“But what do you measure?” Prospects for a constructive critical physical geography

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Abstract

Geomorphology shapes the way we perceive the world around us, making certain ways of understanding and interacting with landscapes more possible than others. Despite this, geomorphologists have a reputation for not engaging with philosophical questions regarding their work, particularly the role of theory, framing and language. Recent calls for a critical physical geography present significant opportunities for physical geographers to engage with questions that often go unasked, and unanswered, in the Earth sciences.

Here we discuss what a critical physical geography might bring to geomorphology, examining the implications of what we measure in our efforts to classify and understand river form and process. While geomorphology benefits from using the approaches and methods of science, it struggles with the fundamental problem of closure. Through the example of river diversity we explore how our decisions, tools and knowledge frameworks shape environmental outcomes. We challenge the assumption that once a landscape is measured it is ‘known’, and argue for geomorphologists to actively explore alternative ways of knowing the landscape towards a discipline which is both more just, and more scientific.

We imagine an inclusive critical physical geography, drawing upon disparate theoretical approaches to constructively critique the practice of geomorphology. We argue that this engagement will be most productive if it is framed in a readily accessible manner. Negotiating such a project is undoubtedly challenging, but there is perhaps more to be gained by building bridges over the science/humanities divide than by shouting across it.

Keywords: Critical physical geography, fluvial geomorphology, place, geodiversity, classification, sociogeomorphology.

Introduction

Just as a river is the product of its valley (Hynes 1975), constrained by it even as it modifies it, so geomorphic knowledge shapes, and is shaped by, the world around it. As we burrow deeper into the Earth's secrets, what we discover depends not only on what is there but on the questions we ask, the tools we use and the frameworks and languages we apply to give meaning to our findings (see Church 1996; Collingwood 1946; Rhoads and Thorn 1993, 1996a). Geomorphic knowledge, in turn, is used to physically modify the world: our perceptions of what is possible affect how we choose to act, and how we choose to act affects our perceptions of what is possible. Understanding how and why geomorphic knowledge is manufactured and mobilised, the processes of co-production through which information, institutions and the physical world interact (Bouleau 2014), is therefore integral to understanding the world around us. People bring a diversity of values, ideas and knowledge to questions of landscape and water: there is no single way to know the world (e.g. Linton 2010). As geomorphology strives for the apparent objectivity of the harder sciences (Massey 1999) it not only creates knowledge, but also shapes possibilities for action.

Drawing upon critical traditions within and beyond geography, a growing number of authors acknowledge the importance of politics and power in the analysis of landscapes and the 'work' that research practices do (e.g. Tadaki et al. 2012, 2015). Resonating with analyses of socio-natures (e.g. Castree 2013), science studies in geography (e.g. Wainwright 2012), critical cartography in physical geography (e.g. Hamylton 2014), the deeply political emergence of the Anthropocene (Castree 2015a; Castree et al. 2014) and socio-geomorphology (Ashmore 2015), these voices draw attention to the role of researchers and research practice in the knowledge we produce (Lane 2014). They suggest that there may be value in interrogating the framings and assumptions underpinning our understandings of the world, exploring possibilities for knowing and making it differently (Blue et al. 2012; Brierley et al. 2013; Tadaki et al. 2015). Some of this work is being compiled under the label of 'critical physical geography' (see Lave et al. 2014), although neither that label nor a broader 'geographical' one can claim a monopoly on these themes (e.g. Turner 2015).

Geomorphology incorporates a broad array of people, projects and politics, encompassing a diverse set of activities: from pure science concerned with unravelling processes and histories of landscape formation to applied science modifying our surroundings to suit societal values and perceived needs. The resulting tangled connections between science, practice and policy provide fertile ground for broadly-based geographical enquiry into human-environmental relations (see Castree 2015b). Geomorphology has a history of engagement with diverse theoretical and methodological approaches (see Butzer 1973; Jennings 1973; Slaymaker 1997); this might be extended to learn from,

and to change, the intricate relationships between 'nature', people and politics as expressed through geomorphology and physical geography. We see critical physical geography as a space for examining the role played by people, power, politics and place in physically shaping landscapes. We hope it will encourage constructive engagement with questions of contingency, context, equity and the material consequences of the ways geomorphologists understand landscapes. It might foster new, productive discussions of empirical rigour, appropriate classification and the role of scientific credibility in creating and maintaining geomorphology's role in developing and using tools to analyse and modify landscapes.

Here we examine how approaches to geomorphic enquiry shape the questions we ask, the data we collect and the answers we produce. We briefly discuss geomorphology's construction as an applied science, subject to demands for precision, predictability and objectivity which can be misleading in a world imbued with uncertainty, power and politics. Using the example of river diversity we explore the relationship between geomorphic knowledge and environmental outcomes, examining the role of measurement and classification in making particular environmental futures possible. Finally we consider the potential for a constructive critical physical geography to develop rigorous, place-based and democratic understandings of landscapes. While we limit our discussion to English-speaking traditions of geomorphology, these themes are likely to have broader relevance.

Measurement as knowing

Not everything that can be counted counts.
Not everything that counts can be counted.

(Cameron 1963, 13)

Scientific knowledge has elevated status in contemporary western society. This privilege has not been earned through, and does not rely on, neutrality and freedom from external influences. Scientific research is, and always has been, deeply connected to the principles, priorities and prejudices that produce it (see Livingstone 2003). Rather, science earns its privilege through ideals of empiricism, openness and freedom of debate. Within the confines of a clearly delineated theoretical context, discrete, carefully defined systems can be examined using transparent methodologies to produce data which, upon interrogation and suitable replication, might be reliable within their given frame of reference. Quantification is essential to contemporary geomorphology, but can also act to obscure the contextual nature of geomorphic knowledge. Effectively using scientific information in environmental decision-making requires understanding the spatial and temporal limitations of these framings.

Commonly constructed and practised as a science (e.g. Rhoads and Thorn 1996b), geomorphology aspires to the associated ideals and privilege. Narratives of 'higher science' are engaged to lend legitimacy to positivist aspects of the discipline (described by Massey 1999; Sack 1992), epitomised by the 1950s shift towards Earth scientists addressing 'modern' problems within narrow spatio-temporal limits (Schumm and Lichty 1965). Criticisms of scientific practices in geomorphology and physical geography as ill-defined and implicit (Ashmore 2015; Castree 2005) suggest, however, that this privilege cannot be taken for granted.

Quantification is an integral component of geomorphology's construction as a science. Asserting a measured value advances an unequivocal position which, given suitable scientific frameworks, can be compared and contrasted with existing knowledge (theory) and tested for representativeness and replicability (c.f. Richards and Clifford 2011). Perhaps because of this potential for rigour, measuring something makes it 'known', providing a sense of surety, of accuracy and of scientific credibility. To borrow from comedian Stephen Colbert , measurement brings a sense of 'truthiness': the feeling that particular information is inherently valuable and a trustworthy basis for decision-making (Colbert et al. 2005). Doing measurement is not necessarily doing science, however (e.g. Brown et al. 2013), and, as many examples from the 'softer' sciences have shown, conflating measurement with knowing can be misleading. This 'truthiness' might encourage potentially misleading confidence in quantitative understandings of landscapes produced or applied without due regard for context.

At the simplest level, river channels are shaped by the transport of sediment by water. Perfect information about that sediment, and the flow of water around it, could in principle be used to produce mechanistic understandings of the entrainment and deposition of individual particles. In practice, however, it is rarely possible to draw upon such data, so analyses typically rely on statistical models and approximations. Even a mechanistic understanding at finer scales would likely offer only limited insight at broader scales of enquiry, such as the reach or catchment, where the imprints of contingency appear to dominate process-form interactions (Church 1996). The resulting river behaviour has been described as emergent or complex (e.g. Harrison 2001), although these words have diverse and contested meanings (e.g. Harrison et al. 2006). Challenges faced in addressing these concerns might be productively understood as a problem of closure, wherein our inability to isolate and capture all potentially relevant information about fluvial systems regularly leads to unexpected outcomes. Morphological conditions and parameters might be unknown, rapidly changing, or operating at scales incompatible with our investigations, threatening bottom-up

attempts to understand rivers from fundamental laws (see Lane 2001). The precision of measurement and the confident language of classification, with its clear, stable categories, belie a 'messy' world.

When we cannot measure everything, what we measure reflects what we think is important. While these decisions are generally justified on scientific and theoretical bases they are also made within, and influenced by, a range of social, political, personal and institutional contexts. Even when disputed (e.g. Lave 2014), these inadvertently value-laden and political decisions can, over time, be fossilised into the canon that informs standard, placeless, 'objective' research and management practice. Might desires for geomorphology to be seen as a legitimate science (e.g. Strahler 1952) have inhibited broader reflexivity, for fear of admitting weakness? Focussing on particular measurable phenomena limits the possibilities for seeing and interacting with the world, with real implications for places and for people. This is manifest in the description and analysis of river form, with potential repercussions for the assessment and management of geodiversity (see Gray 2004).

Analysing river diversity: what do you measure?

As river management priorities have increasingly emphasised sustainable management and improved ecological condition (Downs and Gregory 2004; c.f. Hillman 2009), the focus has increasingly shifted towards the importance of maintaining a broad range of physical habitat, both as a fundamental building block of ecological health and as a river management goal in its own right. The resulting need to assess and communicate river diversity, process and evolutionary trajectory leads us towards a new question: how do we measure them? What we choose to monitor and assess makes possible particular management outcomes and shapes environmental trajectories (Bouleau 2014). What these measures 'should' be is therefore both a scientific question and a political one demanding broader recognition of the social contexts and implications of these decisions (see Ashmore 2015).

The multiple, tangled connections shaping geomorphic systems make capturing all potentially relevant aspects of a system implausible: we must decide what we measure, and what we do not. Even the simplest choices, backed by the firmest scientific frameworks, are influenced by a 'mangle' (after Pickering 1995) of contextual factors. These decisions reflect the knowledges, experiences, mind-sets and motivations of the researchers involved (Roper et al. 2008, 2010). They are influenced by the theory we employ, the language we use and the conceptual models and tools we have available to analyse and interpret the world (Rhoads and Thorn 1996a). They also depend on the

institutional settings within which we work, the socio-political framing of our projects, and the values they represent (Tadaki et al. 2014). Over time the interactions, feedbacks and contestations between knowledge, people and place work to 'co-produce' science, society and the physical world (Ashmore 2015; Bouleau 2014). Acts of measurement therefore instil and embed particular sets of values and associations into the landscape. This might occur through focussing on particular scales of enquiry (Church 1996), through privileging 'ideal', stable forms (Kondolf 2006) over the processes shaping them (Buffington and Montgomery 2013), or through insisting on prescriptively framed, measurable classes rather than open-ended sets of guiding principles framed as archetypes (e.g. Brierley et al. 2013; Tadaki et al. 2014).

A simple example of the challenges inherent to describing and understanding river geodiversity through classification is presented in Figure 1. Identifying and naming particular morphologies sets normative expectations as to how the river 'should' be, and how it should or should not change over time. If the river subsequently begins to adjust, whatever the cause, perceptions of environmental 'degradation' may seem to justify particular interventions in the river and/or surrounding land use, removing features (e.g. Kondolf 1995) or even people (e.g. Blue 2011; Yeh 2013) that 'do not belong'. Rather than protecting geodiversity such interventions might inadvertently, and ironically, act to restrict it to particular sets of named or easily measured variants.

Exploring and negotiating the relationships between science and society, between politics and practice, is integral to contemporary geomorphology. Measuring the right things, in the right places at the right times and for the right reasons presents ongoing scientific, technical and ethical challenges. Geomorphology's history of critically assessing claims to knowledge, exemplified by the rich discussions regarding morphological classification (see Buffington and Montgomery 2013), suggests a robust capacity for this. The slow uptake of critiques of river management in the USA, however, with their limited influence on 'real world' practice (Lave 2014), suggests that these discussions need to be more proactive, and much more explicit, than in the past. Might critical physical geography foster and expand these critiques, more effectively engaging with geomorphology's role in shaping the world? Increased attention to what we measure, how we name the world and why, might be an important step in the right direction (see Richards and Clifford 2011).

Figure 1: How do you measure river geodiversity? What attributes do you measure, and why? The Upper Yellow River at Dari in western China has a transitional form between braided and anastomosing (or anabranching) morphologies (Blue et al. 2013; see Lewin and Ashworth 2014). Braided and anastomosing rivers have different process associations, yet here elements of each are found within the same reach. The 'transitional' label recognises that not all rivers fit within 'normal' classification boundaries, and is applied to avoid inappropriate management interventions based on particular expectations of river character and behaviour. Labelling a river reach as 'transitional' may, however, also de-legitimise potentially important variants of geodiversity by evoking change, in space or time, towards a 'proper' type of river.

Prospects for a critical geomorphology

Appropriately contextualised knowledge is essential to understanding and living in a complicated, contingent world. As increasing attention focuses on the fundamental role of humans in changing the Earth's surface, and we debate the 'Anthropocene' and the possibilities for doing environmental change research differently (Castree 2015a; Castree et al. 2014), it becomes more apparent that our understanding of landscape is, itself, an essential part of that context. We contend that critical physical geography might be one way of opening up space for substantive debate within geomorphology: exploring how environmental outcomes are shaped by the questions we ask, the approaches we bring and the ways we describe them. This might include reconsidering who gets to

ask these questions, renewing and extending geomorphology's rich pluralistic traditions (see Jennings 1973; Rhoads 1999; Slaymaker 1997) by encouraging diverse perspectives on what the key geomorphic questions might be. It might mean recognizing and respecting different ways of knowing the world: for different people, different places and different purposes (c.f. Wilcock et al. 2013).

Geomorphology has at times suffered from a perceived disconnection between theory and observed 'reality', prompting various discussions of theory's role in a discipline so concerned with place (see Baker and Twidale 1991; Rhoads and Thorn 1993, 2011). This "… gap between the world as it is and the world as we understand it" (Rhoads and Thorn 1993, 303) is integral to predominant post-positivist scientific framings of geomorphology. As theory informs the collection and interrogation of data, data may challenge theory by providing evidence for its modification or rejection. Ongoing efforts to reconcile tensions between contingent data and generalised theory are fundamental to advancing geomorphic knowledge (Rhoads and Thorn 1993): without theory we would wander aimlessly between incongruent case studies without guidance as to appropriate methodologies or analyses to deploy. Theory may also play a restrictive role, however, limiting the questions we ask and the understandings we can produce. What we look for in the landscape, and what we expect to find, influences what we see. In providing the frameworks for the 'plots' of the Earth sciences, theory influences the stories we tell (Phillips 2012) and the data we gather. Theory is thus central to enquiry, but must at the same time be treated flexibly in the face of contradictory data. This is integral to such a place-dependent subject concerned with un-boundable systems in which unnoticed or unknown local contingencies might be key controls (see Brierley et al. 2013; Phillips 2007).

In recognising other ways of knowing, whether these be diverse sets and sources of data, alternative theories or entirely different frameworks of understanding, we might find new and perhaps even old ways of addressing disconnections between theory and place. Geomorphology has at times been accused of forsaking earlier approaches to research in favour of 'bandwagons' arriving from other disciplines, usually the 'harder' sciences (Jennings 1973). These grand paradigms have brought to geomorphology new ways of seeing the world, fresh approaches to old questions, and technical and methodological innovations. They have also regularly been over-sold, however, from joyful heraldry of theory's ostensible arrival (e.g. Burton 1963) to the most evangelical claims that complexity and chaos theory will explain everything (see Sardar and Ravetz 1994). Applied overzealously, they risk neglecting local difference (c.f. Baker and Twidale 1991) and potentially leaving fruitful avenues of exploration underexplored in the "creative ahistoricism" (Sherman 1996, 111) encouraged by

processes of fashion (e.g. Sack 1992). We hope that critical physical geography will not simply supplant these with a bandwagon from the 'softer' side, but act to bring fresh energy to questions of how we might know, and act in, the world differently.

In this spirit of pluralism we are wary of attempting to define what, exactly, critical physical geography should be (Lave et al. 2014) and exactly which questions it should bring to geomorphology. Delineating particular lines of inquiry, avoiding 'collisions' between them (Demeritt 2009), risks playing into the very tendencies we are attempting to disrupt. We therefore simply hope that critical physical geography engages directly and constructively with research and management practice, and its ethical implications. This includes questioning the roles played by researchers, institutions and management in mediating our understanding of the environment, helping us to move beyond 'mindless metrics' towards a more flexible, more place-sensitive and more reflexive physical geography. It might also involve greater bottom-up engagement in research processes, recognising people's ability and right to actively lead and participate in investigations into questions concerning them (see Appadurai 2006). The creative possibilities for such opening-up of research processes to different people with different worldviews range from relatively instrumental redistributions of expertise in problem identification and solving (e.g. Landström et al. 2011; Lane et al. 2011; Rhoads et al. 1999), to attempts to inspire alternative ways of relating with the world (e.g. Suchet-Pearson et al. 2013; Wilcock et al. 2013).

If individuals and institutions are asked to abandon wholesale the practices they are deeply invested in, dragging geomorphology through a 'critical turn' might prove difficult and slow. While the theory/place/practice of geomorphic enquiry has developed through much debate (e.g. Rhoads and Thorn 1996b), and discussions of uncertainty in classification are prevalent in methodologies of morphological mapping (e.g. Evans 2012), within geomorphology these questions and critiques rarely extend to their social and political implications (c.f. Ashmore 2015). If Chorley's (1978) geomorphologist felt that theory was best addressed with a soil auger, one wonders how she might face criticisms involving power relations, colonialism, race and gender. The critical physical geography we imagine would not seek the indiscriminate rejection of established perspectives and approaches, many of which have been established on good evidence via thorough discussion (if amongst rather limited audiences). It would not require that all geomorphologists refashion themselves as generalists transcending the social and natural sciences; nor would it claim to be the only answer to the questions and problems we have raised here. We do, however, contend that the responsibility lies with both geomorphologists and geographers to facilitate and engage in respectful

dialogues towards socially-situated, place-based, reflexive understandings of landscapes (see Clifford 2002). Interrogating what we measure, how, and why, is an important step towards a constructive critical physical geography.

Conclusion

Geomorphology has evolved pragmatically over time (Castree 2005). Resulting practices embed particular values, influencing the questions we ask, the ways we seek answers and, as a consequence, the environmental outcomes we produce. Critique in geomorphology certainly pre-dates the existence of something called 'critical physical geography', but has generally been limited to 'objective' methodological or philosophical discussions. An emergent critical physical geography presents significant opportunities for geomorphologists to engage with questions that regularly go unasked, and unanswered, in the Earth sciences. In particular it might bring fresh energy to broader explorations of what we know, what we do not, who knows it and why.

However scientific the approaches and methods of geomorphology, results will inevitably be influenced by where and why they were produced, at what scales and by whom. In a world without closure, consisting not of neat categories but multiple continua of landforms (re)shaped by multiple processes across multiple scales, the knowledge we produce is highly contextual. Engaging with this demands that we explicitly address the limits to our claims of knowing, particularly as geomorphic research may have substantial consequences for landscapes and those who live in and interact with them. Critical physical geography might provide the energy to engage with these questions constructively through a range of theoretical and practical approaches. This could involve challenging the ways in which physical geography is constructed and practised. It might also include doing it differently: adopting more flexible, reflexive practices which explicitly acknowledge the various contexts we are working within to maintain an appropriate sense of place and purpose.

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References

Appadurai A 2006 The right to research *Globalisation, Societies and Education* 4 167–77

Ashmore P 2015 Towards a sociogeomorphology of rivers *Geomorphology* 251 149–56
Baker V R and Twidale C R 1991 The reenchantment of geomorphology *Geomorphology* 4 73–100
Blue B, Brierley G J and Yu G 2013 Geodiversity in the Yellow River source zone *Journal of Geographical Sciences* 23 775–92
Blue B, Gregory C, McFarlane K, Tadaki M, van Limburg-Meijer P and Lewis N 2012 Freshwater geographies: experimenting with knowing and doing geography differently *New Zealand Geographer* 68 62–66
Blue L 2011 International conservation trends: considerations for Sanjiangyuan National Nature Reserve, China in Gang C, Li X, Brierley G J eds *Wetland Types, Evolution and Rehabilitation in the Sanjiangyuan Region* Qinghai People's Publishing House 111–29
Bouleau G 2014 The co-production of science and waterscapes: the case of the Seine and the Rhône Rivers, France *Geoforum* 57 248–57
Brierley G J, Fryirs K A, Cullum C, Tadaki M, Huang H Q and Blue B 2013 Reading the landscape: integrating the theory and practice of geomorphology to develop place-based understandings of river systems *Progress in Physical Geography* 37 601–21
Brown N J L, Sokal A D and Friedman H L 2013 The complex dynamics of wishful thinking: the critical positivity ratio *American Psychologist* 68 801–13
Buffington J M and Montgomery D R 2013 Geomorphic classification of rivers in Wohl E ed *Treatise on Geomorphology* Academic Press, San Diego 730–67
Burton I 1963 The quantitative revolution and theoretical geography *Canadian Geographer / Le Géographe canadien* VII 151–62
Butzer K W 1973 Pluralism in geomorphology *Proceedings of the Association of American Geographers* 5 39–43
Cameron W B 1963 *Informal Sociology, a casual introduction to sociological thinking*, 5th ed Random House, New York
Castree N 2015a Geographers and the discourse of an Earth transformed: influencing the intellectual weather or changing the intellectual climate? *Geographical Research* 53 244–54
Castree N 2015b Geography and global change science: relationships necessary, absent, and possible *Geographical Research* 53 1–15
Castree N 2013 *Making sense of nature* Routledge, Abingdon, Oxon
Castree N 2005 Is geography a science? in Castree N, Rogers A, Sherman D J eds *Questioning Geography: Fundamental Debates* Blackwell Pub., Malden, MA
Castree N, Adams W M, Barry J, Brockington D, Büscher B, Corbera E, Demeritt D, Duffy R, Felt U, Neves K, Newell P, Pellizzoni L, Rigby K, Robbins P, Robin L, Rose D B, Ross A, Schlosberg D, Sörlin S, West P, Whitehead M and Wynne B 2014 Changing the intellectual climate *Nature Climate Change* 4 763–68
Chorley R J 1978 Bases for theory in geomorphology in Embleton C, Brunsden D, Jones D K C eds *Geomorphology: Present Problems and Future Prospects* Oxford University Press, Oxford
Church M 1996 Space, time and the mountain - how do we order what we see? in Rhoads B, Thorn C E eds *The Scientific Nature of Geomorphology: Proceedings of the 27th Binghamton Symposium in Geomorphology Held 27-29 September, 1996* Wiley & Sons, Binghamton 147–70
Clifford N J 2002 The future of geography: when the whole is less than the sum of its parts *Geoforum* 33 431–36
Colbert S, Eichler G, Karlin B and Stewart J 2005 Stone Phillips *The Colbert Report* Comedy Central
Collingwood R G 1946 *The idea of history* The Clarendon Press, Oxford
Demeritt D 2009 Geography and the promise of integrative environmental research *Geoforum* 40 127–29
Downs P W and Gregory K J 2004 *River channel management: towards sustainable catchment hydrosystems* Hodder Arnold, London

Evans I S 2012 Geomorphometry and landform mapping: what is a landform? *Geomorphology* 137 94–106

Gray M 2004 *Geodiversity: valuing and conserving abiotic nature* Wiley, Chichester

Hamylton S 2014 Critical cartography and the use of new technologies for conserving the Australian coastline: a case study from Lord Howe Island *Geographical Research* 52 65–73

Harrison S 2001 On reductionism and emergence in geomorphology *Transactions of the Institute of British Geographers* 26 327–39

Harrison S, Massey D and Richards K 2006 Complexity and emergence (another conversation) *Area* 38 465–71

Hillman M 2009 Integrating knowledge: the key challenge for a new paradigm in river management *Geography Compass* 3 1988–2010

Hynes H B N 1975 The stream and its valley *Verhandlungen der Internationalen Vereinigung fur theoretische und angewandte Limnologie* 19 1–15

Jennings J N 1973 "Any millenniums today, lady?" The geomorphic bandwaggon parade *Australian Geographical Studies* 11 115–33

Kondolf G M 2006 River restoration and meanders *Ecology and Society* 11 42

Kondolf G M 1995 Geomorphological stream channel classification in aquatic habitat restoration: uses and limitations *Aquatic Conservation: Marine and Freshwater Ecosystems* 5 127–41

Landström C, Whatmore S J, Lane S N, Odoni N A, Ward N and Bradley S 2011 Coproducing flood risk knowledge: redistributing expertise in critical "participatory modelling" *Environment and Planning A* 43 1617–33

Lane S N 2014 Acting, predicting and intervening in a socio-hydrological world *Hydrology and Earth System Sciences* 18 927–52

Lane S N 2001 Constructive comments on D Massey "Space-time, 'science' and the relationship between physical geography and human geography" *Transactions of the Institute of British Geographers* 26 243–56

Lane S, Odoni N, Landström C, Whatmore S J, Ward N and Bradley S 2011 Doing flood risk science differently: an experiment in radical scientific method *Transactions of the Institute of British Geographers* 36 15–36

Lave R 2014 Freedom and constraint: generative expectations in the US stream restoration field *Geoforum* 52 236–44

Lave R, Wilson M W, Barron E S, Biermann C, Carey M A, Duvall C S, Johnson L, Lane K M, McClintock N, Munroe D, Pain R, Proctor J, Rhoads B L, Robertson M M, Rossi J, Sayre N F, Simon G, Tadaki M and Van Dyke C 2014 Intervention: critical physical geography *The Canadian Geographer / Le Géographe canadien* 58 1–10

Lewin J and Ashworth P J 2014 Defining large river channel patterns: alluvial exchange and plurality *Geomorphology* 215 83–98

Linton J 2010 *What is water? The history of a modern abstraction* UBC Press, Vancouver

Livingstone D N 2003 *Putting science in its place: geographies of scientific knowledge* University of Chicago Press, Chicago

Massey D 1999 Space-time, "science" and the relationship between physical geography and human geography *Transactions of the Institute of British Geographers* 24 261–76

Phillips J D 2012 Storytelling in Earth sciences: the eight basic plots *Earth-Science Reviews* 115 153–62

Phillips J D 2007 The perfect landscape *Geomorphology* 84 159–69

Pickering A 1995 *The mangle of practice: time, agency, and science* University of Chicago Press, Chicago

Rhoads B L 1999 Beyond pragmatism: the value of philosophical discourse for physical geography *Annals of the Association of American Geographers* 89 760–71

Rhoads B L and Thorn C E 2011 The role and character of theory in geomorphology in Gregory K J, Goudie A S eds *The SAGE Handbook of Geomorphology* SAGE, London 59–77

Rhoads B L and Thorn C E 1996a 2 Observation in geomorphology in Rhoads B L, Thorn C E eds *The Scientific Nature of Geomorphology: Proceedings of the 27th Binghamton Symposium in Geomorphology Held 27-29 September, 1996* John Wiley & Sons 21

Rhoads B L and Thorn C E (Eds) 1996b *The scientific nature of geomorphology: proceedings of the 27th Binghamton Symposium in Geomorphology held 27-29 September, 1996* Wiley, Chichester; New York

Rhoads B L and Thorn C E 1993 Geomorphology as science: the role of theory *Geomorphology* 6 287–307

Rhoads B L, Wilson D, Urban M and Herricks E E 1999 Interaction between scientists and nonscientists in community-based watershed management: Emergence of the concept of stream naturalization *Environmental management* 24 297–308

Richards K and Clifford N J 2011 The nature of explanation in geomorphology in Gregory K J, Goudie A S eds *The SAGE Handbook of Geomorphology* SAGE Publications Ltd, London 36–58

Roper B B, Buffington J M, Archer E, Moyer C and Ward M 2008 The role of observer variation in determining Rosgen stream types in northeastern Oregon mountain streams *Journal of the American Water Resources Association* 44 417–27

Roper B B, Buffington J M, Bennett S, Lanigan S H, Archer E, Downie S T, Faustini J, Hillman T W, Hubler S, Jones K, Jordan C, Kaufmann P R, Merritt G, Moyer C and Pleus A 2010 A comparison of the performance and compatibility of protocols used by seven monitoring groups to measure stream habitat in the Pacific Northwest *North American Journal of Fisheries Management* 30 565–87

Sack D 1992 New wine in old bottles: the historiography of a paradigm change *Geomorphology* 5 251–63

Sardar Z and Ravetz J R 1994 Complexity: fad or future? *Futures* 26 563–67

Schumm S A and Lichty R W 1965 Time, space, and causality in geomorphology *American Journal of Science* 263 110–19

Sherman D I 1996 Fashion in geomorphology in Rhoads B L, Thorn C E eds *The Scientific Nature of Geomorphology: Proceedings of the 27th Binghamton Symposium in Geomorphology Held 27-29 September, 1996* Wiley & Sons 87–114

Slaymaker O 1997 A pluralist, problem-focused geomorphology in Stoddart D R ed *Process and Form in Geomorphology* Routledge, New York 328–39

Strahler A N 1952 Dynamic basis of geomorphology *Geological Society of America Bulletin* 63 923–38

Suchet-Pearson S, Wright S, Lloyd K, Burarrwanga L and Bawaka Country 2013 Caring *as* Country: towards an ontology of co-becoming in natural resource management *Asia Pacific Viewpoint* 54 185–97

Tadaki M, Brierley G, Dickson M, Le Heron R and Salmond J 2015 Cultivating critical practices in physical geography *The Geographical Journal* 181 160–71

Tadaki M, Brierley G J and Cullum C 2014 River classification: theory, practice, politics *Wiley Interdisciplinary Reviews: Water* 1 349–67

Tadaki M, Salmond J, Le Heron R and Brierley G J 2012 Nature, culture, and the work of physical geography *Transactions of the Institute of British Geographers* 37 547–62

Turner M D 2015 Political ecology II: engagements with ecology *Progress in Human Geography* Advance online publication 10.1177/0309132515577025 1–9

Wainwright S P 2012 Science studies in physical geography: an idea whose time has come? *Progress in Physical Geography* 36 786–812

Wilcock D, Brierley G J and Howitt R 2013 Ethnogeomorphology *Progress in Physical Geography* 37 573–600

Yeh E T 2013 The politics of conservation in contemporary rural China *Journal of Peasant Studies* 40 1165–88