A Little Flood Geology

Part V: Conclusion

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Abstract

Part I argued that floods are an important category of geologic processes and showed that hydraulic relationships are nonlinear, resulting in episodic rather than continual geologic change. Part II presented field examples from central Montana in 2011. Part III used information from the central Montana projects to show that geologic processes range from slow and localized to episodic and regional (even unique and global). Geologic paradigms can negatively impact field work for both uniformitarians and diluvialists. These negative effects can be avoided by the "mixed question" approach and "multiple working hypotheses." In Part IV, limitations of extrapolating from local floods to megafloods and from scientific observation to natural history speculation were discussed. Here, evidence is summarized to highlight some important principles to guide geologic research.

Key Words: Flood geology, sedimentation, fluid mechanics, megaflood, scale effects, scientific method, fractal, polygenetic, creep

Summary

Floods are the largest category of natural disasters in the modern environment and an important category of geologic processes (Klevberg, 2019). Flood geology often forms an interface between physics (fluid mechanics), geology (sedimentation), and history (historical geology). How these three areas relate is part of the philosophy of science.

Fluid Mechanics

Flood geology is a specialty within the study of sedimentation and fluid mechanics. Due to the importance of floods in the modern environment, they have been much studied. From both laboratory and field studies, we know that relationships between independent variables and stream behavior are nonlinear. Critical stream power (ω_c) is the point at which the critical bed shear stress is reached to initiate movement of bed load. Below ω_c, bed load transport is negligible. Head loss (dissipation of kinetic energy) results from obstacles in the stream bed and channel configuration, and alluvial channels tend to alter their configuration to minimize this loss. Most streams exhibit unsteady, nonuniform flow, but modeling requires approximating this with steady, uniform assumptions, along with reducing a plethora of variables in the natural environment to a manageable number. Thus, model outputs for scour and other hydraulic processes are conservative, and yet they

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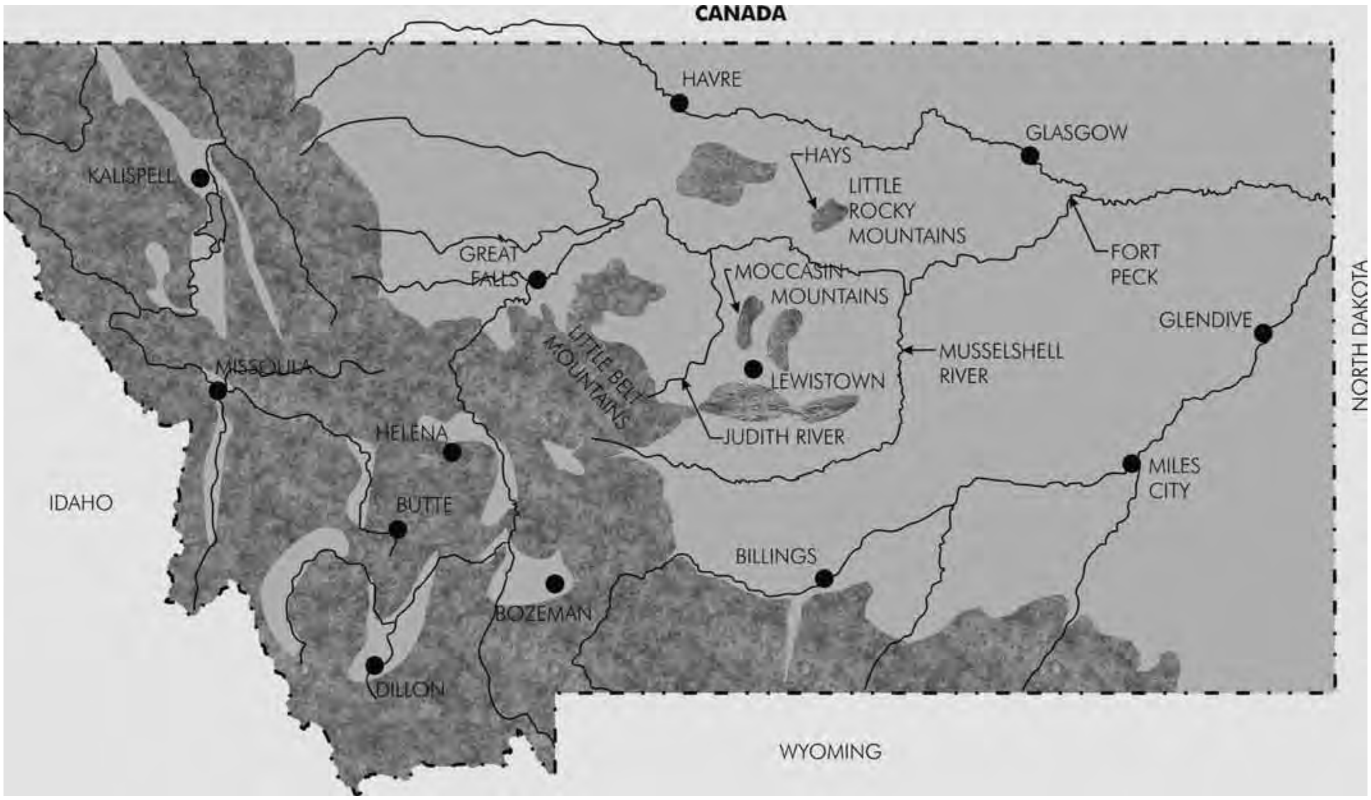

Figure 1. Map of Montana showing major rivers and mountainous areas.

still sometimes undershoot actual observations (Klevberg, 2020a). Laboratory experimentation focuses on sand beds, though gravel may vary greatly from sand bed behavior and show a wide range of responses. Bedrock may also be rapidly eroded as seen at Fort Peck in 2011 and as documented elsewhere.

Sedimentation

Flood *geology* focuses on geologic effects specific to floods—physical weathering, transport, and deposition (sedimentation)—that today are usually confined to rivers. While some studies focus on the architecture of alluvial deposits, most concentrate on erosion since it most threatens man-made structures (McKee et al., 1967; Berthault, 1986; Holroyd, 1990; Froede, 2008a, 2008b).

The term "Flood geology" among creationists is ill-defined. Some use it to refer to the geologic paradigm based on the Biblical historical record and the Deluge. In that sense, it encompasses a great many processes that have nothing to do with flood geology. The idea that every geologic process ceased at the end of the Deluge is a straw man that evolutionists have brandished based on the popularity of this jargon. No creation scientist believes every geologic phenomenon has a diluvial origin. Small-scale processes are in effect today, including those described in this series (Klevberg 2019, 2020a, 2020b).

Historical Geology

Klevberg (2020b) presented cases from Central Montana (Figure 1) showing that geologic processes range from slow and localized to episodic and regional. Geologic *paradigms* can have negative effects on field work, for both uniformitarians and diluvialists. These negative effects can be avoided by using the "mixed question" approach and "multiple working hypotheses."

Slow and stochastic processes characterize small-scale, recent features, especially ongoing processes. Geologic evidence from Montana suggests that both ongoing processes and geologic changes of the past are episodic and unique, not uniform and gradual. Modern processes are far smaller than those that shaped the Central Montana landscape, and in the cases of planation surfaces (benches), they were different in type, not just scale. Scale does differ, however, often by orders of magnitude. Ancient events formed landscapes; modern processes are destroying them.

Klevberg (2021) showed scale changes from local floods to megafloods, and how they might affect extrapolation from scientific observation to natural history speculation. Evidence for megafloods is widely acknowledged by evolutionists and creationists, but this was not always so (Oard, 2004). The first step was acknowledging evidence of a significant *scale* difference. Alluvial bedforms were observed at landform scale, suggesting similar depositional processes at much larger scales. Back calculating from relict channels, paleoslopes, and deposits to infer minimum current flows and depths—known as *paleohydrology*—provides powerful evidence for the reality of megafloods in the past (Klevberg and Oard, 1998). As a discipline, paleohydrology has contributed significantly to flood geology. Field evidence shows a greater diversity of landforms from megafloods (Figure 2), indicating that larger floods are more complex (Benito, 1997). Further complicating the topic, some landforms can be formed by multiple distinct processes, a condition known as *equifinality* (Figure 3).

Historical geology is forensic, not descriptive, and thus primarily an exercise in historical study. The more the science of geology can contribute to natural history, the better. A good understanding of the limitations of science and the scientific method is needed for progress in historical geology.

Practical Philosophy of Science

One's philosophic position on Earth's history has practical consequences. Geology has been more afflicted with confusion on this than most branches of science. Science and natural history have been traditionally conflated, and this affects flood geology. The Corps of Engineers method for predicting flood intervals accepts uniformitarian geology without question. Flood deposits in a particular valley may be dated at tens

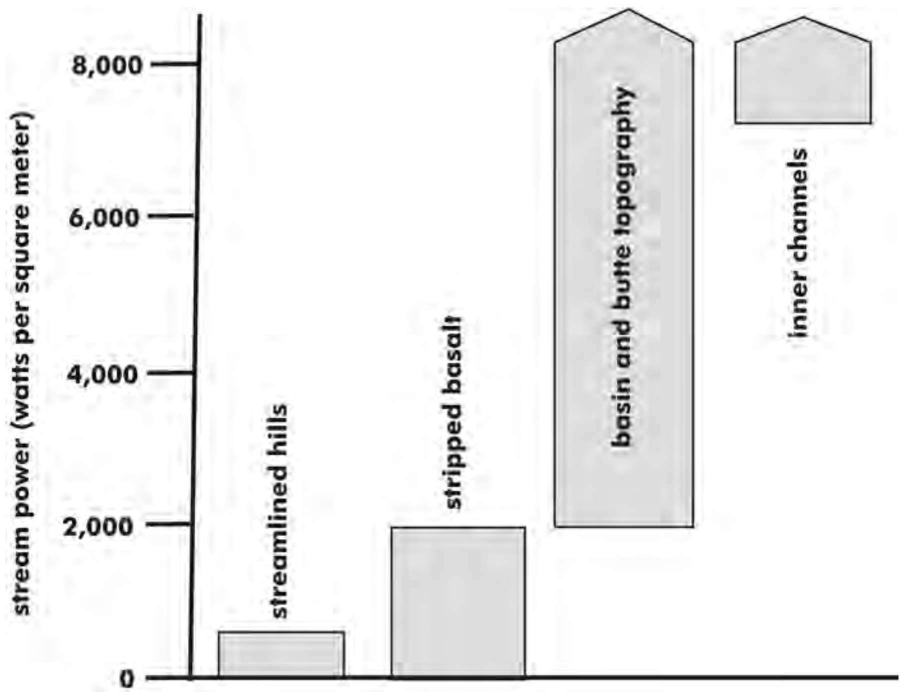

Figure 2. Relation between stream power and landform type. After Benito (1997).

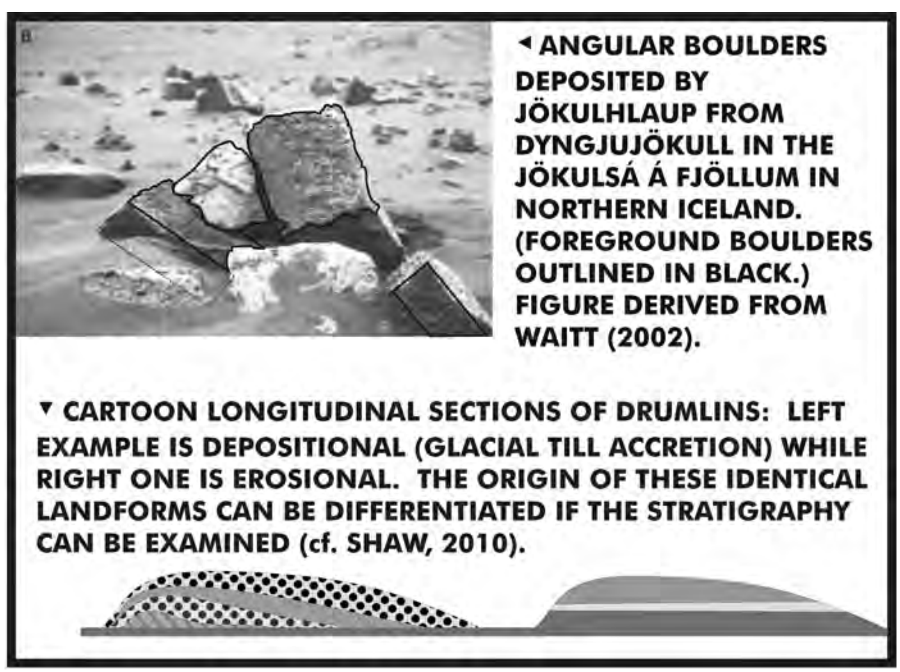

Figure 3. Two examples of equifinality. Upper: angular boulders, commonly associated with glacial transport were here transported by a large flood. Lower: schematic of drumlins formed by glacial deposition (left) and by erosion (right), resulting in identical external form but different internal structure.

to hundreds of thousands of years, leading to a recurrence interval of, say, five thousand years for a catastrophic flood. If the actual dates of those deposits are only a few thousand years, the recurrence interval could be much less and the danger of flooding much greater. Uniformitarianism underlies belief that these floods recur at regular intervals. But if field evidence for huge floods indicates deglaciation, there may be no practical present danger. These are questions of *history*. If they were questions of science, we could go to the field and measure. Assumptions underlie all our estimates, and ideas have consequences.

Historical geology was hamstrung for centuries by insistence it was science instead of history (Rudwick, 2005) or a "mixed question" (Adler, 1965). Traditional education confuses rather than elucidates mixed questions, a carryover from the positivist past (Reed and Klevberg, 2011; Reed, 2013). Descriptive and speculative geology are conflated, and both are equally "science." The solution is more carefully defining "science" (Figure 4) and more practical use of multiple working hypotheses (Chamberlin, 1890).

Many have concluded there is no *scientific method* per se (see, for example, in D'Amico, 2009), since in actual practice, the scientific method is necessarily iterative, not a cut-and-dried series of steps (Figure 4). While science and history are both valuable and distinct fields of study, they have different limitations and require different methodologies, working together in addressing "mixed questions" in a complementary fashion. This approach is superior to the traditional effort to subsume all disciplines into "science" (Adler, 1965; Reed, 2001; Cleland, 2009; Kravitz, 2013; Reed and Klevberg, 2018).

Everyone sees inescapably through a worldview (Chisham, 2012, 2014, 2015, 2018). This needs to be acknowledged as the deductive part of the methodology (Figure 4), and biasing assumptions identified. If acknowledged, researchers with views as disparate as evolution and creation could work effectively together. What can be observed, measured, and tested—the science—is available to all.

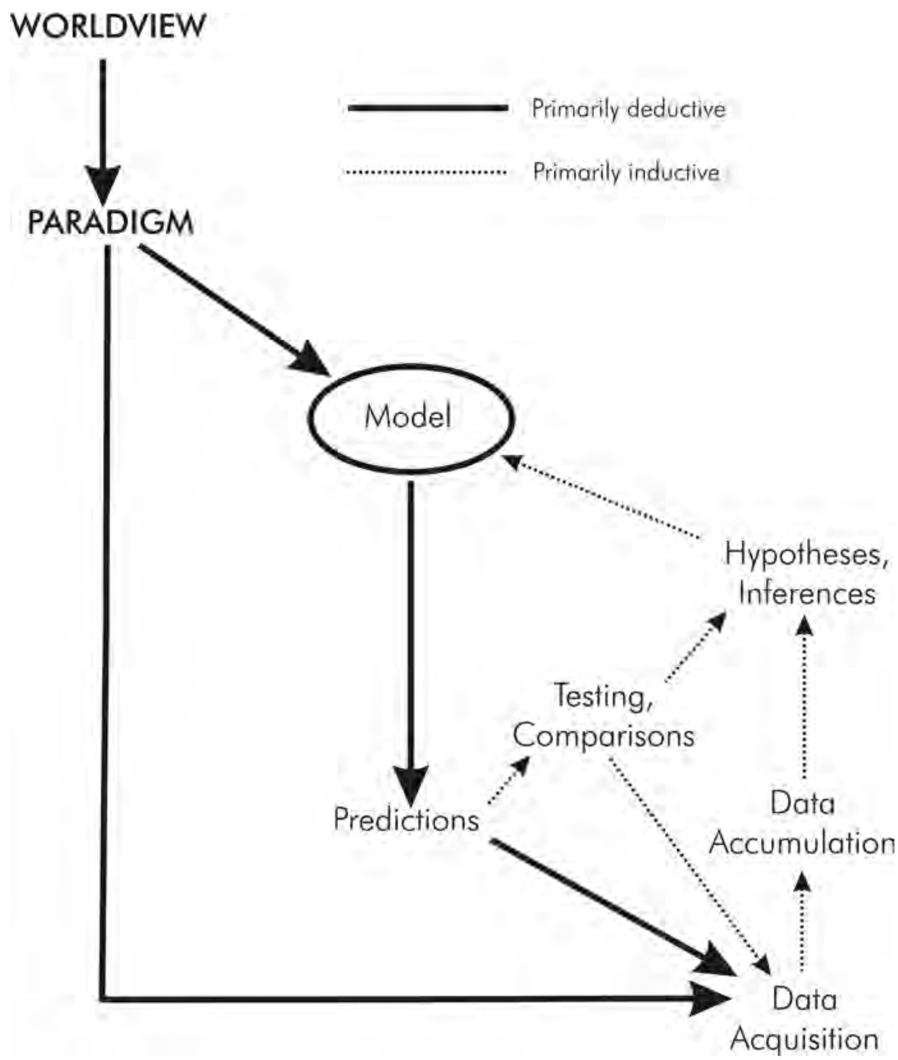

Figure 4. The scientific method is not a step-by-step method, but rather an interaction of deductive and inductive reasoning. Some of these steps are based in worldview assumptions. Bias is inevitable and should be identified. For example, data acquisition (lower right) can be very subjective. Woodmorappe (2018, p. 661), writing about the lack of disturbance research in dendrochronology, said, "This is not surprising, as research in general tends to be paradigm-driven, and nothing in uniformitarianism prompts curiosity in such crossmatches." Figure adapted from Klevberg (1999).

Many problems in geology arise from philosophic biases and this misunderstanding of the scientific method. This stems from a variety of causes:

- Conflation of natural science with other disciplines in traditional education.
- Not recognizing the faith basis of materialism (naturalism).

Table I. Qualitative comparison of various types of floods.

Mechanism	Characteristics			
	Geometry	Duration	Energy	Common Instigators
River flood	channel	prolonged	diffuse	rainfall, snowmelt, ice damming
Storm surge	sheet	prolonged	diffuse	hurricane
Flash flood	channel	brief	focused	rainstorm, dam collapse
Tsunami	sheet	brief	diffuse	subsea earthquake, landslide

- Not understanding that inductive *and* deductive logic play roles.
- Denial of bias.
- Commitment to uniformitarianism *against* evidence (e.g., climate change).
- Commitment to actualism *against* evidence (i.e., denial of unique past processes).
- Specialists who do not understand "big picture" topics—philosophy of science and natural history.

Furthering Research

Natural stream courses are complex. The easiest way to quantify hydraulic variables is laboratory experimentation. But there are significant limits. Flumes are largely limited to sand. To increase the scale to that of a boulder-bedded river would require a river-sized flume! Boulders behave differently from sand. Thus, actual floods are essential to research.

Can modern floods bridge the gap between the laboratory and megafloods? A major problem is the increasing diversity of effects moving up scale, from the laboratory to a river. We would expect even more diversification from a river flood to a megaflood.

Flash floods provide higher stream power but less time and scale. Hydraulic disasters are likewise unpredictable. No one could predict or set up instruments to study man-caused disasters, such as the infamous Malpasset Dam disaster in France (Ricketts, 2012) or the failure of the Vajont Dam in Italy, where a wall of water descending the valley began as a landslide-caused tsunami that overtopped the dam (a case study from my college days).

Natural disasters are also difficult to study. Tsunamis, hurricanes, and other large storms often result in such large-scale destruction; studying them is difficult. The American Society of Civil Engineers (ASCE) created a task force to rapidly deploy and study effects from these events. Sometimes important data may be lost within days. A good example of the ASCE approach to flood geology is the initial report for Hurricane Harvey (Stark et al., 2017). As summarized in Table I, relationships between storm surges, river floods, tsunamis, and flash floods need to be explored and quantitative relationships discovered to accurately infer megaflood processes where some of these properties are combined (Figure 5). Flood geologists are increasingly able to obtain quantitative data.

As illustrated by poor scour estimates in this series, understanding of flood geologic work is far from comprehensive. Amassing more data from floods is necessary, especially larger floods. Rapid data collection, such as attempted by ASCE after Hurricane Harvey, is important. Hurricanes may also provide opportunity to study the interface between traditional flood geology (i.e., rivers) and marine geology, possibly granting insights into the differences between "ordinary" floods and megafloods. It is possible that a fractal relationship will be discovered in these recent deposits as it has been in recent studies of larger scale

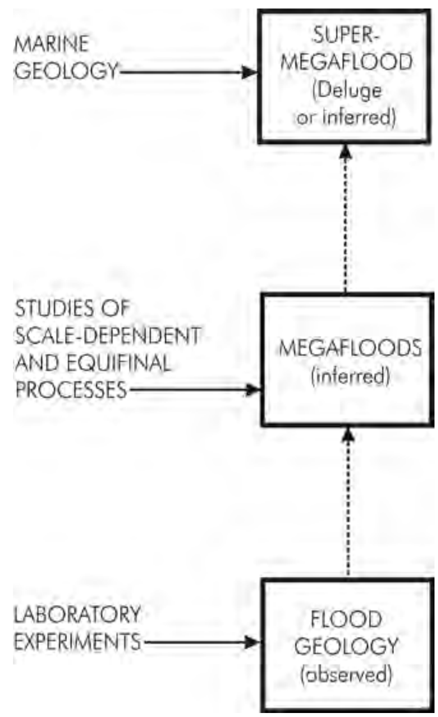

Figure 5. A logical hierarchy exists by which the observations of flood geology can be used to build an understanding of the constraints on probable diluvial processes. This is largely a "bottom up" or inductive process.

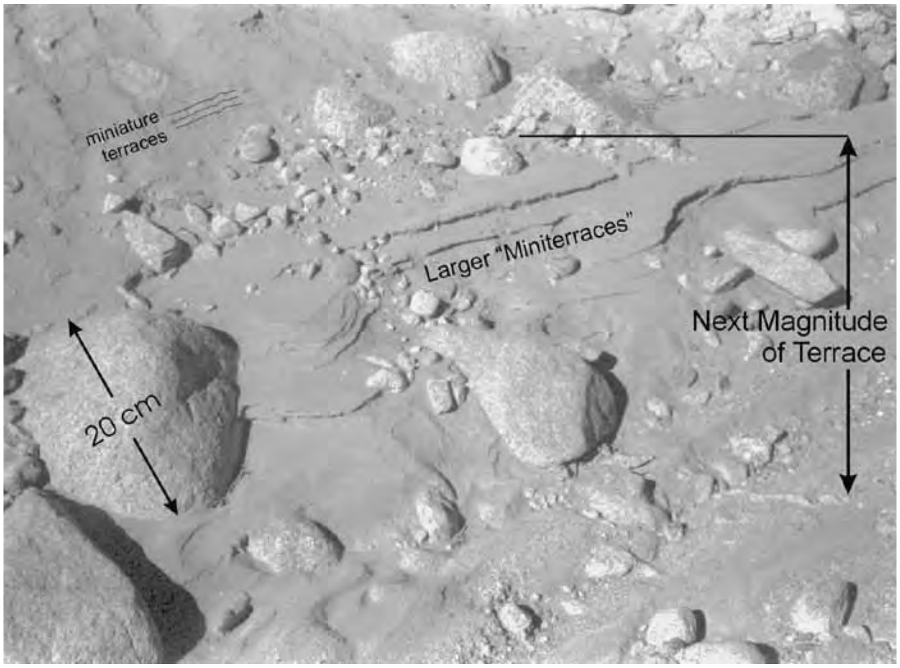

Figure 6. Large terraces have smaller terraces affixed upon their edges. Increasing numbers of geologic phenomena are being recognized as fractal.

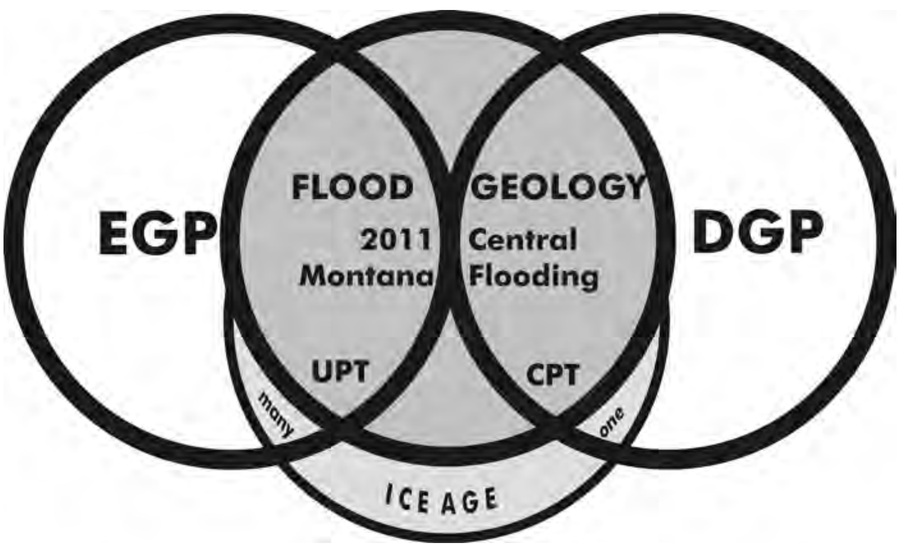

Figure 7. Venn diagram illustrating areas of agreement and disagreement between diluvialists (DGP) and evolutionists/uniformitarians (EGP). Many creationists believe in plate tectonics but hold to a catastrophic version (CPT), while believers in a 4.5-billion-year Earth history hold to the standard uniformitarian version (UPT). Agreement and disagreement are similarly distributed relative to continental glaciation (ice age). Other geologic and Earth history questions could be similarly displayed.

stratigraphy (Neal and Abreu, 2009; Bailey and Smith, 2010). The stratigraphic result must have had a paleocurrent cause (Figure 6). The more knowledge of flood geology increases, the better we can temper predictions and the greater the possibility of unraveling clues in the rock record.

Agreement and Disagreement

Flood geology as science is an area of agreement between evolutionists and creationists; it is in natural history that the viewpoints are opposed (Figure 7). Studying observed floods generally does not undermine either creationist or uniformitarian confidence in their respective views of the overall history of the Earth. The same is true of continental glaciation, though creationists propose a single ice age lasting a few centuries, while evolutionists believe in many ice ages. Evolutionists long downplayed catastrophic events, such as megafloods, but since evidence is now overwhelming, they make them cyclical and thus "normal" and "uniform" and "actualistic." This has often impeded science (Figures 8 and 9). Uniformitarians have been hamstrung in geologic research for generations due to their faith in philosophically untenable and scientifically discredited assumptions. While diluvialists have the advantage of a constraint on their speculations from taking the written Biblical historical account seriously, natural history speculations are still natural history speculations.

A commitment to pure uniformitarianism or pure catastrophism is today untenable. With a proper understanding of the scientific method and commitment to the values that undergird it, there is no reason researchers with conflicting worldviews cannot cooperate effectively in research, even those researchers whose worldviews do not provide adequate philosophic support (coherence and correspondence) for the scientific method.

Figure 8. Judith River in Central Montana from west end of Central Montana Rail trestle. Meander migrated down valley (right to left) and abandoned former channel (midground) during 2011 flood. New channel is at east (distal) side of flood plain. Note channel forms in floodplain gravels that might suggest a long period of meander migration with each curved form representing a distinct flood, but this was not the case.

Conclusions

We have learned much about floods and their geologic work. Knowledge gained from observation of floods and geologic processes has significance for geologic paradigms that guide research and data interpretation. While this series focused on specific Central Montana projects, these conclusions apply to other geologic contexts and should be put to the test wherever possible.

Hydrology

1. Most geologic work by rivers occurs during infrequent floods, contrary to the traditional uniformitarian idea that small changes over extended time produce geologic features seen today. This results from hydraulic relationships:
    - Velocity, and thus stream power, is proportional to flow depth and bed slope; thus, the stream power equation is nonlinear.
    - Head loss, determined by bed shear stress, is partly proportional to the square in the loss of current speed down the reach, resulting in a nonlinear function with considerably more geologic effect as current energy dissipation increases.
    - Since stream power must exceed the bed shear stress threshold before significant erosion commences, flow below that threshold results in very little erosion.
    - The rate of erosion is a nonlinear function of the surplus of stream power above the critical stream power (ω_c).
2. Alluvial channels tend toward a minimal energy loss state. This requires geologic work to reduce dissipative losses from channel constrictions and obstructions.
3. The assumption of steady flow is usually appropriate when the peak flow is of interest. The assumption of uniform flow can be more problematic, especially at larger scales.
4. Estimation of scour depth is complex, and observed scour depths sometimes exceed predictions. Scour depths may significantly exceed water depth, as seen on the Judith River in 2011.
5. Most geologic modeling is based on analogues with only limited ability to maintain controlled conditions and model using dimensionless parameters (e.g., flume experiments). "Ordinary" floods must be *extrapolated* to megaflood scale. Extrapolation is only valid if *scale* does not affect the process.
6. Extrapolating from flume-scale, controlled conditions to rivers is useful but incomplete, since "real world" conditions are more complex. This is illustrated by difficulties in accurately predicting scour.
7. Ground and surface waters often interact, and geologic changes caused by floods can induce sudden changes in ground water systems.

Geology

8. Geologic changes before and after the 2011 floods were "ordinary" effects in both type and scale but provided a good baseline for work during floods.
9. As witnessed in Kootenai and Telegraph Creek Formation claystone and shale strata, ground water can influence strata high in montmorillinite and other smectite physils via lubrication, crystal entrapment, and pore pressure increases to mobilize movement on very low angle faults or creep planes.

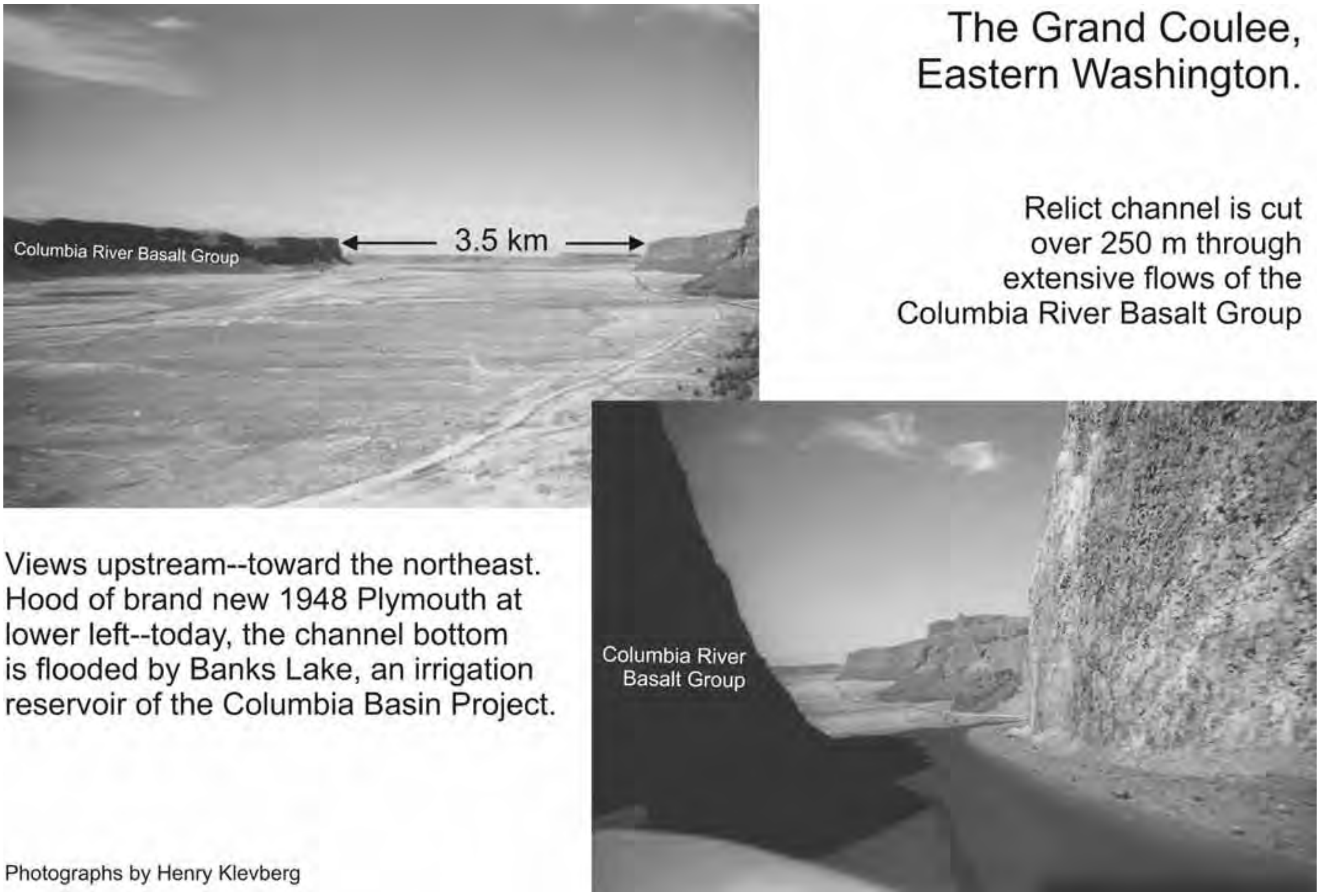

Figure 9. Grand Coulee in Eastern Washington in 1948 prior to filling of the bottom with Banks Lake reservoir. Grand Coulee is a large relict channel, part of the famous Channeled Scablands. Photograph courtesy of Henry Klevberg.

10. Megafloods ($>10^6$ m^3/s) have not been directly witnessed but are inferred from geologic features that resemble those formed during floods. Evidence of megafloods has been observed from many places in the world.
11. Megafloods produced many flood features and landforms, though often at much larger scales, including giant current ripples or antidunes, boulder deltas, and outsized ramparts and terraces.
12. Megafloods also produced landforms and features not commonly observed in floods, including deposits of poorly rounded clasts, streamlined hills and erosional drumlins, hummocky terrain, diamict, fluting, potholes, butte-and-basin topography, and large erratic boulders. Some of these features are common with glacial processes.
13. Care must be exercised in extrapolation. Just as megaflood effects are more varied than those of "ordinary" floods, so the Deluge could have generated more varied features than megafloods. In many cases, megaflood (and particularly diluvial) processes may be more accurately thought of as instances of *marine* geology rather than *flood* geology.

Uniformitarianism versus Catastrophism

14. Floods are major disasters. Their geologic change is a large part of that in the modern environment. Most important geologic processes, like megafloods, appear episodic.
15. The Judith River is a small, underfit gravel-bed stream with a gradient

of approximately 0.5 percent in the vicinity of Kolin and Danvers, Montana. Despite its size and resistant bed, it did considerable geologic work in the 2011 floods, including scouring to or nearly to bedrock—in some places as much as 20 feet. The Judith River Trestle had been in operation for 99 years at that time with only four of the piers having been endangered by river scour previously.

16. Large amounts of sedimentary bedrock were eroded from the spillway plunge pool at Fork Peck Dam in 2011. Similar rapid, flood-related erosion in soft and hard bedrock and in concrete has been observed elsewhere.
17. Geologic formations and landforms observed in the Judith Basin of Montana do not show evidence of gradual accretion from localized floods. The scale of the valleys accords with megafloods, and the Judith Basin planation surfaces exceed that scale.
18. Movement and mass wasting are seen on the relatively steep sides of valleys. Persistence of steep slopes indicates "youthful" ages relative to deep time. The slopes show how large amounts of earth materials lose potential energy through mass wasting.
19. Many features of Earth's crust indicate a catastrophic origin, but not all do. Some processes observed today can explain some geologic effects. These are often orders of magnitude less extensive than catastrophically formed features, but are still important. Each geologic locale must be investigated for itself, and researchers need to recognize the likelihood of polygenetic formations and features.

Philosophy of Science

20. Many geological problems arise from philosophic biases and misunderstanding the scientific method. This is often due to an inability or refusal to recognize the faith basis of materialism (naturalism).
21. Enthusiasm for natural history paradigms or theories may cause researchers to miss valuable data. A "top down" approach can greatly hamper understanding.
22. Historical geology is a "mixed question" that properly belongs in the category of natural history. Geology as a science can contribute to it, but results will be tentative and speculative. The "multiple working hypotheses" approach and field research reduce subjectivity, but never eliminate inherent historical uncertainties.
23. During modern times, historical geology has been mistakenly viewed as natural science, despite its uniformitarian foundation. Geology contributes much to our understanding of erosion and deposition, especially through flood studies; ironically, the *science* has discredited uniformitarian philosophy, though this philosophy still dominates the geologic community.
24. Common flood prediction methods assume deep time, and this assumption may produce false confidence in our ability to predict the magnitude and frequency of floods. Climate change may further complicate this and limit our ability to predict flood events.

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