ART. XI.—*A Theory of the Earthquakes of the Great Basin, with a practical application;* by G. K. GILBERT.

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THERE are many geologists who are very wise, but even they do not understand the forces which produce mountains. And yet it must be admitted, not only that mountains have been made, but that some mountains are still rising. The mysterious forces appear to act in different ways in different places, and it is possible that their nature is not universally the same. Suffice it to say that in the Great Basin the movements they cause are vertical. It is as though something beneath each mountain was slowly, steadily, and irresistibly rising, carrying the mountain with it.

In yielding to this all-compelling upward thrust, the earth's crust sometimes bends and stretches, but more often it breaks; and when it breaks, the fracture occurs in a peculiar place. It does not run along the medial axis of the mountain, but along one margin. On one side of the fracture the crust is lifted and tilted; on the other side it either sinks or remains undisturbed. The uplifted part of the crust is the mountain, and the storms carve out its cañons; the unlifted part remains a lowland or valley, and receives the debris washed out from the cañons.

A mountain is not thrown up all at once by a great convulsive effort, but rises little by little. The subterranean upthrust is continuous and slow, and would produce a continuous upward movement of the mountain if the mountain's weight were the only resisting factor. But there is also a great friction to overcome, the friction along the surface of fracture between the rising and stationary parts of the crust; and friction gives to slow motion an uninterrupted or rhythmic character.

The disagreeable jarring of a railway car while the brake is set is due to the interruption of motion by friction, the wheels alternately sliding and stopping. The musical vibration of a violin string is due to the alternate cohesion and sliding of the bow upon it, and fails when the friction of the bow is insufficient. Attach a rope to a heavy box and drag it slowly, by means of a windlass, across a floor. As the crank is turned, the tension of the rope gradually increases until it suffices to overcome the starting friction, as it is called. Once started, the box moves easily, because sliding friction is less than starting friction. The rope shortens or sags until its tension is only sufficient for the sliding friction, and it would continue in that state but that the box, having acquired momentum, is carried a little too far. This slacks the rope still more, and the box stops, to be started only when the tension again equals the starting friction. In this way the box receives an uneven, jerky motion.

Something of this sort happens with the mountain. The upthrust produces a local strain in the crust, involving a certain amount of compression and distortion, and this strain increases until it is sufficient to overcome the starting friction along the fractured surface. Suddenly, and almost instantaneously, there is an amount of motion sufficient to relieve the strain, and this is followed by a long period of quiet, during which the strain is gradually reimposed. The motion at the instant of yielding is so swift and so abruptly terminated as to constitute a shock, and this shock vibrates through the crust with diminishing force in all directions. Movable objects are displaced, and the soil, which is movable as compared with solid rock, is cracked. In consequence of earth cracks, subterranean waters find new channels, leading to the stoppage of some springs and the starting of others. In fine, all the phenomena of an earthquake are produced.

This is not a universal theory of earthquakes—some of them are doubtless to be accounted for in a different way; but it affords a sufficient, and I do not doubt that it affords the true, explanation of the earthquakes of the Great Basin. In this region a majority of the mountain ranges have been upraised by the aid of a fracture at one side or the other, and in numerous instances there is evidence that the last increase of height was somewhat recent.

Let us look a moment at this evidence. The material eroded from a mountain by the elements is washed out through the cañons and deposited in the adjacent valleys. The coarser part of it lodges at the mountain base, and is built into a sloping mass called the foot-slope, or colloquially the "bench." When an earthquake occurs, a part of the foot-slope goes up with the mountain, and another part goes down (relatively) with the valley. It is thus divided, and a little cliff marks the line of division. A man ascending the foot-slope encounters here an abrupt hill, and finds the original grade resumed beyond. This little cliff is, in geologic parlance, a "fault-scarp," and the earth fracture which has permitted the mountain to be uplifted is a "fault." In the course of time the same slow process of erosion and deposition which originally formed the foot-slope restores its shape and obliterates the fault-scarp. When a mountain ceases to grow, its fault-scarp soon disappears; and conversely, when we find a fault-scarp at the base of a mountain, we are assured that the uplifting force has not ceased to act. Fault-scarps have now been found at the bases of so many ranges of the Great Basin, that it is safe to say that the subterranean forces are generally active in this region, and this is especially true of all the large mountain masses. The Wasatch is a conspicuous example, and residents of this city need not go far for ocular demonstration. A fault-scarp, thirty or forty feet high, divides the powder houses north of the Hot Spring, so that some of them stand above and some below it, and considerable grading was necessary to lead the road to the upper magazines. With one exception, all the lime kilns between the powder houses and the Warm Springs are built in the face of the fault-scarp, the lime rock being conveniently delivered to the kilns from the upper level, and the lime as conveniently drawn out at the lower level. At the mouth of Little Cottonwood Cañon, a smelter has been built on the edge of the upper bench for the convenience of dumping its slag over the fault-scarp. At the mouth of Spanish Fork Cañon, the D. & R. G. Railroad encounters the scarp, and the engineers have started an embankment a long way back to climb it. Similar features may be seen, with rare intervals, all along the mountain base from Nephi to Willard.

The fault-scarps of the Wasatch follow the western base. Those of the Sierra Nevada follow the eastern base; and it happens that one of them has been formed since the settlement of the country. It occurred in 1872, and produced one of the most notable earthquakes ever recorded in the United States. The height of the scarp varies from five to twenty feet, and its length is forty miles. Various tracts of land were sunk a number of feet below their previous positions, and one tract, several thousand acres in extent, was not only lowered, but carried bodily about fifteen feet northward. The ground was cracked in various directions, and several springs permanently disappeared. All houses of adobe or stone in the immediate vicinity were thrown down, and about thirty persons lost their lives. In the little town of Lone Pine, numbering some three hundred inhabitants, twenty-one were killed by falling walls.

There was only one violent shock, and the damage was all done in a few seconds, but for two months there were occasional tremors. Theoretically, the main strain of the earth's crust was relieved at once, but a complete equilibrium was brought about more slowly.

The surviving inhabitants of Lone Pine observed that the only houses that remained standing were of wood, and in rebuilding they employed that material exclusively. Such a course was natural, but I conceive that their precaution was unnecessary. They may, indeed, feel feeble shocks propagated from earthquakes centering elsewhere, but in their own locality the accumulated earthquake force is for the present spent, and many generations will probably pass before it again manifests itself. The old maxim, "Lightning never strikes the same spot twice," is unsound in theory and false in fact; but something similar might truly be said about earthquakes. The spot which is the focus of an earthquake (of the type here discussed) is thereby exempted for a long time. And conversely, any locality on the fault line of a large mountain range, which has been exempt from earthquake for a long time, is by so much nearer to the date of recurrence— and just here is the application of what I have written. Continuous as are the fault-scarps at the base of the Wasatch, there is one place where they are conspicuously absent, and that place is close to this city. From the Warm Springs to Emigration Cañon fault-scarps have not been found, and the rational explanation of their absence is that a very long time has elapsed since their last renewal. In this period the earth strain has been slowly increasing, and some day it will overcome the friction, lift the mountains a few feet, and re-enact on a more fearful scale the catastrophe of Owens Valley.

It is useless to ask when this disaster will occur. Our occupation of the country has been too brief for us to learn how fast the Wasatch grows; and, indeed, it is only by such disasters that we can learn. By the time experience has taught us this, Salt Lake City will have been shaken down, and its surviving citizens will have sorrowfully rebuilt it of wood; to use a homely figure, the horse will have escaped, and the barn door, all too late, will have been closed behind him.

When the earthquake comes, the severest shock is likely to occur along the line of the great fault at the foot of the mountain. This line follows the upper edge of the upper bench from Big Cottonwood Cañon to the rifle targets back of Fort Douglass, cutting across each creek just where it issues from between walls of bed-rock, and passing only a short distance back of the fort. At a point not far north of the targets, the fault divides; one branch continuing northward, across the spur, toward Farmington; the other turning westward, running just back of that hopeless artesian boring, and following the upper edge of the gravel bench to the vicinity of the Warm Springs. Should the earthquake follow the former of these branches, the city will not fare so badly as the fort; should it follow the latter, or follow both, city and fort will alike suffer severely.

What are the citizens going to do about it? Probably nothing. They are not likely to abandon brick and stone and adobe, and build all new houses of wood. If they did, they would put themselves at the mercy of fire; and fire, in the long run, unquestionably destroys more property than earthquakes. It is the loss of life that renders earthquakes so terrible. Possibly some combination of building materials will afford security against both dangers.