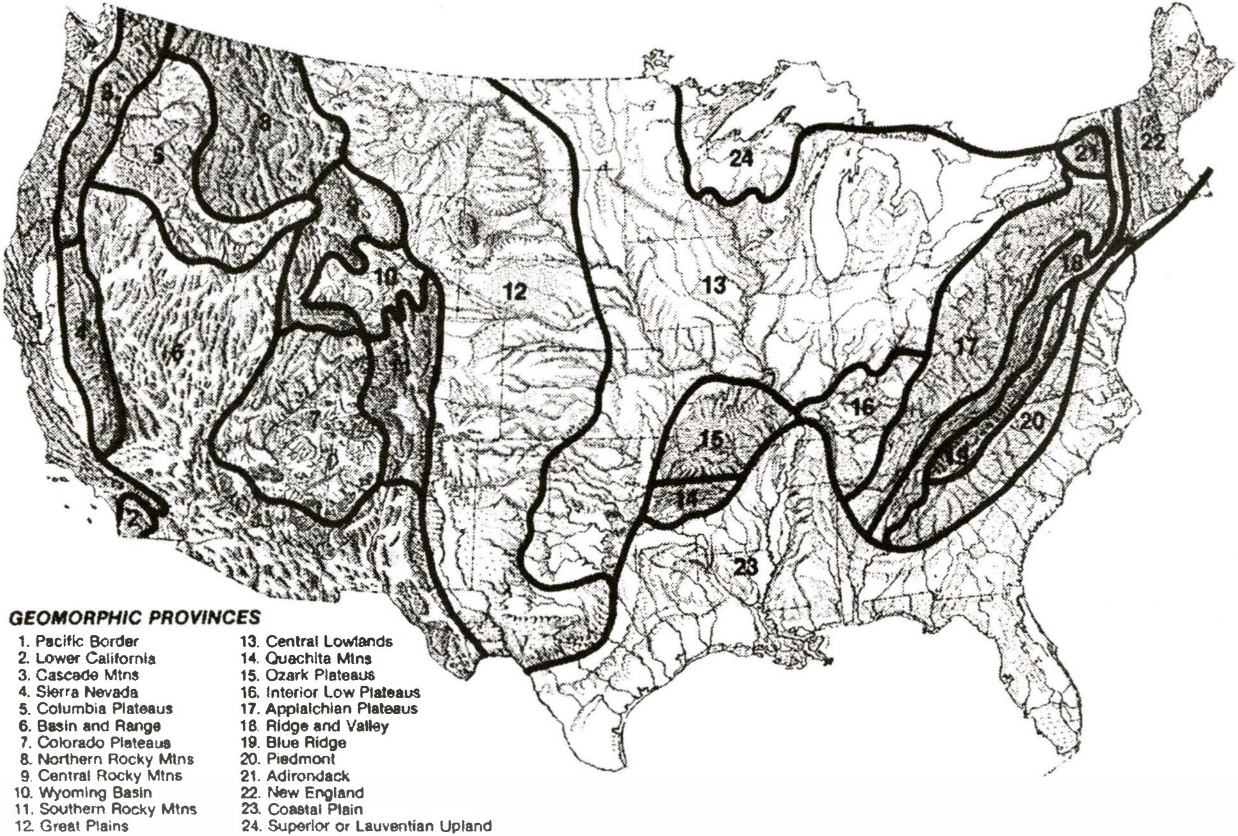

Figure 1.
Geomorphic Provinces of the United States
[Editor's note: map substituted for Fenneman's]

THE PHYSIOGRAPHIC REGION IN PHYSICAL GEOGRAPHY AND GEOMORPHOLOGY: HISTORICAL APPRAISAL AND RE-EVALUATION

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Introduction

An examination of introductory physical geography texts reveals topical coverage exhibiting coherence and a clear sense of spatial pattern, particularly when it comes to climate, soils, vegetation, and hydrology. These interrelated topics establish the notion, necessary for beginning students, that the natural environment consists of a complex web of interdependencies. Unfortunately, when the atmosphere, hydrosphere, or biosphere are exchanged for the geosphere, these interrelations seem to disintegrate in confusion with a loss of spatial coherence. What has happened to the sense of the geosphere's cohesion and its interrelatedness with the rest of physical geography? More importantly, where is geomorphology's spatial aspect which is so necessary in an introductory course?

This paper attempts to draw attention to this inadequate spatial coverage in geomorphology, particularly at the macro-scale, and suggest physiographic regionalism as a partial solution. However, any re-introduction of the physiographic region needs to take as its basis the recent advances in the solid earth sciences, especially those in global tectonics.

Some of the aforementioned confusion in dealing with the geosphere in general and geomorphology in particular is probably due to the two different scales at which geomorphology needs to be examined for even rudimentary understanding. At the macro-scale we are dealing with entire landscapes, those elements of topography that are structurally controlled and which depend primarily upon endogenic processes.[1a] At the micro-scale, we deal principally with the detailed sculpting or etching of landscapes by exogenic processes whose magnitudes and frequencies are interrelated with climate and hydrology. These exogenic processes, interacting with earth materials (rocks and sediments), are responsible for producing the myriad individual erosional and depositional land-forms which are etched into, or superimposed upon, the landscape's major structural elements. In addition to producing individual erosional features, these etching processes also enhance structure's influence on topography through exploitation of any structural weaknesses.

Historical Appraisal

In the development of what we now call geomorphology, the physiographic province was a very important and integral part. One of the earliest mentions of anything akin to a physiographic region in the United States was the early nineteenth-century recognition of the topographic uniqueness of the Ridge and Valley region.[1] The development of regional physiographic concepts occurred later in the same century. Recognition of intraregional topographic similarities leading to delimitation of physiographic provinces came during the period of westward expansion and western exploration in the years immediately following the Civil War. Physiographic regions or provinces received the greatest geologic and geographic attention in the late nineteenth and early twentieth centuries.

An early scheme of nomenclature for the United States' physiographic provinces was that of Powell.[2] Subsequently, Powell's scheme was modified by Lobeck[3] and finally by Fenneman.[4] Fenneman's provincial boundaries and terminology are still recognized and employed by the U.S. Geological Survey (Figure 1). For geographers, the idea of physiographic regions was what made the study of physiography spatial or geographical. Without this spatial element it is doubtful that physiography would have continued to be included within what today is considered physical geography. Following this early period of prominence, however, the use of physiographic regions suffered a sharp decline.

The decline in the intellectual content of physiographic studies in the early twentieth century had many causes. Among these was the split between geography and geology as each field underwent separate development and specialization. Coupled with this was the demise of environmental determinism as a major rationale for physiographic studies together with the rise of human or cultural geography which displaced physical geography from its central role in the field. Finally, there was an unthinking mimicry involved in applying the Cycle of Erosion to landscapes. The Cycle of Erosion or cycle of Landmass Denudation, developed by Davis,[5] was an admirable first attempt at organizing into a meaningful format what was then known, or at least surmised, about the origin and development of the earth's landforms. It was designed as a pedagogical model; and herein lies its problem, since this teaching device was then used as a research model by Davis and his disciples. Uncritically they applied this simplistic cycle to their task of unravelling the denudational history of the world's landscapes. The basic assumption concerning the innate correctness of the cycle was never questioned; and reality was, therefore, made to fit the model rather than the reverse, as would be dictated in a real scientific field. To assume that all landscapes will evolve in a predictable and simplistic sequence of stages ignores reality. Davis himself had said on numerous occasions that a myriad of possible complications are possible within the cycle framework (for example, pattern of uplift). Curiously, neither Davis nor any of his students ever examined, even theoretically, these complications. It was this unscientific and formalistic simplicity passed off as scholarship that those outside the budding science of geomorphology saw and found decidedly wanting in scientific rigor.

Geomorphology's resurrection from its near demise began in the 1940's and 1950's, as a result of Strahler's development of morphometric studies based on the seminal work of Horton.[6] These studies included a strong areal element and clearly demonstrated the importance of spatial organization in the landscape. In fact, morphometric studies gave rise to the many ideas which eventually caused the collapse of the classical, or Davisian, school of geomorphology. Coupled with these morphometric studies the U.S. Geological Survey's Hydrologic Studies of Rivers, initiated in the 1950's, forever turned geomorphology's attention away from hypothetical studies of landscape evolution, based on deductions from unsubstantiated premises of the classical geomorphologists, and redirected it toward exogenic processes. The rationale for this change in scale and perspective was that if we are to understand landscape development we must first understand what occurs on the landscape's surface. For too many years postulates about an entire landscape system had been constructed without any attempt to study, understand, or even identify the system's constituent parts. However, in our recent fascination with the study of exogenic processes, we have tended to ignore that spatial element which can be a significant link in physical geography courses-the physiographic region. This is true not only at an advanced level in geomorphology, but also and especially at the introductory course level.

I think geomorphology has maintained its place within the body of physical geography more by tradition and historical precedent than by any meaningful spatial rationale. As a geomorphologist and a geographer (but not a geographical geomorphologist), I have always had an interest in physiographic regions and have desired to see them incorporated in a meaningful and appropriate manner into the body of physical geography courses. After all, climatology has its climatic regions, and soils and vegetation are frequently discussed regionally. How, though, can geomorphology and geomorphic regions in particular be most effectively presented? Maps such as Murphy's,[7] while providing some spatial information for the initiated, offer little in the way of insights or integration for the beginner. Fenneman 's maps, coupled with unrealistic and fanciful notions of peneplains, even though spatial or regional in intent, are justly viewed as historical curiosities, singularly unrewarding to the knowledgeable and particularly so to any beginning student.

Most physical geography texts maintain a schizophrenic treatment of geomorphology. Our geological roots are acknowledged in chapters dealing with the rudiments of mineralogy and petrology. Chapters on the dynamic and stratigraphic influences on topography are often the last in a book. Such is the usual geographic treatment of endogenic processes, but exogenic processes are generally covered in detail, often with a definite bias toward climatic geomorphology. ***

A desire for regionalism brings us back to the physiographic province or, in more modern parlance, the geomorphic region. What is needed is a regional approach which is shorn of classical geomorphic trappings. A search of the contemporary literature for some guidance on geomorphic regions leads to only two texts that deal with regional aspects of geomorphology, namely, Thornbury[8] and Hunt.[9] While Hunt is probably the more physiographic *(sensu stricto)*, it is written without any insights which recent advances in global tectonics could provide. Thornbury on the other hand, although analyzing each physiographic/geomorphic region, does so primarily in the light of the voluminous and outdated literature in classical geomorphology. How then can the physiographic region be tied into the body of modern geomorphology and, by extension, provide a useful framework for beginning as well as advanced physical geography or geomorphology students?

Re-evaluation

A scientific revolution occurred in the solid earth sciences during the 1960's and early 1970's. This dramatic shift in perspective involved the rise and eventual acceptance of the plate tectonic paradigm as a basis for explanation of global patterns of tectonics and volcanism, among other phenomena. This same paradigm can, with imaginative application, provide a basis for re-evaluating the meaning and significance of our physiographic or geomorphic regions. The physiographic region is usually defined as a spatial analog based on geologic structural regions. While physiographic regions are recognized and delimited on the basis of surface morphology, gross surface morphology is in turn an expression of underlying structures. Geologic structure is the key to understanding physiographic regions because structural elements owe their existence to the three major stress regimes (compression, tension, and shear), which in turn are functions of plate motions and interactions occurring at plate boundaries. Where crustal consumption occurs, as in subduction zones, compression tends to be the dominant stress. Tension tends (though not exclusively) to occur where new crust is being generated, and shearing is found along those plate boundaries in which crustal conservation is favored.

In the tectonically active western United States, there is a growing and voluminous literature relating present plate motions directly to structural geology. From there it is an easy step to relate it directly to structural geomorphology. In the central United States, it is doubtful if much can be applied directly from plate tectonics except as pertains to the Mississippi embayment. This is not to say, however, that structural geomorphology has no application in this area. Structural elements are present, but because of the absence of tectonism and volcanism they are far more subtle than on either coast, being primarily associated with lithology and stratigraphy. In the eastern United States, there is a growing trend toward re-

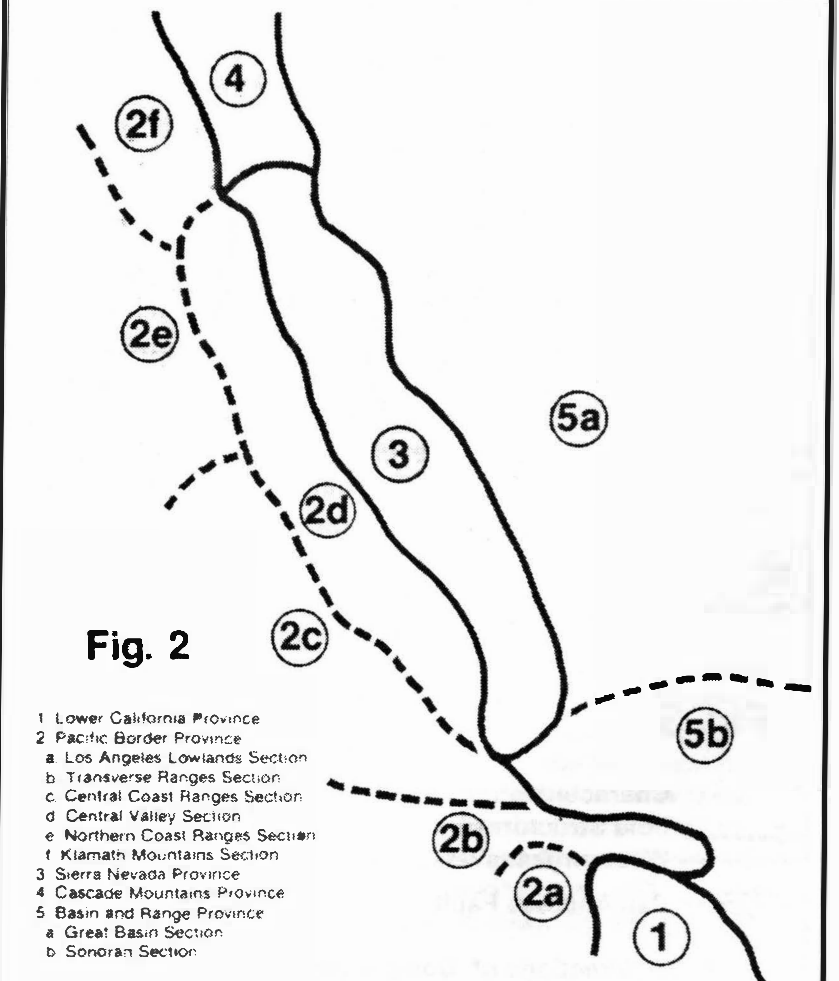


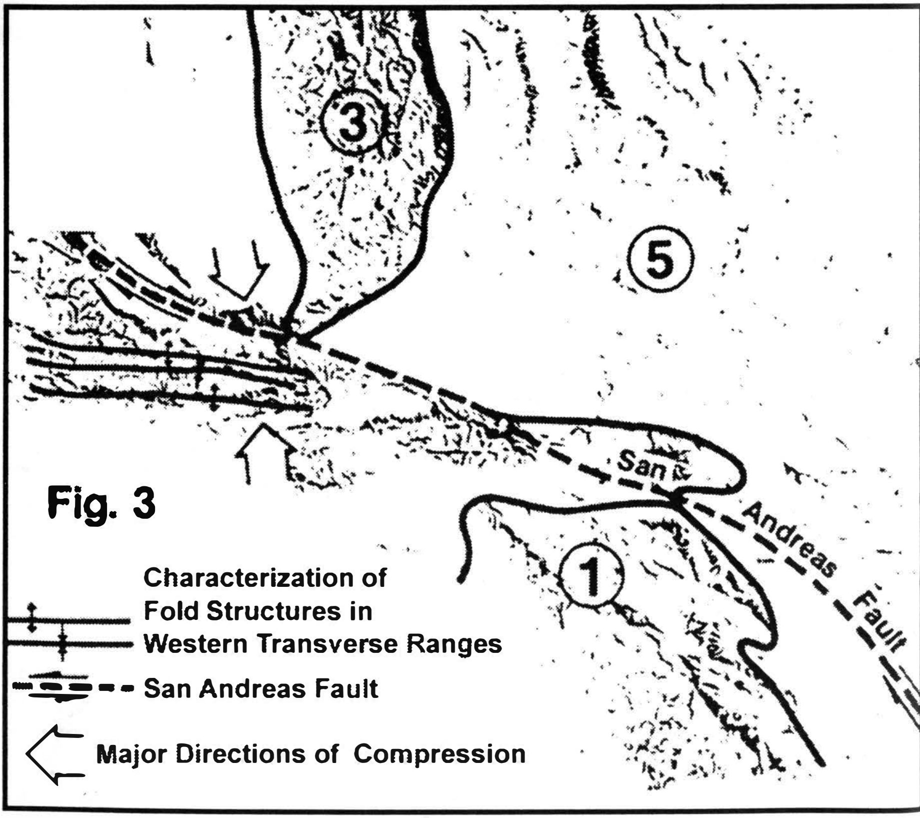
Fig. 2

1 Lower California Province
2 Pacific Border Province
a Los Angeles Lowlands Section
b Transverse Ranges Section
c Central Coast Ranges Section
d Central Valley Section
e Northern Coast Ranges Section
f Klamath Mountains Section
3 Sierra Nevada Province
4 Cascade Mountains Province
5 Basin and Range Province
a Great Basin Section
b Sonoran Section

evaluation of regional geology in view of the plate tectonic paradigm, although here the re-evaluation applies to more ancient, and thus more problematical, prePangaean plate motions. Some tentative but profitable beginnings have been made in this direction; and, though still a long way off, the implications for structural geologic and physiographic explanations are far reaching.

Imaginative application of the plate tectonic paradigm enables one to re-evaluate the various physiographic regions in more rewarding and meaningful historical terms. At the same time, a more complete spatial synthesis of structural geomorphic notions, coupled with our geologic/earth science roots, can be achieved. Ultimately, this re-evaluation and synthesis yields a meaningful regionalism in macro-geomorphology.

Examples of the possible re-evaluation of western physiographic regions or sections that might here be mentioned in very brief synopsis include the California Coast Ranges and Transverse Range Sections of the Pacific Borderland Province, the Cascade Range Province, the Sierra Nevada Province, and the Great Basin Section of the Basin and Range Province (Figure 2).



Prior to the complete subduction of the Farallon Plate and the East Pacific Rise off of what is presently coastal California, compression was the principle stress. This compressive stress regime resulted in a squeezing and an east-west shortening of the crust, producing the characteristic thrusts and folds found in the present Coast Ranges.[1c] Once the East Pacific Rise was subducted, a process commencing some 30 million years (m.y.) ago, the apparent oblique subduction was replaced by strike-slip motion.[10] This strike-slip motion now concentrated along the San Andreas fault provides the final structural detail that is now being etched into relief by present exogenic processes.[1d]

The east-west trend of the Transverse Range section in Southern California appears to be due to the opening of the Sea of Cortez, thus separating Baja California from mainland Mexico, some 4 to 5 m.y. ago. This opening resulted in a bend or "dog-leg" in the San Andreas fault. Right-lateral strike-slip motion proceeds relatively unimpeded in a northwest-southeast direction to the north and to the south of the Transverse Range section. In the vicinity of the Transverse Ranges, however, compression is also occurring in addition to the shearing because of this bend in the fault (Figure 3). At the eastern end of the section this compression has resulted in the squeezing and upthrusting of massive basement crystalline rocks of the San Gabriel Mountains south of the San Andreas fault and the San Bernardino Mountains to the north. Both of these mountain masses, in addition to being separated from each other by the San Andreas strike-slip fault, are further bounded by thrust faults which serve to take up the necessary crustal shortening in this zone of both shearing and compression. In contrast to the crystalline rocks of the eastern portion of the section, the western Transverse Ranges have yielded to this crustal compression by developing massive folds in their Tertiary sedimentary rocks. The axes of these folds trend east-west, as would be expected from the north-south directed compression.

The Cascade Range of today has many elements in common with the Sierra Nevada of perhaps 40 or 50 m.y. ago. The subduction of the Juan de Fuca Plate (a segment of the Farallon Plate, most of which is now long since subducted) provides the "wet" oceanic crust which, when partially melted, provides the intermediate composition magmas that have erupted for the past several million years to form the majestic Cascade stratovolcanoes. This extremely dynamic link between plate tectonics, subduction, and volcanism is further exemplified by the eruptions at Mount St. Helens since May of 1980.

The Sierran block is, in many respects, genetically related to the Basin and Range Province, of which it forms the western boundary. It is given separate status as a physiographic province primarily because of its rather uniform lithology (principally granitic) and its sheer massiveness. Since it is genetically related to the Great Basin Section of the Basin and Range, its reasons for uplift are probably related to the extensional activity of the Great Basin.

The extensional tectonics in the Great Basin Section of the Basin and Range, which has continued for about 30 m.y., has had several explanations. Probably the most rewarding, and the one which offers the best explanation with the fewest problems, is related to the nature of shearing. It can be easily demonstrated that a shear stress regime will possess elements of both tension and compression. As a result, the right-lateral northwest to southeast shearing along the San Andreas fault in the lithologically heterogeneous crust of the western United States should yield an east-west extensional component. The topographic expressions of this extension-normal fault scarps, faultline scarps, grabens, horsts, or tilted fault blocks-should trend north-south. A glance at a topographic map of the Great Basin reveals rather strikingly the north-south trend of the fault-block mountains and their intervening basins of internal drainage.

As these all too brief sketches indicate, the integration of plate tectonics, geologic structure and ultimately topography as the surficial expression of structure, is easily accomplished for any of the West's physiographic provinces. This is facilitated because of the recency of tectonic and volcanic activity. This is more difficult in the eastern United States because of the absence of recent endogenic activity. These difficulties can be ameliorated as more information is developed on the period of geologic time prior to the creation of Pangaea and the subsequent breakup of the supercontinent. For example, Pangaea's break up is probably responsible for the various Triassic-aged lowlands of the East Coast. Pre-Pangaean plate motions will eventually help to explain not only the Ridge and Valley Province's folds, but also the structure and topography of, say, the New England Province as we come to understand the nature of the Acadian or Caledonian orogeny in terms of collision between the Paleozoic American and European Plates.

Exogenic Activity

As noted above, all landscapes are historical documents whether viewed on macro- or micro-scale. This is due to the fact that no landscape can maintain steady-state over its entirety. The dynamic equilibrium that characterizes landscapes allows relict landforms to continue in existence until their processes of formation have adjusted to new conditions. Relict landforms are eventually effaced because they are no longer in equilibrium with existing processes.

What is needed is a way in which exogenic processes may be integrated into physiographic regions. In order to avoid the obscuring influences of climatic or climatogenetic geomorphology, the individual exogenic processes are best studied systematically. In the systematic approach, room is easily made for showing the interrelationships between the earth surface processes, the hydrologic cycle, and climatic patterns.[1e] But once a rudimentary understanding of external processes is achieved by the introductory student, the influence of these processes on each physiographic region can be initiated. A benefit of this approach is that discussion of contemporary, as well as historical, activity inevitably emphasizes or reinforces the notion of environmental change.

Conclusions

It is particularly appropriate that any rebirth of regional geomorphology be made here in the West. After all, the stark physiographic differences across the United States were noted by the decidedly eastern physical geographers, geologists, or physiographers of the King, Hayden, Wheeler, and Powell surveys who worked in the West. Powell, Gilbert, Dutton, and even Davis wrote about these differences based largely on their western experiences, and Holmes illustrated them in his striking drawings for the works of Gilbert and Dutton.

I believe there is an environmental perceptual problem for eastern physical geographers and geomorphologists that prevents them from realizing the inherent value of the reevaluated physiographic region. They live in a tectonically quiescent, humid environment where internal processes are a thing of the past. The humid climate forces them to emphasize not just running water (our most important exogenic agent even in the dry west) but chemical weathering, soil development, hillslope creep, and all those other natural humid processes which lead to a mantling of rocks and a rounding off of the landscape. As far as macro-geomorphology is concerned, these surficial props (particularly soils and vegetation) mask the geologic stage upon which all else depends. In the West our arid to semiarid climates act to inhibit vegetation as well as to reduce chemical weathering, soil development, and hillslope creep, thus generally leaving the rocks exposed so that their influence on topography becomes obvious. An elementary student shown a landscape photograph of, say, the Colorado Plateaus quickly appreciates the influence of sandstones, limestones, or shales on individual slope segments and thence their cumulative influence on the entire landscape. The immediate grasp of this simple relationship is far more problematical when shown a photograph of the Appalachian Plateaus. Although the structures are the same and the rocks are quite similar in age and lithology, the landscape has a vastly different appearance than that of the Colorado Plateaus. The frequency of tectonic and volcanic activity in the western United States also forces us to pay more attention to internal processes.

This plea for a return to the re-evaluated physiographic region serves two purposes. First, it introduces a nonartificial and more precise spatial unit into the geomorphology taught in physical geography. This can have the effect of eliminating the use of climatic regionalism as the spatial basis for geomorphology. It also offers a means whereby we can synthesize and integrate the research of the other earth sciences into physical geography in a coherent manner. Second, this re-evaluated physiographic region offers new insights and research opportunities in an atrophied aspect of geomorphology long overdue for renewed attention.

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NOTES

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[See page 73 for Footnotes]

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