The Artesian Water-Supply of Australia from a Geographical Standpoint: Discussion
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the Western States of America, where irrigation from bored wells on the closely settled farms induced a larger and more regular, although light, rainfall than that which took place in the unsettled prairie lands of the country.

When I first began to practise as a subterranean water-supply engineer in Australia—in the pioneering times in 1877—the lack of surface water in that fine country, and the evils attendant thereon, was, after an experience of Great Britain and five years' practice in the United States of America, a revelation to me. In the pastoral districts of Australia, in which artesian water has been since obtained, great benefits have accrued. The water has, in many cases, flowed in a natural course for over 50 miles from the bore, and it is now ready for the fullest utilization; but irrigation for the purposes of pasturage or crops is, as I have indicated, only in its initiative stage.

Many inland towns of the Downs country are supplied by reticulation from the bore-water under its natural high pressure. Single bores are there supplying an ample and constant supply for domestic purposes, and also for vegetable and flower-gardens *ad libitum*, and one scarcely knows which to admire most, whether the fruit trees in bloom or the blanched linen on the laundry-women's lines. The beneficial change already induced by the use of artesian water is apparent on every hand in those districts where it has been largely obtained. Live stock have been saved by thousands, and man made better, physically and morally, and with a fuller utilization of the water, the one great drawback of a great country will be largely neutralized.

Lord LAMINGTON: I believe, in almost every case where tried, bore-water after two or three years deposited such a sediment as proved harmful for agricultural purposes. Of course, water differed in the several bores, and some might be found adaptable. It seemed certain that lands that only required irrigation to make them fertile should, either by this method or by conservation of water, be turned to better use. But in the meanwhile, with hundreds of thousands of acres of rich lands on the coast, with a fair rainfall and more agreeable conditions of life, and which yet required to be settled and developed, it was unlikely that agriculture on a large scale would be taken up in the western country.

Sir T. FOWELL BUXTON: I think, from all we have heard, the prevailing opinion is that the artesian supply will go on perpetually flowing. We know if we have any receptacle in England, such as a gardening water-pot or anything else, and we draw from it, we run it dry. Well, I have never heard anything on that point, but when we are dealing with the water-supply of a great continent and talk of creating large rivers by which to reach the sea, it becomes a very important question whether there is any chance of running it dry. So far as I know, there was no solution of it in South Australia in my time. The object seemed to be to make a reasonable supply along certain tracks along which cattle and sheep might be driven. Now, it was considered very important to establish a cattle-track between Queensland and South Australia, going from the railway near Lake Eyre into Queensland to the head of the railway there, and the scheme which was more or less begun in my time was to try and establish an artesian well at every 20 or 25 miles.

I do not know whether that has been maintained, or whether it has been taken up by the Government of Queensland on that side. But there certainly was no attempt, so far as I understood it, to produce a supply, a big enough irrigation scheme, that would mean cultivation of land. It was only attempted for the supply of cattle; large troughs, as I saw them in South Australia, were established for the feeding of cattle, and I think I was surprised and rather disappointed by seeing a large chute, almost as high as some of those we have been seeing pictures of this afternoon, a considerable chute going up nearly as high as this room, yet apparently, when used for irrigation, go such a little way. I remember seeing a garden just south of Lake Eyre, where an attempt was made to produce dates, and there were certain gardens laid out with date palms and other things; but the irrigation seemed to go such a small way, it may be five, or six, or eight, or ten acres, but it did not extend to anything like a large area, and apparently it would have gone if the supply had been large enough. I hope I have made my question clear, and have not occupied too much of your time.

Dr. H. R. Mill: There are several points in this most interesting paper on which I should like to speak, and I should like to put my remarks in the form of questions, or, at least, to ask the opinion of Mr. Cox upon what I have to say. Of course, the importance of the subject is apparent to all geographers, and I think Mr. Cox deserves special thanks for bringing forward so very clearly the enormous importance of underground water-supply in the case of this particular continent of Australia. But then comes the question, Is that water-supply going to be continuous? Is there under the surface of Australia a great accumulation of water stored up from remote periods in the past? That is a theoretical point which, to my mind, is of vast importance. I do not know, but there were several statements in this paper which suggested the idea that the author possibly considers that the water stored up in these rocks dates back, some of it at least, to comparatively remote geological periods. Now, from the study of the general phenomena of physical geography, one is inclined to believe that the condition of things should assume a state of equilibrium; that the storage of water in the strata would go on to a certain point, beyond which any fresh accession would be counterbalanced by loss, either a flow off into the sea, or perhaps by the rising of the water to the surface and its removal quietly by evaporation; and I would put it as a question whether it is not extremely probable that the available supply that can be drawn from artesian wells is not simply that proportion of the rainfall of the country which percolates into the soil. We know that in our own country there is an immense quantity of water saturating the chalk which lies beneath the London clay, and that water has been taken from that supply to a greater extent, I suppose, than in any equal area on the surface of the Earth, and we know that as a consequence of the flowing of artesian wells, and the pumping of non-flowing bores, the level of saturation in the chalk has been steadily going down. The amount of water removed now almost entirely by pumping—because the artesian wells no longer flow on the surface—is probably in excess of the amount of water brought in by the rainfall, hence the wells have always to be deepened in order to yield. The same, I am very much inclined to believe, will be the case in Australia if any particular artesian basin is treated as if its supply were inexhaustible; but then we must remember that even if that is so, the amount, though not inexhaustible, and though perhaps not even incalculable, is still so very large that it will admit of an enormous amount of development before these limits begin to be practical problems. There is another point of very great interest which is mentioned in the paper, and that is with regard to the effect of a surface of water in attracting rainfall. Mr. Cox referred to the reservoirs supplying Manchester.

I suppose he meant the Longdendale reservoirs, and there it would be easy to ascertain whether it is really the case that the existence of this water surface has produced any increase in the amount of rainfall, or even in the frequency of showers. Our usual experience is that when you have a level surface of water, the amount of evaporation is greater than any increased rainfall that would be induced by the lower temperature of the water, which, of course, is the only way in which condensation would be produced on the surface. As a rule, we find a slight rise in the elevation of the land will produce a greater rainfall than a lowering of temperature over the surface. I have been extremely interested in the paper, and the practical outcome of it seems to be that, side by side with the utilization of the artesian water, we must go on with the study of the rainfall, which in Australia is perhaps more capricious than in any other part of the world, and so requires a longer series of years of observation in order to ascertain the average rainfall; in fact, I do not believe that as yet we know the true average rainfall of any part of Australia, because the records have not yet been kept up long enough.

Mr. Langler: Might I inquire what is the basis of the remark made in this paper with regard to the absence of artesian water in Western Australia? Is it based on geological theory, or is it on actual experience?

Mr. Gibbons Cox: In regard to the remarks made by Lord Lamington, I think irrigation water, that is to say, all water for irrigation purposes, must vary in quality; even some of the best of the river-water is not good for irrigation. And, further, a good deal of the water that comes from these bores, on being exposed to the air for a time, does very well for irrigation. I think it is a local matter to a great extent. When we take into consideration that immense areas of land have been irrigated in Algeria, America, and Europe, I think there is every reason to believe we shall get the same results in Australia. As there is such an enormous area of artesian rocks in that country, there is, in all probability, a vast quantity of water adapted for irrigation. There may have been some cases in Queensland where it has not been a success, but that must have been because the water was not adapted for the purpose. I think you will find that neither the Government nor private engineers claim that all water is good for irrigation. Some is adapted for wool-washing, other is good potable water and for irrigation, and I do not think it is safe to assume that all the artesian water of Queensland is unfit for raising crops. Irrigation is only in the initiative stage. Of course we cannot be certain, but I am inclined to believe that the future will see a very extensive system of artesian irrigation.

In answer to Sir T. Fowell Buxton, with regard to whether artesian rocks exist in the Lake Eyre district; the most recent researches of geologists and engineers show that such rocks do exist.

Sir T. Fowell Buxton: My question was, Do they exist there exclusively, or almost exclusively?

Mr. Gibbons Cox: I do not know that; but in the Lake Eyre district there are remains of the old Cretaceous ocean, and certainly Cretaceous deposits took place there. Although the lake-water is salt, I think that in the future very fine artesian water will be obtained from below.

In reply to Dr. Mill, as regards permanence of supply; I do not think there is any doubt about that. If the enormous areas of artesian country are taken into consideration, the areas proved by actual boring down to the water-bearing rocks, which have given large flows of water; if you take also the outcrop areas as proved by actual surveys by the Government geologist, and the fact that there has been quite an average of certainly 20 inches of rainfall as shown by the

official gaugings of the last fifteen or sixteen years, you will get at such an enormous volume of water stored up repeatedly, or naturally conserved, in the ground, that to my mind the quantity is almost incalculable. Although we find that the daily flow in Queensland is 351 millions of gallons from 530 bores, that quantity is in reality a mere bagatelle. I think there can be no doubt as to the permanence of supplies providing the rainfall continues, and we have no reason to suppose it will not do so. Another matter is, that if you take into consideration the porous nature of the rocks of the crust of the Earth—even granite, as I have remarked, is so constituted — and that the Earth has been receiving rainfall from the very earliest times, it will be apparent that the crust must have been fairly saturated irrespective of the rain that has fallen in our time. The Earth is absolutely charged with water, and a portion, no doubt, of the artesian flows has been accumulating for ages. But we are inclined to think, from the fact of the water being comparatively fresh, that it is not in a state of utter stagnation, or, in other words, that as it is not highly impregnated with saline and other alkalies of the Earth, it is moving. The water (referring to the map) is, in fact, slowly passing down through the porous water-bearing rock until it enters the great Australian bight below the surface of the ocean, and also, in all probability, into the Gulf of Carpentaria. Further, as regards permanency, I think it will take very many thousands of bores before an effect is appreciably made on the supply. Dr. Mill said that, the draught having been very great on the London basin, the head of water had naturally been reduced, although it took a great many years to produce that result. Now, if we take the area—and I scarcely like to make a comparison of my native country with countries like that one—if we, however, compare the area of Queensland with the London district, and if we assume that the Cretaceous water-bearing rock of Queensland is highly porous (and it is a question in my mind whether it is not equally as porous, and equally as good a water-conveyer, as the London Chalk; it certainly parts with water more freely), the accumulation of water in that State is, as I have desired to impress upon you, so enormous that the comparison will not, I think, hold with regard to the London district.

With regard to the question Mr. Langler put to me as to Western Australia. The artesian rocks in that state are of a rather different nature. They are calcareous sand-rocks, belonging to the same Cretaceous formation, and are called Œolian sandstones. At Perth they have been very successful in boring, and have produced splendid water at a depth of 700 feet in the railway yard. It is a very fine flow—it is, in fact, so strong that the Railway Department could not use it all, but made arrangements with the municipality, the money paid by that body covering the interest on the cost of the bore. It has been found at Bunbury, on the south-west coast, and at Guildford, about 18 miles up the Swan river from Perth, where there are many fine flows. The Cretaceous belt is not confined to the south-western coast, but extends to Geraldton and Onslow, on the western coast, and they have it up here at Freycinet Point, and are also boring in the Kimberley district. Much of the artesian water in the south comes from the Blackall ranges. The northern district has had a bad name for dryness, but I think it extremely likely that artesian water could be obtained all over there. An amount of experimental work—and it may be to a great extent so called—has been left to private enterprise, the Government not having supported the matter as much as I think it ought to have done.

The CHAIRMAN: I think it is very encouraging for us to hear from Mr. Cox that he has great faith in the permanence of the water-supply of these artesian wells. Certainly that was not the opinion of everybody in Queensland when they were first started. When I was in Queensland, there was a good deal of doubt on

the part of some persons as to whether the supply would be permanent, and endeavours were made to prevent waste in the water. It was turned on at certain hours and turned off again. No doubt a better opinion has prevailed since then, and it is believed that the water-supply will be practically permanent. And, as Mr. Cox says, of course the number at present in Queensland, compared with the area of the country, is very small indeed. There are many interesting points connected with artesian wells which have not been touched upon, and about which perhaps a good deal is not known. I would remark on the extraordinary difference in the temperature of the water. I believe there is a very great difference indeed. That very beautiful artesian well at Charleville (?), to which the lecturer referred, and which I have visited on various occasions; the water comes out at a temperature of about 100°, and I believe it is very much higher in some other wells, and possibly lower in others. That water is utilized in various ways. For instance, there is a nice bath, where you can get a very good warm bath for a charge of a penny. Then there is a good deal of difference, I believe, in the taste of the water of these various wells, as is natural, as they come from different soils; but I believe most of the artesian water is quite palatable to animals, but a good deal is not agreeable to us to drink. I am sure you will all agree with me that Mr. Cox deserves our thanks, not only for his lecture on the artesian wells and the readiness with which he has answered all the questions put to him, but because long before this time he commenced to make a general study of the question of artesian supply, and I may say a great part of his life has been devoted to that study, and I believe with a great deal of success. I would ask you all to allow me to convey your thanks to him for the interesting lecture he has given us.

Mr. Cox: I am extremely obliged to you for the very kind way in which you have received my paper. It has been a great pleasure to me to read it before the Geographical Society, because it is a Society of very considerable scientific research and importance. The questions that arise out of this artesian water-supply are very great and very voluminous, but I think, as I said before, that there is immense quantity of water in the crust of the Earth which can be got out, and I believe it can be used for irrigation purposes to a very great extent.

Dr. R. Logan Jack, who was unable to attend, sends the following remarks on Mr. Cox's paper:—

Much credit is due to Mr. Cox for having so clearly drawn attention to the benefits of irrigation. There can be no doubt that at present all the surplus of the bore-water beyond what is drunk by stock is practically wasted, except for the slight improvement in the humidity of the climate which must result from the creation of a number of open water-bearing gutters. To cultivate rice on the low-lying grounds in the vicinity of the bores would improve the climate, as it has done in China and India, but Australian bushmen are not large consumers of rice, and the factor of freight to the market will determine whether the cultivation will pay. The question of the cultivation of fodder for the sheep will be looked upon by the squatter in the cold light of figures. He will cipher it up something like this:

"My bore yields, beyond what the stock drink, 100,000 gallons per day. What can I do with that? I could (after making reservoirs) pour 6 inches of water four times a year over 70 acres of land, and cultivate lucerne. As a continuous growth of lucerne may yield eight crops, or 12 tons per acre per annum, let me assume that my partial irrigation will yield four crops, or 6 tons per annum. My 70 acres will yield 420 tons, or 940,000 lbs.

"To keep a sheep alive for, say, 90 days in the year when the natural grasses fail, or the animal cannot reach them, will take 8 lbs. of fodder per day, or 720 lbs.

in the year. My whole 70 acres will thus tide 1300 sheep over the average annual period of drought. The capital value of my sheep is 9s. per head; thus 1300 sheep represent £582. What will it cost me to save 1300 sheep, value £582, which would otherwise be lost? I have my doubts about getting labour for the tropical west at coast or southern rates, and I must reckon up the capital value of reservoirs, etc., but say that my 420 tons of fodder cost me, as I believe is about the average on the coast, 25s. per ton, or £525; the difference between that and the £582 is very small."

With reference to the above, Mr. Cox writes—

In putting such words in the mouth of the cold-blooded squatter, I admit that every one of the figures I have supposed him to use may be erroneous, because I have little practical knowledge either of pastoral or agricultural pursuits. In many cases, however, I believe the squatter knows very little more about agriculture than I do, and no doubt he will seek expert advice on that subject from the farmer. Personally, I should be delighted if, when the two lay their heads together, they find some radical error in my *data*—much as, for instance, that eight crops of lucerne can be cut annually in place of four, or that the cost per ton will be only half what I have supposed, or that some other crop will be more profitable than lucerne. Nevertheless, I assume that the squatter, like the sensible man he is, will reason on such lines as I have indicated. If, with the help of the farmer, with co-operation, and perhaps with the assistance of the Government, he can see his way to make irrigation profitable, the whole country will benefit, and the full value, in place of an infinitesimal proportion, of the generous provision of nature will be realized. It is difficult to contemplate the present waste philosophically.

I am pleased to find that so high an authority as Dr. Jack confirms my opinion as to the capabilities of the present outflow of artesian water in Queensland, and that there is, in his opinion, a means of practical irrigation from that source.

		Gallons per diem.
The present outflow is		351,295,000
Allow for non-irrigable water 10 per cent. Allow for soakage and evaporation per diem 10 per cent.	20 per cent. 70,259,000	
Water used per diem by maximum number of sheep (year 1892)—22,000,000 sheep at two gallons each per diem	44,000,000	
	————	114,259,000
		237,036,000

1 inch of rainfall gives 22,622 gallons per acre.

20 inches per annum (allowing four waterings of 5 inches each) gives 543,485 gallons per acre; and 237,036,000 gallons per day would irrigate 151,191 acres with 20 inches of bore water per annum, or would irrigate at the rate of nearly 300 acres at each of the 532 bores treated upon.

THE RUSSIAN TIBET EXPEDITION, 1899–1901.

By Captain P. K. KOZLOFF.

In the spring of 1899 the Russian Geographical Society sent out under my direction an expedition to Central Asia and Tibet, organized with the money granted for that purpose by the Emperor. My