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THE

QUEBEC LAND SLIDE

OF 1889.

BY

C. BAILLAIRGÉ, M. CAN. SOC. C. E.

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Thursday, 4th May.

E. P. HANNAFORD, President, in the Chair.

Paper No. 79.

THE QUEBEC LAND SLIDE OF SEPTEMBER 19, 1889.

By CHAS. BAILLAIRGÉ, M.Can.Soc.C.E.

In 1879 and for years past there had existed dangerous fissures in the cliff opposite the King's Bastion of the Citadel, Quebec. The attention of the Federal Government having been called to the alarming aspect of these "crevasses," the author was instructed by Sir H. Langevin, then Minister of Public Works, to make a survey of the locality and report thereon, with such suggestions as might be deemed advisable in the premises.

Plates IV and V, together with a vertical section of the cliff at each of the proposed buttresses, were prepared at that time and sent in with the author's report in January, 1880, with the exception, of course, that as the accident had not then occurred, it did not appear in Plate IV, as since indicated as comprised within the area *A B C D E F G*, and the line to which the debris were projected, as shown, on the opposite side of the roadway.

Plate IV is a plan or bird's-eye view of a portion of the Citadel and Glacis, the south-western extremity of Dufferin Terrace, and that part of Champlain street overtaken by the avalanche, or which was likely to be in case of an eventuality.

Plate V is an elevation or front view of the cliff, etc., showing the outcrops of the almost vertical strata of the face of the cliff, as shown in Plate VI.

The conclusions of the author's report were that, should the rock give way, it would take the houses on both sides of Champlain street, and that they must either be vacated, or a series of buttresses erected to stay the danger.

The rock being at the time in a state of stable equilibrium, and the portion of it which has since fallen not exceeding 36,000 tons, the aggregate counteracting weight of the buttresses being some 12,000 tons, would, no doubt, have proved effective for many years to come; but as the author laid greater stress on the recommendation to have the premises vacated, as the surer mode of conjuring the evil to be apprehended, the Government engineers advised the purchase of the property at the foot of the cliff and its demolition, as being also the cheaper alternative.

This suggestion was carried out, and a wall *a b c d e* on plan and *w* on section was erected, increasing the width of street by eight feet, and to answer as a screen or fender to prevent falling stones from rolling over to the opposite side of the street, and thus possibly avoiding accident to life, limb or property.

It is, of course, to be regretted that the property on the river side of Champlain street, at the site of the accident, was not also bought up and demolished (or, as Major Mayne suggests, the houses vacated, but left standing and filled in as a screen against falling debris), since, in the author's report, he repeated the warning that "when the cliff falls, it will be sure to destroy the property on both sides of the street."

There is another point in which both the plan and elevation now submitted differ from the originals of 1880; to wit: the indication thereon of the drain which from the King's Bastion runs along the foot of the rip-rap facing of the lower glacis, and thence under the Terrace flooring and through the wall as shown, towards Champlain street and the river; the existence of this drain being unsuspected at the time the plans were made.

Referring now to the following conclusions as to how the slide occurred, it will be understood that *C D E* is the line of outer crevasse along which the cliff parted, *A B C D E F G* that portion of the cliff which was forced out and fell over, the debris reaching, as shown on plan and section, to about 40 feet on the river side of Champlain street.

The crevasse indicated on plan and elevation as "present crevasse" is the one now existing, into which the water poured from the broken drain at *D*, filled the crevasse as hereinafter described, forced out the rock between the two fissures, and caused the portion beyond *C D E* to fall forward.

Intermediary fissures, not at first shown on plan, or not then known to exist, are now sketched in and shown on section, giving the strata their present fan-like, diverging or radiating appearance, and accounting for the fact, that while the present inner and main crevasse is almost vertical and, in fact, inclining towards the left or westward, the outer crevasse leans over or inclines towards the right or eastward by not less than 1 in 10.

The Quebec rock is, geologically, of the Utica slate formation, and, like other sedimentary strata, originally more or less horizontal. The subsequent tilting up of the strata to almost verticality is, one need hardly be reminded, due to the puckering, folding of the earth's crust under the seismic effects of contraction of the interior nucleus in cooling, and the outcrop of the strata to still subsequent erosion and wearing away of the upper portions of the folds by the hand of time.

There appeared in the *Canadian Architect and Builder* for October, 1889, a section of the cliff and description of the Quebec land slide of 19th September, 1889. The author had not at that time reduced the accident to calculation, nor had he then the necessary data so to do. Since then he has had to work up the case for the Exchequer Court and give evidence as to how the fall of the cliff was brought about. Having visited the Citadel ditches, he found that the whole ground fell some 40 ft. in level from the western to the eastern end; that the area, including roofs of casemates, draining towards the King's Bastion just opposite the centre of the avalanche of rock, was such that, into the depth of rainfall for the 12 hours immediately preceding the accident, it gave some 30,000 cubic feet of water, the average of rain and melted snow per annum for the last twenty years being 24".06 of rain and 15".45 of melted snow—a foot of snow being assumed equal to an inch of rain—or over one-quarter of a million cubic ft. per annum which had been pouring down the cliff for years past, instead of finding its natural outlet towards the river through the drain already alluded to, which had probably been built for 60 years or more, but which the author found to be completely choked with earth and rubbish, and so solidly packed that not a drop of water could find its way through it.

This drain, some 20" in diameter, though uselessly large for the duty it had to perform, was found to be burst or broken just below the King's Bastion already alluded to and immediately to the eastward of the stairs reaching from the Terrace to the Citadel. The aperture in the drain was just above the point at which it was so completely choked as not to allow of the water getting any further, so that all the water found its way directly into the fissure which now exists and has existed for years in rear of the Terrace, and, as already stated, opposite the very centre of the land slide.

Referring to Plate VII at *A* on plan and at *A D C* on section, is the present crevasse or fissure into which the water poured and has been pouring for maybe 30 years past, or ever since the drain, which ran north-eastward down the cliff towards the river, ceased to be operative, as evidenced by the author from the fact that from its outcrop half way down the cliff no water had been running for fully that number of years.

This fissure has existed for longer than anyone now can remember, and there is no doubt that the drain was built to prevent the Citadel ditch water from finding its way into it and thus hastening a land slide; but the drain seems to have been, in after years, entirely forgotten or paid no attention to, and nearly all that portion of it north-eastward of the break in the side of the brick barrelled portion of its continuation up the cliff being a mere deeply imbedded surface drain, it soon became filled in by the fall of the crumbling face of the shaly rip-rap work of the glacis front above it, dust and vegetable growth.

This fissure *A* up to the time of the accident had been mostly hidden from view by debris from above fallen into it at its outcrop, and public attention was concentrated on, and that of the Government called to, the alarming appearance of the fissure at *B*, where the rock gave way at the south-western end of Dufferin Terrace.

As already stated, the author was called by the Federal Government, in the year 1880, to report, when he said that if the rock fell it would take the houses on both sides of Champlain street, and recommended the erection of a series of buttresses of heavy masonry some 6 ft. thick, 50 or more ft. in depth between the roadway and the cliff, and some 80 ft. in height, and rising, say, to *F*. The cliff, or the portion of it *E B F G* which fell, being, like the leaning tower of Pisa, though inclined, in a state of perfectly stable equilibrium, and such that the buttresses proposed, and which were to have been erected at distances of about 40 ft. apart—seven of them in the 300 ft. from *H* to *K* on plan—must and would have proved effective in staying the catastrophe. Major Mayne's advice, who, as stated, had recommended that the range of houses at the foot of the cliff after being vacated be allowed to remain, was disregarded, or at least their gable end walls, which, abutting or nearly so, as they did, against the rock, might have so broken or checked the fall as to prevent the debris from rolling to the opposite side of Champlain street, and there destroying the houses which, heedless of the author's written warning that the rock in falling would sweep away the residences as well on the river as on the cliff side of the street, had been allowed to stand, and in the destruction of which more than 50 persons lost their lives.

Much more apprehension was felt about the crack at *B* than that at *A*, and the Government caused the upper portion of it for some feet below the outcrop to be filled in with concrete, with the idea of preventing water from above from reaching and falling into it, which it was supposed, acting both by its disintegrating power and by swelling under the effect of frost, might gradually overthrow that portion of the cliff which has since fallen. This was a very foolish thing to do, as will soon be made apparent; for first of all, no water from the Citadel drainage above could reach the fissure, since it must on its way be intercepted by and enter the crevasse *A*; and secondly, by bringing about a contact between the opposite faces of the crack at *B*, which were some two or more feet apart, any shock or push from the rear must inevitably thrust forward that portion of the cliff to the right of *B* (as you look at the section), and hasten its destruction.

A is the crack, if any, which should have been filled in; but, being hardly noticeable to the untutored eye, and so remote from *B* or *F*, was not suspected of any foul intent.

The author had the crevasse *A* gone into and sounded to a depth of more than 70 ft. below the surface, or to *N* on section; and as at that depth there was still the breadth of a man's body, it was made evident by "similar triangles" that the total depth of the crack was 125 ft. below *A* and 100 ft. at *D*—the general level of the rock and earth beneath the terrace flooring—and to which level *D* any water filling the crevasse from *C* could rise without any possible issue below said level *D*.

Professor Laflamme of the Laval University, Geologist, in his evidence before the court, stated that he did not know enough of the cliff to lead him to infer that the fissure *C A* could fill with water, as, from the very broken and disintegrated appearance of the rock as seen along Champlain street, one would certainly be led to infer that if such disintegration and looseness of structure extended to the interior, any water pouring into *A* must leak out from below as fast as it entered from above; but it so happened that having seen and examined this cliff ever since the land slide of 1841, in view of the likelihood of a recurrence of such an avalanche, and more especially during the last 20 years, the author knows it to be a fact that the water from the fissure could only find its way out of it by a very slow process of filtration through the intervening space of over a hundred feet between the crevasse and the face of cliff at *F G*.

The author repeatedly watched the water running from out the foot of cliff after heavy rains, and particularly while surveying the cliff in rear of the houses for his report of 1880, and never saw anything more all along and beyond the 300 ft. of rock frontage towards the St. Lawrence than a mere trickling of the water from the cleavage fissures and others to be seen, and it always took several days after each fall of rain before the slowly running water from the fissures ceased, showing that the crevasse *A* would eventually become clear of water, but by an extremely slow process.

And even at this time, when the front rock has fallen away from *B*, and leaves the face *BP* exposed, the closeness of the component elements is anything but conducive to the view that water flowing into *A* would flow out from below as fast as it passed in at top; and if the face of the cliff as now exposed at *BP* is a little shaky or of apparently loose structure, that is no reason to infer that at 60 to 70 ft. in the interior of the mountain, and where so far removed from atmospheric and disintegrating influences, the texture of the separate strata is anything like as loose, if loose at all, as the view at *BP* would lead one to infer.

The component strata of the cliff just alluded to, which the section shows to be vertical or nearly so, having, of course, been tilted up from their originally more or less horizontal position by an uplifting force from beneath the earth's crust, similar to that which on a smaller scale throws the crust of a sea pie into hills and ridges by the expanding forces of the imprisoned vapours underneath, or, as geologists also incline to think, by the puckering effect on the earth's crust of lateral pressure due to the contraction of the surface incident on the cooling down of the interior, subsequent erosion and denudation of the apices of the folds leading to the outcrops now visible at the surface on a bird's-eye view thereof.

In the section of the cliff published, as already stated, in the *Canadian Architect and Builder* in 1889, or shortly after the accident, all the strata are shown parallel and leaning outwards from the vertical; but a closer survey and actual measurements, levellings and plumbings have disclosed the fact testified to by the author before Judge Burbridge, that the inclination outward or overhanging at *B* is 6 ft. in the 60 ft. from *B* to *P*, or 1 in 10, while at M and O on plan Plate VII, the strata incline inwards just as they do at *A* on plan and section. The author was for some time at a loss to account for this, until, after digging away the overlying earth, he discovered a series of crevices between *A* and *B* on plan and section, varying in width at the outcrop from $1\frac{1}{2}''$ to $2''$ and $4''$ and $8''$, to as much as $11''$ and $20''$ as seen on section, and which fully accounts for the present non-parallelism of the strata.

Coming now to the actual solution of the problem as to the hydrostatic power of the water to bring about the accident, the following are the data: The crevasse at *A* extends and can be followed for 150 ft. or more from *A* to *O* on plan, where it thins out to nothing. In the opposite direction, or from *A* to *M*, it is also assumed to close or come to nought at a like distance of 150 ft., together 300 ft., and this assumption is based on the fact that the crack was gone into in that direction to say 70 ft. from *A* towards *M*, and its breadth at that point such—that of a man's body—as to warrant the assumption.

It has already been said that the depth of crevasse is from *D* to *C* on section 100 ft. At *A*, the outcrop, the amplitude of crack is now $3\frac{1}{2}$ ft. and at *D*, 3 ft.; but before the accident occurred it was but $2\frac{1}{2}$ ft. at *D* or 3 ft. at *A*, the crevasse having opened by some 6 inches at its centre of position or at *A* on plan and section at the time of the catastrophe. Now, $2\frac{1}{2}$ ft. at *D* and nought at *C* gives 15 inches at *N*. Again, these 15 inches at *N* or half way down beneath *A* on plan, and as the crack dies out at *M* and *O*, give a general average of $7\frac{1}{2}$ inches for the breadth or width or amplitude of the crevasse.

The face of the crevasse is, as already inferred, 300 and 100 ft., or 30,000 square ft., and the average breadth being $7\frac{1}{2}$ inches, gives 17,500 cubic feet capacity, or say from 15,000 to 20,000 cubic ft. The 30,-000 cubic ft. of rainfall, which during the 12 hours, or from 8 a.m. to 8 p.m. of the 19th Sept., 1889, precipitated itself through the side aperture in the drain, and which is in about the same vertical plane as *A B* on plan and section, found its way into this crevasse and filled it up to *D* (the spare 10,000 to 12,000 being more than abundantly sufficient to allow for any leakage out at the bottom or sides as it entered at the top), exercising therefore on its opposite faces a separating effort of not less than 6,250 lbs per square ft. at *C*, $4,166\frac{2}{3}$ lbs. at the centre of pressure, or $\frac{1}{3}$ up from *C*, 3,125 lbs. at the centre of gravity of the figure, or half way up, the figure being a parallelogram, and a total thrust on the whole surface of 46,875 tons.

Now, the cliff between *A* and *B* on plan and section is, as already said, 300 ft. in length, and it is an average of 65 ft. in breadth or thickness from *N* to *R* and an average height of 85 ft., the height decreasing towards *K* on plan. These figures give 1,657,500 cubic ft. for the portion of the cliff which was thrust forward against the rock *P B F*, and caused it to topple over; but it still remains for the author to show that the hydrostatic pressure of the water in the crack *D C* could produce this effect. The weight per cubic foot of one specimen of solid stone from the debris of the cliff being, as weighed in water, 160 lbs., while another specimen gave 152 lbs., an average of 156, or within a lb. of that given by the author in 1866. This, as just stated, is for solid stone; but the debris at the site of slide show that there is a large proportion of rotten shale and earth variously estimated at from 20 to 33 per cent. of the whole. Taking this at only 20 per cent. to be on the safe side, and this earthy or shaly matter at 100 lbs., reduces the average weight of the cliff to, say, 145 lbs. to the cubic ft. Another way of arriving at this same average weight of the still persistent cliff is the allowance to be made for the earth-infiltrated and mostly empty fissures between *A* and *B* on plan and section.

The cubic feet of cliff which was thrust forward, and which pushed over the rock beyond *B*, is 1,657,500; this into 145 lbs. average per cubic ft. gives 240,337,500 lbs. or 120,169 tons.

Now, had the rock *A B C E* on section, or *H M O K* on plan been a solid monolithic block of stone, and supposing it even to be detached or non-adherent at its base *C E*, but subject to the friction there due to its weight, and incapable of moving forward along *C E*, or of starting to move forward, under a less force than .71 of its own weight (the coefficient of friction of dry stone at rest on dry stone on a horizontal plane) if unobstructed, but which it could not do in this case, because obstructed by a weight of cliff beyond it much more than equivalent to the remaining ·3 of its said weight: the stress against the rock at *A C* could, had it been a single homogeneous mass, have acted only in a way to turn or topple it over, by causing it to rotate on its outer edge at *E*. The force to be exerted by the water to do this must have been equivalent to half the weight of cliff or to 60,084½ tons, while, as already shown, the total hydrostatic pressure exerted did not exceed 46,875 tons or less by over 28 per cent. than the force required to lift the cliff at *C* and cant it forward at *B*.

But as already seen, the cliff is not a homogeneous mass, and on the contrary the section shows it to be thoroughly divided into nearly vertical and parallel strata ranging from a few inches to several feet in thickness; and these strata are again divided by planes of cleavage, as indicated by the lines drawn obliquely across the strata* into

* These lines indicated in the original sketches or manuscript have been inadvertently ignored by the engraver.

layers lying in a more or less horizontal direction from east to west along the River front. The angles of the planes of cleavage, of which the author measured several among the fallen debris, varied between 17 and 23 degrees,—an average of 20.

The planes of cleavage, therefore, had the strata been vertical at *B E*, would have inclined some 20° from the horizontal, or say 1 in 3; but it has already been shown that the inclination outward at *B E* is 1 in 10 or another 7 degrees, together 27°, an inclination of 1 in 2, and such that just one-half the force need be exerted to thrust the rock forward as would have to be exerted on a horizontal plane.

As stated incidentally, the co-efficient of friction of stone on stone at rest is .71 on a horizontal plane, wherefore, to start the cliff at *B* and down to *P*, where unlike at *E* it had liberty to move forward or through a portion of the vacant or partly earth-filled and therefore compressible and reducible space in the chasm *B E*, would have required .7 of its weight or of the 120,169 tons weight of cliff *B C*, say 84,118.3 tons, which the hydrostatic pressure could not have done had the planes of cleavage or of motion been parallel to the horizon; but on an inclination of 27°, or of 1 in 2, it would only require one-half that force to thrust the rock forward, it being absolutely as if made up of so many more or less vertical piles of dry stone on dry stone, set at such an inclination as to cause them to move forward under a stress or pressure of much less than half their own weight.

The conclusion therefore is that the 46,875 tons water pressure could and did cause the still existing portion of the cliff *B C* to move forward at *B* or along *B E*, where it came in contact with the portion *E F* and caused it to fall forward.

But the resistance of the cliff to a motion forward of some 6 inches may have been, and probably was, much less even than assumed, as it had been raining continually for 3 or 4 days before the accident (showing that no allowance need be made for evaporation from soil so thoroughly saturated as it must have been under the circumstances), and the planes of cleavage and other fissures in all directions must have been so well lubricated, there being thin beds or strata of unctuous clay between them, as to have allowed the rock to move forward by the mere effect of gravity almost as does a vessel on its ways set at a much less inclination to the horizontal.

That the movement forward was at *A* only some 6 to 7 inches is still evidenced by the fact that the dislocation in the stairway from the Terrace level, 182 ft. above the St. Lawrence, up to the rampart heights, gives just that separation, and the Terrace flooring, which had been scribed to fit the rocky crags along the rear line thereof show to this day, as they did the very moment after the avalanche, a separation of a like number of inches north-eastward of *A* and decreasing or dying out at about 150 ft. still eastward therefrom.

If there still remains any doubt as to the cause which brought about the result, what other force can it be ascribed to? The only other cause that could be assigned would be an earthquake, a momentary quake or shock of the earth's crust at the point in question, and this could not have occurred without being noticed by someone at an hour when everyone was up and doing, as was the case when the accident occurred between 7 and 8 on the evening of the date recorded; and the very fact of the still persistent portion of the cliff having moved forward by only a few inches is proof incontrovertible that it must be due to the cause assigned, as any other force like that of an earthquake could never have been so instantaneous as to stop short at a mere 6 inch move, while this is fully explained in the case of the cause assigned, where, the moment the cliff moved forward, thereby increasing the capacity of the fissure, the water level at *D* immediately sank and decreased the pressure against the rock in a way not to continue it, and even though the co-efficient of friction of stone on stone in motion is but .7 of what it is at rest, or the resistance only .5 (.71 x .7 = .497) of the total weight of cliff.

The greatest stress the author supposes to have been exerted at the "centre of pressure" and upwards, or between it and the centre of gravity, where the loose material filling the fissure *E B* would allow of being crushed into a less bulk, and thus brought about a contact between the pushing rock and that pushed over.

General Cameron and Major Mayne of the Royal Military College, Kingston, who reported to the Federal Government on the subject in 1889, or just after the accident, were of opinion that the fallen portion of the cliff had given by sliding out at the base; but this view, the author submits, can hardly be maintained, as in such case the vegetable mould, grasses and other growths at *B* would have been found at *P*, while, on the contrary, they were found at the extreme outer edge of the fallen debris, showing that, as testified to by several witnesses, the cliff actually fell forward from the top.

DISCUSSION.

Mr. Cuningham said it was an extremely interesting paper and on a very unusual subject. It seemed to him that the principal point is that the remaining rock is in very great danger of falling, and that some means might be devised to prevent this filling in of water which appears to have been the initial cause of the upsetting. Possibly the best thing to do would be to drive a tunnel from the face to drain off all these crevasses, so that as the water falls in it will be carried off by the tunnels and drain away. If it is as Mr. Baillairgé states, and such would appear to be an incontrovertible fact, then the remaining portion of the cliff under the present conditions will also go. Mr. Cuningham.

Mr. Baillairgé said yes, this would no doubt be effective in removing infiltrated water, which even if insufficient in quantity to fill one or more of the crevasses between *A* and *B* on section, Plate VII, and act by hydrostatic pressure, or pressure due to head, might, as in the past, act by pressure due to swelling under frost, thus separating the component vertical layers or strata more and more during each successive year, until the outer stratum were pushed over, to be succeeded in course of time or followed up by other strata in the rear. Mr. Baillairgé.

Mr. Peterson asked what was the part of the cliff that fell out? Mr. Peterson.

Mr. Baillairgé :—This is shown on plan, Plate IV, between letters *A B C* to the left, *E F G* to the right, *C D E* to the rear, and the front line by the words, "foot of cliff before accident," as also by the words, "fallen-cliff say 300 ft." between *B* and *F*, the average length. Mr. Baillairgé.

The same is shown in section, Plate VII, between letters *B P* and *F G*, and again in section, Plate VI, leftward of *D*, where the words occur, "fallen portion of cliff say 36,000 tons."

Mr. Cuningham said, was not the idea of tunnelling in from the front and draining all these crevasses the most practical one? Mr. Cuningham.

Mr. Baillairgé :—The most practical, the surest and safest plan would be to demolish or cut down the cliff, allowing the fallen debris to find their own level at about 1½ horizontal to 1 vertical (as such material does when dumped into embankment for a railway, etc.), thus hastening what the hand of time is sure to do in the long run. Mr. Baillairgé.

This, however, would destroy some 300 ft. of the south-western end of the Terrace, which our people are loath to part with, and necessitate the shifting of that portion of Champlain street further towards the St. Lawrence, the estimated cost of doing which is not less than $60,000.00.

Now to save the Terrace and avoid the necessity of shifting the roadway, the author proposes that a retaining wall be built some 300 ft in length, 40 ft. high, 20 ft. thick at bottom and 15 ft. at top, battering back 5 ft. in the 40 or 1 in 8, and with layers perpendicular to the batter or dipping towards the cliff, so that any effort to thrust the wall forward must be increased by the necessity to lift the wall along an inclined plane of 1 in 8, the rock foundation having to be cut or stepped to this slope for the purpose.

The outlying debris which now cover the roadway to a depth of say 20 ft., and render access to our drainage and water mains an almost hopeless and very expensive task, would be lifted and swung into the space between the cliff and wall, thus clearing and relieving the roadway and leaving some 10,000 yards of stone to be brought from Cap Rouge or elsewhere and dumped down from the edge of the terrace to complete a slope reaching high enough to prevent future slides and accidents.

One or more drainage tunnels as proposed by Mr. Cuningham would further eliminate any danger of additional pressure by water or frost.

Mr. Cuningham. Mr. Cuningham asked has there been anything done to check the probable giving away of the rest of the rock?

Mr. Baillairgé. Mr. Baillairgé:—Nothing as yet.

Mr. Walbank. Mr. Walbank asked had the drain been noticed before the accident?

The author replied it had not.

Mr. Walbank. Mr. Walbank asked what portion of the rainfall went into this drain?

Mr. Baillairgé. Mr. Baillairgé:—The whole of the rainfall of the 11½ hours preceding the accident, and which was 3·4 inches during that interval of time. The area draining towards the land slide is 90,000 square ft., and this into 3·4 inches gives 25,500 cubic ft. of water, while the rain falling direct on the area intervening between the crevasse and the Citadel and glacis gives another 5,000 cubic ft., together some 30,000 or more cubic ft. as stated; nothing, as already explained, having to be allowed for absorption, since, as evidenced by the data from the Observatory, it had been raining continuously for the three or four days preceding the land slide, and that the soil must have been and certainly was most thoroughly drenched and saturated in a way not to require any allowance for absorption. Nor did such weather require any allowance for evaporation, the air being, like the soil, so thoroughly saturated as to be incapable of further absorption, since it was so laden as to have to be relieved by precipitation.

The retaining wall at *a b c d e* on plan, Plate IV, was merely some 8 ft. high and 3 to 4 ft. thick, intended to act as a screen or fender to prevent falling debris from reaching the opposite side of Champlain street, and thus causing accidents to life, limb or property.

Mr. Hannaford asked if they had noticed any sign of its moving since the accident, or had there been any change? **Mr. Hannaford**

No increase has been noticed in the breadth or amplitude of the crevasse at *A*, Plate VII, though possibly the leaning over at *B R* may have been slightly increased since 1889 by the continued opening of the intervening fissures by frost expansion pressure. **Mr. Baillairgé.**

Mr. McNab would like to know if, when Mr. Baillairgé made his first survey, he had noticed this drain? **Mr. McNab.**

Mr. Baillairgé replied:—No, this drain had not been noticed at the time of survey in 1880, it being, though only a deep-set surface drain along the foot of the rip-rap face of the glacis, completely filled in and grown over with long rank grasses and shrubs. **Mr. Baillairgé.**

Mr. Cuningham asked, after a rain such as we have had just now (4 days), could you sound the crevasses? **Mr. Cuningham.**

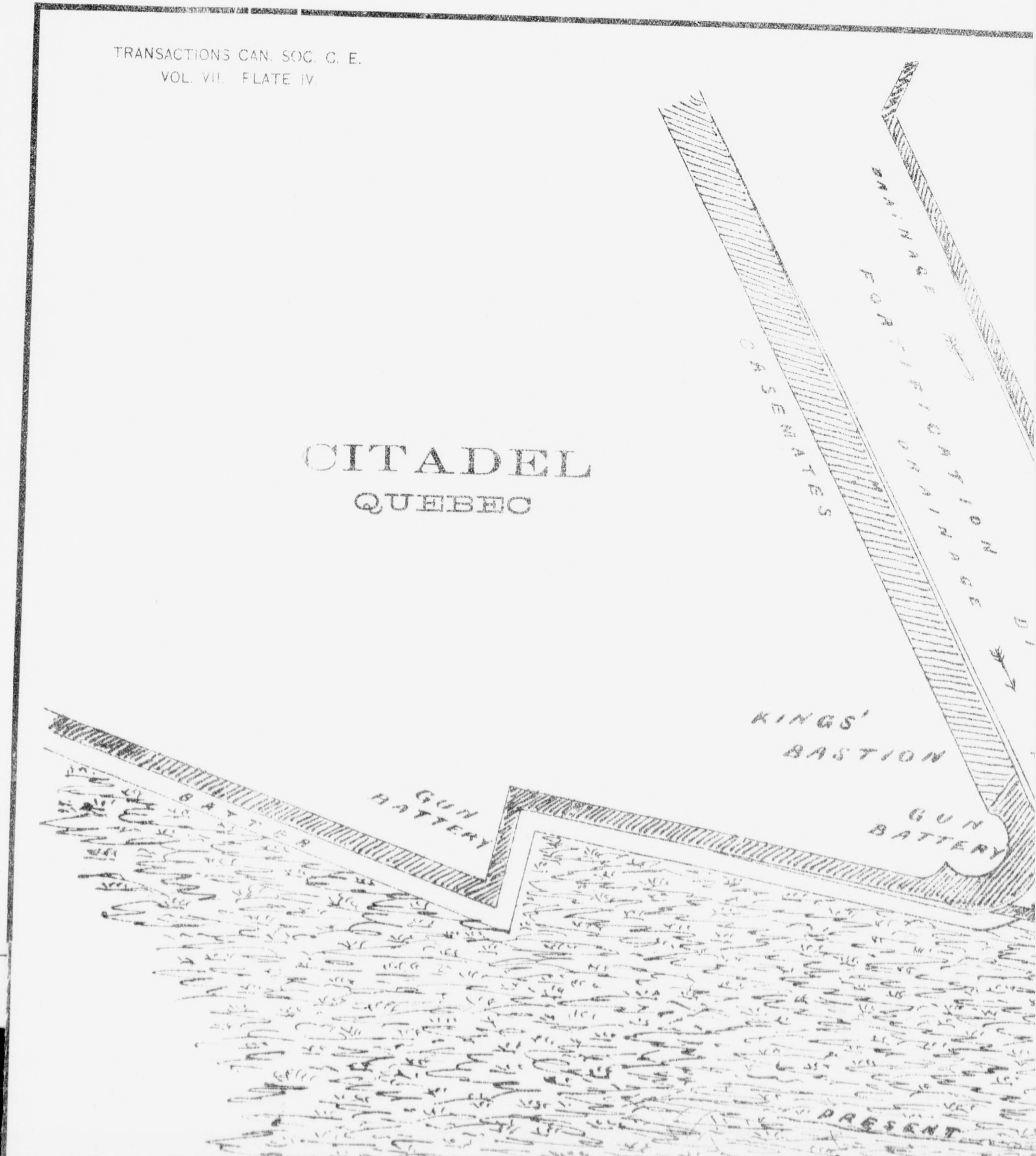
Mr. Baillairgé:—Yes, the rain of the last few days at Quebec would hardly have done more than saturate the soil, and not have filled the fissure *A* to a depth capable of preventing its being gone into and explored. **Mr. Baillairgé.**

The author would say in conclusion regarding the planes of cleavage that the inclination of the surface of the cliff at *B* and *F* on section, Plate VII, shows the direction of these planes, which his original or manuscript sketches indicate as existing all through the cliff between *A* or *N* and *F*; but they have been mistaken by the engraver for mere etchings, and a false impression conveyed by etching the engraving at nearly right angles to the planes of stratification.

He would also add that for any one wanting to take in the whole case at a glance, the note at the head of Plate I is sufficiently satisfactory.

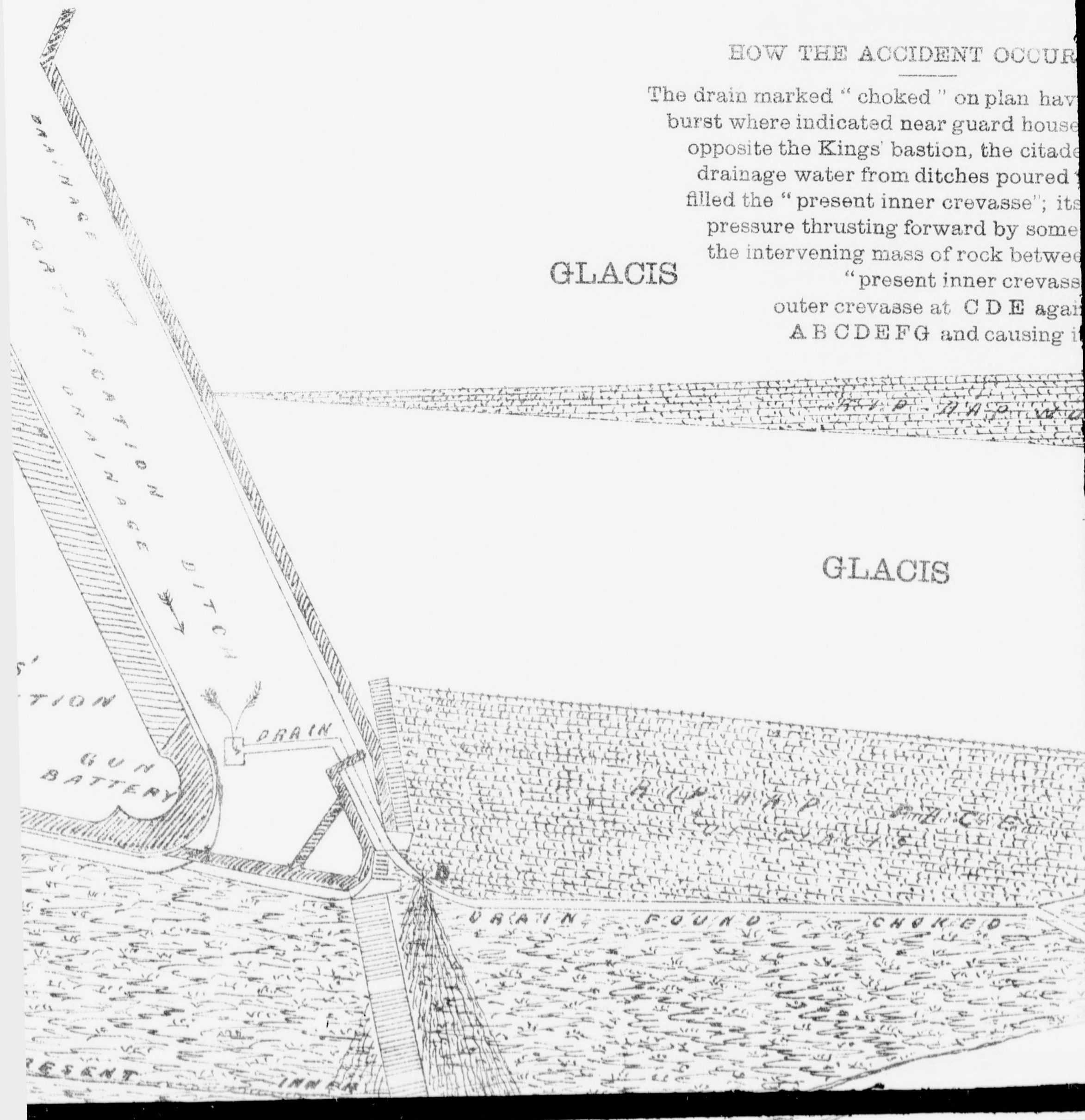
Mr. Baillairgé said he would leave a piece of the stone from the debris of the slide, illustrative as it is of the highly rhomboidal figure of the component elements of the cliff. **Mr. Baillairgé.**

TRANSACTIONS CAN. SOC. C. E.
VOL. VII. PLATE IV.



HOW THE ACCIDENT OCCUR

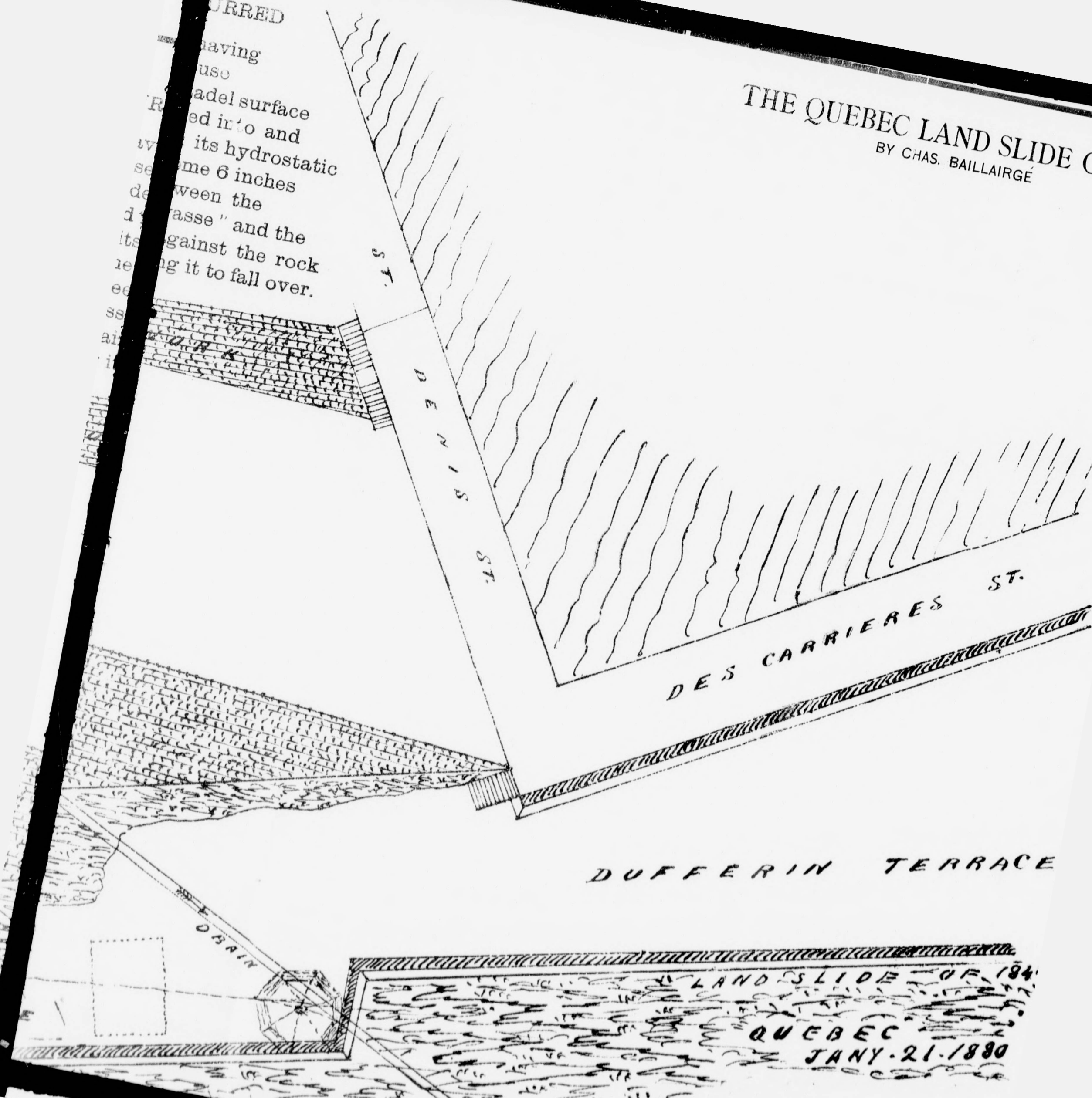
The drain marked " choked " on plan hav
burst where indicated near guard house
opposite the Kings' bastion, the citade
drainage water from ditches poured
filled the " present inner crevasse"; its
pressure thrusting forward by some
the intervening mass of rock betwee
" present inner crevass
outer crevasse at C D E agai
A B C D E F G and causing i



THE QUEBEC LAND SLIDE OF 1889

BY CHAS. BAILLAIRGÉ

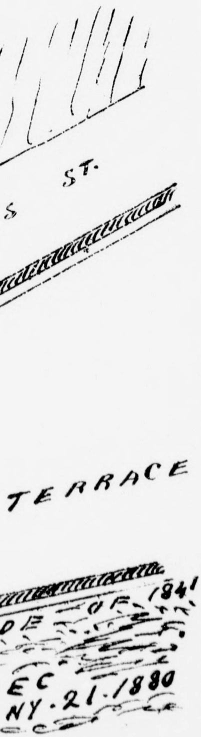
URRED
having
use
adel surface
R ed into and
its hydrostatic
se me 6 inches
de ween the
d asse" and the
its gainst the rock
ne g it to fall over.



Ground plan of dangerous
cliff and property between
old land slide of 1881 and Smith's
nd between Champlain
cliff a
1881 a
in

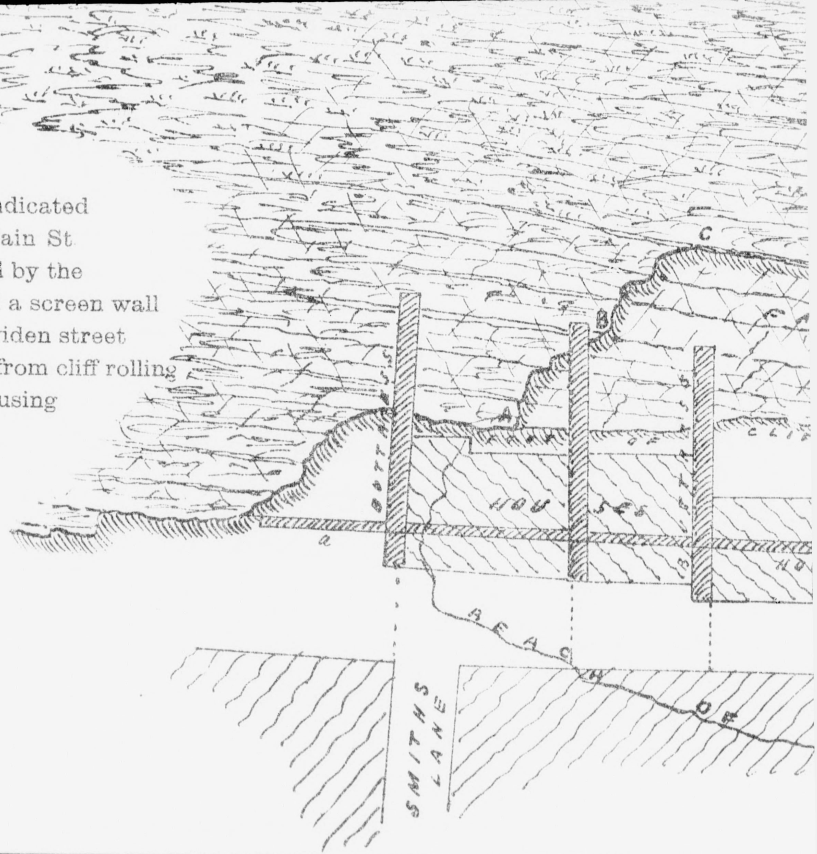
LIDE OF 1889

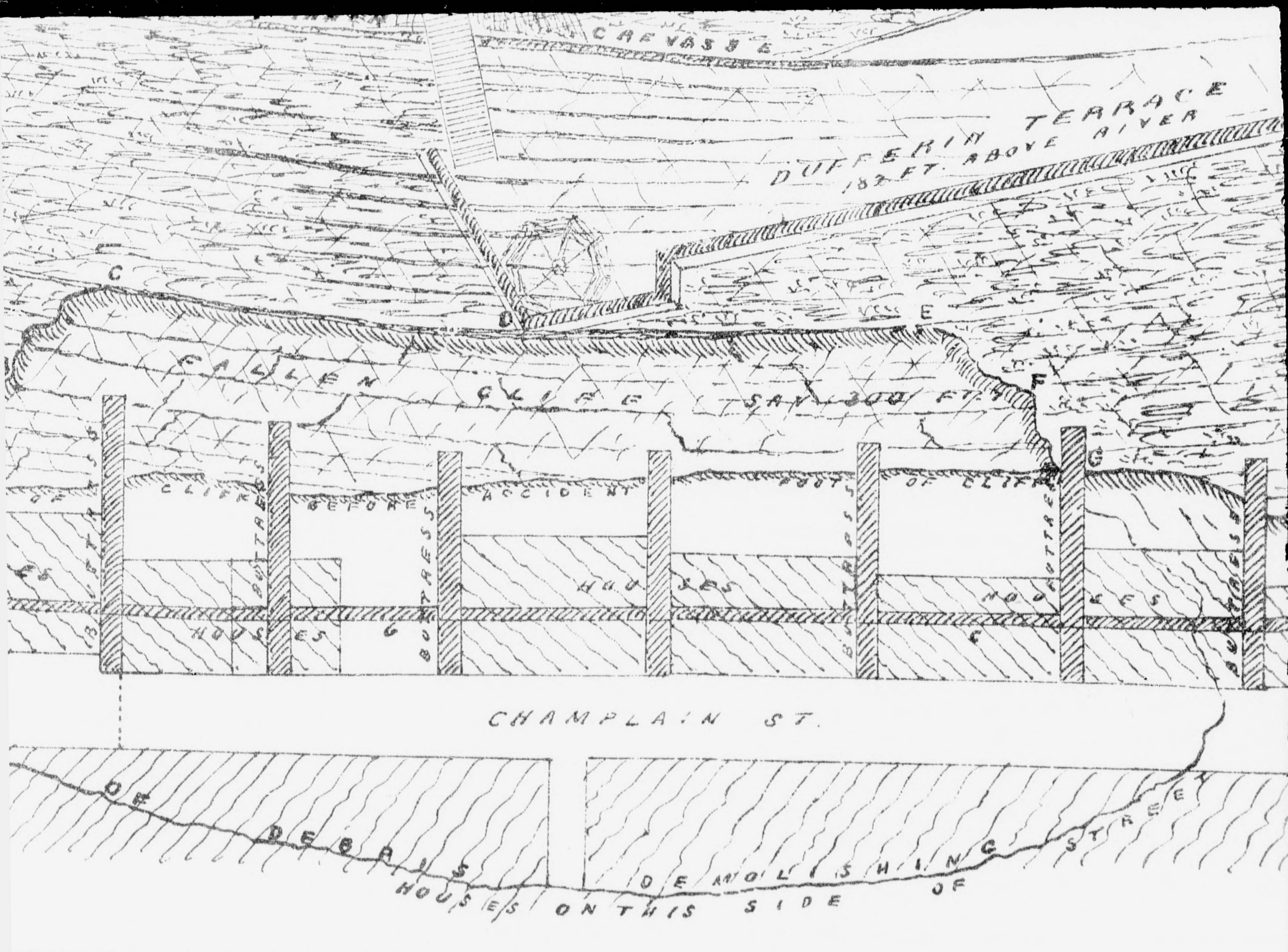
RGÉ

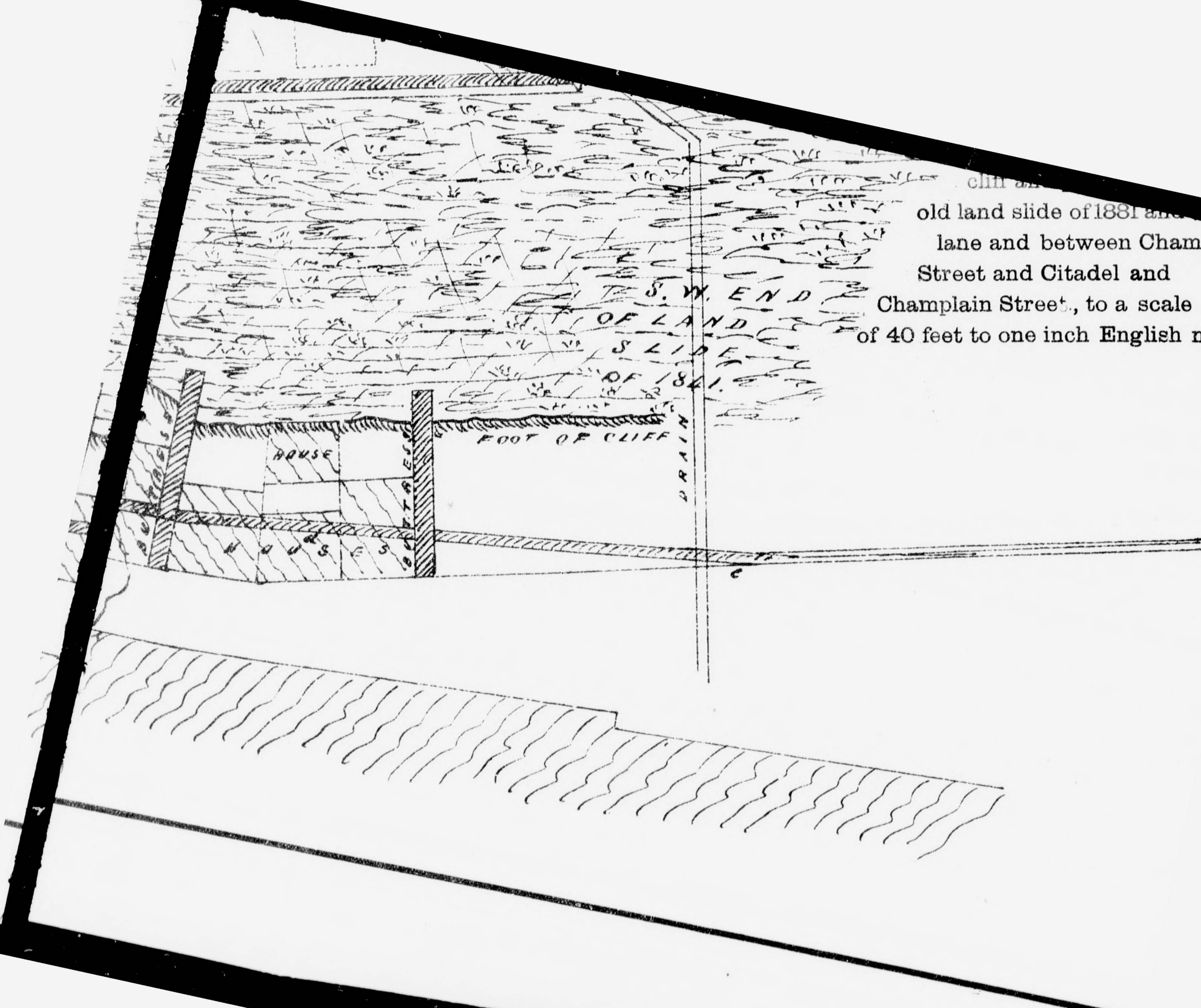


of dangerous
erty between
381 and Smith's
een Champlain

N. B. The "houses" so indicated along west side of Champlain St were after 1880 purchased by the Fed. Govt. demolished and a screen wall built along a b c d e to widen street and guard against stones from cliff rolling over roadway and thus causing accidents.




CREVASSE
DUFFERIN TERRACE
182 FT. ABOVE RIVER
C
D
E
F
G
FALLEN CLIFF SAY 300 FT.
CLIFF BEFORE ACCIDENT
FOOT OF CLIFF
BUTTRESS
HOUSES
CHAMPLAIN ST.
DEBRIS OF DEMOLISHING HOUSES ON THIS SIDE OF STREET

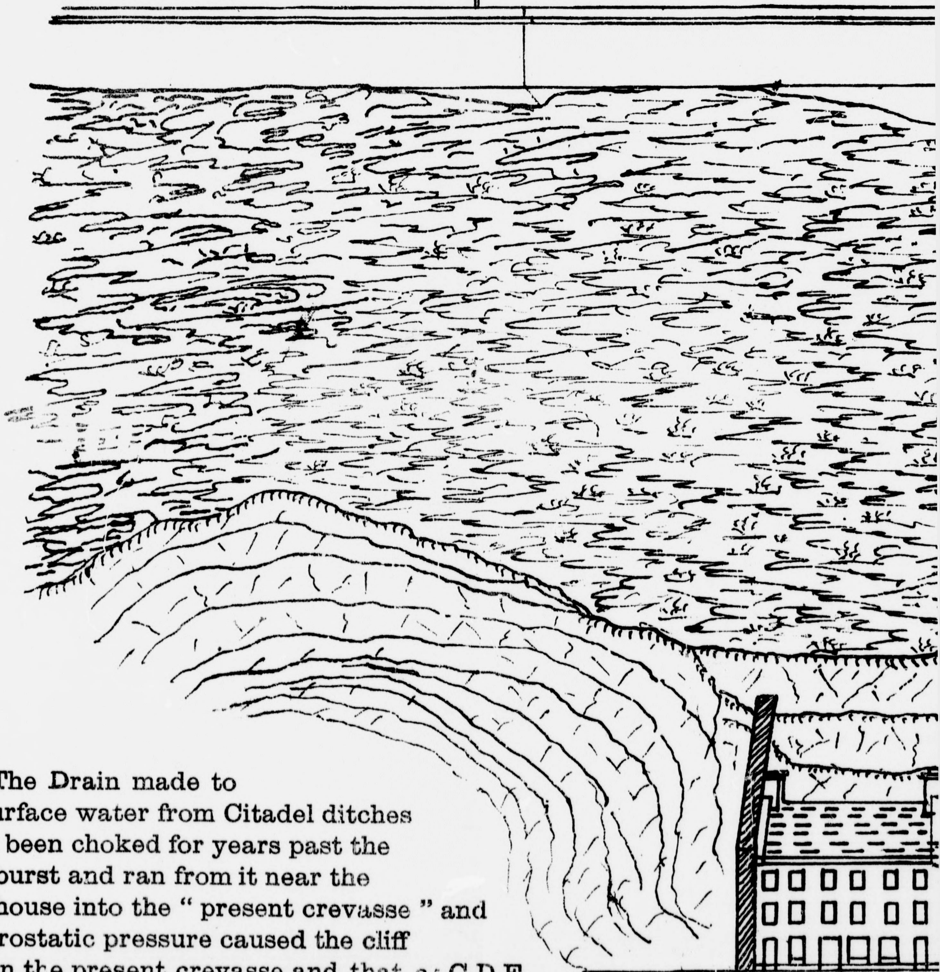


cliff an
old land slide of 1881 an
lane and between Champlain
Street and Citadel and
Champlain Street, to a scale
of 40 feet to one inch English measure

81 and
en Champlain
el and
o a scale
English measure

7

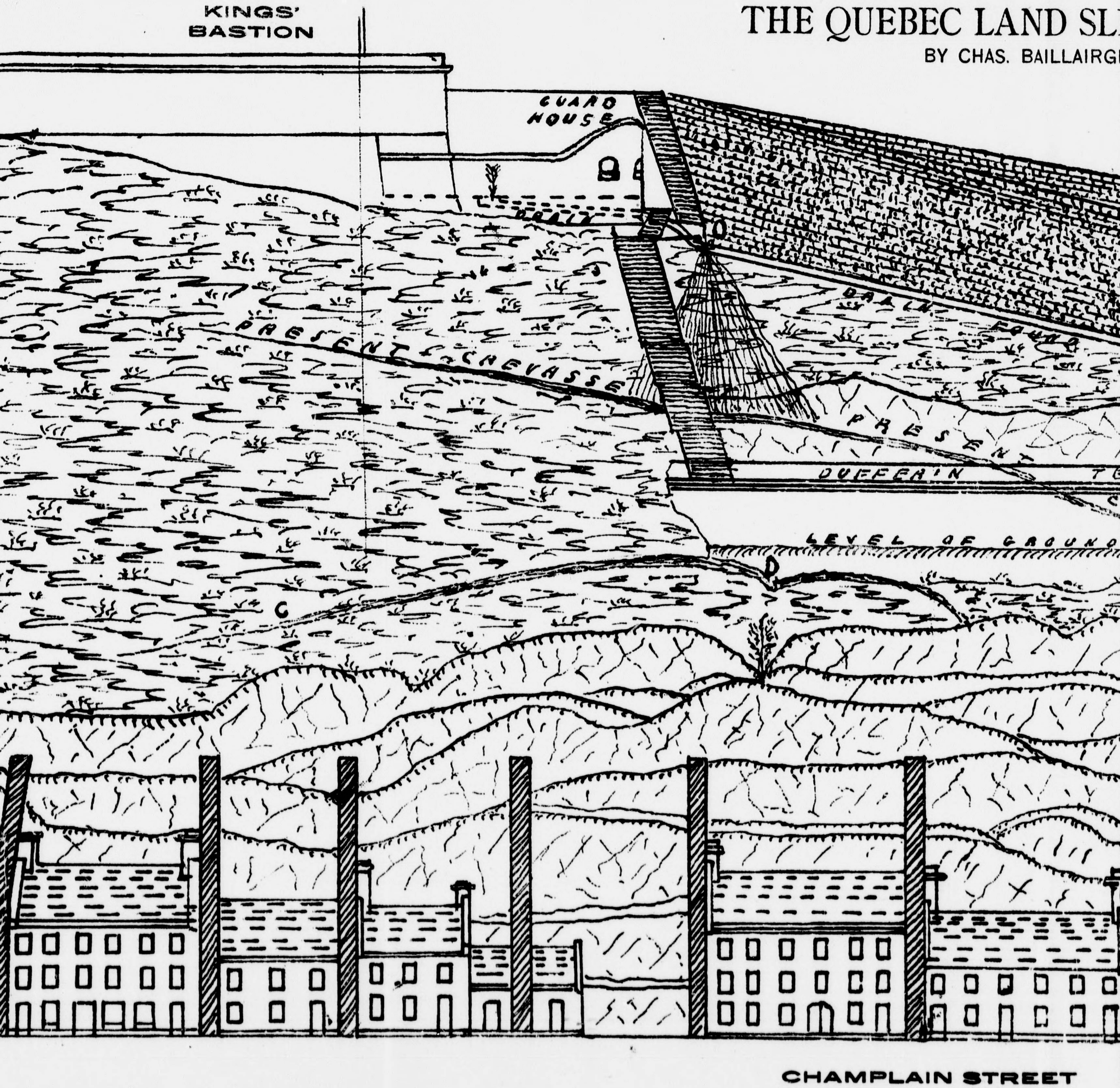
QUEBEC CITADEL



N. B. The Drain made to take surface water from Citadel ditches having been choked for years past the water burst and ran from it near the guard house into the " present crevasse " and by hydrostatic pressure caused the cliff between the present crevasse and that at C D E to move forward some 6 inches at D which pushed forward the rock beyond D and caused it to fall over.

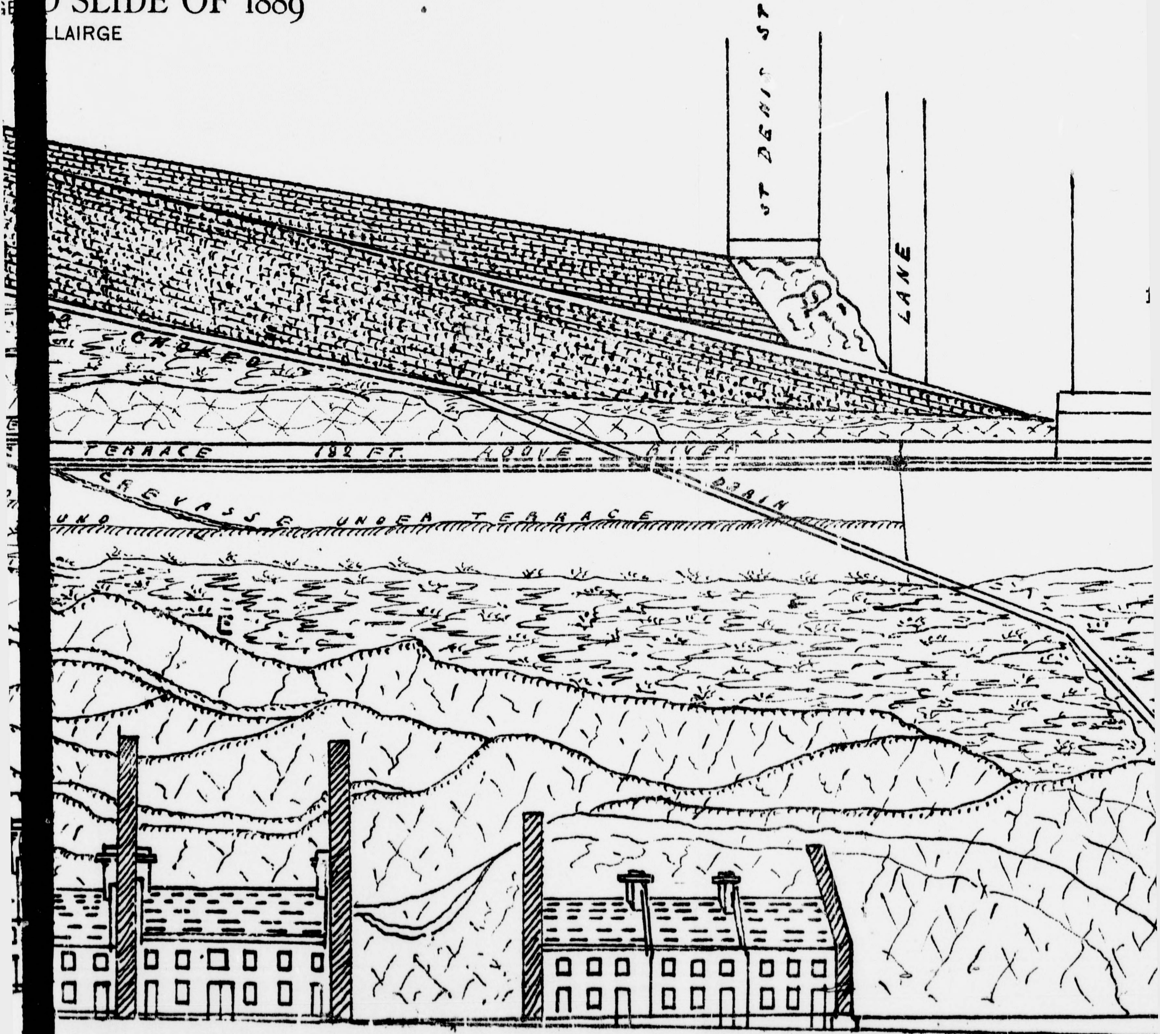
THE QUEBEC LAND SL

BY CHAS. BAILLAIRGE



D SLIDE OF 1889

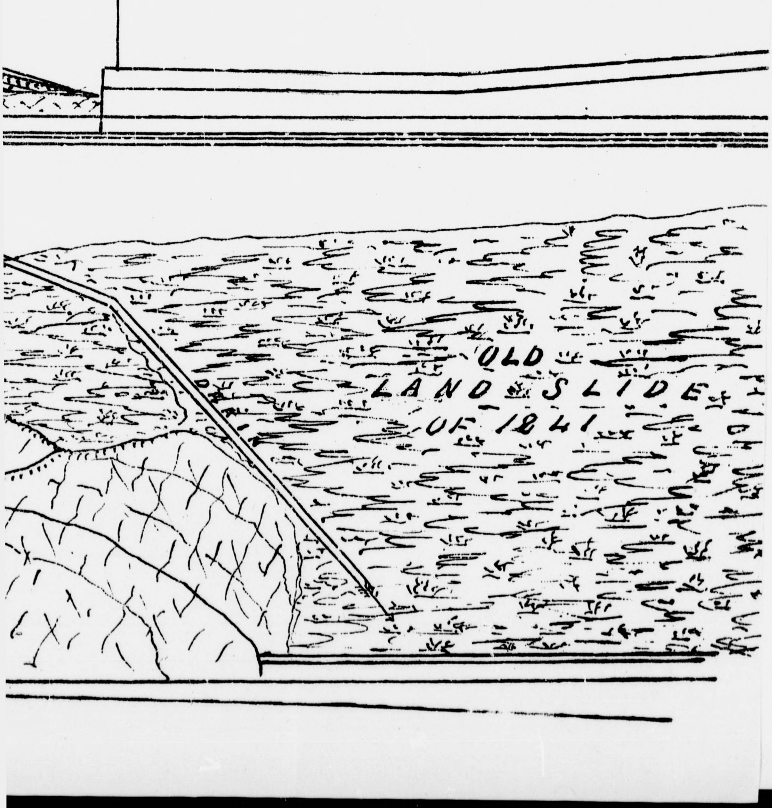
LLAIRGE



T

JANY 21 1880

Elevation or front view of dangerous cliff along Champlain Street from old land slide of 1841 to Smith's lane or to the U. S. S. Co's. office, a distance of say 675 ft. Scale 40ft. to one inch English measure



TRANSACTIONS CAN. SOC C. E.
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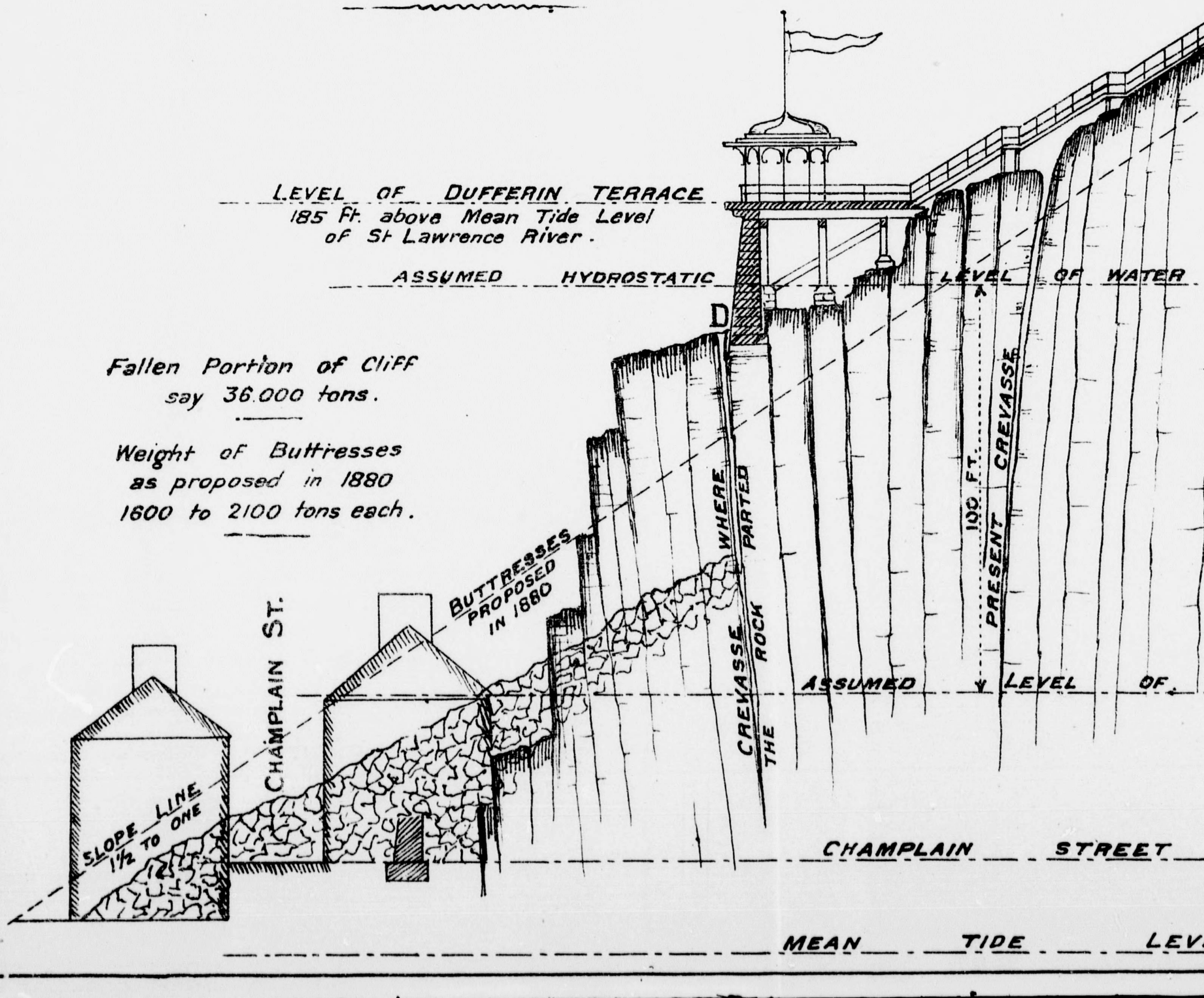
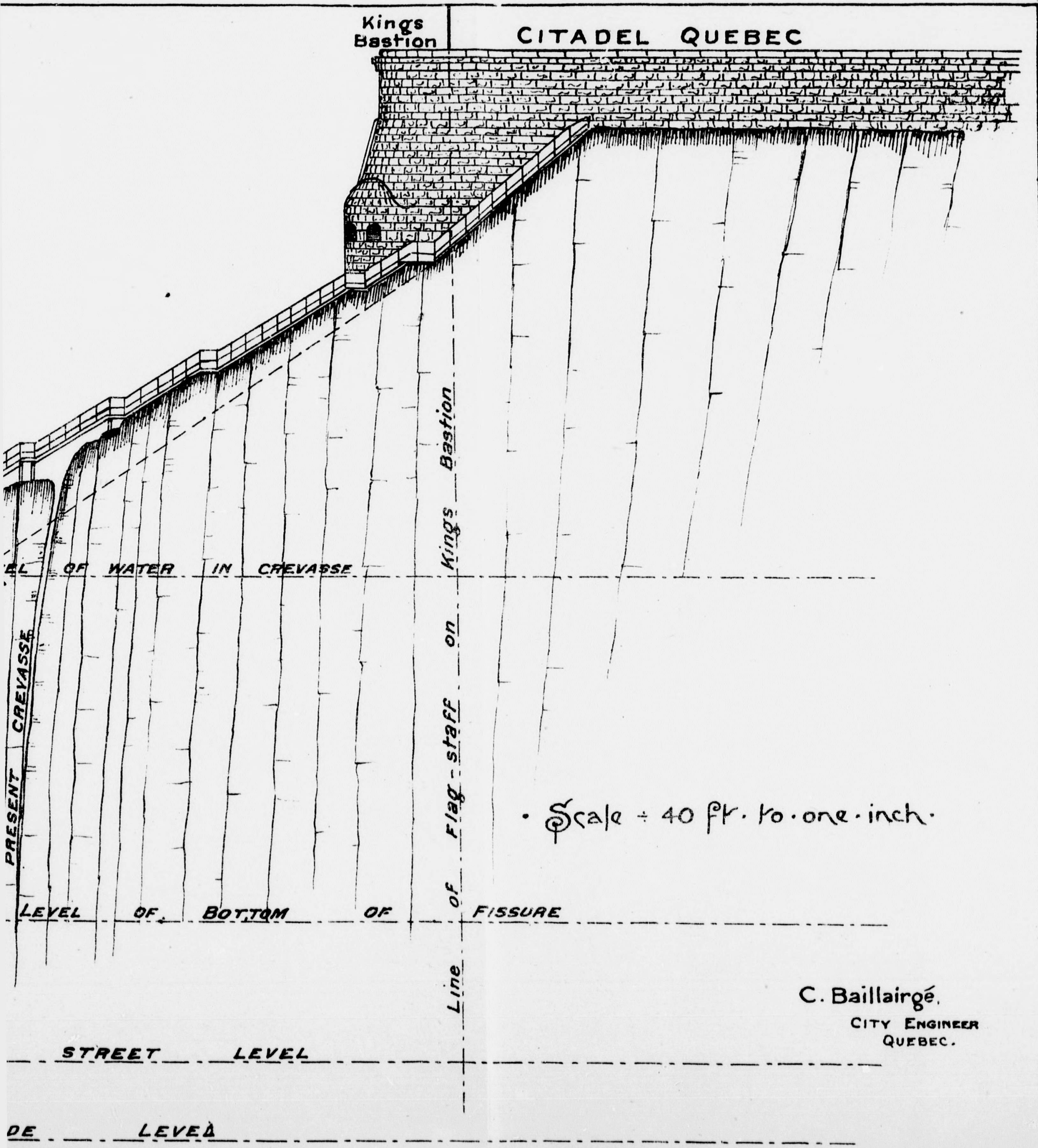
THE · QUEBEC · LAND · SLIDE · · OF · · SEPTEMBER 19TH · 1889 ·

· VERTICAL · SECTION · THROUGH · D · · ON · PLAN · AND · ELEVATION ·




Kings Bastion
CITADEL QUEBEC
…EL OF WATER IN CREVASSE
PRESENT CREVASSE
Line of Flag-staff on Kings Bastion
Scale : 40 ft. to one inch.
LEVEL OF BOTTOM OF FISSURE
STREET LEVEL
…DE LEVEL
C. Baillairgé,
CITY ENGINEER
QUEBEC.

TRANSACTIONS CAN. SOC. C. E
VOL. VII. PLATE VII.

THE QUEBEC LAND SLIDE OF 1889

BY CHAS. BAILLAIRGÉ

· SKETCH · BIRDS-EYE · VIEW · OF · CLIFF ·
· BETWEEN · A · AND · B · ON · SECTION ·
· Scale ÷ 50 feet · to · one · inch ·

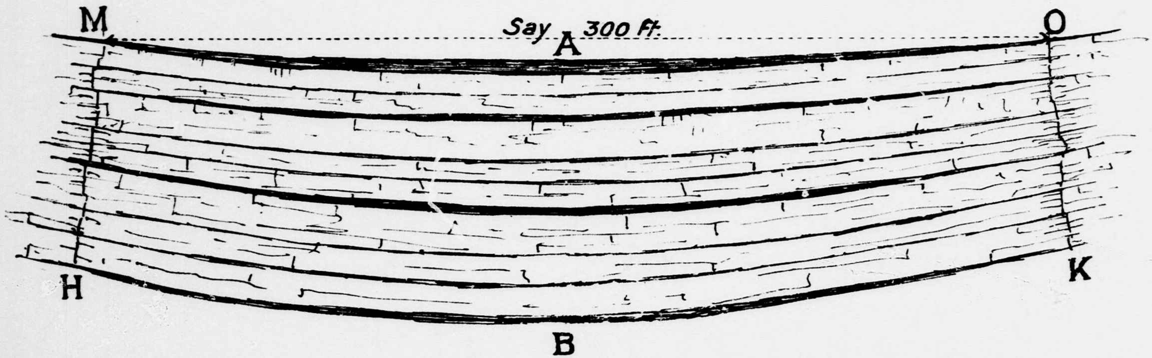
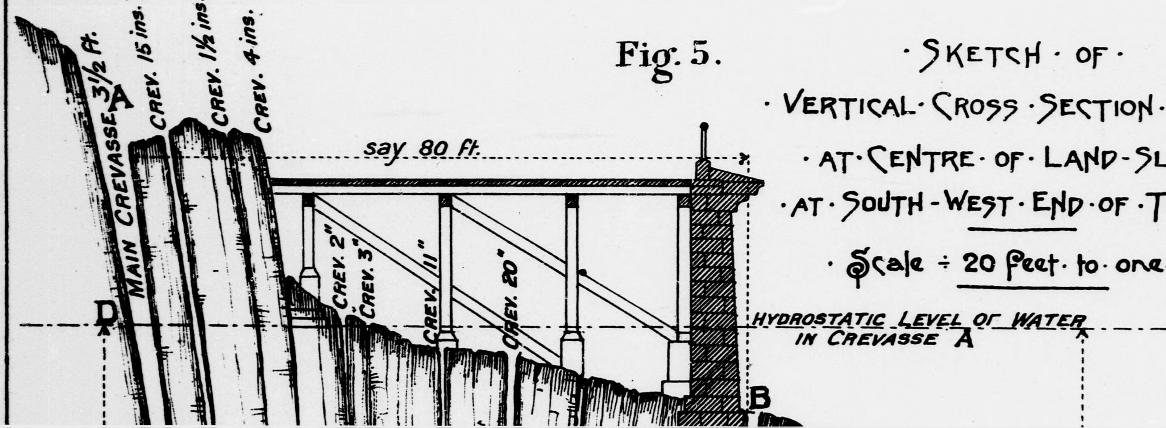
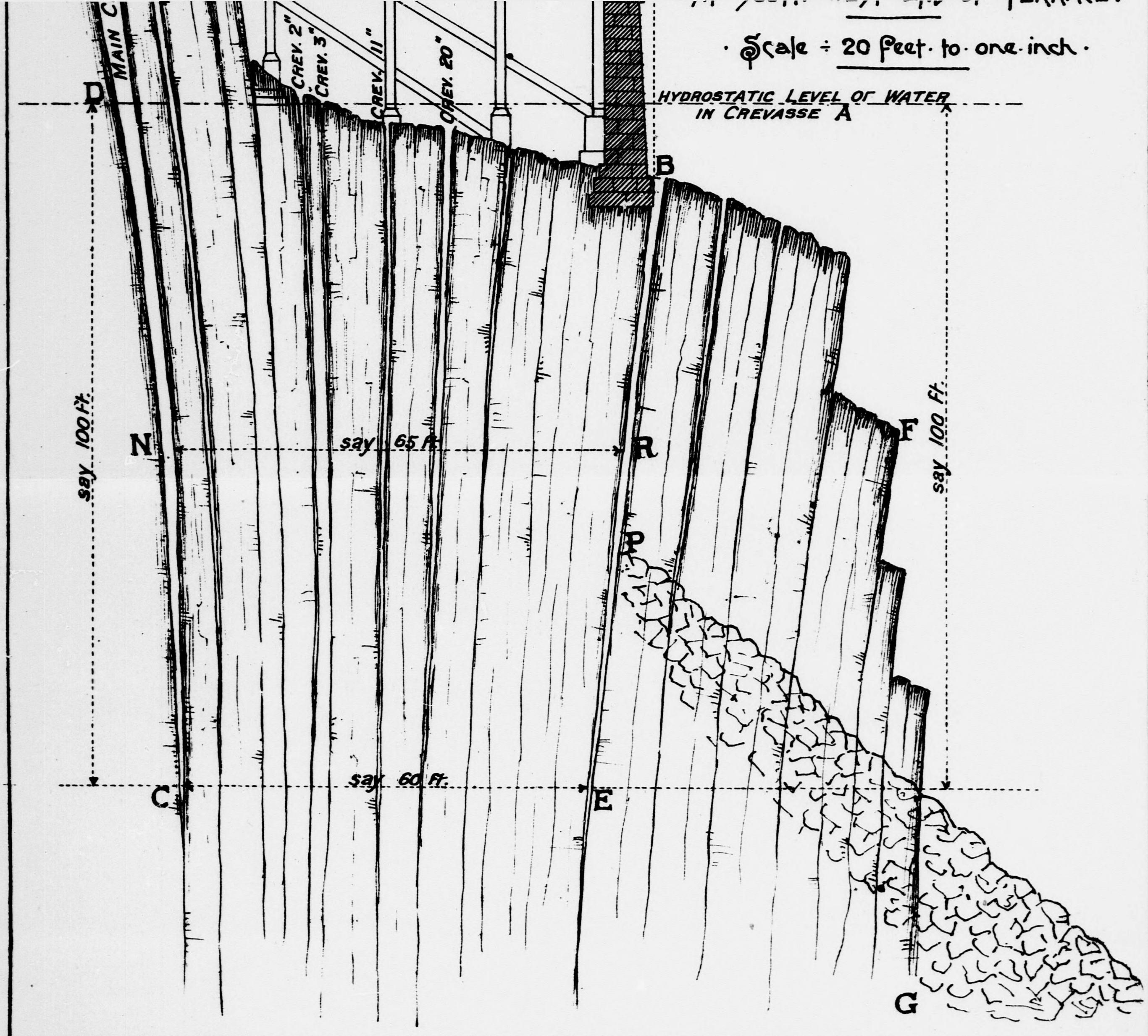


Fig. 5.

· SKETCH · OF ·
· VERTICAL · CROSS · SECTION · OF · CLIFF ·
· AT · CENTRE · OF · LAND-SLIDE ·
· AT · SOUTH-WEST · END · OF · TERRACE ·
· Scale ÷ 20 feet · to · one · inch ·





· Scale ÷ 20 feet · to · one · inch ·
HYDROSTATIC LEVEL OF WATER IN CREVASSE A
MAIN C
CREV. 2"
CREV. 3"
CREV. 11"
CREV. 20"
D
B
N
say 65 ft.
R
F
P
say 100 ft.
say 100 ft.
C
say 60 ft.
E
G