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BASIN RANGE TYPES

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DURING the first 30 years following Gilbert's explanation, offered in 1874,[1] for the mountains of the Basin and Range province as dissected fault blocks, the evidence of their uplift on faults was physiographic in the sense of being dependent on facts of surface form; namely, a simple base line indifferent to the structure of a range-block along at least one of its sides. The evidence was all the better if post-faulting erosion had advanced so little as not to have altogether destroyed those modified remnants of the fault face seen in the spur-end facets by wearing them too far back from the initial fault plane; it was all the worse if post-faulting erosion had advanced so far as not only to consume the spur-end facets, but also to wear the mountain face well back from the fault trace and thereby give it an irregular base line. Physiographic evidence of faulting would then be lost and the origin of a range so much eroded would remain, as far as such evidence goes, uncertain.

The second 30 years of the Basin Range problem was opened by Louderback's account of the Humboldt Lake ranges of northwestern Nevada,[2] which proved their fault-block origin by evidence of a geological nature, in the sense of involving the repetition of a similar structural sequence in two adjacent ranges. This evidence was all the better if the structural sequence was highly specialized; all the worse if it were not. In the case that Louderback brought forward, the sequence involved a body of compressionally deformed and well-worn-down strata unconformably covered by lava sheets of prefaulting eruption, the lava sheets and the surface of erosion on which they rest unconformably dipping in the same direction

1 G. K. Gilbert, Wheeler Survey, Progress Report, 1874, 50; also, *ibid.*, Vol. 3, 1878, 735, 744.

2 G. D. Louderback, Basin Range structure of the Humboldt region [Nevada]. Bull. Geol. Soc. Amer., 15, 1904, 289-346.

in the two ranges; and that sequence has, I believe, been regarded by most American geologists as sufficiently specialized to lead them to accept faulting as the cause of its repetition. But such evidence of faulting would be wanting in ranges that have no lava cover on their back-tilted slope.

Many Basin Ranges have been much eroded since their upheaval or have been upheaved without previously receiving an unconformable lava cover, and the origin of such ranges is uncertain. But as all the ranges that have not suffered erosion enough to give them an irregular base line or that possess an unconformable lava cover are thereby shown to be fault blocks, that origin is, to say the least, rather probable for their less communicative neighbors also. Such origin may very probably be either proved or disproved for the taciturn ranges by modern geophysical methods in the third 30-year period of Basin Range study.

A simplified historico-explanatory terminology that I proposed for fault-block Basin Ranges seven years ago[3] is as follows: The mountains which occupied the Basin and Range province in Cretaceous time were shown by the geologists of the Fortieth Parallel Survey[4] to have been produced by compressional deformation; they may be called the King Mountains, after the director of that survey. The surface of generally low relief to which these mountains were reduced by erosion in later Cretaceous and Tertiary time may be named after Powell, who first inferred its occurrence in 1876.[5] Curiously enough, Gilbert overlooked this important contribution of his senior,[6] in spite of the intimate terms on which the two worked together for many years in Washington, and attributed it to Dutton, who, although he announced it more explicitly than Powell did, was 12 years later in making the announcement.[7] The uplifted and more or less tilted blocks may be called Gilbert blocks, their initial back slope being a part of the Powell surface and their front face originating as a fault scarp; both back slope and front face now being less or more modified by erosion consequent upon faulting.

Wherever the Powell lowland happened to be unconformably covered by a lava sheet, a fault block there uptilted would have a back slope as revealing as it is enduring, and such a back slope should be called a Louderback. And it may be further specified that wherever the Powell surface happened to have been covered by an unconformable series of imperfectly consolidated strata (often including much volcanic ash and erroneously called "lake beds" by earlier observers in accordance with the views of their time, but more probably representing subaerial deposits that accumulated where a moderate down-warping of the Powell surface received the wash of detritus from up-warped areas), these weak strata are soon stripped from the back slope of upfaulted range blocks and reduced to relatively low relief in the inter-range depressions, where they constitute weak-rock pediments, to the occurrence of which Blackwelder has recently given special attention.[8] Also, wherever the period of mountain upheaval is so remote that a good share of the deformed and resistant rocks of a range have come to be consumed under the arid conditions there obtaining, the residual mounts are surrounded with a hard-rock floor or pediment, such as has been described and explained by McGee, Paige, Lawson, Bryan and others.[9] Some simplified diagrams of several of these varied forms are given in one of my recent papers.[10]

The above scheme of explanatory description has been criticized as too simple by certain observers familiar with the geological history of the Basin and Range province; and it is too simple, geologically speaking, for the occurrence of later geological movements than those which produced the King mountains is eminently possible; and some account of such movements, Miocene in date and fairly strong in measure, has indeed been lately given me personally by H. S. Gale. But the scheme is less condemnable physiographically, for a physiographic scheme need take account only of those past occurrences which are of importance in explaining the visible forms of to-day; and from that point of view the original statement of the scheme need be modified only so far as to say that not only the King mountains but also any other mountains of later production were rather effectively consumed in the production of the prefaulting Powell lowland. It must be understood, however, that the lowland was hilly, even submountainous, in certain areas, as in parts of southeastern Arizona, referred to below.

3 W. M. D., "The Basin Range Problem," Proc. Nat. Acad. Sci., 11, 1925, 387–392.

4 Fortieth Parallel Survey, Vol. 3, 1870, pp. 2, 451.

5 J. W. Powell, "Geology of the Uinta Mountains," 1876, 32.

6 G. K. Gilbert, "Studies of Basin Range Structure," U. S. Geol. Surv., Prof. Paper 153, 1928; see p. 3.

7 C. E. Dutton, "Geology of the High Plateaus of Utah," Washington, 1888. See p. 47.

8 Eliot Blackwelder, "Origin of Desert Basins of the Southwestern United States," Bull. Geol. Soc. Amer., 39, 1928, 262–263.

9 W. J. McGee, "Sheetflood Erosion," Bull. Geol. Soc. Amer., 8, 1897, 87–112; Sidney Paige, "Rock-cut Surfaces in the Desert Ranges," Jour. Geol., 20, 1912, 422–450; A. C. Lawson, "The Epigene Profiles of the Desert," Univ. Calif. Geol. Bull., 9, 1915, 23–48; Kirk Bryan, "The Papago Country, Arizona," U. S. Geol. Surv., W. S. Paper 499, 1925.

10 W. M. D., "Physiographic Contrasts, East and West." *Scientific Monthly*, 30, 1930, 394–415, 500–519.

During the past seven years I have had opportunity of seeing a number of Basin Ranges in the arid region of the Southwest, and have found it profitable to collect examples of fault-block ranges that have individual physiographic peculiarities of one sort or another, apart from a vast variety of structural peculiarities and of differences in length and height. Here are to be included, for example, more or less manifest spur-end facets at the base of the dissected fault-scarp front of a range, or a more or less extensive Louderback on the back-tilted slope. The collection now includes the following examples.

First, the short Peacock Range in Arizona, next west of the Grand Wash cliffs in which the plateau trenched by the Colorado Canyon is terminated by down-faulting; this range being peculiar in having only a pair of tell-tale little Louderbacks at the end of two of its many back-sloping spurs;[11] second, the northern part of the Oquirrh Range in western Utah and, third, parts of the Panamint Range in southeastern California, which are alike in having suffered a pronounced second upfaulting of 1,000 feet or so, whereby the valleys maturely eroded in the first-formed fault scarp now stand in a hanging position above their downfaulted fans, over which small new fans are forming; the hanging valleys and the new fans being connected by sharp-cut, fault-face gorges.[12] These two examples are further peculiar in showing, not mere spur-end facets as modified remnants of their initial fault face, of which the best examples I have seen are, fourth, in the Spanish Fork section of the Wasatch Range of Utah, but large parts of their new fault faces, little modified. Fifth, the House Range of southwestern Utah,[13] which like most of the other Basin Ranges has been so much eroded that it has lost its spur-end facets, although the base line drawn along the rounded ends of its retreating spurs is of simple pattern and still very clearly transects the deformed structures of the range block: this range has, moreover, a historic interest as it appears to be the one which first gave Gilbert the idea of a tilted fault block.

Sixth, is the trebly peculiar Galiuro Range in southeastern Arizona, first in having a markedly uneven Powell surface, second in having something like 2,000 feet of lavas in its heavy and gently inclined Louderback, third in showing a renewed movement of upheaval but without renewed faulting; for here the detritus outwashed from the fault-scarp valleys of the first movement has been raised with the range instead of depressed from it in the second movement.[14] Seventh, come the Bear River mountains of northern Utah, in part of which the downfaulted block has not sunk out of sight, so that the valleys eroded across both blocks give exceptionally good opportunity of determining the dip of the fault surface between them, which proves to have the low value of from 35° to 30°.[15] Eighth, are the Santa Catalina Mountains of southeastern Arizona, which are believed to be of fault-block origin because of the transection of their deformed structures by their relatively simple southern and western base lines, and which, after reaching a sub-mature stage of erosion consequent upon a first uplift, have later suffered an upheaval of 1,000 feet or more in their northern or back slope, thus gaining a hump-backed quality.[16] Ninth, come the Sierrita Mountains near Tucson in southeastern Arizona which are not proved to be of fault-block origin, but around which a rock floor or pediment has been developed such as should have been developed around a fault-block of somewhat remote date of uplift.[17] And tenth is a remarkably perfect granite dome, also not proved to be of fault-block origin, which may take the name of Cima (Spanish for summit) from a near-by railroad station in a pass at the southern end of the Ivanpah Range in southeastern California. This dome has been instanced by Lawson as a type of what he has called a panfan in the sense of being the form to which an upfaulted mass of granite would be reduced in the penultimate stage of a cycle of arid erosion.[18]

The eleventh and latest addition to the collection is the Argus Range, the second Basin Range east of the southern end of the Sierra Nevada in southeastern California. It was first seen to be Louderbacked over several square miles in the southern part of its eastern slope when I passed along that part of its base in company with Dr. L. F. Noble on my first trip to Death Valley in the spring of 1925. The northern end of the range was crossed with the same companion on a second Death-Valley trip a year later, when not only the eastern or back slope was seen to be irregularly Louderbacked, but the western or fault face was found to exhibit a series of down-stepping, lava-capped fault slabs of very convincing appearance; they are figured in outline in the account of the Peacock Range, above cited. But a long and high middle

11 W. M. D., "The Peacock Range, Arizona." Bull. Geol. Soc. Amer., 41, 1930, 293–313.

12 W. M. D., "The Basin Range Problem," Proc. Nat. Acad. Sci., 11, 1925, 387–392.

13 W. M. D., "The Wasatch, Canyon and House Ranges, Utah." Bull. Museum Comp. Zool., 40, 1905, 17–56; see pp. 19–21.

14 W. M. D. and Baylor Brooks, "The Galiuro Mountains, Arizona." *Amer. Jour. Sci.*, 30, 1930, 89–115.

15 R. W. Bailey, "The Bear River Range Fault." *Amer. Jour. Sci.*, 13, 1927, 497–502.

16 W. M. D., "The Santa Catalina Mountains, Arizona," *Amer. Jour. Sci.*, 22, 1931, 289–317.

17 W. M. D., "Rock Floors in Arid and in Humid Climates." *Jour. Geol.* 38, 1930, 1–27, 136–157.

18 A. C. Lawson, "The Epigene Profiles of the Desert." Univ. Calif. Geol. Bull., 9, 1915, 23–48.

section of the eastern slope, of which I had a good view in 1931, in company with a former student, Samuel Storrow, of the Harvard class of 1887, now a retired engineer in Los Angeles, is without a lava cover, and taken by itself affords no satisfactory evidence of its manner of upheaval.

Since then I have secured from R. W. Mumford, chemical engineer of the American Potash and Chemical Company at their works at Trona on the saline sheet known as Searles Lake, next east of the southernmost part of the range, several airplane photographs, and some of these show a typical Louderback of small area at a considerable altitude, about midway between the eastern and western margins of the range. This spring I have been fortunate enough to visit that isolated lava sheet, again in company with Mr. Storrow and under the guidance of Mr. Mumford, whose car carried us along a rough road up a submature valley eroded in the western or fault front of the range, where no traces of spur-end facets survive. We drove to within half a mile of the lava cap, so that we had to make but a short distance on foot before reaching its long, smooth surface.

The view there disclosed was notable in several respects. It was of course a treeless view, although a good part of the surface is occupied by the spaced growth of bushy, knee- or waist-high vegetation, with the 5- or 6-foot creosote bush (Covillea) overtopping all the rest; for the range stands well within the arid area of the "Great American Desert," as Frémont properly named the region nearly a century ago, and the desert is still present in spite of its having been, in the flattering phrase of its venturesome settlers, "taken off the map." It is indeed a formidable feature of the Southwest to those who happen to be lost upon it, although invitingly entertaining to those who can dominate its dangers in this modern era of automobile travel.

From the higher, western end of the lava cap, we could see most of its extent gently slanting eastward before us; but instead of holding the same slant to the foot of the range, after the fashion of the evenly inclined Louderbacks of the Humboldt Lake ranges, the continuation of this lava sheet was upwarped or upfaulted in a series of separate, more or less convex and moderately inclined swells, between which a number of valleys were sharply incised. Not until it approached the eastern side of the range, was it lost to view on pitching down at a decidedly steeper slope. To the south several granite mounts rose with craggy and bouldery forms of moderate acclivity above the height at which the prolongation of the local lava cap would reach their flanks, as if they had held their heads up on the Powell surface like islands in the shallow lava sea, just as Steptoe Butte, southwest of Spokane, has stood up above the much heavier lava floods of Washington. The much higher mid-length of the Argus Range may also never have been lava covered, for it shows no trace of lava caps to-day.

This range may therefore be taken as a new type of fault-block mountain on three counts. First, in that its southern Louderback was exceptionally thin and markedly discontinuous; second, in that its uplift, near the southern end at least, was characterized by irregular upfaulting and upwarping; and third, in that the northern end of its fault face shows several close-set step faults. The exceptional thinness of the southern Louderback was noted on my first sight of it. None of its well-exposed edges, where numerous ravines are cut through it, appeared to have a greater thickness than 20 feet,[19] and as the part of the Powell surface that it covered appears to have included an area of several score square miles, that surface must have been very nearly a level plain before it was irregularly upheaved to its present attitude. It must have in that respect rivalled the Powell surface of the Humboldt Lake region, which is described by Louderback as being "of very low relief, approaching, to say the least, a peneplain," and as having "at many places closely approximated a plain." Residual mounts may, however, have survived there as well as in the Argus region; for an outflowing lava sheet would necessarily spread upon the lowest and flattest ground it could reach.

It may have been noticed that the foregoing pages treat different parts of the longer Basin ranges as if they were individuals; for nothing is clearer than that the upfaulting of the Gilbert blocks frequently varied in measure and in date along their length. This is manifest in the long Wasatch Range of Utah, where one can distinguish major, minor and minim faulting movements diversely developed at different points, as well as major, minor and minim detrital fans that have been formed in consequence of such movements. Several major fans are to be seen, hardly disturbed, near the town of Nephi, 75 miles south of Salt Lake City; minor fans abound farther north where minor movements have taken place; and minim fans may be seen some 40 miles north of Salt Lake City, where extremely recent movements have not only raised the mountains but have at the same time depressed the previously formed larger fans, so that the marshes of Great Salt Lake come almost immediately to the base of the range.

Another physiographic feature that gives some

[19] Since writing this statement, Mr. G. W. Richards, Jr., one of my students at Stanford University three years ago, has shown me several photographs of the Argus Louderbacks he has lately taken, in which a local thickening of the lava sheet to two or three times its ordinary measure appears at several points, as if the Powell surface were there rather strongly channeled.

variety to Basin Ranges is the occurrence of landslides on their fault fronts, as Russell years ago showed for some of the youngest ranges in the northwestern part of the Basin and Range province.[20] A large slide stretches several miles along and forward from the front of the Canyon Range, 70 miles southwest of Salt Lake City; but it is, like the range itself, so well dissected that little idea of its initial form can be gained; it is indeed of pre-Bonneville date, as bluffs of the Bonneville shore-line are cut along its outer margin. Its scar in the mountain front is completely effaced.[21] What I have taken to be a much younger slide in the northern part of the Wasatch Range, 70 miles north of Salt Lake City, has left a manifest cavity in the range front and has heaved up the piedmont alluvium in broad swells, little dissected.

It may well be that there is so great a physiographic variety displayed by the Basin Ranges that every one must be regarded as showing individual features. Hence when all the ranges have been professionally studied and made known in published reports the above-presented beginning of a collection to illustrate their variations, which might even now be enlarged by fuller reference to studies by other observers, may be extended to a comprehensive completeness. I wish some younger physiographic geologist, preferably one living in or near the Basin and Range province, might make the extension of the collection his specialty.

[20] I. C. Russell, "Topographical Features Due to Landslides." *Pop. Sci. Monthly*, 4, 1898, 480–489.

[21] See the above-cited article on the Wasatch, Canyon and House ranges.

OPENING OF THE CANADIAN NATIONAL RESEARCH LABORATORIES

SCIENCE offers the greatest of all adventures. Science has no night, the dawn is always here. The scientific leaders of each generation open before the eyes of the world new avenues of activity, new sources of human enjoyment, new powers to be utilized in human development. May I say to the Government of Canada and to the people of Canada that we of the National Research Council are grateful for the opportunity that these laboratories will give us to take our share in the future development of our country, and will you believe me when I add that we shall regard these laboratories as a sacred trust given to us to be utilized for the upbuilding and strengthening of the nation.—*Dr. H. M. Tory, president of the National Research Council of Canada,* upon the occasion of the formal opening of Canada's National Research Laboratories.

IN the presence of more than 2,000 invited guests of the Honorable H. H. Stevens, the chairman of the Committee of the Privy Council of Canada on Scientific and Industrial Research, including the Right Honorable Stanley Baldwin, head of the Department of Scientific and Industrial Research of Great Britain, and the leaders of other delegations to the Imperial Economic Conference then in session in Ottawa, the Earl of Bessborough, Governor-General of Canada, formally declared Canada's new national research building open on Wednesday evening, August 10.

Dean J. W. Barker, of Columbia University, represented the National Research Council of the United States and the Bureau of Standards of the United States Department of Commerce. The official ceremony took place in the engineering laboratory, which, with the addition of the assembly hall, to which the addresses were carried by loud speaker attachments, provided ample accommodation. Arrangements were made for the transmission of the addresses by radio throughout the British Empire and the United States.

The Honorable Mr. Stevens, as chairman; the Right Honorable R. B. Bennett, the prime minister; His Excellency the Governor-General, and Dr. Tory, who, as president of the National Research Council of Canada, has directed its development since 1923, delivered addresses.

Following the official ceremony of opening, a reception in honor of Imperial Economic Conference visitors was held in the building, and guests inspected the exhibits prepared to illustrate the work of the four divisions into which the work of the laboratories has been divided: Biology and agriculture, directed by Dr. Robert Newton; chemistry, directed by Dr. G. S. Whitby; physics and engineering, directed by Dr. R. W. Boyle and J. H. Parkin, assistant director, and the division of research information, directed by F. E. Lathe.

The National Research Council of Canada was organized by the Government of Canada during the world war and proceeded to its work along three main lines until 1928, when the organization of National Research Laboratories at Ottawa was commenced: (1) The granting of scholarships to train research personnel; (2) the granting of assistance to individuals in university or other laboratories to make particular researches possible; (3) the coordination and stimulation of group research efforts.

In what is now known as the National Research Laboratories Annex, the division of physics and engineering and the division of chemistry commenced operations in 1929, and construction of aeronautical