referred to in the foregoing paper, and especially the part surrounding the Spencer Mountains, presents features which, properly investigated, are calculated to assist materially in solving many moot points in connection with the action of glaciers.

ART. LI.—*On the Glacial Action and Terrace Formations of South New Zealand.* By J. T. THOMSON, F.R.G.S.

(With Illustrations.)

[*Read before the Otago Institute, 11th February,* 1873.]

THIS paper is limited to the post-tertiary period, as will be seen by its designation, and the remarks are drawn from occasional observations that I have been able to make during these last seventeen years, while proceeding over the country in various directions on official duty in connection with the Survey Department. For the facts and figures availed of I am largely indebted to the work of the officers of the survey staff, as set forth in the topographical maps. As I have always been engaged in duties which claimed attention before the subject in hand, I bring forward my results as those of an occasional, and not those of a regular, observer. Much as I have travelled over this part of New Zealand, I have seldom had time to diverge from the trodden path to follow up or trace formations; my essay can, therefore, be at best incomplete, but if it induces those who have more learning and leisure at their command to pursue the enquiry, the time of this meeting taken up in listening to me will, then, at all events, not be entirely lost.

We live here, at this epoch, in what we settlers from the British Islands call the most agreeable temperature of the temperate zone, our annual mean being that of Devonshire, England. That the temperature should ever have been different, probably the earnest money-seekers of our fellow colonists have never enquired. To the members of this Society, who are lovers of science by natural bias, and who spend much of their time in seeking knowledge for its sake only, the question, if it has not arisen to their minds before this, will now interest them.

In the older formations abundant proof is to be obtained of the great alternations of heat and cold to which this world was subjected, information on which point is to be obtained from the works of Lyell, Ansted, and others. To notice these would be to take us out of the limits of the present theme, and to hold to it we must consider the old geological periods to have passed—to have performed their functions, as it were, in raising the mountains and lowering the sea beds, in producing the contortions and anticlinations of strata, and in levelling and abrading their surfaces; again, and most of all, what affects man of this nineteenth century most nearly, in utilizing the products of the carboniferous period, by depositing them in our coal beds and alternating them, for this, our age of iron—the age of accelerated intercourse by steamships and railway—with the valuable black band. These events, then, have passed, and our consideration is confined to an epoch immediately preceding the present, and our range of actual observation to a small portion of the most remote of British colonies.

But we must pause a little yet, and borrow information from abroad, for we must not speak too abruptly of the glacial epoch, an epoch of constantly frozen ground, covering those pleasant spots where now the Taieri and Oamaru farmers gather in their golden crops of wheat and barley. We must look a little over the world, and, with the help of one of Keith Johnston's physical atlases, bring home certain facts to the mind. Our latitude is 46° south; longitude, 170° east. Now, there are two extensive regions in the world situated in the same latitude north, and ranging between 60° and 150° east, and 60° and 120° west, longitude, whose ground is constantly frozen, and whose glaciers, when on the coast, stretch down to the sea level, *i.e.*, in Asia and North America. The circumstance suggested to have existed in New Zealand has therefore extensive exposition on the earth at this present time. With so much of preface, then, in deference to the tender consciences of the doubtful, we may proceed with our demonstration.

That the limit of constantly-frozen ground overspread this region will not only have to be proved, I hope to your satisfaction, but that the present surface of the earth was also under water will have to be demonstrated. In support of this latter proposition, were I to appeal to your belief I think I would have ready concurrence, for this is an idea implanted in the mind by our earliest lessons, and, further, it is an universal one maintained by all nations, whether civilized or barbarous. But in this arena of philosophy you have a right to demand proof before belief, and I will shortly recount a few examples. In Europe the lofty Apennines and Pyrenees, in their limestone formations bearing marine fossils, convey a practical and convincing argument that their slopes, and even summits, were once below the ocean, and that they had either, in the course of geological ages, risen or the water had become depressed. And, as it has been in Europe, so it has been no otherwise with us, for we have the limestone in various parts of this portion of New Zealand bearing marine fossils now raised considerably above the level of the ocean.

First, I may mention, because it is nearest to hand, the Caversham freestone, attaining an elevation of 400 feet above the sea level, from which are gathered, as may be seen in the Museum, the *Terebratula*, *Pecten*, and other shells; also the vertebræ of fishes of the whale species. Limestone formations of somewhat analogous structure are found in the Waitaki Valley, notable for their profuse possession of marine fossil remains (a list of which has been published by Mr. Traill), and rising with a recorded elevation of 1,059 feet above the sea; but, as the survey has not extended over the whole district, this is by no means the limit of elevation to which the formation attains. Then, again, in the Waihemo or Shag Valley, a limestone patch of the same age, and with similar fossils, occurs, rising to an elevation of 1,428 feet. At Waikouaiti another occurs, rising 531 feet. Many others are necessarily unnoticed, but mention may be made of those in the southern districts, such as Forest Hill, south end of Turingatura Downs, Point Pleasant, and Oreti plains; also, Orawia and Waiau, the limits of whose altitudes I am unable to obtain, but which vary from 200 to 1,000 feet above the sea.

Thus, over a confessedly limited area of New Zealand, ample proof is given of the surface of the land having been under the sea level, by these limestone formations carrying sea animal remains; and if we admit the depression to have been 1,428 feet, by actual observation, so may we admit a much greater if need be. Thus, while we see that the ocean had covered our dry land, so, in passing, I may bring to your notice that the converse had taken place.

In Europe proofs of this are abundant in the fossil trees and plants found in the coal mines at a depth reaching down to 2,500 feet below the ocean surface. Here, in the infancy of mining, we have but limited examples, but as sure in their indications as the others. These we have in the Shag Point and Molyneux coal mines, now being worked at the sea shore, and whose dip is under it; and at Green Island, where mining is now carried on below the sea level. Hence it comes home to the mind that the earth has had no rest, but rises and falls in the cycles of geology. But that it has been in practical quiescence for 100,000 years we also have close proof and ready assurance, as exhibited in the alluvial plain at the head of this harbour (Otago), whose formation must have required that, to our standard, enormous period, and whose surface shows no indication of rise or fall exceeding at most one or two feet.

Having gained one step in my essay, viz., that in the tertiary period our land had been much lower than it now is—for I may meet an objection which might be started, that these limestone formations might have been mere local upheavals, by stating this to be impossible, they lying on the older formations as their basis, and which they do not do at one part only, but in a manner enclosing half the circumference of the Province, and inserting themselves between the plutonic and metamorphic rocks of Stewart Island and the great western range of mountains.

The next step in my theme is to show that this region was within the limits of constant frozen ground—that is, the region of glaciers and icebergs; and, in the first place, I use, as my stepping-stone, the remains of moraines that are to be, at this day, seen at the lower extremes of our interior lakes, three of which I have personally examined, viz., at Pukaki, Ohau, and Wakatipu. Here a geological lesson may be read as plain as the A B C, that the extremities of the glaciers—now only to be discovered in the far distance, high up in the recesses of Mount Cook, Mount Stokes, and Earnslaw—once reached to these lower levels, at which time they pushed forward rocks, stones, and masses of ice, in the manner that alpine glaciers do at the present day. The action may be termed that of *mountain* glaciers. The remains of the moraines are the proof of that action, and so of the existence of the glacier itself; but we have to do with glaciers of another description, preceding these, and far exceeding them in extent and influence. These I will term, for the sake of distinction, as *terrene* glaciers. The proof of the existence of these, with their accompanying icebergs, is to be found in the boulder deposits so numerous in many parts of this Province; and of those nearest at hand I may mention the deposits on the Kaikorai and Caversham ranges. Here the surface of the ground is bestrewed with them, and the cuttings of the road and railway works exhibit them imbedded in marl and clay, overlying the sandstone. At the various eminences of the ranges, they have served, by their having been deposited in clusters, to preserve the ground from erosion—even when that ground consisted of easily transported sand beds—and their original position is easily to be indicated on the spurs of the Waikari Hills, from whence portions of terrene glaciers stretched down the Kaikorai Valley to the ocean, bearing with them stones and material, and casting them off at intervals, as parts of the congealed masses broke off and fell into what, at that time, was the bed of the sea. But the most remarkable and extensive boulder deposit that I have seen exists at the gorge of the Kawarau and plains of Cromwell, strewed between the gorge and the town of that name in greater numbers as the gorge is approached, and placed in such a manner as small icebergs floating out of the valley would not fail to do, being parallel with the water's motion, and tending to the eddies on each side of the channel. Some of these boulders are larger than shepherds' huts, and being laid on the surface of the gravelly plain, far from their original locations, are a subject of wonder to the simple and unlearned. Boulders in the same manner appear below the Clyde Gorge, but not to so great an extent, yet in principle bearing out the same glacial action or floatage proceeding therefrom by icebergs.

Other proofs of terrene glaciers and icebergs are to be found in this district, in numerous boulders with striæ, or ice-scores, on them. I first had the pleasure of pointing out these to my friend, Mr. L. O. Beal, who read a paper to this society on a kindred subject. (See Trans. N.Z. Inst., Vol. III., p. 270.)

These striæ are not to be mistaken for harrow-marks, often seen on stones where fields are in cultivation. They are always found on the lower surface of the boulder as it lay on the ground bedded for ages, and by which position alone were the marks preserved from disintegration. They are never found on the upper surface of the stone, and are only to be sought for by turning over the block. At one of Sidey's fields almost every tenth stone has the ice scores on it, deeply indented in the surface, and which marks it had received in remote ages. Yet there are the marks, as patent and as certain as on the day they were made—a proof of ice action—a proof that this country was once the region of perpetual frost and snow, and unfit for the habitation of man.

The grooved rock in the Kaikorai Valley presents another lesson tending to the same conclusion. This rock juts out at a sharp turn of the main road, and appears at one time to have offered considerable opposition to the descending masses of ice, for over its whole surface grooves, nine inches to a foot in depth, are worn in the direction of the axis of the valley, and which have been preserved from disintegration by having been covered by a layer of clay after the ice action had ceased.

Thus, according to my limited observation, I have advanced such facts as have occurred to me, proving the ice-bound nature of the surface and shores of this island as it existed in remote ages of this recent geological period. More extended observations may be made by those having more time and opportunity; but I trust I have said enough.

While we may admit, then, that much colder temperature than now exists has been proved, so also the converse has to be accepted, though it be not necessary to the present argument. In Europe, the existence in prior geological periods of tropical vegetation is abundantly exhibited in the fossil remains of low latitudes, and, as a matter of near interest to us, in the case of one of these fossils the Norfolk Island pine is, in our age, the only remaining and living example. In New Zealand we have a parallel case tending to prove the same fact—the remains and gum of the kauri are found at this end of the islands, while the living tree is only to be found north of Auckland. No doubt, a more comprehensive knowledge of the geology of New Zealand, than I can claim to have, will confirm an alternation of temperature, not once, but for many times.

With these preliminary observations I may now proceed with the more immediate object of the paper. In looking over some of the topographical maps executed by the officers of the Survey Department, I was struck with the regularly curved beds of the valleys, notwithstanding that the country through which they wandered was of the most rugged and mountainous description. My attention was first drawn to the Manuherikia, a drawing of which is on the table, copied from a sketch which I made on its first exploration in November, 1857. On plotting a section of the lower terraces, from the summit of the Hawkdun Mountains to Alexandra, I found the curve approach that of a conical section, excepting at that point below the mountains where the ford, instead of the terrace, had been given on the maps by the surveyors. This led me to surmise that—in the hollowing out or moulding, as may be, of a valley 45 miles in length, and 5,500 feet in depth from the apex of the culminating mountains to the lower river bed at its exit from the valley—there must be a law, a law that only the most obdurate materials can oppose. Thus the Manuherikia, in its course, crosses two great bars of schist rocks situated below the junctions of the Ida and Spottis, yet these bars appear to have had but a moderate influence in modifying the curve of the valley bed, as shown in the diagrammatic section.* The power of water alone could never have done this. Then, if it were with the aid of moving ice, at first blush I anticipated that the conic section would be a parabola, for here we would have the gravity of the ice tending downwards perpendicularly, with the flow of water tending horizontally.

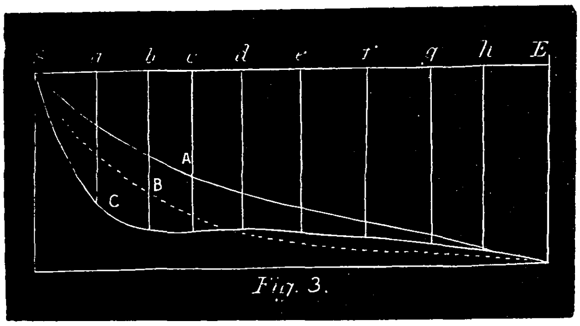

Fig. 3.

Comparing, therefore, the curve of the Manuherikia Valley, as shown by actual survey, with the parabolic one, we have VA the length of the valley, AB its rise from the exit to the source of its waters, and VC the distance of a point from V. Then VA and VC abscisses, and AB an ordinate being given, to find CD, the other ordinate; $\therefore \sqrt{\text{VA}} : \sqrt{\text{VC}} :: \text{AB} : \text{CD} \therefore \sqrt{262,800} : \sqrt{35400} :: 5598 : 2054$.

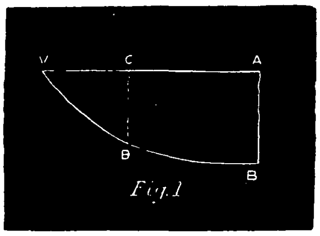

Fig. 1

The other ordinates having been calculated in the same manner, as given below, afford us a comparison with the results of actual survey :—

		By Parabola.	By Survey.	Differences.
At source	(*a*)	0000 ...	0000 ...	000
Intermediate points	(*b*)	2054 ...	3625 ...	1571
	(*c*)	3272 ...	4307 ...	1035
	(*d*)	4172 ...	4987 ...	815

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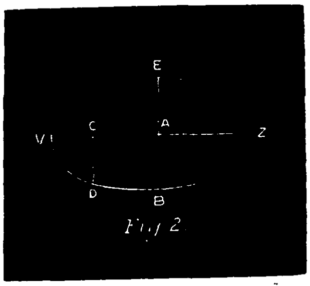
* Eleven sectional plans were appended to this paper, to illustrate the curves of the different valleys described. But as the same principle is repeated in each case, and the *data* for the construction of the valley curves are given in the text, the above general diagram has been substituted, in which S is source of river ; SE—length of valley ; A—parabolic curve ; B—the elliptic, and C—the actual curve from survey ; *a*, *b*, *c*—the intermediate points. The difference between the two curves B and C has been slightly exaggerated for the sake of clearness.—Ed.

		BY PARABOLA.	BY SURVEY.	DIFFERENCES.
Intermediate points	(*e*)	4776	5207	431
	(*f*)	5130	5251	121
At exit	(*g*)	5598	5598	000

Thus, as will be observed by these differences, and the form of the parabola, the curve of the valley bed does not conform to the same. It was evident that the hyperbola would be yet more unconformable. The ellipse was then tried with the following results :—Let VA the length of the valley, AB its rise, and VC the distance of any intermediate point from V be given, to find CD. Let A be the centre of the ellipse, then VA will be the semi-axis major, AB the semi-axis minor, VC and CZ will be abscisses to the ordinate CD. $\therefore VZ : BE :: \sqrt{VC \times CZ} : CD$. Again, VZ and BE being double of VA and AB, we have 525600:11196 :: $\sqrt{35400 \times 490200}$:2804, the ordinate required.



The other ordinates having been calculated in the same manner, afford the following comparison :—

		BY ELLIPSE.	BY SURVEY.	DIFFERENCES.
At source	(*a*)	0000	0000	000
At intermediate points	(*b*)	2804	3625*	821
	(*c*)	4212	4307	95
	(*d*)	5012	4987	25
	(*e*)	5384	5207	177
	(*f*)	5523	5251	272
At exit	(*g*)	5598	5598	000

As the *data* of the actual survey are given for the lower terraces close to the river, I may state that these vary from 80 to 100 feet in difference of level from the river surface. The point marked with an asterisk, as stated before, is also given, not for the terrace, but for the ford, which accounts for so great a difference ; otherwise it will be seen that the actual curve of the bed of the Manuherikia agrees surprisingly with that of the ellipse, and, where it differs materially, such deviations are in the positions to be expected, viz., where the eroding forces have had to expend themselves on the hard bars of schist rock already alluded to as crossing the valley. Here, then, we have in our first tried example a valley bed, whose length is 45 miles and difference of level 5,598 feet, conforming practically to the curve of the ellipse. That such might be a rule with other valleys was then surmised, though, no doubt, modifications would take place from peculiar contour of country and other natural obstructions.

The next valley, then, which the *data* in the Survey Department enabled me to test was the Waitaki. The length of the Waitaki, from its source in the Mount Cook ranges to the sea, is 720,080 feet, and the altitude of the mountain out of which it issues 8,500 feet. Testing the curve of the valley bed by the elliptic curve, in the same manner as given for the Manuherikia, we find the following result:—

		By Ellipse.	By Survey.	Differences.
At source	(*a*)	0000	0000	000
At intermediate points	(*b*)	6672	7123	551
	(*c*)	7834	7725	109
	(*d*)	8411	8138	273
	(*e*)	8475	8291	184
At exit into sea	(*f*)	8500	8500	000

The Waitaki is about 140 miles in length, rising some miles to the north-east of Mount Cook, whose elevation is 12,460 feet, and a painting of which is lying on the table, the copy of a sketch that I made when exploring the country in December, 1857. The scenery is the most grand and rugged in New Zealand, and can scarcely be surpassed in barrenness and wildness in any part of the world. I, at that time, with the privilege of an explorer and surveyor, named the feeding waters of the Pukaki Lake "Upper Waitaki," and their valley "The Valley of Sand." Dr. Haast, following me some years afterwards, has, no doubt inadvertently, altered these names to "Tasman," and the great mountain next to Mount Cook, which I, appropriately I opine, named "Mount Stokes," he has altered to "Sefton." From its alpine valley the Waitaki issues out on the Mackenzie Plains—named after a notorious sheep-stealer, by way of relief to the other good names in the Province—passing in its course through the Pukaki Lake; from thence it pierces the deep gorges of the Ben More and Kurow Mountains, after which it issues on the Waitaki Plains, near the sea. That one of the largest rivers in New Zealand, such as this, in passing over so many obstacles, should yet have its bed in such near conformity with the curve of the ellipse, was again striking, and wherein the divergences occur just where the mountain and rock obstructions are greatest. Thus a law of erosion of great power was again indicated, and so further enquiry stimulated; and I may here remark that while one great abrasion of surface has undoubtedly taken place, another, of no less significance, is exhibited by the section in the upper valley and Pukaki Lake—the effect of the action of mountain glaciers, whose effects have already been pointed out by my friend Mr. McKerrow (Trans. N.Z. Inst., Vol. III., p. 254), and to which subject I may recur.

Leaving the Waitaki Valley, I then proceeded to investigate the levels of the bed of the Shag River. This river has a short course of about 39 miles, having its source in Kakanui Peak, whose elevation is 4,978 feet above the sea. The river has a course through very rugged country; it is very tortuous, yet the section proves another very close approximation to the ellipse. For the calculation of the ordinates, we have: length of valley equal to 199,700 feet, rise 4,978; from whence the following comparison was made, with actual survey *data*:—

	By Ellipse.	By Survey.	Differences.
At source	0000	0000	000
At intermediate points	3548	3934	386
	4390	4541	151
At exit to sea	4978	4978	000

Again, taking the survey *data* of the Taieri River, we find the same conformity. This was less to be expected than in the preceding rivers, as its course is more than ordinarily tortuous, rising, in the Lammerlaw, at a distance of only 35 miles from the sea, yet it has a total length of nearly 128 miles. Here again, where the country is free from rocks and mountains, its bed approaches the ellipse; where the course is obstructed by hard rock and precipitous hills, as in Strath Taieri, it is modified in the manner due to the indicated cause.

For the calculation of the ordinates we have: length of valley equal to 640,920 feet, rise 3,820 feet; from whence the following comparison was made, with the *data* given by actual survey:—

	By Ellipse.	By Survey.	Differences.
At source	0000	0000	000
At intermediate points	2476	2620	144
	2993	2834	159
	3523	3165	358
	3776	3802	26
At exit to sea	3820	3820	00

So far encouraged, I next investigated the levels of the Molyneux or Clutha, using such points as had been settled by actual survey; and here I first met with apparent non-compliance with my rising convictions. The properties of the Clutha appeared to differ from all other rivers yet investigated. Its course was seen to cross the great valley systems of this part of New Zealand, and its source would have more fairly belonged to the western slopes of the great backbone of the Middle Island than to the eastern. It passes through the Wanaka Lake (a painting of which is on the table, taken by me on its first discovery, in December, 1857) within 26 miles of its fountain, which I have placed in Mount Nix, but which might as fairly have been placed in Mount Brewster on the opposite side of the valley, or in Haast's Pass, at the low elevation of 1,716 feet. Leaving the Wanaka it crosses the great hollow that stretches from Timaru, by the Lindis, Kawarua, and Dome Passes to Invercargill; then it pierces the Dunstan range; then it crosses the hollow of the Manuherikia and Pomahaka; after which, piercing the Beaumont Gorge, it issues in the plains and delta near the sea. Thus, while its course runs counter to prior experience, its levels are also equally divergent. It will be observed that, though the divergence is more at the ordinate nearest its source, yet this principle prevails that the curves gradually approximate, showing that had the source been accepted at a lower point than Mount Nix, the law would have been vindicated.

For the calculation of the ordinates of an ellipse for the valley of the Molyneux, we have: the length equal to 944,040 feet, rise 9,101 feet.

	By Ellipse.	By Survey.	Differences.
At source	0000	0000	000
At intermediate points	5050	8127	3077
	7405	8477	1072
	8084	8601	517
	8670	8890	220
	8781	8929	148
	8886	8951	65
At exit to sea	9101	9101	00

The next valley that the maps of the Survey Department enabled me to examine was that of the Cardrona, a rapid mountainous torrent flowing into the Molyneux near to its issue from Lake Wanaka. The length of the valley is about 31 miles, and the rise, from the Molyneux to the Crown Mountains, 4,799 feet. This example, considering the features of the mountain district, shows a tolerably near approximation to the ellipse, as given below:—

	By Ellipse.	By Survey.	Differences.
At source	0000	0000	000
At intermediate points	3433	3923	490
	3609	4000	397
At exit	4799	4799	000

The last example with which I will trouble you is that of the Mataura, with its east and west bends, a painting of whose scenery is on the table, taken on its first exploration, in January, 1857. The east branch being the shorter is not properly the main river; it will thus be seen that its curve is not so near the ellipse as the other, but both are exceptional to the general rule, and curve more under the classification of the Molyneux; the western branch crossing the low depression already mentioned that stretches from Timaru to Invercargill, and both crossing the remarkable valley that stretches from Molyneux Bay to Lake Te Anau. Thus the features of its bed have the same remarks applicable as have been made in regard to the Molyneux. The comparison of the east branch gives the following results:—

	By Ellipse.	By Survey.	Differences.
At source	0000	0000	000
At intermediate points	3201	4547	1346
	4216	4773	557*
	4620	4905	285
	4904	5009	105
	5110	5129	19
	5173	5160	13
At exit to sea	5224	5224	00

and the west branch, as follows:—

	By Ellipse.		By Survey.		Differences.
At source	0000	...	0000	...	000
At intermediate points	5295	...	6034	...	739
	5494	...	6079	...	585*
	6209	...	6315	...	106
At exit to sea ...	6530	...	6530	...	000

It may be remarked here that the points marked with an asterisk being common to both branches, viz., 557 and 585, the near agreement from such widely diverging *data* seems to tend to prove a common principle, such as it has been my object to illustrate.

Having thus endeavoured to follow out the indications of a law that nature pursues, in scooping out the beds of the valleys on the face of the earth, I will now point out one or two examples of extensive abrasions as collateral or confirmatory evidence of some great eroding power acting, which does not exist in this latitude at the present day. Taking a position near to Dunedin, we have the Kaikorai stream, a small mill power issuing from the south end of Flagstaff Hill. This streamlet pursues its course till it falls into the lagoons near Green Island. On examination it will be found to run in a well-defined and permanent bed, within which it would appear contented to remain to eternity—if its once pellucid waters had not been sacriligiously interfered with by wool-scourers, tanners, and railway contractors—yet do we see that it has had prepared for its tiny little self a capacious valley of 600 to 6,000 feet in breadth, and 150 to 200 feet in depth. That this valley has been scooped out for the dignity of the little stream is amply proved by the Caversham fossil-bearing limestone of the tertiary period, bounding it almost continuously to the eastward, and underlying it, also showing itself frequently on the western side. The strata of this limestone further give evidence, by its deposition and strike, that it once filled up as level land what is now a spacious valley. If the scooping out of this valley be sought to be accounted for by the petty stream now running through it, we would indeed have a monstrous effect from the most puny of causes. The causes must certainly be sought for elsewhere. Again, on the northern seaboard, we have the immense formations of Oamaru limestones stretching along the coast and up to the mountains. These, again, have been eroded and carried away by forces issuing from the valleys and gorges of the interior, and acting on them in a manner that adheres to a principle, viz., the erosions widen with the distances from the gorges, and creating along the limits of their influence steep and straight lines of escarpment which, at this day, display the interesting cliffs of fossiliferous strata of that district.

The erosions of the Waitaki, 300 to 500 feet in depth, extend 40 miles into the interior, of ¼ mile in width at the gorge, and 10 miles in width at the sea shore; of the Kakanui, 20 miles, with a varying width of ⅛ of a mile to 1 mile; and of the Waiariki, 10 miles, with a varying width of $\frac{1}{8}$ to $\frac{1}{4}$ of a mile. Thus has the undulating and varying surface of this part of our territory, during the post-tertiary period, been moulded to its present form, great valleys have been scooped out, and hills removed. Under what conditions, then, could these mighty works have taken place, is a question now to be considered.

To approach this question we must now turn to higher latitudes, and fortunate it is that a solution is to be attained not far distant, through the discoveries and researches of the eminent explorer Sir James C. Ross, whose works I read, with intense interest, in 1848, and which I have the pleasure to lay on the table. Just 23 degrees due south, *i.e.*, only six days distant by steam vessel, lies South Victoria, a region which now possesses the climate that New Zealand had; whose physical geography is the same; and, being volcanic, may be said to be a continuation of our colonial territory. The beautiful drawings given in the work display the same serrated ridges which are now to be seen in our great western mountains (see Reid's Antarctic Voyages Vol. I., page 183), and the smoking summit of Tongariro is to be discovered in that of Mount Erebus (see page 216, Vol. I.). To illustrate the subject, I cannot do better than transcribe the explorer's own words. He says:—

"It was a beautifully clear evening, and we had a most enchanting view of the two magnificent ranges of mountains, whose lofty peaks, perfectly covered with eternal snow, rose to elevations varying from seven to ten thousand feet above the ocean. The glaciers that filled their intervening valleys, and which descended from near the mountain summits, projected in many places several miles into the sea, and terminated in lofty, perpendicular cliffs. In a few places the rocks broke through their icy covering, by which alone we could be assured that land formed the nucleus of this, to appearance, enormous iceberg."

Again: "The height of Mount Sabine was found, by means of several measurements, to be rather less than ten thousand feet, and about thirty miles from the coast. The elevations of the other mountains were not determined with accuracy, but we judged them to vary from seven to nine thousand feet; and, altogether, they presented as grand and magnificent a view as can well be imagined."

Again: "We found the shores of the mainland completely covered with ice, projecting into the sea."

"We stood to the southward, close to some land which had been in sight since the preceding noon, and which we then called 'High Island.' It proved to be a mountain 12,400 feet of elevation above the level of the sea, emitting flame and smoke in great profusion. At first the smoke appeared like snow-drift, but, as we drew nearer, its true character became manifest. The discovery of an active volcano in so high a southern latitude cannot but be esteemed a circumstance of high geological importance and interest, and contribute to throw some further light on the physical construction of our globe. I named it 'Mount Erebus,' and an extinct volcano to the eastward, little inferior in height, being by measurement 10,900 feet high, was called 'Mount Terror.'"

Again: "At 4 p.m. (January 28th, 1841), Mount Erebus was observed to emit smoke and flame in unusual quantities, producing a most grand spectacle."

Again: "We made good progress to E.S.E., close along the lofty, perpendicular cliffs of the icy barrier. It is impossible to conceive a more solid-looking mass of ice; not the smallest appearance of any rent or fissure could be discovered throughout its whole extent, and the intensely bright sky beyond it plainly indicated the great distance to which it extended to the southward."

Again: "This extraordinary barrier of ice, of probably more than a thousand feet in thickness, crushes the undulations of the waves, and disregards their violence. It is a mighty and wonderful object, far beyond anything we could have thought or conceived."

Such is the description by an experienced arctic and antarctic voyager of a land such as New Zealand had once been in the glacial epoch, and I beg to refer you to page 232, vol. 1, of his work for an admirable drawing of the south polar barrier of ice which he discovered, and which rises 160 feet above the sea level, being also 1000 feet thick and 450 miles in length. With these facts before it, then, the mind may be presumed to be in preparation to perceive how the great erosions of surface had taken place here. The effects we see, and the power, indeed, is undeniable; for within six days' steaming from this we have the very extremes of the terrene glaciers, which have for ages been subject to the melting influence of the sea, yet maintaining a thickness of 1,000 feet, then in the valleys and at the mountain bases we have a right to conclude that in such places the glaciers may exceed 2,000 to 3,000 feet in thickness. Such being the case, then, the eroding force is only a matter of mere rule-of-three calculation, as below:—

Ice weighs 59lbs. per cubic foot. Ice, then, 1,000 feet in thickness will have a crushing power of 409lbs. per square inch; of 2,000 feet, 818lbs.; and of 3,000 feet, 1,227lbs. Now, chalk, according to Rankine (which has about the consistency of Caversham limestone), is crushed under a weight of 330lbs. per square inch. Thus, in the glacial epoch, would the Kaikorai Valley be scooped out by nature in as easy a manner as the potter's tool shapes the clay vessel. Limestone, such as most of that to be found on the Oamaru Plains, crushes under 2,200lbs. per square inch; this, then, with the alternate clays and soft shales, under half or third of the pressure, would yield to the glaciers of the thickness above given when in motion; and, when not in motion, yet the more readily by the power of water, under hydraulic pressure, finding its way out to sea between the ice and the earth, bearing with it the hard gravels drawn from the interior mountains, which would act as an abrading substance, in the manner that emery polishes even steel. It is thus that we see the Waitaki Downs levelled to their mathematical curves, but this only where the glacial forces could have acted where the downs have been protected by the position of the intervening Kurow Mountains; there they remain in preservation, and we see the lesson of the past as shown in the experience of the present, when our antarctic voyager remarks, as already quoted, of South Victoria mountains, that "the glaciers filled their intervening valleys, and which descended from near the mountain summits, projected several miles into the sea, and terminated in lofty, perpendicular cliffs." Such, then, was the face of nature on our shores, and such the action that formed our valleys and stretched out our plains. South Victoria Land, our neighbour in the great Pacific Ocean, is now undergoing the process of the great glacial action with which we are done, and which I have feebly attempted to illustrate. There now, at that short distance from us, is the glacial age; ours has passed and gone many hundreds of thousands of years ago, when our age was then, and at that time—in the simple but sublime language above given—a glacier filled the valley of the Waitaki, descending from the mountain summits, and projecting several miles into the sea, terminated in lofty, perpendicular cliffs. This wild scenery did not exist at the Waitaki alone, but was the character common to all our valleys and our coast lines.

Now, as the effects of glaciers have been apparent in our valleys, so will they be seen also in our hills and ridges, scoring them out into angular gutters and ravines, in the direction of least resistance, from the tops or watersheds, thus proving a strict adherence to the directions that bodies would take impelled by their gravity, and, in so doing, wearing away or scoring out the slopes, however hard their formations be, or however uncompliant their strata—this, of course, with modifications. On the table are some illustrations of this action, supplied from the topographical surveys of the Province. Supposing the lower hills and surfaces of the Province to have glaciers superimposed, their effect could be no otherwise, for, as they melted annually during the summer influence, the water would find its way between the ice and the earth, and so gradually work out a channel to the valleys by its nearest and readiest access. This done, as the first process, then, in time, would the overlying congealed masses break up by fracturing on the edges of the ridges, and by sliding down into the valleys assist disintegration of the surface by their weight, and so enormously increase the erosion begun in the first place, in a minute manner, by the water. Hence the furrowing of the hills and ranges so remarkably general in this part of New Zealand.

Having said so much, I may now proceed to terrace formations. The most striking are those of the Upper Clutha, near Cromwell; of the Manuherikia, near Alexandra; and of the Mataura; but they are found everywhere—from near the mountain tops to the sea shore—having the greatest dimensions to the most diminutive. Those of the Upper Clutha—a type of the former—rise 200 to 300 feet, looking in the distance like a huge wall, and attracting the astonished gaze of the beholder.

These terraces are found to consist of shingle and gravel, bound more or less loosely by clay and sand, *i.e.*, where the prior, or tertiary, deposits are not yet preserved from abrasion and transport; and this principle universally prevails—that the shingle becomes larger as you approach the mountains, and smaller as you near the sea. Thus there has been a law of deposit: the particles becoming smaller as the transporting power became weaker. Further, there has also been a law of deposition and formation, for the terraces incline as you close in with the mountains, and they tend to be level as you leave them, and only becoming perfectly level on the sea or lake shores. And here I may remark that in this part of New Zealand I have missed detecting any raised beaches, so frequently spoken of by European geologists, excepting on Lake Wakatipu, where those that exist there have been formed by the unusual circumstance of the lake once having an outlet by a different direction than the present one, and at a higher level, viz., by the valley of the Mataura.

In illustration of the varying inclination of terraces, I beg to adduce the following facts from actual survey. Commencing from the sea shore at the Waitaki plain, and following up the lower terrace parallel to the river, we found—

From	Z to X,	Papakaio,	in distance	14,400	feet,	the rise is	52	feet, or	3·6	per 1,000.
,,	X to V,	,,	,,	10,600	,,	,,	40	,,	3·8	,,
,,	V to Q,	,,	,,	13,400	,,	,,	59	,,	4·4	,,
,,	Q to R,	,,	,,	12,700	,,	,,	22	,,	1·7	,,
,,	R to S,	Awamoko	,,	14,300	,,	,,	25	,,	1·7	,,
,,	S to G,	,,	,,	10,300	,,	,,	29	,,	2·8	,,
,,	G to X,	,,	,,	25,600	,,	,,	77	,,	3·0	,,

It is so evident that the cases are similar with the terraces of the Molyneux, Taieri, Mataura, and other large rivers, near their mouths, that to detail them would be tedious and of no use; we therefore go at once to the interior. On the Manuherikia the following are the inclinations of the terrace that abuts near Alexandra:—

From	W to K,	Liang Rock,	in distance	12,300	feet,	the rise is	84	feet, or	6·8	per 1,000.
,,	K to H,	,,	,,	9,100	,,	,,	99	,,	10·8	,,
,,	H to E,	,,	,,	13,200	,,	,,	234	,,	17·7	,,
,,	E to C,	,,	,,	16,000	,,	,,	1,250	,,	78·0	,,

At the Upper Clutha, with one terrace abutting near Cromwell—

From H to I, Cromwell, in distance 16,400 feet, the rise is 728 feet, or 44·3 per 1,000.

And, with another terrace abutting near Wakefield—

From J to K, Cromwell, in distance 12,400 feet, the rise is 731 feet, or 59·0 per 1,000.

Thus, there is a law indicated in the nature and formation of these terraces, and when we examine their contents we find that they consist of particles of broken, worn, and ground-up rocks, whose originals are in the enclosing mountains; hence, as travelled particles, we conclude they come from thence.

To estimate the importance of the power that brought them to their present site is, for the human mind, difficult. The formation of the Manuherikia I roughly estimate at 900 feet in depth, 4 miles in breadth, and 20 to 30 miles in length; those of the Upper Clutha may be one-third less than these. Then, if we were to try to imagine what power would transport the Peninsula of Otago to Green Island, we would have some notion. We are, then, conclusively led to the glacial action that we have been already considering for a satisfactory solution of the problem. This alone could do the work, and this—on pondering on what has already been adduced—would do it so naturally that I need not take up more of your time on the subject, but rather confine myself to an explanation of the *modus operandi.*

It has been proved, I hope to your satisfaction, that terrene glaciers at one time covered our island, and that also the island itself was sunk considerably under the ocean. How these things came about does not matter to the present argument. That they were so is all that we want to know. Whether we had borrowed water from the Northern Hemisphere, and then lost it; or, whether the internal forces of the earth sank our land, and then raised it, is of no consequence. Indeed, great savans, as well as great preachers, allow of no obstacles to a favourite theory or belief. Thus, Lyell, to prove alternation of heat and cold, by the exercise of a little imagination puts Europe, Asia, Africa, and America, at the equator, and as quickly sets them at the poles; and Dr. Lang, of Sydney, to prove that the Polynesians and Americans descended from a common stock, lays dry the mighty and deep Pacific, and even Madagascar and New Zealand have been joined that the moas might have social intercourse.

Then, if the facts be admitted, even though the causes be unknown, we will have the mountains at near 3,000 feet less in elevation; Mount Cook, instead of towering 12,460 feet, would yet be majestic at 9,460; and the valleys of the Waitaki, Clutha, Taieri, etc., would be under the sea, and, in their upper portions, inlets thereof. At this epoch the dry land and shores would be covered with glaciers, the sea with icebergs, the temperature and constant attrition of which would allow no shell fish to exist. Hence their absence in the drifts.

Now, to form an idea of how the terraces are left on dry land in their present aspect, we must observe miniature operations of the present date; the principle being the same, the results of similar nature. If we take the shores of a lake, such as that of Wakatipu or Wanaka, or the banks of a large river, such as Molyneux or Waitaki, which are subject to periodical rises and falls, and which, also, have numerous rivulets running into and joining them, we will have the examples required. Then observe the banks of the lake or river at full flood, and you will see no indications of terraces, unless under water. Above the flood-line, no doubt, will be seen the terraces of former ages, but within the limits of rise and fall of the lake or river itself is only to be seen the action, in miniature, which is of use in illustration. Then it is by receding waters, or waters that have receded, that the terraces became apparent—of a river or lake in a few months; of the great ocean in many centuries. Yet the action and results are precisely similar; for, looking at the conformation of the surface of the shores of a lake or river where the feeder, or rivulet, enters, you will see the slopes divided into terraces: highest near the flood marks, lowest near the low water; most inclined near the flood mark, least inclined near the low water; the largest particles or pebbles near the flood mark, mere sand or mud near the low water; thus conforming, in every respect, to the gigantic formations which we are now considering. And let two streams enter a lake or river closely adjoining—the spurs between will be the same—sloping with the opposite terraces, and the talus will reach out in the manner that the receding waters had tended. If this be the law in small areas, so it is in great. It is, therefore (after glacial action had filled up the valleys with *débris*), to the receding waters of the ocean, assisted by influx and reflux of tide, with the feeder from the mountains at the head, that we may, without fear of contradiction, ascribe the hollowing out of the gullies in the terraces, and the transport of the smaller gravel and sands towards the ocean shores. Thus, while the glaciers brought down the shingle and deposited it all over the valleys, the succeding action of scoring out the terraces themselves into gullies was effected by the land rising, or, in other words, the ocean receding.

And while we see the terrace formations most prominent in the interior, most inferior near the coast, this is also due to the interior ones having been protected from the ocean surf by the enclosing mountains, while those on the seaboard have been subject to the full force of this degrading power. The whole formation of terraces, as we now see them in Otago, therefore, we may reiterate, have been the result of the mechanical action of nature operating, first in the long period of the glacial age, then afterwards by the rise of land, in which the tides of a receding ocean and the fresh waters of the mountains together acted as moulders of the present forms in their bold fronts, long reaches, abrupt rises, deep indentations, and mathematically-curving slopes.

With the well-known fact before us, that gold is found disseminated in quartz veins, and reefs intersecting the schist rocks, of which the mountains of the interior are principally composed—a fact so intimately connected with one of the most important industrial pursuits—some allusion to it is called for. The allusion must necessarily be a mere passing one, as no justice can be done it by one, such as myself, who has been but a mere occasional observer. Indeed, to pursue the enquiry with credit to oneself and advantage to the public, close application and very extended observation would be required for some years. All that I may therefore venture on is rather by way of suggestion than confirmed opinion.

If we admit that our auriferous mountains have been eroded to the depth of 600 feet, more or less, according to position—and this is a very moderate estimate—then will the gold particles have been submitted to the same action as we have seen other particles to be; and this principle will pervade, that the heavier will be found nearest the sources in the mountains; lighter, till they become impalpable dust, nearest the sea coast.

Practical gold miners will tell you that this is the fact. With a knowledge of this principle then, and indications of what was the trend of the glacial masses that caused the erosions and transport, these may give us a clue to follow up gold-bearing drifts to their sources, and so to the reefs. Further, glaciers are observed to grind down the softer constituents of the schist rocks to impalpable dust; this becomes deposited in beds by the action of water, and so forms, in time, a strong cementatious matter, which, with the larger particles of quartz, hornblende, chert, etc., became auriferous conglomerates. Where such a deposit is found with the shingle and gravel but little water-worn, then may we conclude that the original sources of the precious metal are not far off; for, if the sources were distant, the heavy shingle would not only have been well rounded, but the impalpable dust (imponderable in water) forming the concrete would have been dissipated and separated therefrom.

But there is another action that must have had considerable influence in the transport and deposit of gold, viz., icebergs or masses breaking off from the termini of the glaciers. These are known to bear large collections of rock and shingle, so, while they stranded along the terraces of the valleys or bars of the inlets, would they part with their burdens as they melted. The rocks and shingle would then disintegrate by the force of the waves or currents, and so part with the gold enclosed in them. It is by this action alone that I can see to account for the gold-bearing shingles of the shores of Southland and Molyneux, a distance so far from the mountains.

In regard to mountain glaciers, as contradistinguished from terrene glaciers, I need offer but few remarks, as they have been already fully and ably discussed in a paper (already mentioned) before this Society. What I have to offer are views taken from different aspects, such as they occurred to myself personally when visiting the localities at different times. The mountain glaciers, when viewed by themselves, are most stupendous in their dimensions and apparent effects; when viewed relatively with terrene glaciers their magnitude and influence are very circumscribed and diminutive. As the snows of the mountains in this district show their influence in the last month of the year, by melting and flooding the torrents, so may the mountain glaciers be said to have a marked epoch, special to themselves, at the end of the glacial age, which epoch is recorded by the moraines now extending round or at their ancient lower termini. Speaking from recollection, and going back seventeen years, I was struck with the immense hillocks of confused rubble, earth, and boulders extending round the southern shores of Ohau to Pukaki, and rising near 300 feet in elevation. There was, now, no apparent cause for this until we turned our eyes to view the receding glaciers, to be descried in the distance, high up in the mountains. So, at the southern end of Lake Wakatipu, similar phenomena are to be observed, leading to the same conclusions. The Francis Joseph Glacier, on the West Coast, extends down to 700 feet from the sea level, and those on the eastern slopes of the Southern Alps to 2,774 feet. Thus, in a particular valley on the West Coast, the glacial age may be said to be only 700 feet perpendicularly distant; while, horizontally, it is, as stated before, 23 degrees of latitude southward. On comparing the measurements, it will be at once noted that those of the valleys of the Waitaki and the Clutha are much modified; this is owing to the Pukaki and Wanaka Lakes forming portions of the valleys of the Waitaki and Molyneux. The cause of this exception has been ascribed, by one class of observers, to the scooping effects of mountain glaciers, while, by another class, it has been ascribed to the original depressions when the mountains and valleys assumed the geological arrangement now existing. As much has been advanced on both sides of the question, I will content myself by suggesting that we will not be doing much violence to either theory by giving both of them weight in modelling the surface of our valleys to their present form. Thus, I may ask those gentlemen who adhere to this lake-scooping action alone, why the Ahuriri had not a lake as well as its neighbour the Ohau; the Shotover and Arrow as well as the Dart and Rees; and the Oreti as well as its neighbour the Mararora; all flowing out of glacial mountains and under similar conditions? May we not give weight to the axiom, that where there are high elevations, so must there be low depressions; and where one varies in height, so will the other in depth? Thus, may not the valley of the Wanaka have been originally lower than that of the Matukituki, as their respective passes are lower; and so, while the valley of one is filled with water, the other is filled with the bed rock, overlain with sand and shingle.

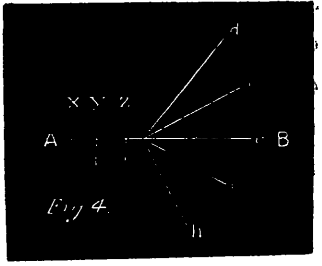
Then, to revert to the influence that glaciers of probably 3,000 and more feet in thickness would have in scooping action, or modification of shores and bottom, we must consider the nature of the rocks acted on.

The resisting power of the hard schists, being as hard as granite, that line the Wakatipu Lake, varies from 5,500lbs. to 11,000lbs. per square inch. Now, the crushing power of ice 3,000 feet thick, as already stated, only amounts to 1,227lbs. per square inch; thus its effect would be slight by way of crushing, though there might be large erosions by the disruption of blocks and strata from their beds on the face of the mountains, where gravity would also lend its aid. Yet, in the valley beds, as there would not be this aid, it is difficult to assent to such great erosions as would be required for the whole scooping out of the lake areas by a power equal to 12 against a resistance equal to from 55 to 110. Hence a middle course between two opposite theories appears to me to be the correct one. Speaking of this geological era, the lake beds were there *ab initio*, though much modified, it may be deepened and widened by the action, originally of terrene, and latterly of mountain, glaciers. Thus we cannot give the same weight to glacial power, for erosion and transport of material in broad lake or valley beds composed of hard rock, as we can to the same power on the slopes of the mountains, or in narrow gorges, or on the soft tertiary formations of the coast, such as we have on the Waitaki Plains. As a support to this opinion I adduce a case known to you all, viz., the Water of Leith and Kaikorai. The former, having a much larger drainage area and steeper mountains around it, yet passing through hard trap rocks, has but a very narrow valley bed; while the latter, with a much smaller drainage area and low hills around it, yet passing through soft sandstone rocks, has a spacious valley bed. This is clearly due to the relative powers of erosion and and resistance; so it is with the most stupendous operations of physical geography.

I now come to the subject of alluvial formations—a subject more immediately connected with the welfare and existence of mankind than almost any other—as on these are the most fertile plains and densest populations. How glacial action and terrace formation have to do with these will not immediately appear, but I hope to show they do so intimately. For a proper understanding of the subject—or, in other words, to grasp at one view what are very prolonged and diffused operations of nature—I must invite you to look at what is now going on, under your eyes at this present time, in many parts of this Province. I allude to the gold miners' sluicing works, for by them we see in one day what nature commonly displays in a thousand years; and if, in relation to the forces, you will agree with me that one day is as a thousand years, so you will admit the aptness of the illustration.

The gold miner, in pursuing his avocations, sometimes has recourse to what is called sluicing—that is, washing down the auriferous strata from the hills into the plains—by which means he separates the gold from the gravel and earth. In doing this he performs, in miniature and in a few months' time, what glacial action did so extensively in the course of many ages—that is, out of the hills he creates new alluvial deposits in the plains; unfortunately, being so hurriedly done, he does not at the same time, like nature, mix his earth with vegetable matter, and so replenish the plains with fertile soil capable of bearing fruit for the sustenance of man, but otherwise his sluicing avocations are the same in principle as glacial action.

Now if we watch sluicing operations from the commencement to their conclusion, we will see a parallel to one of the most benign provisions of nature most closely carried out. Let us take a hill-side bordering on a flat, such as at Gabriel Gully, or Weatherstone's; we will see that the shingle is deposited from the sluice nearest the hill; then the gravel; furthest off is carried the mud and silt. Thus, let A be the hill that is sluiced, and B the plain; first, the *tailings* are carried in the direction of AB, then, as the earth rises, the channel gets choked, so they are carried in the direction of *c*; this being filled up, then in the direction of *f*; then of *d*; then of *h*; then of *e*; and so forth; spreading out the material in the form of a fan, in separate layers, these layers varying with the quality of the soil taken out of the hill. Thus, if *z* were blue it would be spread in a thin layer over the portions of the fan it was carried to; if *y* were red it would be spread out at other parts in the same manner; and, if *x* were white it would appear at its proper time and in its proper layer, and this might be done over a thousand times.



Thus the modern gold sluicer answers the enigma that puzzles the Taieri farmer, when he discovers trees so far below the present surface, by telling him that these trees grew at a time when the glacial sluicing operations were at *z*, and whose tailings were deposited far below those of *x* and *y*.

If such be the process by which the gold miner, in his sluicing operations, spreads out *débris*, drift, alluvial sludge, or tailings, in strata all over the plain, such we may anticipate is the precise process by which the same matter is made to cover the plains of New Zealand, wherein terrene and mountain glaciers perform the functions of the sluicer. And we have only to look to the neighbouring Province of Canterbury to see the effects of the process developed in its most prodigious grandeur. I allude to the fan-like deposits of the Rakaia, Rangitata, and Waimakariri, on the spacious plains of that part of the Middle Island. In Otago, except on the Waitaki, probably we have no such examples, though we have great numbers on a minor scale, which may be called lateral alluvials, brought out from the small gorges of the limestone ranges at Papakaio, Waikari, Kakanui, etc. But in all cases, whether the deposits have been the result of natural or artificial causes, whether great or small, they all appear to conform to one principle, and to adhere to one shape, vertically and horizontally.

This led me to enquire if there was a law of deposit, and, in going over all the surveys and levels to be obtained in this Province, I found that all were more or less deficient in completion, excepting the very careful survey of the Taieri Plain by Mr. Adam Johnston. Here the information was as complete in every respect as could be desired, though the extent of deposits are very small in comparison with those of the Canterbury rivers. However, the essentials were the same, viz., alluvial deposits spread out over a plain from a narrow gorge in mountains running parallel with the plain. Thus the deposits, as brought out, had free scope for extension over 180 degrees of the horizon, and the result is precisely that of what may be seen in the "tailings" of many of our gold workings. The Taieri, bearing the *débris* from mountain glaciers originally, and now that of floods, issues on the plain at Outram Bridge, and meets the low-water mark of the tide at Adams', a distance of 12½ miles measured by the sinuosities of the channel. The difference of level between the river, in its ordinary state, at Adams' and Outram Bridge, is 17·57 feet; and the levels of intermediate distances are given respectively, showing a curve of a very decided contour. The curve is neither that of the hyperbola nor circle. With the *data* given, and by the formula already used in given cases, it was compared by computation with the parabola, but found not to accord therewith. It was then tested by the properties of the ellipse, with the following result, so nearly approximating that it may be said to be one and the same:—

	By Ellipse.	By Survey.	Differences.
At Outram Bridge	00·00	00·00	0·00
At intermediate points ...	11·55	10·75	0·80
	14·12	13·26	0·86
	15·06	14·95	0·11
	17·12	16·78	0·34
At Adams' Accommodation House...	17·57	17·57	0·00

Thus, in this instance (and I have no doubt the agreement will be the same in all similar conditions of water scooping out the gravel, clay, and mud), water descending to its level, through alluvial soil, digs or scores out its bed to the curve of the ellipse; and thus, in a remarkable manner, imitates the semi-liquid glacier in its operations on the valleys of the earth.

This, then, is the law of erosion, but not of deposit, the next subject of enquiry. In searching for a law of deposit we again refer to Mr. Johnston's survey, which gives us ample *data*. Taking his levels between the same points, we find the distance by flood-channel 59,730 feet, or about 11 miles; and the difference of level 30 feet. Levels are also given at intermediate points, resulting in a decided curve. In this case the summit of the alluvial banks are taken, the effect of many floods, and not of one in particular; as Mr. Johnston's map elicits the curious fact that separate floods have very unconforming levels at different parts of their courses. This curve of deposit, as I may call it, was first tested by the properties of the ellipse, but found not to accord; it was then tested by the parabola, with the following results:—

	BY PARABOLA.	BY SURVEY.	DIFFERENCES.
At Outram Bridge	00·0	00·0	0·0
At intermediate points	13·3	14·4	1·1
	19·1	19·5	0·4
	23·2	22·7	0·5
	25·7	26·1	0·4
At Adams' Accommodation House	30·0	30·0	0·0

Thus, the curve of deposit may be said to be identical with the parabola, varying from it, in a course of eleven miles, on an average of six-tenths of a foot. The theoretic course of a cannon ball is in a curve of the parabola, subject, as it is, to unequal resistance and deflection of the atmosphere and its currents; it, in practice, does not excel water in its mathematical truth, as here displayed.

Here, then, are two laws proved in the Taieri "tailings," as the gold digger would term them. The law of scooping out is as the ellipse; that of spreading out as the parabola. And what practical objects do these lead us to. Many, no doubt, will develop themselves in various minds; one or two I may shortly state.

The first is one of geological interest. When the plains were being covered by detritus to the parabolic curve, glacial action was, of necessity, in full force. The valleys were filled with moving ice and turbid water, grinding against the sides and bottom of the earth. At the time this was in process the torrents issuing on the plains would have no more certain beds than the sluice waters of the miner, but would diverge to and flow over 180° of the horizon, depositing its "sludge" where there was readiest outlet or lowest level.

But as the cycle pursued its course, so, with the increase of temperature, the ice of the glaciers would melt or retreat in diminished bulk to the tops of the valleys; then the depositing power would virtually cease, and the opposite, or eroding action, by the torrents finding for themselves a confined channel, would take place. Thus we arrive at the present era. As it is with great, so it is with small, things. No sooner are the miners' claims worked out than deposits, spread out in the parabolic curve, cease, and the clear water, now unused, seeks for itself a confined channel in the elliptic curve.

The other question may be called an engineering one. If detritus is deposited as the parabola, and scooped out as the ellipse, then we may conclude that such rivers as the Waitaki, on whose outlet the sea is encroaching, will more and more adhere to a confined channel—the elliptic curve following a lower course than the parabola; but that such rivers as the Waimakariri, Wairarapa, and Oreti, whose outlets are advancing on the sea, being into deep bays with shallow waters, will tend intermittently to diverge from their channels. Hence, if the theory prove a correct one, there might be some utility in the careful investigation of the curves of these rivers in regard to their ordinary flood and glacial drift marks, *i.e.*, their highest banks, which would clearly display the points where the two first tend, in any measure, to overflow the latter.* It is certain as noonday that nature always works by law, and there can be no waste of human energy when it is expended in the investigation of the course that law pursues.

In conclusion, I may venture to state that the more we study these subjects the more we will be convinced that nature as much abhors cataclysms and sudden catastrophes as she is said to abhor a vacuum. Her changes are gradual, and her operations, in changing from latitude to latitude, present themselves to us merely as accelerations in one zone and retardations in another. Thus, if the scoring out of the valleys by glaciers is in full force in Victoria Land at the present day, such action, to all intents, has ceased here. That the ceasing has been gradual, prolonged over hundreds of thousands of years, I think will be a generally-received opinion; so, also, will this be accepted, that the commencing of the glacial age, with its prodigious overflowing and deadening influences, was also as prolonged. To living creatures the change would come on so slowly as to be harmless and unobservable, and what may now be the tendency of our climate could only be indicated by rigidly scientific observations continued over a century.

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* Drainage and embanking operations will be under the same law, also the cutting of sludge channels in mining. Here embankments should be as the parabola; drains and channel beds as the ellipse. In large works the money saved would be enormous by the adherence to correct principle.