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The Alluvial Deposits of Western Australia.

BY T. A. RICKARD, STATE GEOLOGIST, DENVER, COLORADO.

(Buffalo Meeting, October, 1898.)

I.—General Geological Considerations.

The interior of West Australia is an arid table-land, elevated 1400 feet above the sea. This plateau is flanked to the south by the Tertiary limestones which fringe the Great Australian Bight. It is bordered northward by the Carboniferous beds of the Fitzroy river and westward by the granite of the Darling hills, while to the east this wide area, about 900 miles square, slopes downward imperceptibly into an undulating plain of sand, which stretches with dismal persistence across the boundary of South Australia. The waters of the ocean receded from this tract of land long ago; it is probably the oldest land-surface on the globe, and represents the basal wreck of a much larger continent. Fig. 1 is a map of this region.

The Coolgardie and Kalgoorlie gold-fields are situated in the southwestern part of the region. The rock-formation consists of granite penetrated by diorites and andesites. The latter are occasionally associated with tuffs, which have been readily mistaken for sedimentaries. There are no fossil-bearing rocks, such as would afford a datum-line from which to measure the relative geological age of the prevailing formation. On the extreme edges of the mining territory there are, it is true, remnants of sand-rock which are considered identical with the "Desert Sandstone" of Queensland, determined by Daintree to be of Mesozoic age. But even this formation has evidently been laid down so long subsequent to the underlying rocks that it serves merely to emphasize their much greater antiquity.

In their characteristics and in their relations to each other, the granite and the diorite of the Coolgardie region appear to me much to resemble the Laurentian granite and the Huronian

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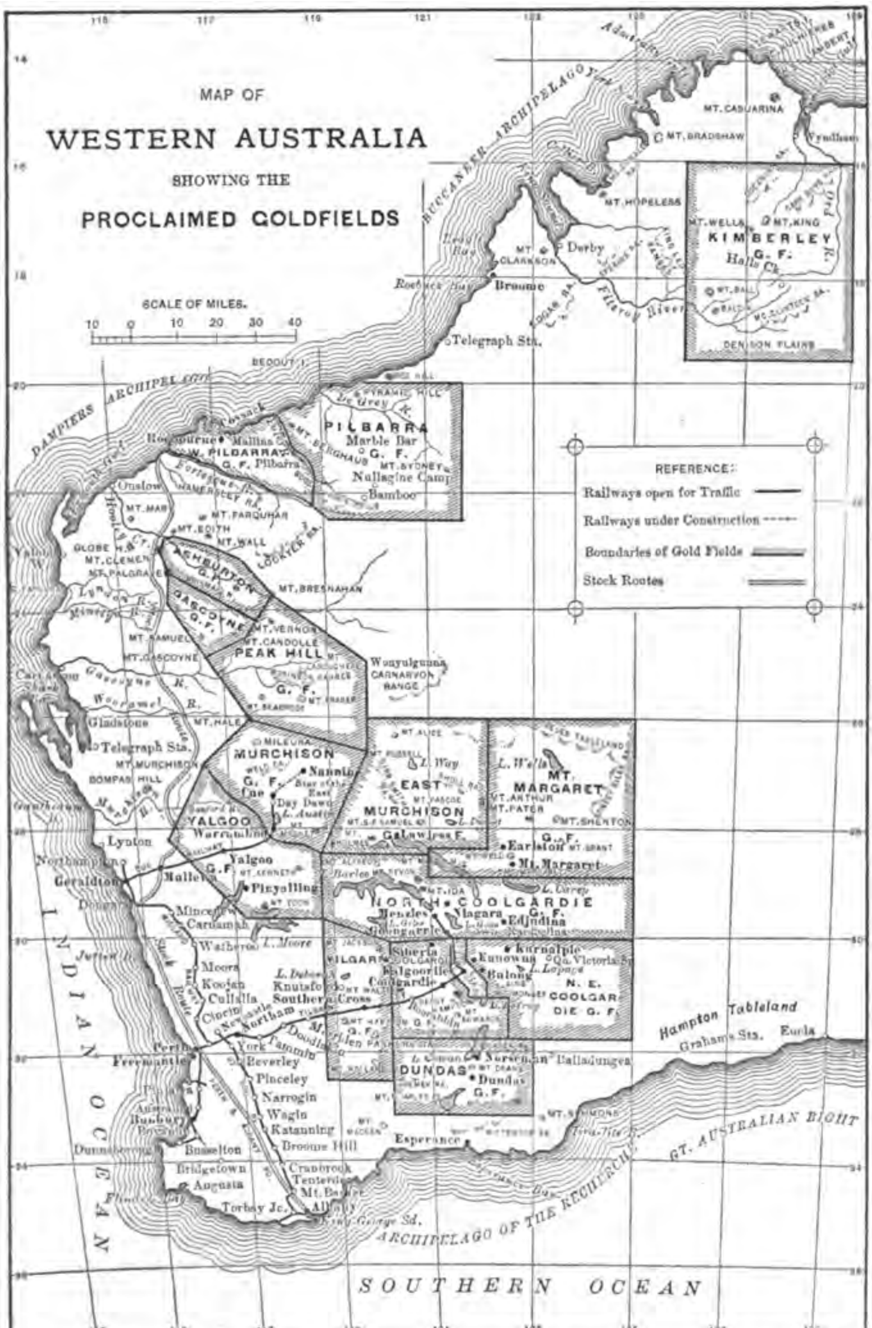
FIG. 1.



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schists of Ontario, in Canada.* Their age can only be vaguely described as Archæan.

On many parts of the earth's surface a long-continued, slow movement of continental uplift, interrupted by intermittent periods of rest or subsidence, has permitted the transfer of land to the sea by the erosion of the exposed parts and the deposition of their detritus as ocean sediment, thus causing the upbuilding of a mountain-system composed of a series of rocks belonging to successive epochs. In this particular region, on the contrary, all diversity is wanting, and a sameness of aspect wearies the observer. In the absence of an elevatory movement, more than sufficient to balance the slow degradation of the higher parts of the region, there has been no compensation for the effects of atmospheric erosion, so that this tract has become a dreary flat, strewn with the sandy wreck of weathered rocks.

The United States offers both a contrast and a parallel. In the Rocky Mountain region the movement of uplift which commenced in pre-Cambrian times has only been interrupted so as to permit of the laying-down of younger sediments; and the degradation of the high places has been compensated, and sometimes exceeded, by an elevation which has resulted in the formation of a mountain mass flanked by a long succession of strata now enclosing a great variety of mineral wealth. The interior of Australia can be likened to the Great Basin, occupied by Nevada and parts of Utah, Idaho and Arizona, between the Rocky Mountains themselves and the Sierra Nevada. There is only one large river in Australia which reaches the sea, namely, the Murray, which rises near the boundary-line of Victoria and New South Wales, and then flows toward the interior, to be saved by a backward sweeping curve, which permits the river at length to empty itself into the sea at the border of South Australia. There are many "lost rivers," like the Carson

* The mass of the granite is penetrated by the mass of the diorite, the latter being therefore the younger; but puzzling evidence is afforded by the fact that the diorite at the contact is sometimes traversed by embranchments of granite, which are explainable on the supposition that subsequent metamorphism gave the granite a renewed mobility, permitting it to penetrate fractures in the diorite. At Rat Portage, Ontario, the overlying, younger Huronian schists are intercalated and penetrated by the older Laurentian granite at certain places along the line of contact.

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and the Humboldt in Nevada. During the rainy season they are tempestuous torrents; during the succeeding dry months their course is marked by sandy bottoms, dotted with an occasional water-hole. The mountains are near the coast, so that the Australian Alps and the Blue Mountains do the same service as the Sierra Nevada and the Cascades, in that they interrupt the warm, moisture-laden winds, and compel them to precipitate on the seaward slope. The consequence is that the eastern parts of the colonies of Queensland, New South Wales and Victoria, between the mountains and the sea, resemble the valleys of California and Oregon, just as the interior region beyond them bears a likeness to the dry tracts of Nevada and Arizona.

The sea retired from the interior of West Australia in the very dawn of geological time, and the movement of elevation, which raised the land above the waters, continued with but little interruption until the beginning of the Tertiary period. Since then, slow subsidence has robbed the Australian continent of a part of its extent, and made Tasmania an island. There is evidence of a much larger continental area, which at one time extended toward Southern Africa. The encroachment of the sea has crowded a wonderful variety of flora into the small stretch of fertile country lying between the desert and the Indian Ocean.*

The main drainage of the interior is to the south. The last retreat of the sea was accompanied by the formation of broad valleys, which have lost their former outlines, and now appear as long depressions, largely filled up with the products of erosion.

II.—The Physiography of the Gold-Fields.

The principal gold-field of West Australia is situated in the southwestern part of the desert plateau. The chief towns are

* This corner of Australia is celebrated among botanists for the extraordinary variety of its flora. Baron Ferdinand von Mueller, the celebrated botanist, may be quoted: "A marvellous exuberance of plants, different in species, and often gay or odd in aspect, exists within a triangle formed by a line of demarkation drawn from the south of Sharks Bay to the west of the Great Bight; and within this space are chiefly located those species which are exclusively restricted to West Australian territory."

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Coolgardie and Kalgoorlie.* They are connected by 350 miles of railway with the coast. During the year 1897 the total rainfall amounted to 5⅝ inches at the one place and 4¾ inches at the other.† In contrast to these figures, it may be added that the rate of evaporation in this region is estimated to be equivalent to 7 feet per annum.

The country consists of a sandy plain, the monotony of which is intensified by a series of alternating low rocky ridges and equally slight depressions, having a northwesterly direction. Most maps indicate the occurrence of lakes and the occasional course of a stream, but these are the mirages of the cartographer. The "lakes" are shallow basins with clay bottoms, in which, during the rainy season, a little water lingers, and the "streams" are sandy channels, where sinking will sometimes tap a trickling flow of brine.

The surface is devoid of vegetation, except in spring, when flowers‡ of a brilliant hue, but with the texture of hay, leap into brief existence. Animal life is infrequent. An occasional bustard may be provoked into leisurely flight, a troop of paroquets throws a momentary gleam athwart the dull gray of the bush, or a solitary kangaroo hops across the trail. These, however, are but infrequent interruptions to the sullen silence of the wilderness.

The real nakedness of the region is hidden by the "bush," consisting of scrub from 20 to 60 feet high, chiefly mulga and ti-tree.§ This covers all things as with a garment (see Fig. 2). The roads are cut through it with the monotonous regularity of a canal. One portion of the journey is but the counterpart of another. The sameness is wearisome beyond words. And

* These localities are not found save on recent maps. Kalgoorlie is in latitude 30° 45′ south and longitude 121° 30′ east, while Coolgardie lies in latitude 30° 57′ south and longitude 121° 10′ east. They are 25 miles apart.

† The rainfall at Denver is 14½; Alexandria, 10; Paris, 22; London, 35; Canton, 39; Calcutta, 76; Vera Cruz, 180; and at Cherrapongee, in Assam, 610 inches per annum.

‡ The "Everlastings," as they are usually called, belong chiefly to the genera Helichrysum, Helipterum, Waitzia, Podolepis and Angianthus. For about three months they appear as magnificent splashes of color, carpeting the desert with splendor. They are wholly devoid of perfume, and have the brittle texture of artificial flowers.

§ Both acacias. The characteristic tree-shrubs of the country belong to the genus Acacia. Many of them have a fragrant bloom in the spring.

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when an elevated spot is attained the eye commands, from north to south, from east to west, one dark unbroken sea of trackless bush.

Gold-mining caused this desert to be invaded. The first discovery was made by Anstey, in 1887, at Yilgarn, which is 210 miles east from Perth, the capital of the colony. This started the Southern Cross mining district. Prospectors began to scatter further inland. In 1892 Bayley made the discovery which marked the birth of Coolgardie, and the commencement of an activity which culminated in the mining excitement of 1895. A series of rich finds, scattered over the surrounding desert, gave rise to the settlements of Menzies, Goongarrie, Kanowna, Kurnalpi, Kunanalling, Wagiemoola, and a score of other patches of corrugated-iron hideousness labeled with euphonious aboriginal names. In June, 1893, Patrick Hannan pegged out a discovery-claim at Kalgoorlie,* 25 miles east of Coolgardie. The find which he made was of no particular importance, and the neighboring area, like many others, became the scene of the purposeless digging which was at that time sufficient to give an impetus to a great deal of reckless company-promoting. However, just as, in Colorado, the Mt. Pisgah fiasco of 1884 preceded the real development, eight years later, of Cripple Creek, so the vagaries of irresponsible schemers led to the accidental opening up and the eventual recognition of the magnificent series of rich lodes that have now placed Kalgoorlie among the few great mining camps of the globe.

In 1897 West Australia produced 674,993 ounces of gold, to which Kalgoorlie alone contributed 306,000 ounces. During the same period the mines of the colony paid $2,400,420 in dividends, and out of this total Kalgoorlie is credited with $1,775,000. The growth of the industry is exhibited by the accompanying statistics:

Year.	Kalgoorlie. Ounces.	West Australia. Ounces.
1895, ...	36,000	231,513
1896, ...	103,000	281,265
1897, ...	306,000	674,993

It is estimated that the yield of the colony for the current

* See the interesting paper of my friend, Mr. George J. Bancroft, "Kalgoorlie, Western Australia, and Its Surroundings," read at the Atlantic City Meeting, February, 1898, and printed in the present volume, page 88.

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year will reach a million ounces, and that of this one-half will come from the Kalgoorlie district.

The development of a group of very rich telluride lodes amid this immense desert country, dotted over with the unhappy failures which were based on small pockets of specimen gold-quartz, did not happen without a sad expenditure of money and human life. With the whisper of every new discovery, crowds of reckless gold-seekers plunged madly into the outer desolation. Eager horsemen jostled the awkward camels, whose swinging gait carried them in turn past the mobs of diggers who trudged wearily to the scene of each successive excitement. One knows not whether to admire the pluck or to deride the foolishness of men who died of thirst and perished of fever in the mad search for gold. The incident known as "the Siberia rush" will be typical of early days. A man came into Coolgardie one night with a story that gold had been found at a locality thirty-odd miles to the north. Hundreds started off on horses or on camels; many went on foot, carrying their billies* and blankets upon their shoulders or trundling their packs in wheelbarrows. Some took the wrong direction, and of these many never reached their destination, but died miserably in the bush. Four hundred eventually reached Siberia.† The only water near the discovery was a soak,‡ seven miles distant. It was soon drained dry by the crowd of diggers. News came to Coolgardie that a water-famine was imminent. The superintendent of water-works, a government officer, instantly despatched a dozen camels§ to the succor of the adventurers. In the meantime, they, realizing the impending danger, had left the gold, and were making for the nearest condenser.‖ Many died on that return journey, and many more would have been lost save for the water brought by the camel-train. But in a few days there was another stampede in another direction. Thus the gold-fields were opened up. *Sic Etruria crevit.*

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* The "billy" is the tinned iron vessel, of from 2- to 4-quarts capacity, in which the miner makes his tea and does his cooking.

† What a satire is the name! The locality has a mean annual temperature of 78°, and the summer heat is 112° to 120° in the shade.

‡ A "soak" is the morass of the desert, where water has accumulated in a depression, and is got by digging through the sand which covers it.

§ A camel carries two tins, each holding 20 gallons.

‖ All the drinking-water is the product of the "condenser," of which a description is given below. See Figs. 3, 4, 24, and 25.

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The peculiar character of these "rushes" is directly traceable to the nature of the gold-occurrence. Gold is found lying on the very top of the ground, and the first surface-mining yields extraordinary profits. The search for the particles of gold scattered over the surface is called "specking." In the early days hundreds of ounces were thus picked up in a few hours by the men first to reach a rich spot. When the cream has thus been skimmed off, the sandy soil underneath is treated, the dirt being winnowed by pouring it from one pan into another. After that, actual digging begins, the shallow deposits being trenched and pitted in the search for those patches of rich ground through which the gold is found sporadically distributed. "Specking" is still a recognized occupation on Sundays,* even at the established mining centers. I have seen as many as a hundred men walking about with their hands in their pockets and their eyes intent on the ground, for all the world as if they were in disgrace. A five-ounce nugget may be found; and everyone hastens to the spot. Perhaps nothing more is picked up; or it may be that sufficient gold is discovered to attract troops of "dry-blowers" to the place. The "dry-blower" is brother to the "gulch-miner" of America and the "alluvial digger" of the eastern colonies of Australia. In the investigation of the methods of the dry-blower and the occurrence of the deposits out of which he wins the gold, I observed many facts of such interest, it seemed to me, as to warrant the preparation of this contribution to the *Transactions* of our Institute.

In mountainous regions the disintegration of the surface is mainly caused by the frost. Water penetrates into crevices and cracks, and, because its maximum density is at 4° C. and not at zero, it undergoes such expansion in the immediate approach to the freezing-point as to become a powerful lever for tearing the rocks apart. Thus is loosened that material out of which eventually the alluvial deposits of the valley are formed. In warmer climates the contraction and expansion of water is likewise a ceaselessly destructive agent. Even in a dry, hot region, such as the interior of West Australia, the difference

* Sunday labor is generally forbidden throughout the Australian colonies; hence the opportunity to go "specking," as above described.

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between the heat of day and the cold of night causes the dew to play an important part in moulding the physiography of the country. For it must be remembered that the changes of volume caused, in water as in other substances, by changes of temperature, are well-nigh irresistible in energy, however minute in amount. The cool nights, which alone make life bearable on the Coolgardie gold-fields, are thus beneficent in two ways. To them is ultimately owing the formation of those accumulations of gold-bearing dirt out of which many a prospector has dug himself a competence for life. The tables on page 499 from the government meteorological reports exhibit this variation in temperature.

In mountainous lands the melting of the winter snows yields the water employed in that process of concentration which begins as soon as the rock is shattered, and continues until each ultimate particle has been classified by the untiring machinery of nature. The "tailings" are the mud and sand which go to build new continents upon the ocean-floor, the "middlings" are the great masses of alluvium covering the plain, and the "heads" are the gold-bearing gravels of the mountain-valley. The soft is separated from the hard, the heavy from the light, until at length the metal once incased in quartz and enclosed within the rock is set free, to be collected wherever the eager stream has so abated its force as to permit the particles of gold to find a quiet resting-place.

It is a great sifting-process. The motion of the water is governed by the slope of the surface. In a flat country the conditions resemble those surrounding a mill so situated as to be incapable of getting rid of its accumulating tailings. Should the water-supply of the mill also prove insufficient to carry out its operations, then the analogy with a desert plateau is complete. The process of concentration must in both cases remain unfinished.

The gold-bearing gravels of California and Victoria, for example, usually rest on a hard bed-rock, whose water-worn surface speaks of the agency which made it so. The particles of gold and heavy iron-sand have been washed clean; the overlying pebbles and quartz gravel are comparatively free from material less resisting than themselves; and, if there be any clay, it is found in distinct layers, in positions testifying to the varia-

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TABLE I.—*Meteorological Conditions at Coolgardie*, 1897.

Month.	Temperature.					Temperature of Dew-point.		Rainfall.	
	Mean Max.	Mean Min.	Highest Max.	Lowest Min.	Greatest Variation in One Day.	Mean. 9 A.M.	Mean. 3 P.M.	Total Inches.	Days.
	°	°	°	°	°	°	°		
January	94.1	63.2	104.3	53.0	42.2	53.5	54.0	.56	4
February...	89.4	58.5	104.6	47.4	47.3	51.8	53.6	.54	5
March........	85.6	57.7	98.4	50.0	41.0	49.2	55.0	.10	2
April	81.2	53.9	96.1	39.1	36.5	51.3	57.4	.01	1
May...........	71.4	46.6	88.4	38.2	41.5	46.9	53.5	.09	3
June..........	62.9	43.9	71.2	31.5	29.8	44.2	49.7	1.04	9
July...........	65.1	42.4	74.0	36.5	33.5	43.5	47.5	.34	6
August	63.8	41.5	81.0	33.0	34.6	40.8	43.7	1.08	10
September..	75.0	47.5	92.0	35.0	39.7	43.7	49.5	.29	6
October......	81.0	49.8	91.0	41.0	39.7	......	......	.06	2
November..	90.6	58.4	105.0	47.3	44.6	......	......	.09	1
December..	91.7	59.5	109.2	51.0	44.2	......	......	1.31	4
					1898.				
January.....	97.6	65.1	111.2	54.0	43.2	60.1	68.2	Nil.	...
February...	89.3	62.5	107.2	48.0	37.7	57.0	60.2	.27	1

TABLE II.—*Meteorological Conditions at Kalgoorlie*, 1897.

Month.	Temperature.					Temperature of Dew-point.		Rainfall.	
	Mean Max.	Mean Min.	Highest Max.	Lowest Min.	Greatest Variation in One Day.	Mean. 9 A.M.	Mean. 3 P.M.	Total Inches.	Days.
	°	°	°	°	°	°	°		
January.....	92.9	66.0	105.0	55.0	34.2	51.1	52.0	.38	2
February...	88.2	61.6	103.0	49.0	34.7	51.2	51.5	.02	1
March........	83.8	58.9	98.4	51.0	39.0	49.0	49.4	.52	6
April	80.0	55.9	95.4	38.8	32.8	48.0	46.8	.20	1
May	69.8	48.0	88.1	37.0	40.4	46.5	45.0	.10	1
June..........	62.9	47.4	73.2	36.2	30.2	46.4	49.1	1.26	14
July...........	64.4	48.3	74.0	33.2	29.8	42.8	43.7	.22	3
August	63.8	43.3	82.0	34.0	29.1	40.0	41.7	.65	9
September.	74.2	48.8	90.8	37.2	40.2	41.6	43.8	.41	5
October......	78.5	51.8	90.2	41.0	38.0	42.0	40.4	.11	2
November..	90.2	59.0	103.0	48.0	49.0	46.8	48.7	.06	1
December..	90.7	61.6	109.2	49.4	39.0	48.3	49.5	.82	4
					1898.				
January.....	98.0	66.8	113.2	55.0	41.0	51.3	50.3	.02	1
February...	90.5	63.4	109.8	48.2	38.6	51.2	49.9	.36	3

tions in the velocity and volume of the stream which laid down the deposit as a whole. It is an orderly arrangement of assorted material.

Compare with this the alluvium of the desert. A low ridge is crested with the outcrop of a gold-bearing quartz-vein which, amid that surrounding sea of dark-blue scrub, justifies its colonial designation, a "reef." On its flanks there is a thin cover of

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sandy soil which gradually thickens, a little lower down the slope, to a deposit of several feet. Sink a hole and you will find, first an inch or two of loose sand and dust, then a more solid layer of gravel and dirt, which in turn passes imperceptibly into a compact material consisting of fragments of rock and quartz, held firmly together by clay. It is called "cement," and it might better be termed an "agglomerate." It is an unclassified product of erosion, and lies close to the place of its origin, as a mere collection of unsorted *débris*.

The rock on which the deposit rests is so softened by decomposition that it is frequently taken for a part of the overlying detritus. If the hole be continued so as to become a well or shaft, it will penetrate through additional oxidized ground until this suddenly gives place to diorite or granite (the two prevailing formations) at a depth varying from 75 to 200 feet, which is the drainage-level of the region.

This deposit owes its existence to the wind and rain, assisted by gravity acting on a slightly inclined surface. Wind is ordinarily an insignificant geological agent, but in the constant and violent draughts of a high plateau there is a force which, working during long periods of time, is capable of producing notable results. In the vicinity of Coolgardie and Kalgoorlie, especially the latter, which has the less broken topography, the dust-storms are almost ceaseless, and bear forceful testimony to the amount of material which can be conveyed in the air. The wind careers over the country in gyrating whirls, to which the aborigines give the name of "willy-willy," nor have the white invaders ventured to call them otherwise; and as these whirlwinds go waltzing across the wretched town, they gather up in their skirts all the scattered refuse of a border civilization. I formed the impression that the wind had a prevailing direction from the southeast to the northwest, that is, from the nearest sea toward the heated interior; but the meteorological reports of the government do not confirm this supposition. In the accompanying table, Beaufort's scale of wind-force is employed. It will be observed that the meteorological reports confirm the impression that Kalgoorlie is more windy than Coolgardie, and that a quiet condition of the atmosphere is unusual in both districts. Nor is there any consistency of direction, as is proved by the observations made, for example, at

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Kalgoorlie during the month of September, 1897. It is evident that the wind blew where it listed, and no man could tell whence it came. The following is Beaufort's scale of wind-force:

Number.	Description.	Speed of wind in miles per hour.
0	Calm.	3
1	Light air.	8
2	Light breeze.	13
3	Gentle breeze.	18
4	Moderate breeze.	23
5	Fresh breeze.	28
6	Strong breeze.	34
7	Moderate gale.	40
8	Fresh gale.	48
9	Strong gale.	56
10	Whole gale.	65
11	Storm.	75
12	Hurricane.	90

TABLE III.—*Wind-Force*, 1897.

Month.	Coolgardie.				Kalgoorlie.			
	9 A.M.		3 P.M.		9 A.M.		3 P.M.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	3	1	3	0	2	1	3	3
February	4	2	4	1	7	2	7	2
March	3	2	3	1	5	2	2	0
April	4	0	3	2	2	1	9	1
May	8	2	3	0	5	2	2	2
June	2	1	3	2	9	2	5	2
July	5	1	6	1	3	2	4	2
August	5	1	6	1	6	2	8	2
September	9	1	9	1	6	2	9	2
October	5	1	8	1	7	2	6	2
November	6	1	9	1	5	2	8	2
December		1	4	1	2	2	3	2

TABLE IV.—*Variation in Direction of the Wind at Kalgoorlie during September*, 1897.

9 A.M. Direction of wind.	Days.	3 P.M. Direction of wind.	Days.
N.	4	N.	4
N. to E.	5	N. to E.	4
E.	3	E.	1
S. to E.	5	S. to E.	3
S.	1	S.	4
S. to W.	6	S. to W.	7
W.	1	W.	5
N. to W.	2	N. to W.	2

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Observations such as have been quoted in Tables III. and IV. necessarily fail to record the really characteristic play of the wind in this region. The whirl-storms, referred to already, spring up suddenly, rush madly across the plain, suck up everything lying loose on the surface, and as suddenly subside. These apparently erratic air-disturbances are responsible for the transport of the greater part of the material which weathering and erosion have disintegrated. So far as I know, measurements of the transporting-power of the wind have not been made in this particular region; but elsewhere in Australia scattered observations have been made; for example, that fences 4 feet high are buried by drifting sand in a period only slightly exceeding two years. In the Libyan desert, bordering the Nile valley, the same results can be seen. Thus, for instance, the sand-storms bury the temple of the Sphinx every summer, and the road built by Ismail Pasha, from the Mena House to the Pyramids, is filled with sand up to the level of the 6-foot parapet in less than ten days.*

In West Australia there is much evidence of that which geologists euphuistically term the Æolian agency. The wind has been stirring and sifting the material lying loose on the surface until it has become classified to a remarkable degree. In traveling over the country, one is soon called upon to notice the broken white quartz scattered over the ground, in big patches many acres wide. These alternate with stretches, steel-gray in the morning and blue-black toward the close of day, of ironstone fragments. Leave the trail; go a short distance into the bush; and you will find the surface covered with dust in which each step leaves an evident footprint. It is the veritable dust of ages, not the earth-smoke blown from man's restless to-and-fro. The wind has sorted the quartz, the ironstone and the dust. The latter has been scattered in contemptuous carelessness all over the face of the weary desolation, but the heavy ironstone remains not far from where it was broken off the decomposing diorite until, shattered and comminuted to powder, it also is winnowed by the dust-storm. The numerous veins, large and small, traversing the country have contributed the quartz which the wind has collected, so that it sometimes covers the ground with the glittering whiteness of a snow-drift.

* So my dragoman informed me when I was there last February.

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From these stretches of ironstone and quartz one would naturally infer the occurrence, somewhere underneath the surface, of large masses of both. Owing to the extreme slowness with which denudation progresses in this arid region, and the consequent very gradual lowering of the zone of oxidation, the rocks exhibit, above the drainage-level, a marked intensity of chemical action. The granite is kaolinized to an almost incoherent clay, and the diorite is rendered abnormally heavy in iron by the surface-concentration of decomposition-products. And, as the rock is eroded, the quartz, on account of its hardness, persists, so that a series of small stringers eventually yields an accumulation suggestive of its derivation from a large mass. It is a process of concentration which, there is reason to believe, has also affected the gold-occurrence, the upper portions of veins being enriched by the deposition of the gold left behind from lode-matter which was long ago disintegrated and removed by erosion.

If we now turn to the "dry-blower" and watch him at his work we shall see the same processes utilized in the winnowing of the gold.

III.—Dry-Blowing.

In West Australia the absence of running water renders unavailable the cradle and the sluice-box of ordinary placer-mining, with the result that the prospector has learnt, intuitively, to utilize the agency which he sees incessantly at work in the nature around him. Wind replaces water. The method is simple. Taking two pans,* he places one of them on the ground, empty, while into the other he puts a shovelful of the "dirt," that is, the sandy detritus containing the gold. The material is shaken up so as to bring the big lumps on top, and then, resting the pan on one knee and holding it with his left hand he uses the right hand to skim off the coarse particles (as shown in Fig. 5). Then standing erect and facing at right angles to the direction of the wind, he slowly empties the full pan into the empty one at his feet (see Fig. 6). As the stream of dry dirt falls, the wind selects the fine and blows it in a cloud of dust to leeward. The operation is then reversed, the pan which has just been emptied being placed on the ground so as

* The Australian calls them "dishes."

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to receive the contents of the other. This is repeated three or four times, according to the degree of concentration effected. In a strong breeze one operation may prove sufficient. To prevent the loss of the fine gold which is sometimes carried away with the dust it is customary to spread a piece of canvas on the ground, one end being placed under the pan and the other extending to leeward.* The next stage is to further winnow the material by tossing it up and down in the pan (see Fig. 7); the latter is held slanting forward, and is jerked so as to throw the dirt from the front to the back of the pan. The light particles are separated, as chaff is driven from grain. Then, giving the dish a vanning movement, the prospector again removes the coarser particles that come to the surface by skimming them off with his hand. There now remains about half a pint of material, and this is diminished by panning, just as in water, the dry particles having a mobility permitting this method of treatment. Finally he drops on his knee, and, holding the pan (see Fig. 8) so that it is tilted forward, he raises it up to his mouth and uses the breath of his lungs to complete the process. The particles of gold are seen fringing the edge of the iron sand. If the yield consist of only a few minute particles,† he puts his moist thumb on them, and so transfers them to his pocket; but if there be any coarse pieces—nuggets—they are put into the leather wallet attached to his belt.

In watching a dry-blower at work, it becomes evident that the operation, like every process of concentration when properly conducted, consists of sizing and classification. The wind removes the fine sand and the dust, the operator's hand skims off the larger lumps of dirt, so that there finally remains a collection of those heavy particles of ironstone which, as in ordinary placer-mining, accompany the gold.

Owing to the perfect dryness of the dirt and the heat imparted to the surface of the iron pan under a tropical sun, the material behaves with much of the mobility which it would have if water and not air were the vehicle employed. It reminds one of the behavior of a charge in the roasting-furnace, in which the hot air cushions each particle so as to give to the mass an apparent fluidity.

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* As illustrated in the Figs. 5, 6, 7, and 8. These were reproduced by Mr. Henry Reed, of Denver, from photographs taken by me at Kalgoorlie.

† "A few small colors," as we would put it in the United States.

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The rapidity and completeness of the operation depend on the strength and uniformity of the wind. There is a constant light breeze on the gold-fields, even during those happy intervals when the dust-whirls have temporarily subsided; but the cloudy mornings of the wet season and the sultry days of the hottest summer months are alike unfavorable to dry-blowing, because at such times the air is dead. Many of the mining-camps are situated on a slight rise of ground, overlooking those desolate sinks of salt and sand which are called "lakes;" and the difference of level is marked by a constant breeze which is a good friend to the dry-blower.

In the history of ordinary alluvial mining, washing with the pan was succeeded by the use of the sluice-box and the cradle. Similarly the "dishes" of the dry-blower are replaced by machines of several types, all of which, however, are based on the idea of a shaking movement in the presence of a current of air. The simplest contrivance is represented in Fig. 9. This machine is 2 feet wide and 4 feet long. A is a hopper with a sheet-iron bottom punched with 1-inch holes, B is a 12-mesh screen, C is an 18-mesh screen, and D is the final product of the operation. The dry-blower empties a shovelful of dirt into the hopper, places his hands on the two sides of the machine and shakes it from side to side. There is sufficient play in the frame itself to permit a movement which causes the material to pass through the series of screens and accumulate underneath. It is then treated by hand, as previously described and illustrated. One man will put through about 5 tons of loose dirt in a working-day of seven hours.

Another and more elaborate contrivance is exhibited in Fig. 10. It consists of a series of four trays, hung on a triangular frame, B C D. The trays are 22 inches in diameter. They are comparatively flat and have screen-bottoms, through the center of which an iron rod passes to the eccentric, G, which receives the required movement through the lever, A E F, of which A is the handle. The trays are 5 inches apart and are held in place by wires, H H. The material to be treated is placed in the uppermost tray, which is a hopper pierced with inch-holes. No. 2 has $\frac{3}{8}$ holes, No. 3 has a 10-mesh screen and No. 4 has an 18-mesh screen. The lowest, No. 5, is flat and serves as a receptacle for the final product, which is dry-blown by hand, as heretofore described.

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In these two contrivances no attempt is made to supplement the wind by an artificial air-current. The next step is to use a bellows. Fig. 11 shows such an arrangement. It consists of a hopper, A, and a series of screens, B, E, F, G and H. By turning the handle, M, the disk, K, is revolved; and this, by means of a belt, transmits its movement to the pulley, which shakes the screen, B B, through the eccentric-rod, C, and at the same time operates the bellows, D, through the disk, K. Fig. 12 illustrates the machine when in operation.

When the material is placed in the hopper, A, and the machine is set in motion, the large lumps run off over the grizzly or sizing-screen, B B, the upper part of which is made of parallel wires $\frac{3}{16}$-inch apart, and the lower portion of 8-mesh. The finer stuff falls down into the shoots, C C and E E, respectively, and reaches F, which is another (12-mesh) screen, supplied also with riffles. As it descends through the screens at G and H, both 18-mesh, the blast from the bellows keeps the material in agitation, and aids the requisite separation between the particles of gold and the dust. The final product is panned by hand.

One of the most popular dry-blowing machines is that made by Steve Lorden, at Freemantle. It is illustrated in Fig. 13. The essential parts are:

A. Feed-hopper, sheet-iron bottom, punched with inch-holes, hinged at A_2 and provided with riffles, A_3, which arrest the heavier particles of gold, while the coarse lumps of dirt pass out of the machine over the shoot, B_2, and the fine stuff falls through into

B. Second hopper, which has riffles and smaller perforations, repeating the process. To examine this hopper, the upper one, A, is sprung out of position at A_4.

C, C. Return-shoots which lead the reduced material for further sizing upon the sloping screen, E, which also has a series of riffles, and is placed directly over the air-chamber, F.

D_2 is a discharge-shoot for the screen, E. G, G are air-channels from the bellows, H, H.

H, H. Double blast-bellows, one on each side, which ride on carriers, H_2, so arranged as to give the requisite play and to relieve the bellows from undue strain when in operation.

I, I. Rockers, bolted firmly to two foundation-blocks, I_2, which form the stand, the only part of the machine that is not

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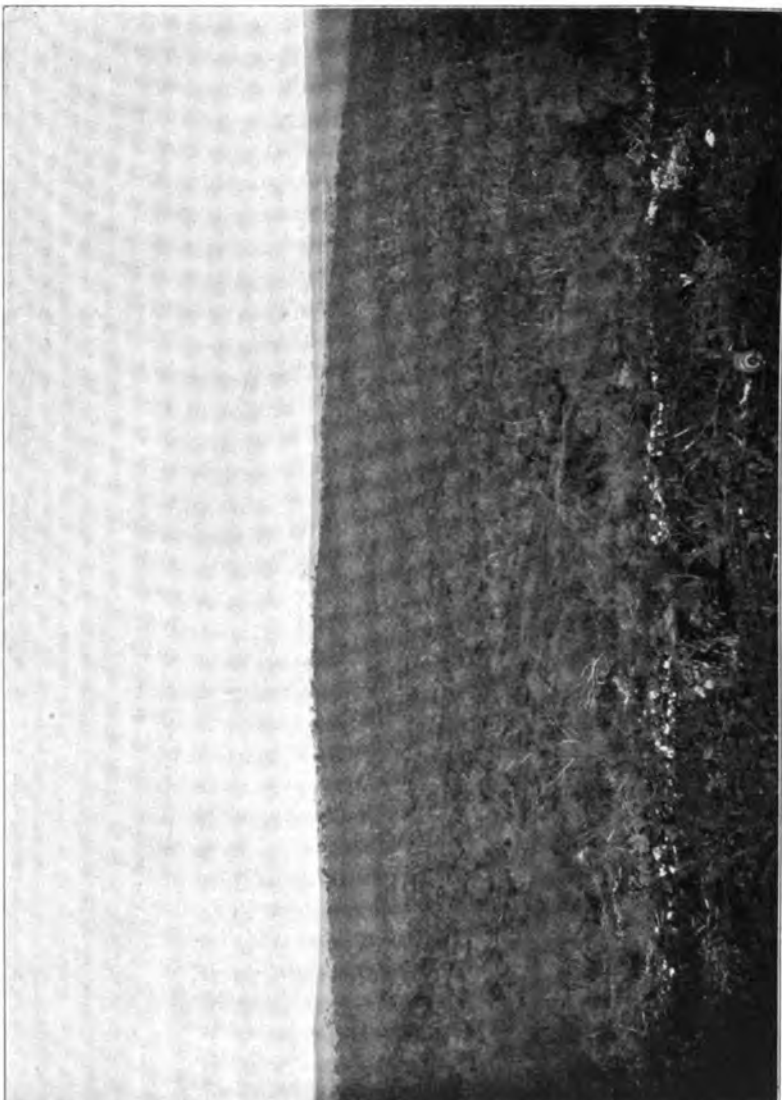
Fig. 2.



A Typical Scene in West Australia.

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Fig. 3.

Buying Water at a Condenser.

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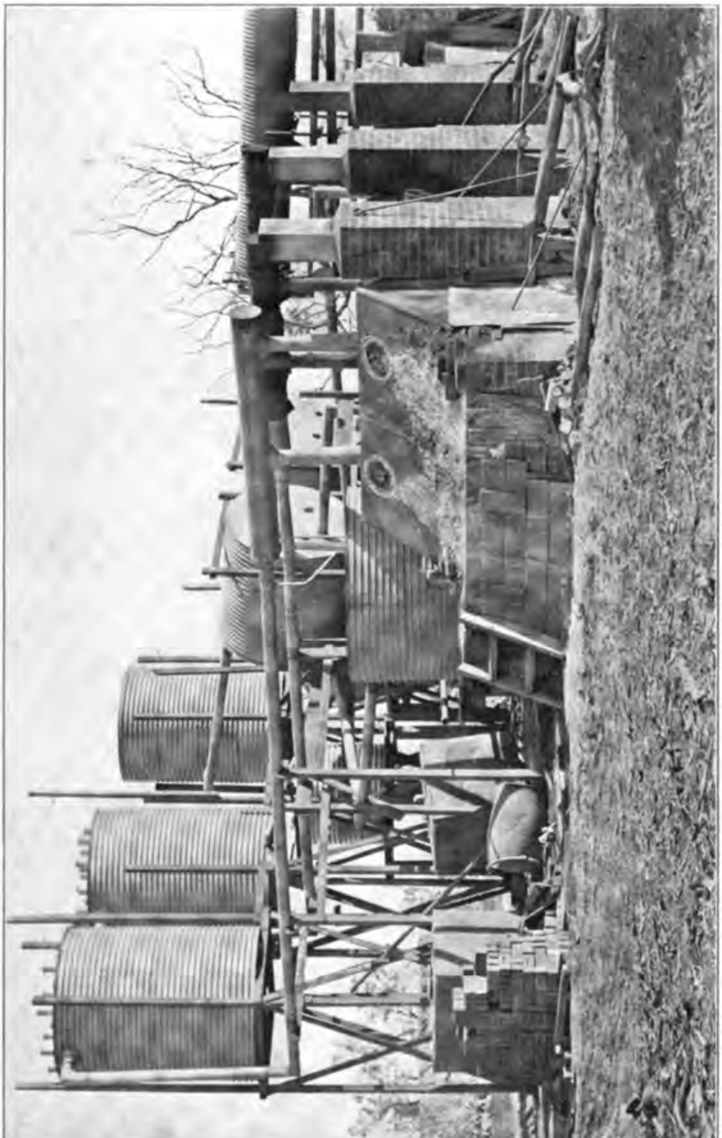
FIG. 4.



Condenser at the Lake View and Junction Mine, Kalgoorlie.

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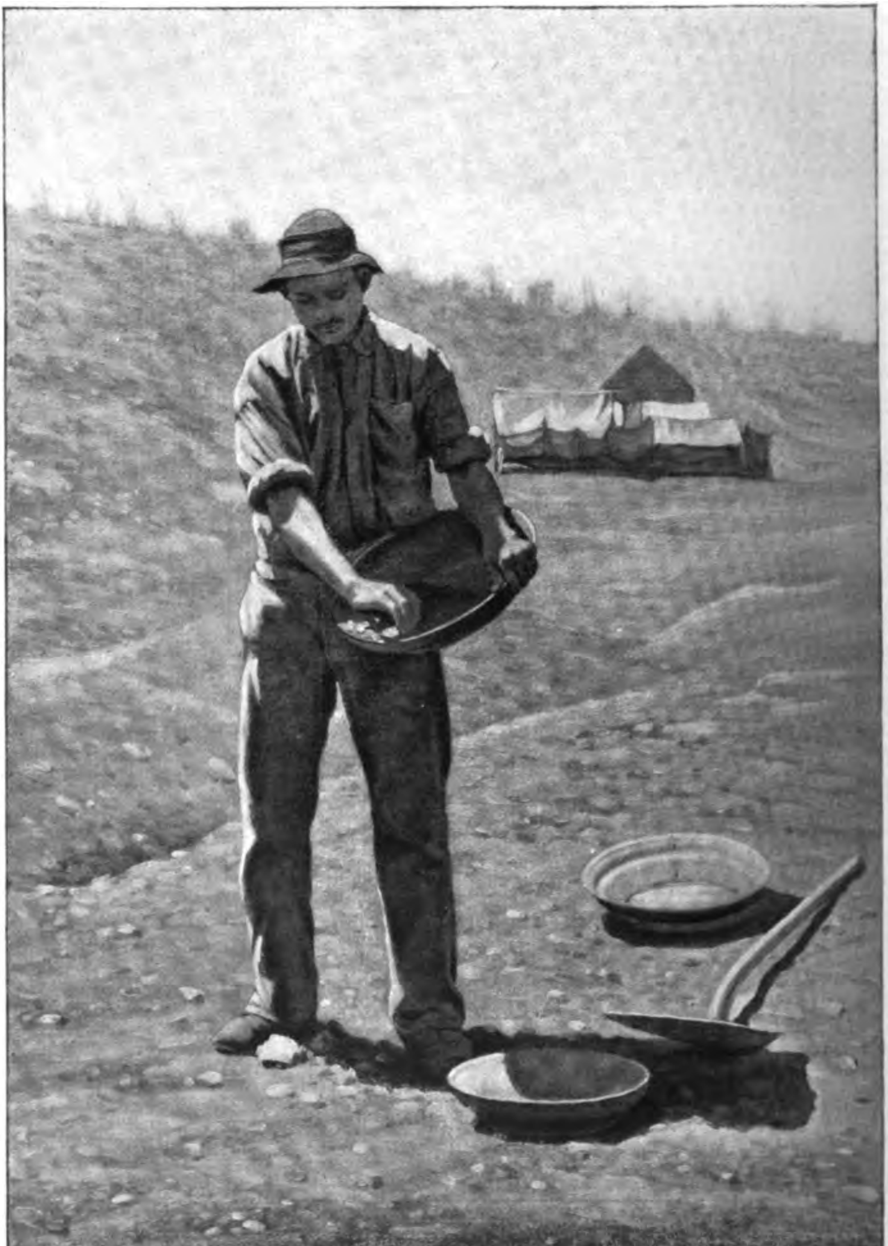
FIG. 5.



Dry-blower at Work.

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Fig. 6.

Dry-blower at Work.

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FIG. 7.

Dry-blower at Work.

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Fig. 8.

Dry-blower at Work.

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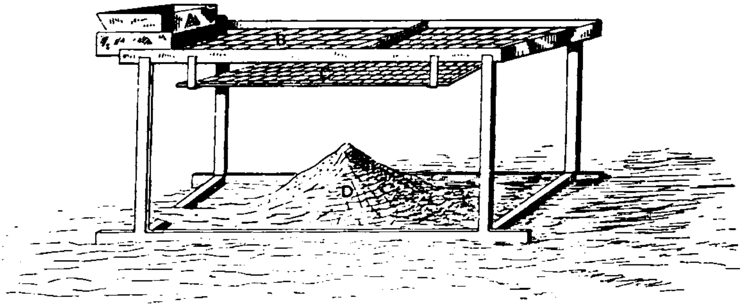
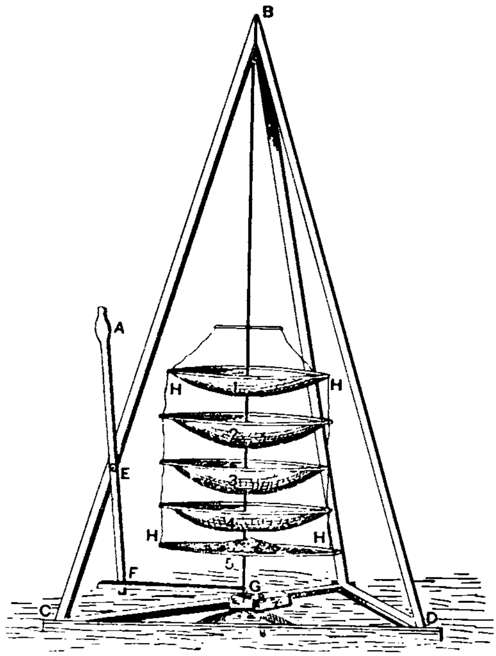
Fig. 9.



DRY BLOWING MACHINE

Fig. 10.



DRY BLOWING MACHINE

PLAN OF TRAY

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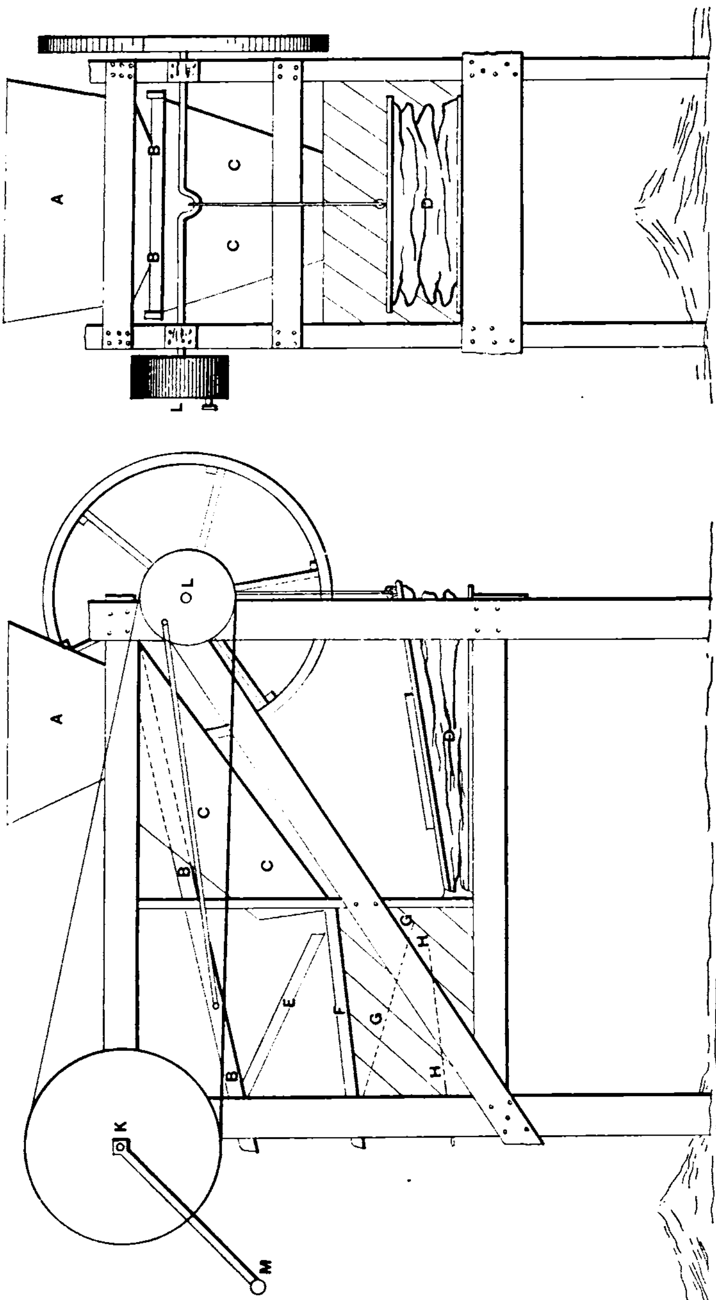
FIG. 11.



DRY BLOWING MACHINE
Scale 1" = 1 Foot

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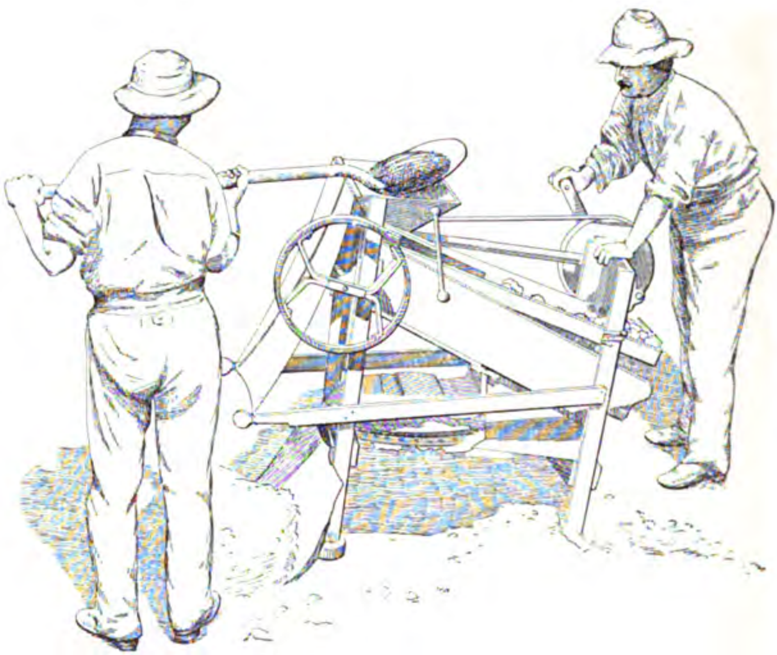
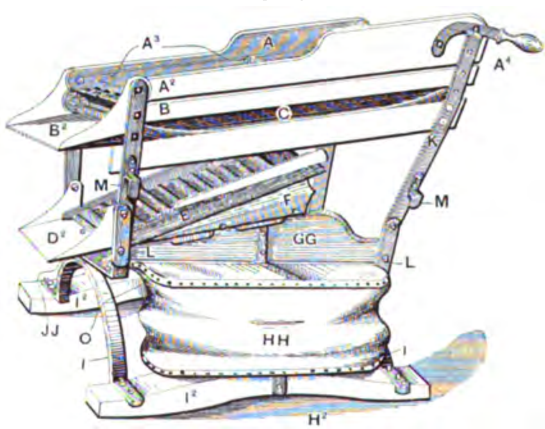
FIG. 12.



DRY BLOWERS AT WORK

FIG. 13.



Lorden's Dry-blowing Machine.

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Fig. 14.

Dry-blowers at Work.

Fig. 15.

Dry-blowers at Kalgoorlie, West Australia.

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Fig. 16.

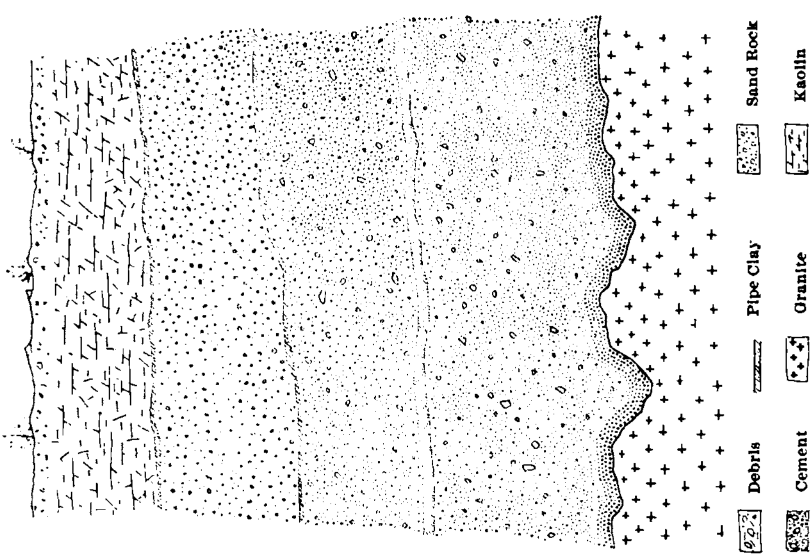

Fig. 17.

Sections in the Open Cuts at Kintore.

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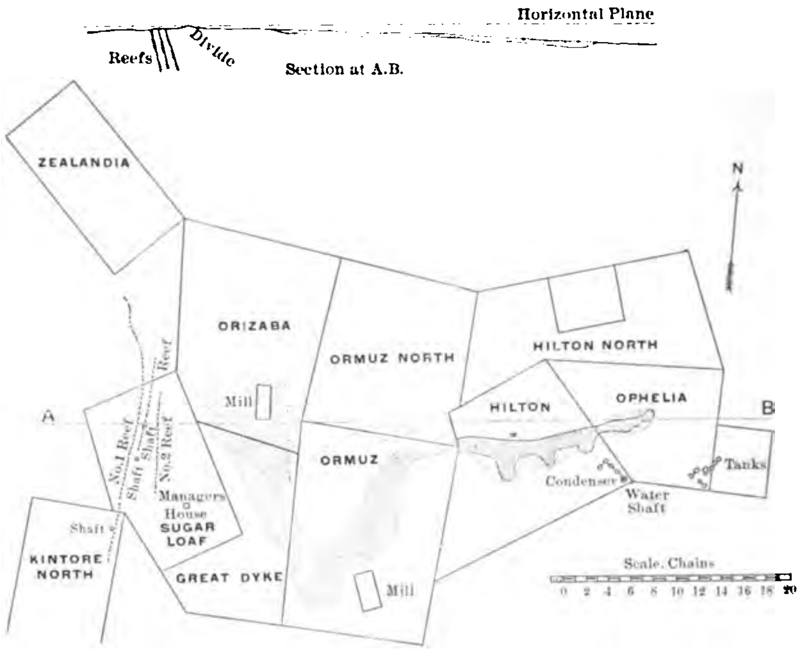
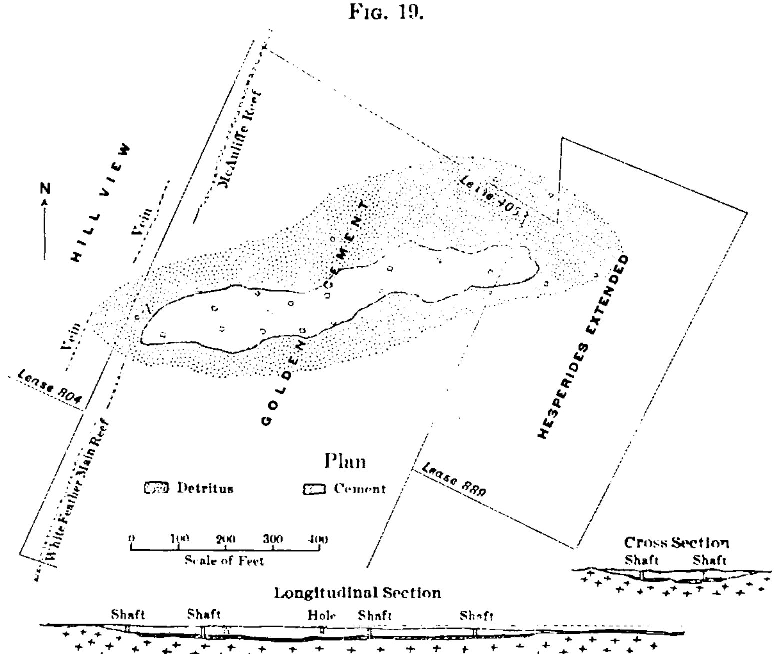
FIG. 18.



CEMENT DEPOSIT, KINTORE, WEST AUSTRALIA

FIG. 19.



THE CEMENT DEPOSIT AT KANOWNA

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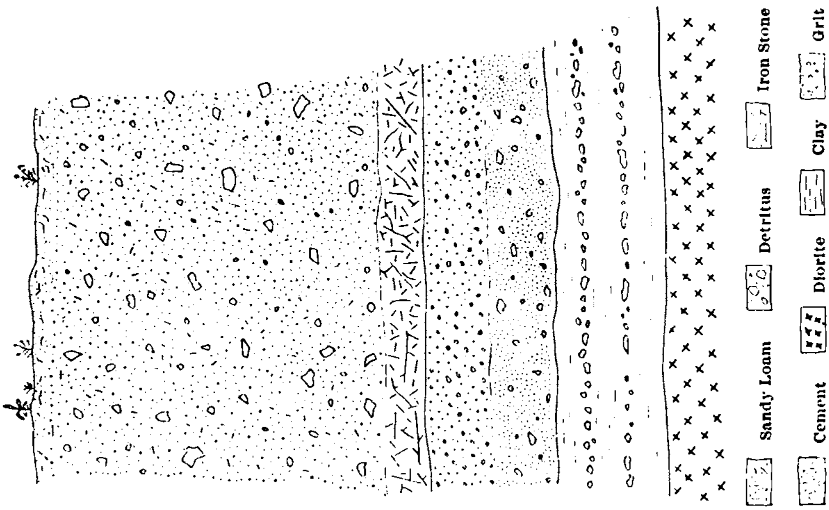
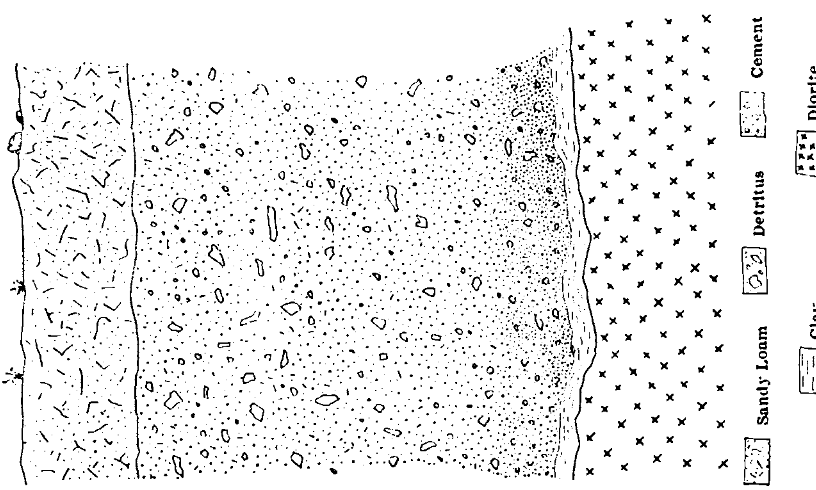
FIG. 21.



Section in Fitzroy Cement.

FIG. 20.



Typical Section at Kanowna.

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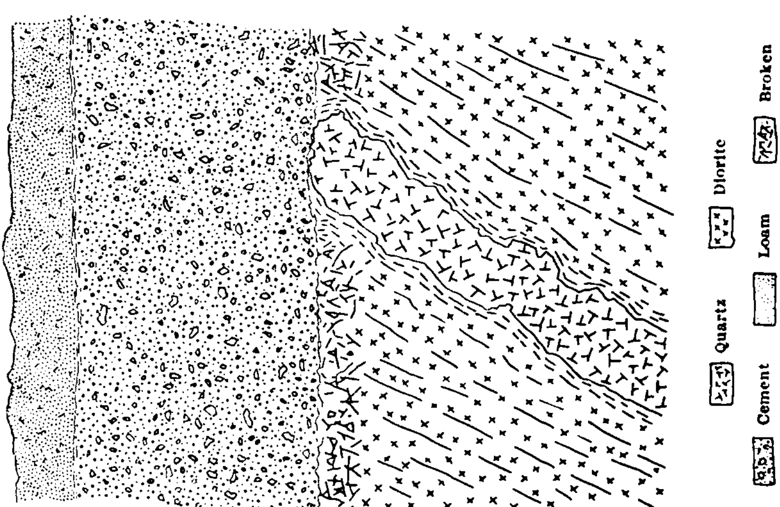
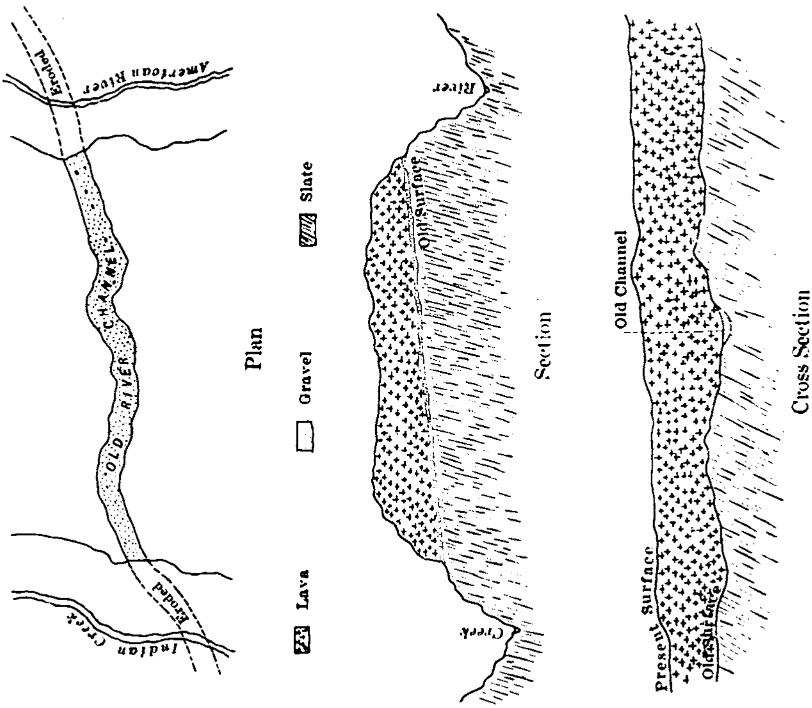
FIG. 22.



VEIN CAPPED BY ALLUVIUM

FIG. 23.



A TYPICAL DEEP LEAD

PLACER COUNTY, CALIFORNIA.

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in motion. The curve of the rockers allows all dirt to fall away from the pivot-pins, J, J, by which the apparatus swings.

K, K. Standards, hinged at L, so that the machine folds up, as shown in Fig. 14.

M, M. Brackets for the insertion of two poles, by means of which a couple of men can carry the machine conveniently.

The operator holds one handle, at A_4, in each hand and rocks the machine, this serving simultaneously to put the bellows, hopper and screens all into movement. The machine weighs 124 pounds and has a capacity of from 10 to 14 loads (a load is roughly one ton) per day. The price at Freemantle is £16 or about $80.

The deposits exploited by the aid of these machines (see Fig. 15) are of a generally patchy character and lie at the upper ends of the depressions formed where the surface slopes away from ridges traversed by the veins of gold-bearing quartz. The prospector has an eye for the contour of the ground, and looks for the point where the rock-surface disappears under the fragmentary overburden which he calls "made ground" as distinguished from the underlying "bed-rock." In his search he is usually guided by seeing the outcrop of quartz, marking a possible source of detrital gold, and by the actual finding of specimens on the surface.

The distribution of the gold in these deposits reminds one of its position on a vanning-shovel. It may be traced up to the outcrop which yielded it, or it may be scattered in the sand for half a mile; but the rich and only workable part of the deposit will ordinarily be found at a distance of 30 or 40 feet from the reef.

Underneath these patches of superficial gold-bearing detritus there are found partially consolidated accumulations, which are more extensive and, quite apart from their greater economic value, are also of superior interest, because of their better-defined geological features.

IV.—The Cement-Deposits.

In the ordinary course of professional work I examined the two most important of these deposits, at Kintore and Kanowna, respectively. Since then a third formation of a similar character has been opened up, also at Kanowna. This I happened to see when in the stages of early development, and before it had been extensively exploited.

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The deposit of cement at Kintore was one of the earliest worked. It is situated 23 miles northwest of Coolgardie, on the road to Menzies. The West Australian Proprietary Cement Company mined the ground with a success which was short-lived, because of the restricted quantity of material rich enough to pay the high costs of treatment. In four months, 7335 ounces of gold were obtained by treating 4115 tons in a stamp-mill, supplemented by cyanide-vats.

Enough work has been done to disclose the character of the deposit. Figs. 16 and 17 are representative sections obtained in the open cuts. Under a thin covering of sand and dust there occurs a bed of kaolin, ranging from a couple of inches to a foot in thickness; and this overlies from 15 inches to 2 feet of "sand-rock," which in turn gives place to the gold-bearing cement, which has an average thickness of 2½ feet. The last lies directly upon an irregular surface of decomposed granite.

The several layers composing the deposit are separated by seams of pipe-clay, which, like the kaolin, are simply the product of the decomposition of the constituents of the granite, particularly the feldspar. The sand-rock may be described as a coarse, incompletely consolidated sandstone or grit, consisting mainly of iron-stained particles of quartz, loosely cemented. The cement has a bluish-gray tinge, owing to the play of light on the quartz fragments. This, too, is not quite compacted, since fractures through the material do not break across the pebbles, which are harder than the clay binding them together. In this respect the cement differs, for example, from the South African "banket," to which it has been compared. From a distance, the cement looks like a coarse sandstone and exhibits a rough-joint structure. The materials of which it has been made up have undergone incipient sizing, so that different layers of varying coarseness are distinguishable.

The bed-rock is granite, so softened by decomposition as to be mistaken by the miners for a part of the alluvial deposit. It is kaolinized to a depth which the neighboring mine-shafts prove to reach a maximum of 130 feet. The surface on which the cement lies is marked by pot-holes having a maximum depth of 2 feet and a diameter reaching to 3 feet. These holes are filled with cement, which is usually poor save at the rims, where some of the richest mill-stuff has been obtained.

All the members of the deposit, from surface to bed-rock,

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contain some gold, the kaolin being the poorest. The cement itself attains a maximum thickness of 5 feet. The richest parts occur in lateral embranchments from the main body of the deposit. The kaolin has become hardened and dried. It breaks like shale; and its true character is obscured by the down-filtering of red sand through cracks reaching to the soil overhead.

The deposit extends through a number of mining claims, as shown on the accompanying map (Fig. 18). It has been traced for a length of three-quarters of a mile. At the east end it begins as a narrow neck about 15 feet wide, and then enlarges steadily to 100 feet. Occasional bulges increase this width to a maximum of 250 feet. At the edge it gives place, as it thins out, to 2 or 3 feet of ironstone gravel, carrying 3 or 4 dwts. of gold per ton. The best part, economically, of the deposit lies in the Ophelia and Hilton claims, which, it will be noted, are situated at the lower end of the basin.

The bed-rock rises westward at the rate of 15 feet per thousand. This fact suggested that the origin of the gold-bearing cement was to be found in the reefs which were being profitably mined by the Sugar Loaf Company. The workings were 136 feet deep at the time of my visit in September, 1897. The veins traverse granite which has been kaolinized to 130 feet from the surface. They consist of white quartz and are narrow (4 to 12 inches), but they carry short shoots of very high-grade (3 to 10 ounces of gold per ton) ore. The gold occurs native, in flakes penetrating the cleavage-planes of the quartz like a golden mosaic, and also in coarser particles, which, under closer examination, prove to be octahedral crystals with curiously rounded edges. A comparison of these veins and their enclosing rock with the material composing the cement-deposit unquestionably indicates the derivation of the latter from the former. The cement carries gold which is exactly similar to that seen in the reefs; the quartz fragments in the alluvial are identical with the stone broken in the Sugar Loaf mine. Samples of both lie before me as I write, emphasizing the conclusion just stated. In the cement occur particles of quartz showing gold. The loose gold in the cement has been but slightly worn, and the quartz pieces are rather subangular than rounded, so that they can hardly be termed "pebbles;" and the deposit itself is better defined as an agglomerate than as a conglomerate.

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The binding-material, the overlying layer of kaolin and the sand-rock capping the gold-bearing stratum of cement, all exhibit very clearly their derivation from a decomposed granite, similar to that which encloses the reefs and forms the bed-rock of the alluvium itself.

The topography confirms this supposed relationship. The highest point along the major axis of the cement-deposit is a very low ridge separating the workings of the Sugar Loaf from the alluvial ground. The house of the manager of the Sugar Loaf is on this divide. The reefs are 462 feet westward, and only 15 feet lower where they appear at the surface. The cement deposit begins on the Great Dyke lease, at a point 530 feet eastward, and only 8 feet lower. The cement then extends on a gentle down-slope of 15 feet per thousand for a distance of 3500 feet.*

It occupies a very shallow depression, and in its structure bears internal evidence of considerable geological age, suggesting that it was formed at a time when the Sugar Loaf reefs reached the surface at a level superior to the slight ridge now separating them. Reference to the map and longitudinal section (Fig. 18) will aid the above description.

Another deposit of similar character has been explored at Kanowna, 25 miles northeast of Kalgoorlie, and about 60 miles east of the locality just described.

The discovery was made in 1893. Each digger secured a claim 50 feet square, and sunk a shaft to the gold-bearing cement which the dry-blowers had uncovered in the course of their prospecting. The deposit became in due time "gophered" with holes and shafts, so that the boundaries of the cement were accurately determined. In 1895 an English company secured the property and consolidated the claims into larger leases. The expectations held out freely by responsible engineers that an extremely profitable enterprise could be based on the remnants of gold-bearing ground were wholly dissipated in the succeeding two years.†

The deposit lies in a shallow trough, the longer axis lying

* I am indebted to the courtesy of Mr. Alexander Brand and Mr. T. G. Paisley, the managers of the two companies, for the measurements quoted.

† A gross blunder was made, simply through insufficient and unsystematic sampling.

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east and west. The body of gold-bearing cement has a length of about 700 feet and a maximum width of 105 feet (see Fig. 19). Vertical sections exhibit an overburden of sandy loam, from a few inches to 2½ feet thick. This was the material worked by the dry-blowers. Then comes a layer of detritus, called "wash" by the miners, composed of fragments of ironstone and quartz imbedded in clay, and reaching to a maximum of 25 feet from the surface. This overlies the cement itself, 6 inches to 5 feet thick, and easily distinguished from its roof of detritus and its floor of clay. The cement consists of particles of quartz in a greenish clay. Near the rim of the trough the quartz occurs in larger and more angular pieces. A typical section, obtained from a pillar in the old workings, is given in Fig. 20.

The gold-contents are irregular. The whole body of cement probably averaged one ounce per ton; but only the richest parts were worked, and these carried many ounces to the ton; so that the remnants now accessible average, from the surface down, about 3½ dwts.* The clay carries 2 dwts. per ton. The material was treated at neighboring stamp-mills.

When the neighboring mines, the White Feather Reward and the White Feather Main Reef, were visited, it seemed as natural to deduce this cement-deposit from the erosion of gold-bearing quartz-veins as it had been to relate the Sugar Loaf reefs at Kintore with the deposit worked by the West Australian Proprietary Cement Company. Further investigation confirmed this inference.

The McAuliffe vein (worked by the W. F. Reward mine) and the Main Reef (worked by the W. F. Main Reef mine) traverse diorite at or near the line where large dikes of granite-porphyry penetrate. The two reefs are probably identical, and have a strike which takes them right across the longer axis of the cement-deposit at a point near the head of the trough in which it lies (see map, Fig. 19). A shaft recently sunk to a depth of 200 feet by the Golden Cement Company, at a point marked A, reached this reef by means of a crosscut, and found a comparatively barren quartz-vein, carrying small spots of rich ore. The enclosing rock was diorite, and the quartz itself was encased on both sides by bands of clay fully 2 feet thick.

* Information which I owe to the courtesy of Mr. S. H. Williams, the manager

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On comparing the veins and their encasing rock, as seen in the workings of the two mines on opposite sides of the alluvial deposit, it is not found necessary to go further for the origin of the latter. The cement is underlain by a clay which is essentially steatite, and is as readily traceable to the neighboring diorite as the kaolin at Kintore was deducible from the granite. The green color of the cement is imparted by chlorite, derived from the decomposition of the epidote in the diorite. The "ironstone" of the detritus overlying the gold-bearing part of the deposit consists of fragments of altered diorite. The quartz in the cement and the gold accompanying it are both identical with those of the reefs close by.

Here also the topography confirms the suggested explanation. The cement lies in a shallow depression, at the upper rim of which the quartz reefs cross the country. Furthermore, these reefs traverse a low divide, which in a rough way separates the deposit from another, which slopes in the opposite direction. The latter is known as the Fitzroy cement. In this deposit rich discoveries were made during October, 1897. A typical section is exhibited in Fig. 21.

Apart from their importance as depositories of gold, the cements have played an interesting part in the development of the gold-fields, because they often cover the tops of reefs. In Fig. 22 such an occurrence* is illustrated. A similar feature proved a serious hindrance to the recognition of the lodes at Kalgoorlie, where worthless quartz veins were worked for some time before a trench traversing the cap of cement accidentally uncovered the top of one of the rich deposits of telluride ore, which did not outcrop, on account of the comparative softness of the lode.

V.—Theories of Origin.

Of course, several theories have been mooted, the most fanciful of which have naturally been those of the working miner himself. The fact that the gold-bearing cement is in places overlain by a considerable thickness of partially-consolidated rock has led to the supposition that the deposit was a "deep lead;" while the resemblance to a conglomerate has caused more than one Africander to liken it to the "banket" of the Transvaal.

* It is the top of the Lady Shenton reef, at Menzies.

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The latter is an immense shore-deposit of gold-bearing conglomerates, now covered by a series of later sediments. Its dimensions, comparative homogeneity and persistence are in striking contrast to the narrow, restricted, irregular patches of detritus which have been described as occurring in West Australia. This total unlikeness renders unnecessary any discussion of a fancied similarity of origin.

But because this alluvium disappears under an overburden of rock,* the Australian digger easily fancies he is working a deposit similar to the "deep leads" with which he became familiar at Ballarat, for example. A distinguished government geologist from a neighboring colony visited Kanowna in October, 1897, and gave authority to the term "deep lead" by using it himself. "Deep" it may be, for that is a comparative adjective, but a "deep lead" in the technical sense it most assuredly is not. On the Forest Hill divide,† in Placer county, California, and at Creswick, in the Ballarat district, Victoria, the typical "deep leads" occur. They are, as is well known, old (Miocene) gold-bearing river channels, which have been saved from erosion by a cap of lava. The lava probably overflowed the original surface as a steaming mud, and is now found consolidated into a volcanic rock sufficiently hard to need little timbering when penetrated by underground workings. The cement deposits of West Australia occur under an overburden of "made ground;" that is to say, both the deposit itself and all the material under which it dips are of distinctly detrital origin, the products of weathering and erosion accumulated in shallow depressions of the much-decomposed surface of granite or diorite.

It is the placer of a country destitute of running water. The climatic conditions and the physiography of the Coolgardie gold-fields have been carefully described, in order to make it evident why these deposits differ from those of more favored countries, like California or New Zealand. Surely it is not in keeping with the scientific method to seek for fantastic or far-fetched explanations, when processes in operation to-day

* Using the word in its geological sense. Mud is "rock" as much as granite.

† I append a drawing (Fig. 23) of a typical deep-lead recently examined by me in this particular locality.

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are able to supply an adequate understanding of the observed facts.

The quartz of the cement is subangular; it has evidently undergone very little attrition, and suggests, therefore, that it has not traveled far. On comparing it with the matrix of neighboring veins, an identity appears obvious. The examination of the topography renders highly probable the derivation of the one from the other. The cementing material is similarly found to be the clay resulting from the decomposition of the rock encasing the quartz-veins, and varying according to the composition of that rock, whether it be granite or diorite. Finally, the gold particles which have rendered the cement worth mining are found to be identical in fineness and physical appearance with the gold of the neighboring veins, and their scarcely-rounded edges invite the conclusion that the gold also has not been borne far from the place of its origin. The comparatively unclassified condition of the deposits is in keeping with the evidence afforded by the material of which they are composed. The absence of running water on this desert plateau has prevented any such sifting-process as in other regions leads to the deposition of well-defined layers of clay, gravel and gold upon a clean bed-rock. It is an exceptional illustration of the working of those agencies to whose unceasing play is due the configuration of the earth's surface; it is geological action in its most instructive form.

VI.—Water-Supply.

The early history of the gold-fields of West Australia is the record of a struggle to exist amid conditions which were inimical to human life on account of the scarcity of water. That great necessity has been, in some sort, satisfied by the energetic action of the government, supplemented by private enterprise. The gold-fields are now dotted over with condensing-plants, which turn the brine of the wells into water fitted for the use of man and beast. Existence is thus rendered endurable; but the mining industry is still handicapped by an item of cost unknown in more favored regions.

The water of the country is salt, sometimes almost to the point of saturation. Sea-water contains 3½ per cent. of salts, three-quarters of this percentage being common salt, the

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chloride of sodium. At Menzies, in September, 1897, I found one* of the two important mines of that district using water which contained 17 per cent. of salts, and the manager informed me that in December evaporation increased the amount to 30 per cent.† For this liquid he paid 25 shillings per thousand gallons. It came from a neighboring "soak." The condensed (distilled) water, bought for use in the boilers, cost £1 per hundred gallons. Milling in a ten-stamp-mill was carried on at an average cost of 30 shillings or $6 per ton, the item of water alone amounting to 13 shillings or $3.25 per ton.

Under these conditions a wet mine becomes a source of revenue. Many properties at Kalgoorlie, unable to find pay-ore, lessened the expenses of development by selling their water to those that had mills. The price varied according to the season. At the Great Boulder Main Reef mine, for example, the lowest price paid for water during 1897 was £3.10s. per thousand gallons, and the highest £11.5s. This was piped from neighboring shafts, and had not passed through the condenser; it therefore had the character of sea-water, but it was four times as saline.

An analysis of the water of the Great Boulder Proprietary mine gave the following results. The sample was turbid, and it was found that the matter in suspension amounted to 5.25 grains per gallon, or .075 gramme per liter. The clear water on analysis yielded:

	Grammes per liter.
Silica (SiO_2),	0.038
Alumina and ferric oxide (Al_2O_3 and Fe_2O_3),	0.024
Lime (CaO),	1.878
Magnesia (MgO),	8.106
Soda (Na_2O),	48.470
Carbonic anhydride (CO_2),	0.064
Sulphuric anhydride (SO_3),	6.026
Chlorine (Cl),	67.230
	131.836
Deduct oxygen equivalent to chlorine,	15.150
	116.686
Combined water, organic matter and loss,	8.534
Total solids,	125.220

* The Queensland Menzies mine.

† The water of the Dead Sea varies from 20 to 26 per cent. salts, and of this, 10 per cent is common salt.

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The chief salts probably present were, therefore:

	Grammes per liter.
Calcium carbonate, $CaCO_3$,	0.145
Calcium sulphate, $CaSO_4$,	4.365
Magnesium sulphate, $MgSO_4$,	5.189
Magnesium chloride, $MgCl_2$,	15.144
Sodium chloride, NaCl,	91.467

Expressed in grains per gallon, the results appear more striking. The proportion of common salt amounts to no less than 6402.7 grains per gallon. Ordinary drinking-water contains about 3 grains of common salt per gallon.

The water-supply of the region comes from two sources, namely, that which has collected amid the purely superficial deposits of *débris* and drift covering the actual rock-surface, and, secondly, that which has penetrated through the decomposed rock down to the zone where oxidation ceases.

Wherever a depression occurs, the prevailing rocks, granite and diorite, are overlaid with a variable thickness of their own detritus, which allows the collection of rain-water and affords protection from too rapid evaporation. These are known as "soaks." The government geologist defines them as "valleys silted up with a thin covering of recent superficial deposits more or less saturated with water."* At Hampton Plains, 8 miles from Coolgardie, a supply of condensing-water has been obtained from beds of this nature. The section† was as follows:

	Thickness. Feet.	Depth. Feet.
Clay, with ironstone gravel,	27	27
Fine sand,	30	57
Coarse yellow sand,	43	100
Clay,	4	104
Land wash,	11	115
Kaolin,	8	123
Bed-rock,	39	162

Water was struck in the third stratum, described as coarse yellow sand. The bed-rock was granite.

During the wet season, some of the depressions filled with such accumulations of detritus will receive more water than

* Report in connection with the water-supply of the gold-fields. 1897. A. Gibb Maitland.

† From the report just referred to.

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they can hold, and then the eye becomes gladdened for a few days by the sight of water running over the surface. As it becomes diminished by evaporation it disappears from view, but will be found to linger in the rock-holes, where the supply is maintained by the slow drainage of the surrounding porous area. These are called by the aborigines "guamma" holes. The life of such natural wells depends, of course, on the dimensions of the water-bearing depression and upon the relative porosity of the deposit which it drains.

These supplies are in their nature uncertain. The next and more important source of supply is found at the ordinary drainage-level of the country, namely, the horizon where the oxidation of the surface ceases and the relatively hard unoxidized rock offers a partial barrier to the free descent of the waters which have percolated through the overlying formation. The depth of this zone will depend upon the permeability of the superficial rock-formation; it varies from 40 feet at Earlston to 202 feet at Kalgoorlie. A characteristic section is that given by the well put down on Reserve 3096, Coolgardie, where the Gold-fields Water Supply Department sunk 165 feet and found 7 feet of sand, 47 feet of conglomerate and 111 feet of decomposed granite. The water was found at the base of the last, just above the unaltered granite.

Condensers.—Frequent mention has been made of the condenser. This is a characteristic feature of every mining settlement in the interior of Western Australia, and occupies the position accorded to the public well of a European village. Without this process of distillation, which renders the brackish water of the wilderness fit for human consumption, the mining industry could never have progressed beyond the merest prospecting.

The introduction of condensers is traceable to the sailors who took a prominent part in the early exploring expeditions. The name itself suggests this; for a landsman would be likely to call the condenser a "still." When the rush to the new gold-fields occurred, the government, by erecting condensers at intervals along the main lines of travel, did much to diminish the loss of life otherwise inevitable in times of wild excitement by reason of the recklessness of those who joined the stampede without due care for the great necessity of life in a tropical desert.

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The process of converting brine into drinkable water is simple. The salt water is put into a boiler and converted into steam, which is then condensed in vessels presenting a maximum of cooling-surface. Ship-tanks, having a capacity of 400 gallons, are commonly employed as boilers, and the condensing apparatus is constructed out of the corrugated iron which is everywhere employed for roofing-purposes. The tanks used as boilers are usually set on edge in pairs, as shown in Figs. 24 and 25. The average product of each 400-gallon tank is about 300 gallons of distilled water daily. Two vertical short iron pipes draw off the steam, which passes into condensing chambers or "coolers." The latter were originally plain circular tanks, which were increased in capacity by the addition of sections, increasing the height. Sheets of corrugated iron were bent round until the ends met, and these were united by riveting and soldering. Several such sections were united, and a tubular tower, about 30 feet high and 3 feet in diameter, was the result. The top and bottom were closed by a flat sheet of iron. A 6-inch pipe connected the towers, and steam traveled up the one tower and down the next.

This type has been superseded of late by annular chambers. An outer corrugated iron cylinder, 2.5 feet in diameter, surrounds an inner 1.5 ft. cylinder, so as to leave an annular space, 6 inches wide, which becomes the condensing-chamber. No attempt is made to supplement the cooling effect of the surrounding air, though a brush shelter is sometimes erected so as to ward off the direct rays of the sun.*

The daily expenditure includes the labor of two men, one on each shift, and the cost of the fuel consumed. A typical condenser is that erected on the Lake View and Boulder Junction mine, shown in Fig. 4. This plant has a capacity of 1,500 gallons of condensed water per day and cost £100. The water treated comes from the mine and shaft and has a specific gravity of 1.03385, the total solids amounting, according to the analyses of Mr. E. S. Simpson, to 4.9308 per cent. and the chlorine to 2.3933 per cent. The cost averages, during the cool season, 5 shillings, and during the summer 6.5 shillings

* For many of these details I am indebted to Mr. Frank G. Grace, Kalgoorlie, and to Mr. Edward S. Simpson, Government Assayer, Perth.

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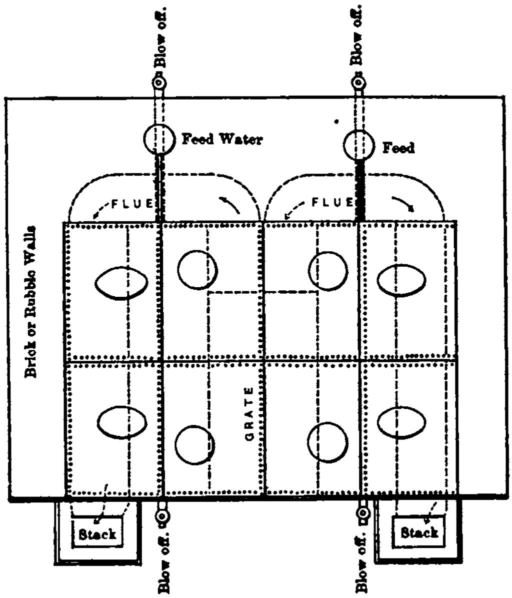
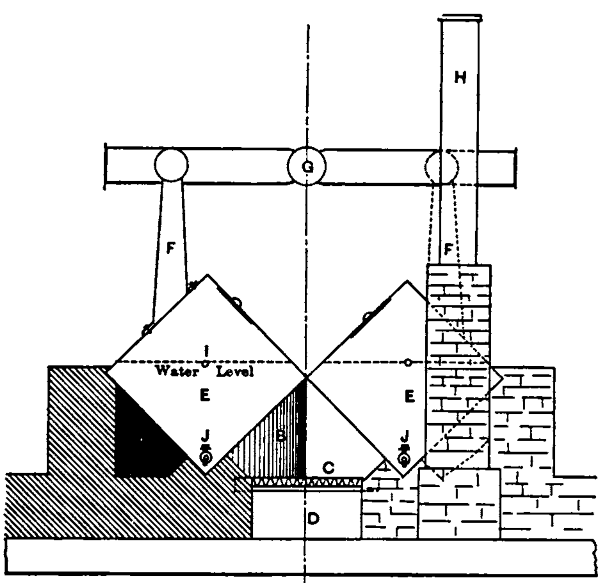
Fig. 24.



Plan of Ordinary Condenser.

Fig. 25.



Section and Elevation of Ordinary Condenser.

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per hundred gallons of condensed water. The condensed water is sold at from 10 to 12 shillings per hundred gallons. A first-class condenser would consist of at least 8 boilers, each having 400 gallons capacity and a daily output of 300 gallons of condensed water, giving the plant a daily yield of 2,400 gallons. The salt water is usually bought for from 2 to 4 shillings per thousand gallons. Fuel costs 20 shillings per cord, and is consumed at the rate of 1 cord per thousand gallons of condensed water. Thus the cost would be:

2 men at £4 per week of 6 days, ...	27 shillings.
2½ cords of wood, ...	50 "
3,200 gallons of salt water, ...	10 "
Total, ...	87 shillings.

This would be at the rate of 36 shillings per thousand gallons. During November, 1897, condensed water sold for 100 to 150 shillings per thousand gallons.

Concerning the use of salt water in the stamp-mills and leaching works of Western Australia, I would say that its density is an obstacle to amalgamation because of the facility with which slimes are created. The finer particles of gold are thus prevented from settling on the copper plates of the tables, and are carried away in the tailings. At Kalgoorlie the cyanide works use the natural brine successfully; its magnesia being precipitated by lime, so as to prevent the decomposition of the stock-solution.

In order to aid the development of the mining industry, which is still severely handicapped by the want of a sufficient supply of water, the government of West Australia has decided to carry out a hydraulic enterprise of great magnitude. It is proposed to supply 5,000,000 gallons of fresh water per day to the Coolgardie gold-field by building a pipe-line from the Darling range, where the Helena river will be impounded by a concrete dam 100 feet in height and 650 feet long. The source of supply is 320 feet above sea-level, while the service-reservoir at Coolgardie will be on Mt. Burgess, at a height of 1670 feet, or 1350 feet higher. These two reservoirs will be connected by 330 miles of 30-inch steel-pipe. Nine pumping-stations will be required. The appropriation for this work is $12,500,000. The annual operating expenses will probably

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approximate $1,600,000, and water will be delivered through a hundred miles of distributing pipes at a cost of 3 shillings and 6 pence, or 84 cents, per thousand gallons.

It will occur to the reader to ask whether boring for artesian wells has been attempted. Yes; in obedience to the public demand, the government put down a bore at Coolgardie which reached a depth exceeding 2000 feet and found—granite. The geological conditions render an artesian flow of water highly improbable. Nevertheless, in this colony, as elsewhere among the arid tracts of Australia, there is a whispered hope of finding a subterranean river. As the Carson and the Humboldt are swallowed up by the alkali wastes of Nevada, so in the desert plains of this southern continent there are many streams which flow into the interior and lose themselves in the sand or find for themselves an undergound channel.* This fact has given rise to conceptions, more poetic than scientific, of a great subterranean river yet to be discovered, and destined in days to come to make the desert break forth into fertility. It is a dream. No irrigation can turn the wastes of quartz-sand into waving fields of wheat. Time, geological time, covering a period to measure which the duration of a man's life is an inadequate unit, can alone render the wilderness fit for human habitation.

Mineral Lode-Locations in British Columbia.

BY WILLIAM BRADEN, HELENA, MONTANA.

(Buffalo Meeting, October, 1898.)

In view of the current discussion of a proposed change in the United States mining law, abolishing the feature known as the extralateral right of a lode-location, it is an interesting circumstance that in the neighboring Province of British Columbia this feature was tried for eight years and then abandoned. The results of that abandonment have been such as to disprove the proposition, so confidently advanced by many

* This occurs in Queensland, where the geological conditions are quite different. Several very successful bore holes have been put down, an abundant artesian flow being obtained at depths of 2000 feet and over.

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