Southwestern portion of United States Geological Survey Topographic Map of the Concord Quadrangle, showing behavior of drainage courses crossing the Haywards Rift and the contrast in topography resulting from vertical-component faulting in the Berkeley region and warping in the Lake Temescal-Diamond Canyon Sector. The Haywards Rift extends from the "B" of Berkeley through Lake Temescal and a point somewhat west of the southeast corner of the map. (Scale approximately one inch to the mile; contour interval twenty-five feet.)
NATURE OF THE LATE MOVEMENTS ON THE HAYWARDS RIFT, CENTRAL CALIFORNIA

By JOHNP. BUWALDA

INTRODUCTION

San Francisco Bay, with the cities of Berkeley and Oakland on its eastern shore, lies on a depressed block which is demarked rather sharply from a higher-lying dissected area to the northeast. In his masterful discussion of the geology of the region published in the *San Francisco Folio* Professor Lawson applied the same San Francisco–Marin Block to the lower area. The mountainous area to the northeast was designated the Berkeley Hills Block. The latter presents a rather steep and regular front toward the southwest for seventy miles or more, from San Pablo Bay on the north to beyond Mount Hamilton on the south.

The boundary zone between the depressed and the elevated blocks has usually been termed the Haywards fault zone. Professor Lawson indicated that this zone is characterized by both faulting and warping.

It is not the purpose of this paper to question generalizations previously published regarding movements along the Haywards fault zone, with which the writer agrees in the main, but to emphasize certain new evidence and to point out its logical interpretation.

REVERSAL IN VERTICAL POSITION OF THE BERKELEY HILLS AND SAN FRANCISCO–MARIN BLOCKS

In examining the geologic maps in the *San Francisco Folio*, and others, one is struck by the fact that the pre-Quarternary rocks exposed along the southwest side of the Haywards fault zone are almost entirely pre-Cretaceous formations. The only exceptions mapped or known to the writer are a very few small areas of Knoxville lower Cretaceous, probably faulted into the Franciscan. On the other hand, the surface

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1 Read before the Cordilleran Section of the Geological Society of America, Berkeley, February 20, 1925.

rocks of the Berkeley Hills Block, northeast of the fault zone, are dominantly Cretaceous and Tertiary formations.

The physiography, shown on the Concord, San Francisco, and Haywards Quadrangles, indicates clearly that the Berkeley Hills Block has been uplifted in late geologic time 1,000 to 1,500 feet above the level of the block on which the bay rests.

A rather unusual relationship therefore presents itself. We observe a depressed block composed of pre-Cretaceous rocks lying adjacent to an elevated block made of Cretaceous and younger formations. This relation is of course just the reverse of that found along most fault zones. The depressed block usually bears the younger formations, since on it they lie protected from erosion, while the uplifted block normally is being stripped or has been stripped of the strata which form the surface of the depressed block.

The logical interpretation of all the facts set forth above seems to be that the two blocks had a topographic relation to each other at an earlier stage in the history of the movements which was precisely the reverse of the present relation; that the San Francisco–Marin Block stood high and was stripped of its Cretaceous and Tertiary formations while in that position; that the Berkeley Hills Block meanwhile stood low and the younger formations on it were preserved by virtue of position below base level. The most interesting feature of these tectonic events is the reversal of direction in the vertical component of movement along the Haywards fault zone from upward on the southwest to downward on the southwest.

Alternative explanations can be formulated to satisfy the existing geologic and physiographic conditions set forth above. The Cretaceous and Tertiary strata in the Berkeley Hills Block very commonly dip northeastward into the face of the hills, and one might regard the San Francisco–Marin Block as the stripped core of an anticline or of a broadly up-arched structure of more complex nature, of which the northeastward-dipping strata lying northeast of the fault merely constitute the northeastern limb. But the fault or fault zone and the fault scarp exist, and the anticlinal explanation would require invoking the unlikely supposition that the fault followed almost precisely, and for a very long distance, the contact between the pre-Cretaceous and the Cretaceous rocks determined by erosion. But even if it had done so, there should occur either extensive strips of pre-Cretaceous rocks in the face of the fault scarp or long patches of Cretaceous and Tertiary rocks along the southwest side of the fault, since the latter is known
to dip much steeper than the strata lying to the northeast of it. Moreover, the fact that the folds in the Cretaceous and Tertiary strata on the Berkeley Hills Block trend somewhat more westerly than the Haywards fault and are cut off by it emphasizes further the failure of this explanation to satisfy the observed facts.

A second explanatory suggestion is that the scarp is a fault-line scarp produced by erosional removal of the upper part of the southwestern block, which under this view might have moved only upward with reference to the northeastern. But the well-known superior resistance to erosion of the pre-Cretaceous rocks constituting the southwestern block immediately denies this suggestion.

A third alternative hypothesis is that the great difference in the rocks on the two sides of the Haywards fault zone has resulted from horizontal movement along that fault. While it is clear, from their lithologic character, that the Miocene and earlier strata in the Berkeley Hills Block must originally have extended farther westward and across the fault over parts at least of the San Francisco–Marin Block, it is quite possible that certain portions of the latter block lying adjacent to the Haywards fault may not have been so covered. Such areas of pre-Cretaceous rocks might by horizontal shifting come to occupy positions opposite areas of Cretaceous and Tertiary strata in the Berkeley Hills Block. This would obviate the necessity of postulating vertical movement.

But decisive objections to this hypothesis exist.

a) The southwestern block does not bear, within reasonable distances to northwest or southeast, areas of sediments which can legitimately be considered as the former western extensions of the strata outcropping in the face of the Berkeley Hills. They are lacking in the Haywards, Concord, and San Francisco quadrangles in the areas southwest of and adjacent to the fault; this means for a distance of some thirty-five to forty miles from San Pablo Bay southwards. North of San Pablo Bay Dickerson has located a zone of recent movement along the southwest side of Sonoma Mountain which he considers the northwestern extension of the Haywards Rift. The Sonoma volcanics, presumably of Oligocene age, occur northeast of the fault; to the southwest of it are extensive areas of other Tertiary sedimentary rocks. But the latter formations do not correspond to the Berkeley Hills section. It might be argued that the post-Monterey freshwater strata and volcanics

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of the Berkeley Hills did not ever extend across the fault and over the San Francisco–Marin Block; if not, the best explanation would be that the latter block presented a face or scarp to the northeast at that time, in just the reverse direction from the present scarp, and formed the southwest wall of the later Tertiary basin of deposition. This is our postulate.

b) A second objection to the hypothesis that horizontal movement has brought about the present distribution of rocks on the two sides of the fault is that, according to published maps, notable areas of pre-Cretaceous rocks do not appear in the southwestern margin of the Berkeley Hills Block north of the latitude of San Jose. The northern boundary of the area of Franciscan rocks northeast of the Haywards Rift in that region is about sixty miles distant from the northern boundary of the Franciscan area southwest of the presumed Haywards Rift north of San Pablo Bay. The explanation of the present areal geology by horizontal movement would require a northward shift, of that magnitude, of the western block relative to the eastern. While certainly possible, this seems rather improbable.

In summary then it may be said that the explanation first set forth for the present geologic conditions along the Haywards Rift, i.e., that the San Francisco–Marin and the Berkeley Hills Blocks have suffered reversal in direction in the vertical component of movement, satisfies the facts of observation, while the other three hypotheses suggested fail to do so.

Structurally this conclusion is interesting because it indicates reversal in direction of movement on one component of many hundreds of feet along a half-hundred or more miles of a fault. Geomorphically it presents the uncommon case of a northeastward hill face or scarp being supplanted, along the tectonic line genetically responsible for its development, by a southwestward-looking scarp. Scarps sometimes face in opposite directions along different parts of a single fault; this is a change of relation in space. The Berkeley Hills case is a change of relation in time.

The concept of reversal in direction of vertical-component movement is consistent with Lawson’s view that the Haywards fault is an old structure, antedating the present geomorphology.

Nature of the Vertical Displacement on the Haywards Fault

The physiography of the adjacent marginal portions of the Berkeley Hills and San Francisco–Marin blocks sheds considerable light on the
nature of the recent vertical displacement and marginal deformation. Along some parts of the Haywards fault zone the vertical displacement occurred mainly through slipping along the fault; this was the case along the two- or three-mile section extending from the University of California campus to the neighborhood of Lake Temescal. Along other portions the relative uplift of the Berkeley Hills Block was accompanied by warping of the marginal parts of the blocks, with very little slipping in the vertical component along the fault; this was the nature of the deformation from Lake Temescal southward for several miles through the territory lying just east of Piedmont. Physiographic features bearing on these conclusions follow.

Berkeley–Lake Temescal Sector. Along this sector, shown on the Concord Quadrangle, the southwest face of the hills is a rather typical fault scarp, considerably dissected (Plate 19). The base line is relatively straight. It transects the structure of the hills somewhat obliquely in a fashion analogous to the ranges of the Great Basin. Southwestward-flowing streams such as Strawberry, Claremont, and Temescal Creeks, have invaded the block by headward erosion about one and one-half miles; the crests of interstream ridges have relatively even and gentle inclinations to the southwest and fall rather accordantly into a common level, suggesting the former existence of a land surface of subdued relief lying a little above the present ridge crests. The ends of the interstream ridges are truncated by triangular facets; these are somewhat dissected, but their general inclination of slope is several times as great in feet per mile as the southwestward inclination of the ridge crests, and the triangular facets make definite angles with the ridge crests of ten to twelve degrees at their apices. The truncation of Skyline Ridge, just southeast of the University campus, is an excellent example; one basal angle of the triangular facet is at the mouth of Strawberry Canyon, another at the mouth of Claremont Canyon, and the apex approximately midway between them, some seven hundred feet higher, and naturally considerably farther northeast. Similarly striking is the definite angle which the facets make with the relatively smooth land surface extending southwestward from their bases.

A feature of the triangular facets indicative of the recency of their development is the marked steepening at the base. The steep slope immediately east of the Greek Theater is an example; another is the face at the head of Dwight Way, a half-mile to the southeast. The lower part of the face at the latter point slopes thirty-one degrees, an inclination seldom exceeded at the base of the fault ranges in the Great Basin.
It is rendered the more emphatic by the contrast of the Bay region’s twenty-six inches of rainfall, and its correspondingly greater erosion rate, with the relatively arid climate of Nevada.

The depressed block west of the Haywards fault did not, in the Berkeley–Lake Temescal sector, acquire a tilt toward the fault during its down-sinking; quite the contrary. Its central part, covered by San Francisco Bay, and its northeastern part, are receiving sediments and alluvium, but a strip on the northeastern margin of the block along the fault rises from beneath the waste deposits and displays bedrock, the Franciscan formation. Though slightly alluviated locally, it presents a subdued, approximately late mature or early old age, land surface. This northeastern margin of the block slopes southwestward at an angle steeper than it possessed when its surface of mild relief was produced, for it is being actively sculptured now, especially in the Claremont region. Strawberry, Claremont, and other creeks heading in the hills have recently sunk trenches across it. These observations indicate that the northeastern margin of the San Francisco–Marin Block was upturned somewhat during its depression; this margin apparently tended to follow and was dragged upward by the Berkeley Hills Block during the differential movement. Strictly vertical movement on the fault is not of course postulated; the movement could be oblique, only a vertical component of movement being required.

It seems logical to assume that a former subdued land surface on the Berkeley Hills Block, reconstructed from, but somewhat above, the accordant crests of the east-west (and perhaps also north-south) ridges, was before the faulting geographically continuous with the neighboring limited areas of old land surface still to be seen on the northeastern margin of the southwestern depressed block.

Lake Temescal–Diamond Canyon Sector. Lake Temescal lies in the Haywards Rift at the southeast end of the two-mile sector discussed in the previous section. For the next three miles southeastward the rift zone presents a somewhat different geomorphology (Plate 19).

In line with the west base of the scarp discussed in the Berkeley–Lake Temescal Sector a straight, flat-floored fault-line valley extends southeastward between the southeastward continuation of the scarp seen in the northern sector and the highly uplifted margin of the San Francisco–Marin Block. This valley, discussed by Professor Lawson in the San Francisco Folio, is unique; it trends parallel to the face of the hills instead of in the normal transverse direction; it is remarkably straight; its flat floor often has a width of one-eighth of a mile; its
southwestern wall, and sometimes its northeastern, is surprisingly steep and rectilinear for considerable distances; and it contains longitudinal slice ridges and sag ponds as evidences of relatively recent displacements.

The scarp which rises from the rift on the northeast resembles the southwest face of the hills in the sector to the north, of which it is of course a direct southeastward continuation. The interstream ridge crests descend gradually southwestward, and end in triangular facets, of which an excellent example is to be seen just east of Lake Temescal. As Professor Lawson has indicated, the rift valley is probably largely of erosional origin along the rock crushed by the faulting, and the scarp in this sector may therefore be largely a faultline scarp, created by the erosional removal of the crushed zone which lay to the southwest of it.

The margin of the San Francisco–Marin Block rises quite rapidly as one proceeds southeastward from Lake Temescal along its crest, until it stands some six hundred feet above the alluviated plain to the southwest of it. The strip of exposed Franciscan formation on the southwest side of the rift widens to a maximum of nearly two miles measured at right angles to the rift. The northeast slope of this marginal uplifted portion of the depressed block is very short and precipitous; the crest is very near the rift valley. The southwest face, sloping under the Piedmont residence district, is relatively long and gentle, and its physiographic expression is that of late maturity or early old age. It is cut across a variety of old resistant rocks and must have been developed in a position near base level and subsequently tilted, for the streams draining this slope in the present physiographic cycle are trenching it.

If the general profile across this margin of the depressed block is projected northeastward, it rises to merge with the general level of the crests of the southwest-trending interstream ridges on the Berkeley Hills Block; if the rift valley were filled to its top on both sides a nearly continuous and unbroken profile would result. Airplane views of the Berkeley Hills Block suggest strongly that its southwestern margin is bent downward somewhat.

The foregoing observations lead to the conclusion that in the Lake Temescal–Diamond Canyon section, while large horizontal movements may have occurred, as will be discussed presently, fault-slippping in the vertical component was inconsiderable during the relative uplift of the Berkeley Hills Block. Geomorphically the effect is therefore that of a warped surface extending from the San Francisco–Marin Block across the excavated rift valley on to the Berkeley Hills Block.
In summary, taking the two sectors discussed above as typical of the boundary zone between the two blocks, the nature of the late vertical displacement was very variable along the Haywards fault zone, ranging from movement with a vertical component of hundreds of feet and production of bold fault scarps, to movements which in their geomorphic effects were essentially warps with very little fault displacement in the vertical component.

**Recent Horizontal Movement**

Observations along the Haywards fault zone in the region east of Berkeley and Oakland indicate that the net result of the most recent movements has been a nearly horizontal displacement of the two blocks, the San Francisco–Marin Block moving relatively northwestward with reference to the Berkeley Hills Block.

*Mouth of Strawberry Canyon.* Peculiar features in the physiography at the mouth of Strawberry Canyon puzzled the writer for some years during casual examinations.

The creek emerges from the hills with a course somewhat south of west (Plate 20). At the mouth of the canyon it turns to the right more than half a right angle and flows for about 1,300 feet northwestward, parallel to the face of the hills. It then turns westward again and flows through the campus of the University of California in a trench which has a depth of about forty feet near the hills and shallows westward to a few feet at the western edge of the campus. The western section of the creek is offset approximately 1,200 feet from that in the hills.

Claremont Creek, a half mile to the south, shows a deflection in the same direction at its mouth, but of less magnitude.

Previous to the very extensive modification of the topography by man in 1923, a ridge projected in a peculiar manner across the mouth of Strawberry Canyon from the south side. As shown on the map, it paralleled the northwestward-flowing part of Strawberry Creek and continued to the point where the creek turns westward again. It presented a steep face, some forty feet high, eastward toward Strawberry Canyon, and a moderately steep face westward toward Berkeley. It was even crested. A small, rather striking, broad-bottomed valley, also clearly shown on map, extended southward from Strawberry Creek for a short distance between this ridge and the face of the hills, to the head of Prospect Street. While quite wide, this was clearly not a stream valley, for no stream drained through it. It had the characteristics of a fault-line valley.
Portion of a map of the Berkeley hills. The Haywards Rift passes through a point somewhat west of the "L" of University and a point somewhat east of south end of Prospect Street as shown on map. Map shows northwestern offset of Strawberry Creek, ridge lying across mouth of Strawberry Canyon, faultline valley extending southward along east side of this ridge, and Hamilton Gulch, at the mouth of which the ridge once lay. (Scale approximately 1,000 feet to the inch; contour interval ten feet.)
The ridge might at first sight have been regarded as a remnant of an alluvial fan formerly built up by Strawberry Creek and later abandoned when the creek trenched it along its northern edge. But its west slope is far too steep for a fan such as Strawberry Creek would build. The ridge is moreover made mainly of Leona rhyolite and Franciscan rocks, with only a mantle of alluvial deposits. Parts of the ridge are brecciated, and bands of fault gouge occur in it.

Four trenches about eighteen feet deep were dug across the crest of the ridge in 1923. The writer was surprised to find that the mantling materials exposed in the trench walls were quite unlike those being transported by Strawberry Creek today. While some clay and sand were shown, a large part of the material consisted of angular fragments of Chico sandstone. The deposit is a rather typical waste slope deposit such as would form near the base of a steep scarp. The writer was for a time puzzled by finding a few pieces of serpentine among the Chico sandstone fragments. No exposures of serpentine are known in the drainage of Strawberry Canyon. A small area occurs, however, in Hamilton Gulch, the next drainage channel to the south. It might be conjectured that the serpentine fragments were derived from the erosion of the Campan or Orindan formations in the drainage basin of Strawberry Creek, but it seems most unlikely that pebbles of this composition would withstand weathering and transportation a second time incidental to removal from the sedimentary formations and re-deposition at the mouth of the canyon. The matrix in which the fragments were found on the ridge across the mouth of the canyon is moreover not a stream deposit. Hamilton Gulch is short and steep; fragments are detached from the exposure of serpentine and are rapidly transported with angular waste slope material on to the fan at the mouth of the gulch. The writer has recently noted scattered pieces along the dry bed.

The only rational explanation of the physiographic conditions at the mouth of Strawberry Canyon seems to be that, at a date so recent that the topography of the region was already essentially that of today, the southwestern block moved horizontally northwestward with reference to the northeastern. This movement offset Strawberry Creek, pushed the high edge of the western block as a ridge across the mouth of Strawberry Canyon, and carried a waste-slope or high-grade fan deposit formed at the mouth of Hamilton Gulch some 1,400 feet northward and to a position facing its foster mother, Strawberry Canyon.

The elevations of the point where the serpentine fragments were found and the mouth of Hamilton Gulch are essentially the same, four
hundred feet above tide, and the net movement was therefore almost entirely horizontal.

Botanical Garden Depression. A rather broad depression, north of the University of California Library, extends in an east-west direction through the campus. Although obscured somewhat by road grading and the building of the fountain south of the Hearst Memorial Mining Building, it is a persistent feature to the base of the Berkeley Hills. At a point just north of the Greek Theater it is still quite deep but it ends abruptly against the base of the steep front of the hills. Though its form indicates that it was sculptured by an active watercourse it is not continuous with any canyon or gulch in the hills at present, but ends instead against the face of a fault-truncated shoulder of the Berkeley Hills. It is quite certainly the abandoned channel of a stream which issued from the hills and it is altogether probable that Strawberry Creek is the stream which formerly occupied it. The fact that the northern or Botanical Garden Channel has a steeper slope than Strawberry Creek would in all probability have possessed, presumably indicates that slight upturning of the northeastern edge of the southwestern block has occurred since the abandonment of the former channel.

A branch of the Botanical Garden Channel, of considerable width and depth, extends northeastward between the Mining and the Mechanics buildings. It likewise appears to be unrelated to any important drainage line issuing from the Berkeley Hills. It is presumably a still earlier course of Strawberry Creek, abandoned as the result of northwestward movement of the southwestern block; this shifted the creek to the Greek Theater–Botanical Garden Channel. Should this movement continue in the future, the branch passing northwest of the Mining Building will eventually become available for the use of Woolsey Creek, which now issues from the hills two blocks north of the campus.

Lawson Adit. Ten or twelve years ago the College of Mining commenced driving a tunnel, known as the Lawson Adit, into the hill just east of the Mining Building. It enters the slope in rather firm Franciscan sandstone, but within a few feet it passes into the crushed material of the Haywards fault zone, into which it has reached perhaps two hundred feet, nearly at right angles to the trend of the zone. The walls of the tunnel show much gouge, breccia, slickensides, and intermingled blocks of sandstone and rhyolite of various sizes. The planes of movement appear to be approximately vertical in most cases. Evidences of approximately horizontal movement were noted on slickensides. These are consistent with the horizontal striations and grooving on the sicken-
sides so excellently exposed on Founders Rock, a few rods northwest of the adit.

The tunnel therefore offers abundant and convincing evidence of the presence, the location, and the general vertical attitude of the fault zone, and of the horizontal nature of the movements which have at times at least occurred along it.

In the roof of the tunnel nearly horizontal gravels lie across the eroded edges of the nearly vertical fault slices and bands of gouge. While exposures are somewhat limited, the surface on which the gravels lie appears to be nearly flat. Of the vertical fault surfaces seen none apparently passes up into the gravels. The gravels are quite similar to those now exposed in the banks of Strawberry Creek near Bacon Hall and the Power House; these deposits are quite certainly attributable to that stream and are now exposed by partial re-excavation. Like the latter, the gravels in the roof of the Lawson Adit consist of partially rounded and polished pebbles and boulders of basic lava, sandstone, schist presumably derived from conglomerates in the hills, and Monterey shale. It is quite clearly not a waste slope deposit but shows sorting and wear, and was laid down by a rather vigorous stream. The source of the stream was in an area in which basic lavas and Monterey shales were exposed. Woolsey Creek, tumbling down the scarp two blocks north of the campus, is the nearest notable drainage line in that direction, but it could scarcely have deviated from its natural westward course to pass east of the Mining Building. It moreover has no Monterey shale exposed in its drainage basin. Strawberry Creek or Claremont Creek, to the south, could, however, have furnished the materials for this deposit. It is most probable that it was laid down by Strawberry Creek.

Lake Temescal–Diamond Canyon Sector. It might be supposed that if horizontal movement occurred along the Haywards Rift in relatively recent time evidence corroborating that displayed in the Strawberry Creek region should be observable along the rift somewhat farther south. While the physiography of the Lake Temescal–Diamond Canyon Sector accords well with the concept of horizontal movement, the writer has found no directly confirmatory evidence.

In the northern part of this sector all the streams which issue from the Berkeley Hills Block are diverted northwestward along the rift valley; this might result either from horizontal movement northwestward of the southwestern block or from headward erosion and piratical diversion of the headwaters of those streams which originally flowed from the Berkeley Hills Block across the present site of the rift valley and
down the southwest slope of the margin of the depressed block. Farther south Shepard Creek emerges from the Berkeley Hills, crosses the rift valley with a peculiar kink, and proceeds southwestward through the only opening across the uplifted edge of the southwestern block, Diamond Canyon. It is not unlikely, judging from the extremely youthful appearance of Diamond Canyon just southwest of the rift valley that upper Shepard Creek and all the streams flowing out of the Berkeley Hills for a mile and a half to the south originally drained northwestward along the rift valley, through the Lake Temescal area, and that Diamond Canyon as a pirate into the rift valley has diverted the upper portion of that drainage system. Whether this is true or not, Diamond Canyon may well have occupied a position somewhat southeast of its present site with reference to upper Shepard Creek; the drainage pattern and physiography do not appear to be decisive with reference to horizontal movement.

Notches cross the ridge lying southwest of the rift valley south of Lake Temescal; some of these are quite deep and broad and on the assumption that the drainage into Lake Temescal was won by piracy through headward erosion along the crushed rift zone, some of these notches were formerly occupied by streams emerging from the Berkeley Hills Block northeast of the rift valley. The writer has attempted to determine the correspondence between notches and the streams across the rift valley but with indifferent success. If the deep notch southwest of the mouth of Kohler Creek was originally occupied by that stream, a slight movement of the southwestern block toward the northwest is suggested. But the streams flowing off the Berkeley Hills Block may have had irregular courses across the rift valley before passing out of it through the notches, and evidence regarding horizontal movement seems indecisive.

South of Diamond Canyon. Six or eight miles farther southeast, at the southern margin of the Concord Sheet, Arroyo Viejo presents at its mouth conditions somewhat similar to those displayed at the mouth of Strawberry Canyon. While not entirely conclusive, the conditions there are highly suggestive and fully accordant with the concept of relative northwestward movement of the southwestern block along the rift.

R. J. Russell has recently described, in the Haywards and Pleasanton Quadrangles to the south, offsets in stream courses, and also fans on the southwest side of the rift which had been offset northwestward with reference to the mouths of the creeks which had built them on

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* * * "Recent Horizontal Offsets along the Haywards Fault," The Journal of Geology, 34, 507–511, 1926.
issuing from the Berkeley Hills Block. The evidence adduced by Russell for horizontal movement appears conclusive.

The horizontal movement on the Haywards fault discussed above, in which the southwestern block moved northward, is similar in direction to the movement of fifteen to twenty feet which occurred on the parallel San Andreas fault about eighteen miles to the west at the time of the San Francisco earthquake of 1906.

Summary of Evidence for Recent Horizontal Movement. The northward shift of the southwestern block is then indicated by offset of Strawberry Creek, presence of the ridge athwart the mouth of Strawberry Canyon, deposits on this ridge, apparently derived from a gulch 1,400 feet to the southeast and since moved northward, abandoned channels in all probability cut by Strawberry Creek and later shifted, stream deposits presumably laid down by Strawberry Creek and now shown in the roof of the Lawson Adit at the Mining Building, and offset streams and alluvial fans lying on the northeastern margin of the San Francisco-Marin Block cited by Russell as having moved northward with reference to the corresponding canyon mouths on the Berkeley Hills Block.

Summary

The observations set forth in this paper are believed to indicate that:

1. The northeastern part at least of the San Francisco-Marin Block formerly stood higher instead of lower, as at present, than the southwestern part of the Berkeley Hills Block; a northeastward-facing fault scarp, instead of one sloping southwest, presumably rose along the approximate site of the present hill front. This means a rather striking reversal of the physiographic and drainage conditions now existing in the Eastbay region.

2. Reversal in direction of the vertical-component movement along the Haywards fault zone occurred, giving rise to the present topographic relations. This movement was in part warping.

3. The latest movement has been an essentially horizontal northward displacement, relatively, of the San Francisco-Marin Block with reference to the Berkeley Hills Block, by at least 1,400 feet.

The late relative movements of the former block with reference to the latter have therefore been successively upward vertically or obliquely, downward vertically or obliquely, horizontally northward.

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