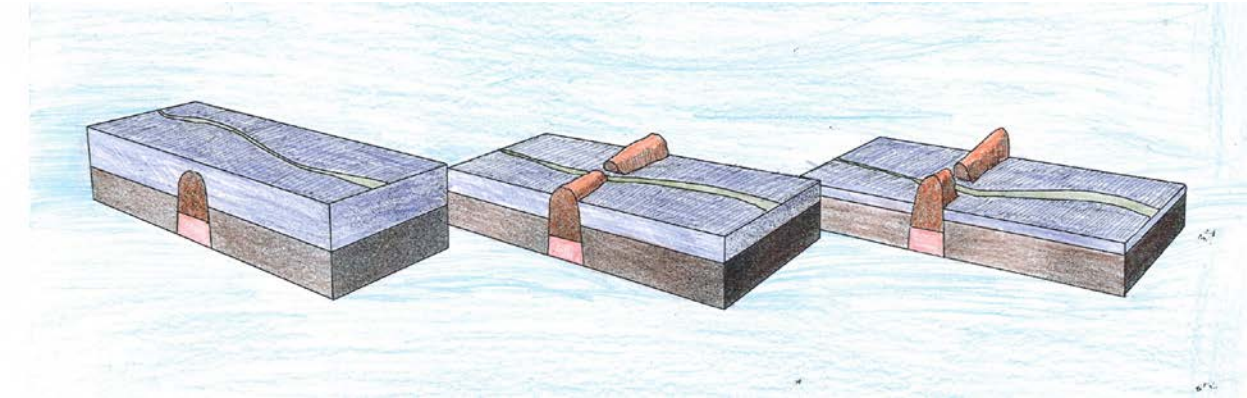

Figure 81.1 Block diagram of the superimposed stream hypothesis. The stream maintains its course as most of the covermass (top layer) is eroded (drawn by Bryan Miller).

At the same time, the rest of the cover mass is eroded or mostly eroded in areas far from the stream, leaving behind the stream or river flowing through ridges or mountains. Apparently, a geomorphologist will default to this hypothesis based on the discovery of *any* remnant of what he thinks is the covermass or even indirect evidence that the covermass once existed.[2] Erosional remnants of eroded sedimentary rock can usually be found in mountains, so a covermass can easily be claimed.

Since the antecedent stream hypothesis was usually the hypothesis rejected, this switch at least shows how weak the antecedent stream hypothesis was all along, as discussed in the

[1] Neuendorf, K.K.E., J.P. Mehl, Jr., and J.A. Jackson, 2005. *Glossary of Geology*, Fifth Edition. American Geological Institute, Alexandria, VA, p. 645.
[2] Twidale, C.R., 2004. River patterns and their meaning. *Earth-Science Reviews* 67:194.

previous chapter. So, the superimposed stream hypothesis seems to be favored for explaining the many examples of anomalous drainage.[3]

The Classic Appalachian Mountains Explanation

Discordant drainage in the Appalachian Mountains (see Chapter 77) was first attributed to antecedent streams, as one might expect since it was the first hypothesis proposed.[4] However, superimposition is now favored, partly because the ridges are believed to define a planation surface.[5] The planation surface is generally level, and rivers flowing on this surface were assumed to have cut down into older deformed sedimentary rocks. The idea is applied mainly to large rivers; smaller streams are generally congruent with the geological structure, in other words the tributaries mostly flow down tributary valleys. Ollier noted that the major rivers were attributed to superimposition while their tributaries usually were not:

> Classic examples of superimposed drainage are found in the Appalachian Mountains. Accordant levels of ridge tops show that the folded Palaeozoic strata were planated, and major rivers such as the Susquehana [sic] originally flowed across this plain regardless of structure. They have later been incised and now flow through superimposed gorges, but tributaries are strongly structurally controlled.[6]

However, even some tributaries also cut through barriers in the Appalachian Mountains (see Chapter 77).Logically, the water flowing through tributaries would be too weak to carve downward through the covermass.

Von Engeln believed that the remarkably aligned water gaps of the Appalachian Mountains are good evidence for superimposition, since it is difficult to conceive of aligned water gaps being caused by antecedence or stream piracy (see the next chapter).[4] (A better explanation for aligned water gaps will be given Part XVIII.) Strahler saw two possibilities for Appalachian transverse drainage: superimposition and fault control.[7] He left no room for stream piracy, and claimed that wind gaps are evidence of superimposition. Fault control has already been eliminated for practically all Appalachian water and wind gaps.[8] Superimpostion seems to have been accepted mainly because of difficulties with other hypotheses, rather than because of strong positive evidence.

The hypothesis proposes the Appalachian covermass developed after uplift and deformation. The mountains sank again during the Cretaceous period of geological time and were subsequently covered by sedimentary rocks from a marine transgression. Upon renewed uplift, rivers formed on the horizontal top of the sedimentary rocks, and over millions of years eroded downward without deviation, eventually cutting through barriers and creating water gaps.

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[3] Small, R.J., 1978. *The Study of Landforms: A Textbook of Geomorphology*, second edition, Cambridge University Press, London, U.K., pp. 238-247.
[4] Von Engeln, O.D., 1942. *Geomorphology: Systematic and Regional*, Macmillan, New York, NY.
[5] Short, N.M. and R.W. Blair, Jr. (editors), 1986. *Geomorphology from Space: A Global Overview of Regional Landforms*, NASA, Washington, D.C., p. 56.
[6] Ollier, C., 1991. *Ancient Landforms*, Belhaven Press, New York, NY, p. 33.
[7] Strahler, A.N., 1945. Hypotheses of stream development in the folded Appalachians of Pennsylvania. *GSA Bulletin* 56:45-88.
[8] Clark, G.M., 1989. Central and southern Appalachian water and wind gap origins: review and new data. *Geomorphology* 2:209-232.

Unfortunately, there is *no* evidence for the proposed transgression and the great volume of "covermass."[9] Furthermore, why wouldn't the stream change course to flow on the presumably softer covermass rather than through hard-rock anticlines? As with the antecedent stream hypothesis, the superimposition idea suffers from a lack of evidence. Mills and others summarized:

> As for superposition from an unconformable cover mass, there is no evidence of such a cover, and unlike in the ancient Appalachians, it is much more difficult to claim that the cover mass has been removed by erosion.[10]

Ollier also admitted there is no evidence for the Appalachian covermass:

> The age of the old planation is controversial, as is the former existence of a Cretaceous cover. The lack of any remnants of a Cretaceous cover makes the idea questionable.[6]

Because of the lack of a covermass, Epstein rejected regional superimposition while accepting "local" superimposition.[11]

Some authors claim that the Appalachian rivers first became established on a "planation surface," but a covermass is a depositional surface not a planation surface, unless they believe the covermass consolidated and was planed off by water, somehow.

Southern England Examples

Superimposition has been used to explain the discordant drainage in Wales.[12] That interpretation is more an *inference* or interpretation, because it assumes the presence of a Cretaceous chalk deposit laid down during a marine transgression and subsequently eroded. Chalk covers much of southeast England (Figure 81.2). Therefore, it is simply assumed that the streams were first superimposed on a level chalk surface. Geologists infer a widespread chalk substrate from erosional remnants. At least in this case, there is a remnant of the "covermass," unlike the Appalachians.

However, these remnants do not necessarily mean that the strata were either continuous or horizontal when first deposited, even though both are commonly assumed. Nor does it mean that streams followed the same course for millions of years, eroding both chalk and then causing water gaps through more resistant rock. There actually is no evidence for the superimposition of the Wales drainage. R.J. Small, although believing in the mechanism, nevertheless admitted: "However, superimposition from a Chalk cover is not the only available explanation of such discordances between streams and structures."[13]

Southeast England also has been considered a classic case of superimposition for the water gaps located there, but this interpretation is also easily questioned.[14]

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[9] Mills, H.H., G.R. Brakenridge, R.B. Jacobson, W.L. Newell, M.J. Pavich, and J.S. Pomeroy, 1987. Appalachian mountains and plateaus, In, Graf, W.L. (editor), *Geomorphic Systems of North America*, Geological Society of America Centennial Special Volume 2, Boulder, CO, p. 13.

[10] Mills *et al*., Ref. 9, p. 14.

[11] Epstein, J.B., 1966. Structural control of wind gaps and water gaps and of stream capture in the Stroudsburg area, Pennsylvania and New Jersey. *U.S. Geological Survey Professional Paper 550-B*, Washington, D.C.

[12] Small, R.J., 1978. *The Study of Landforms: A Textbook of Geomorphology*, second edition, Cambridge University Press, London, U.K., pp. 243-247.

[13] Small, Ref. 12, p. 247.

[14] Chorley, R.J., S.A. Schumm, and D.E. Sugden, 1984. *Geomorphology*, Methuen, London, U.K., p. 21.

Figure 81.2. White Cliffs of Dover, southeast England (Wikipedia).

Little or No Evidence for Superimposition

Besides the problems mentioned in the two examples above, other questions remain on the validity of this hypothesis.

Mabbutt rejected both the antecedent and superimposition hypotheses for the water gaps through the Macdonnell Ranges of central Australia[15] After ruling out stream piracy and structural weaknesses, he concluded the transverse drainage was "inherited" directly from an erosion surface but without superimposition because the main water gaps are aligned. This explanation currently is not even considered as one of the hypotheses for the origin of the water gaps. Regardless, he eliminates all the other suggested hypotheses.

Although geologists at first believed that the Rocky Mountain water gaps were formed by antecedent streams, later most embraced the superimposed stream hypothesis. But Hunt was still skeptical because the valley fill would have to be up to the tops of the mountains:

> However, the stream courses across the various ranges in the Rocky Mountains probably are not superimposed. Too much fill would have been required to bury the several mountain ranges, and too much erosion would have been required to remove that fill.[16]

One of the main problems with the superimposition hypothesis is the river must maintain the *same* course and downcut into both resistant and non-resistant formations, while its tributaries, along with mass wasting, erode the *remainder of the covermass.*[17] C.H. Crickmay was skeptical of the entire process, since erosion would be weak away from rivers and streams:

> Superimposition, on the other hand, demands two distinct requirements: the stream must maintain, by down-cutting, a course across a resistant formation into which, along with all the other formations, it is incising itself; at the same time, it must swing to-and-fro across *all the remainder of the country* (all its tributaries, presumably, doing the same) both upstream and down from the resistant zone, and must remove enough of the less resistant material to make the more resistant stand out in relief … For some reason not

[15] Mabbutt, J.A., 1966. Landforms of the Western Macdonnell Ranges. In, Dury, G.H. (editor), *Essays in Geomorphology*, Heinemann, London, U.K., pp. 112-114.
[16] Hunt, C.B., 1967. *Physiography of the United States*, W.H. Freeman and Company, San Francisco, CA, p. 272.
[17] Douglass, J. and M. Schmeeckle, 2007. Analogue modeling of transverse drainage mechanisms. *Geomorphology* 84:40–41.

> too evident, no textbook has gone far enough in its thinking on superimposition to touch on this requirement, much less, to conceive of a mode of meeting it (emphasis his).[18]

Since there is scant or no evidence of superimposition it leaves the idea without validation:

> Although a plausible mechanism, superimposition is extremely difficult to verify except in the case of very young orogens [uplifted linear, folded, and deformed mountain belts] where vestiges of the original sedimentary cover remain. In ancient mountain belts, denudation will have removed all the evidence of any pre-existing sedimentary cover.[19]

Even if a remnant of a sedimentary formation that would qualify as a patch of covermass, it still has to be demonstrated that the strata were once continuous and horizontal, and that erosion occurred while the major streams remained locked in place. Since most of the strata have been eroded, it is in fact an argument from a lack of evidence—typically one of the weakest types. Table 81.1 summarizes the evidence against the hypothesis.

1. Lack of evidence for a transgression of the sea and/or a covermass
2. Most, if not all, covermass eroded from area while rivers concentrate erosion linearly
3. Usually no evidence
4. Erosional remnants do not prove a covermass
5. In some cases, the covermass volume is huge and erosion must be great
6. Change in geological structure or lithology does not deflect the stream
7. Stream must maintain the same course even after softer valley rocks eroded

Table 81.1. Problems with the superimposed stream hypothesis.

[18] 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. 155.
[19] Summerfield, M.A. 1991. *Global Geomorphology,* Longman Scientific & Technical, New York, NY, p. 411.