NOTES ON THE CREMORNE BORE.

Professor Anderson Stuart said, that upon the whole, the theory as described by Professor David appeared to him to best explain the conditions as he understood them. He thought that Mr. McKinney's remarks as to the hopes entertained by some that artesian water would yet convert the dry arid back country into verdant fields should be emphasized, for he too considered that the hope was vain. One had only to see what vast constructions, what great pipes were needed to irrigate what was after all a mere patch of the surface, to be convinced that artesian water would never be able to do more than make fertile oases in the vicinity of the bores. Further, that even depended, as had been said on efficient drainage being possible—and it was not always so. He concluded by appealing to the Under Secretary for Mines and Agriculture (Mr. Harrie Wood), who was present, to use his influence in fitting all the bores systematically with pressure gauges, so as to give the important information spoken of by Professor David.

NOTES ON THE CREMORNE BORE.


[Read before the Royal Society of N. S. Wales, December 6, 1893.]

I. Introduction.—The problem as to the exact relation between the Newcastle and Illawarra Coal-fields having been at last practically solved by the results of the Cremorne Bores, the present opportunity seems to us a favourable one for bringing before the Society a subject of so much scientific, as well as economic interest. The detailed section of the strata penetrated at the second bore is given by one of the authors in the Annual Report of the Department of Mines for 1893,* now in course of

publication. The present paper, however, is intended to be a short summary of the chief results attained by these bores.

The proving of a magnificent seam of steam coal over ten feet in thickness, at the second bore on the shores of Port Jackson, should mark an epoch in the history of the development of the coal resources of Australia, and shows that the estimates previously formed as to the available coal supply of this country have been probably under estimated.

II. Previous References to the probable occurrence of Coal under Sydney.—The late Rev. W. B. Clarke was probably the first who argued on scientific evidence, the probable occurrence of coal under Sydney. In his evidence before the Select Committee of the Legislative Council on coal enquiry held in Sydney in 1847, Mr. Clarke said, "If we take a dip of only 1° from Newcastle to the South and from Illawarra to the North, the synclinal curve will meet at the entrance to Broken Bay, which is exactly halfway (the extremity probably of the minor axis) at a depth of 4,680 feet, the depth of the coal seams if continuous."*

The late Examiner of Coal-fields, Mr. William Keene, prepared a geological section illustrative of the manner in which the coal seams in the Newcastle and Illawarra Coal-fields respectively, dipped under Sydney. We are not aware whether this section was ever published, but it was exhibited to one of the authors by Mr. T. Adams, the late Mayor of Raymond Terrace.

Mr. J. Mackenzie, F.G.S., the present Examiner of Coal-fields, as early as 1866, referred to the probable occurrence of coal under Sydney, in a lecture delivered in Sydney, and in "Mines and Mineral Statistics 1875," published some sections of the coal measures of New South Wales, dividing them in descending order into (1) Upper Upper Coal Measures, (2) Lower Upper Coal Measures, (3) Upper Marine Series, (4) Lower Coal Measures,

(5) Lower Marine Series. Each of the three groups of productive coal measures above mentioned, is specially characterised by the enormous predominance of Glossopteris or of Gangamopteris in its flora.

Summarising the result of his later researches Mr. Clarke classifies the productive Glossopteris coal-beds of Australia and their associated strata as follows:—1. Upper Coal Measures. 2. Upper Marine Beds. 3. Lower Coal Measures. 4. Lower Marine Beds.*

These productive coal measures are most extensively developed in the Hunter River or Northern Coal-field, the Lithgow or Western Coal-field, and the Illawarra or Southern Coal-field. Mr. Clarke did not definitely state his views as to the correlation of these various coal-fields, but it is clear that he regarded the Illawarra Coal Measures as being newer than the Upper Marine Series and than the Lower (the Greta) Coal Measures, inasmuch as in the work above referred to (loc. cit., p. 169, Section to illustrate the structure of Burragorang), he speaks of the marine beds underlying the coal measures of the Mittagong Coal-field as the "Muree Beds," a name which he had previously given to the Upper Marine Series, or at any rate to a portion of them, which in the type district at Greta in the Hunter River Coal-field overlie the Lower Coal Measures, as illustrated by Mr. Clarke in another Section (loc. cit., p. 171). Mr. Clarke also in his Section of Mt. Victoria (loc. cit., p. 167), refers to certain hard shales occurring there as being like the "Silicated clay of Nobby Island." The island of Nobbys at Newcastle is formed of Upper Coal Measures. It is evident that Mr. Clarke considered the productive coal measures of the Newcastle, the Lithgow, Mittagong, and Illawarra Coal-fields as belonging to the Upper Coal Measures, and Mr. Mackenzie concurred with him in this opinion.

Mr. C. S. Wilkinson, the late Government Geologist subsequently adopted the following divisions for the Glossopteris Coal

Measures of New South Wales together with their associated marine strata:

- Permian
  - Upper Coal Measures or Newcastle Coal Measures
  - Middle Coal Measures or East Maitland Coal Measures
  - Upper Marine Series

- Carboniferous
  - Lower Coal Measures or Greta Coal Measures
  - Lower Marine Series

With regard to the relation of the Illawarra Coal Seams to those of Newcastle, Mr. C. S. Wilkinson, the late Government Geologist, wrote in 1887, that in his opinion the former belonged to the series below the Newcastle beds, probably to the Lower Coal Measures, that is to the Greta Coal Measures. Mr. Wilkinson was led to this provisional conclusion from a consideration of the fact that kerosene shale had been proved to occur in the Greta Coal Measures alone out of the three sets of coal measures developed in the type district, that of the Hunter River, and he thought therefore that as kerosene shale had been proved to exist there and also at America Creek, Mt. Kembla, in the Illawarra Coal-field, that the two deposits occupied an identical horizon. This inference appeared to be corroborated by the fact that at the head of the Clyde River some coal measures, at first considered to be the equivalents of the Illawarra Coal Measures, were found to be capped by marine strata similar to those covering the Greta Coal Measures, and also to contain a seam of kerosene shale.

A subsequent examination however by Mr. Wilkinson of the Clyde Coal Measures in the southern extremity of the Illawarra Coal-field, while it convinced him of the probable identity of these measures with those of Greta, proved at the same time that the Clyde Measures were quite distinct from the Illawarra Coal Measures at Mt. Kembla, and the fact was thus established that in the Permo-Carboniferous strata of New South Wales there existed at least two distinct kerosene shale horizons.

The question still remained to be settled as to whether the Illawarra Coal Measures were a continuation of the Newcastle
Coal Measures or of the Tomago Coal Measures of the Hunter District. The abundance of bands of clay ironstone in the Tomago as well as in the Illawarra Coal Measures inclined Mr. Wilkinson towards the latter opinion.

A later examination of the Illawarra Coal-field, however, by one of the authors, revealed the fact that there was an unconformability between the top of the Upper Marine Series and the base of the Illawarra Coal Measures, as seen in the coast section between Wollongong and Bellambi. This suggested the probability that the Middle or Tomago Coal Measures had been overlapped by the overlying coal measures (the Upper or Newcastle Measures) in the manner illustrated in the sections accompanying the report above quoted.

An examination of the section at the top of the Newcastle Coal Measures confirmed the opinion that the Illawarra Coal Measures were probably chiefly the equivalents of the Newcastle Measures, and the inference was drawn that the Bulli Coal Seam, the uppermost in the Illawarra Coal Measures, was identical with the Wallarah Coal Seam, the uppermost seam in the Newcastle Coal Measures at Wallarah near Catherine Hill Bay, Lake Macquarie. On palaeontological evidence alone, Mr. R. Etheridge, Junr., the Paleontologist to the Geological Survey of New South Wales and to the Australian Museum, had previously arrived at somewhat similar general conclusions.

The classification at present adopted by us is as follows:—

6. Newcastle Coal Measures typically developed at Newcastle, Lithgow, Mittagong, and in the Illawarra District.

5. Dempsey Beds.

4. Tomago Coal Measures typically developed at Tomago and East Maitland.

3. Upper Marine Series.

2. Greta Coal Measures typically developed at Greta, West Maitland, and at the Clyde River.

1. Lower Marine Series.

The following is a table showing the relation of the new classification to those formerly adopted:—

* Annual Report, Department of Mines, 1890, p. 234.
<table>
<thead>
<tr>
<th>Rev. W. B. Clarke —</th>
<th>Permian.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(4) Upper Coal Measures.</td>
<td>(4a) Newcastle Coal Measures.</td>
</tr>
<tr>
<td>J. Mackenzie, F.G.S. —</td>
<td>(4b) Dempsey Series.</td>
</tr>
<tr>
<td>(4a) Upper Upper Coal Measures.</td>
<td>(4c) Tomago Coal Measures.</td>
</tr>
<tr>
<td>(4b) Lower Upper Coal Measures.</td>
<td></td>
</tr>
<tr>
<td>(4a) Upper Coal Measures, Newcastle Coal Measures.</td>
<td>(3) Upper Marine Series.</td>
</tr>
<tr>
<td>(4b) Middle Coal Measures, E. Maitland Coal Measures</td>
<td>(2) Greta Coal Measures.</td>
</tr>
</tbody>
</table>

Rev. W. B. Clarke —
(3) Upper Marine Beds.
(2) Lower Coal Measures.
(1) Lower Marine Beds.

J. Mackenzie, F.G.S. —
(3) Upper Marine Beds.
(2) Lower Coal Measures.
(1) Lower Marine Beds.

C. S. Wilkinson —
(3) Upper Marine Series.
(2) Lower or Greta Coal Measures.
(1) Lower Marine Series.

Carboniferous.
The following are sections of the seams at Amos Brothers Bore near Wallarah and at the No. 2 Bore, Cremorne, placed side by side for comparison:—

**Amos Brothers Bore near Wallarah.***

<table>
<thead>
<tr>
<th>Feet.</th>
<th>Inches</th>
<th>Feet.</th>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0\frac{3}{4}</td>
</tr>
<tr>
<td>6</td>
<td>8\frac{1}{4}</td>
<td>6</td>
<td>5\frac{1}{4}</td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td>10</td>
<td>3</td>
</tr>
</tbody>
</table>

---

Not only do the sections of these two seams agree tolerably closely, but the section of the two seams next below this top seam in the Newcastle and Illawarra Coal-fields respectively, also agrees, a seam four feet in thickness usually underlying the seam at Wallarah in the Newcastle Coal-field and at Bulli in the Illawarra Coal-field, and a seam fourteen feet in thickness underlying the four feet seam in places at both these coal-fields. The last mentioned seam however, in the Illawarra Coal-field is split up into a number of smaller seams at several localities. It is typically developed at Wongawilli near Dapto.

One important scientific result of the Cremorne Bore is therefore the practical settlement of the question as to the identity of the Newcastle Coal Measures with those of the Illawarra Coal-

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* Annual Report, Department of Mines, 1882, p. 128.

C c—Decr. 6, 1893.
field, and it may now be considered almost an established fact that the Tomago Coal Measures have been overlapped by the Newcastle Coal Measures and have thinned out against a rising surface of the Upper Marine Series throughout the greater portion of the Illawarra District.

III. Previous Bores for Coal in the neighbourhood of Sydney.

(1.) A bore was put down to a depth of 1,312 feet at Newington near Parramatta, by Mr. Coghlan, with a view of reaching the coal measures.* According to this report, which was made by the late Government Geologist, Mr. C. S. Wilkinson, the coal measures were reached near the bottom of the bore, and a specimen of Glossopteris was found in part of the core. We are of opinion however, that Mr. Wilkinson in making this statement was merely quoting the information supplied to him, and did not intend to record them as the result of his own observation, as he never, as far as we are aware, alluded to this statement, although he on more than one occasion discussed the subject of this bore with one of the authors. It seems incredible that the coal measures should lie at a depth of only 1,300 feet at Newington, near Parramatta, when they are 2,500 feet deep at Liverpool, about twelve miles southerly from Parramatta, and over 2,900 feet deep at Cremorne, about sixteen miles easterly from the same locality, there being little difference in the respective surface levels, and there being probably but very little dip between Liverpool and Parramatta. In all probability therefore this bore did not reach the coal measures.

(2.) At Moore Park a bore was carried down to a depth of 2,170 feet without striking the coal measures.†

(3.) At Botany a bore was put down to a depth of about 2,200 feet without penetrating the horizon of the coal measures. The chocolate shales were struck at a depth of 1,000 feet.‡

* Annual Report, Department of Mines, Sydney, 1878, p. 155.
† Annual Report, Department of Mines, 1880.—Report by Mr. C. S. Wilkinson, p. 241.
‡ Annual Report, Department of Mines, 1879, p. 208, and Mineral Products etc. of New South Wales, 1887, plate vi.
(4.) At Narrabeen a bore executed by Mr. Coghlan attained a depth of about 1,985 feet and failed to reach the coal measures.* The chocolate shales were struck at a depth of 379 feet 6 inches, and the purple and green tuffaceous shales representing the horizon of the cupriferous tuffs at a depth of 1,715 feet. Natural gas is stated to have been struck in this bore at a depth of 1,560 feet, and also at a depth of 1,200 feet in a bore within a few yards of the first. This natural gas was probably coal gas mixed with atmospheric air. The height of the bore above sea-level was about four feet.

(5.) At Rose Bay near Sydney, Mr. Coghlan bored on the Cowper Estate, to a depth of approximately 1,700 feet. Neither coal measures nor gas were obtained at this bore.

(6.) At Camp Creek, near the present site of the Metropolitan Colliery, about twenty-seven miles from Sydney, a bore executed by Mr. Coghlan was successful in reaching the Bulli coal seam, there about twelve feet thick, at a depth of 846 feet. Height above sea-level 336 feet.

(7.) The bore put down by the Department of Mines between Waterfall and Heathcote, about twenty-three miles southerly from Sydney, struck the upper portion of the Bulli seam at a depth of 1,513 feet, thickness four feet eight and a-half inches, and the lower portion six feet one inch thick at a depth of 1,583 feet ten inches. The chocolate shales were struck at a depth of 307 feet, and the cupriferous tuffs at a depth of 1,047 feet. Height above sea-level 467\frac{1}{4} feet.†

(8.) At Dent's Creek near Holt Sutherland, the Diamond Drill belonging to the Department of Mines, struck the upper coal seam proved at the Heathcote bore at a depth of 2,228 feet, the seam being four feet two inches thick, and the lower seam at 2,296\frac{1}{2} feet, the thickness of the latter being five feet three inches. The

† Annual Report, Department of Mines, 1885, [1866] p. 176.
chocolate shales were struck at 787 feet, and the cupriferous tuffs at 1,728 feet. The total depth of this bore was 2,307 feet.

The results of these bores 6, 7 and 8 proved the Bulli Seam to have a dip from Coal Cliff, where it outcrops near sea level, to Holt Sutherland at a rate of about 139 feet per mile. The height above sea level is 132 feet.*

(9.) At the Liverpool Bore, situated on the Moorbank Estate, three miles southerly from Liverpool near Sydney, three small seams of coal, probably representing in the aggregate the upper division of the Bulli seam, were struck at depths of 2,493½ feet, 2,507 feet 7 inches, and 2,532 feet 8 inches; their respective thicknesses being one foot five inches, one foot four inches, and two inches, and the lower division of the Bulli Seam six feet six inches thick was struck at 2,584 feet 10 inches.

(10.) The first Cremorne Bore put down by the Department of Mines on the shores of Port Jackson, near Mossman's Bay, struck the main Bulli Seam, here probably representing a combination of the two seams struck at Heathcote and Holt Sutherland, and of the four seams struck at Liverpool at a depth of 2,801 feet 9 inches. As however, the seam was much intermixed with dyke material and wholly calcined, this thickness must be considered as only approximate. At a depth of 2,838 feet 9 inches a dolerite dyke was struck, which was not completely penetrated until a further distance of thirty-four feet four and a-half inches had been bored. The bore was continued to a depth of 3,095 feet without proving any other coal seams of importance. The following small seams however were penetrated:—one foot one inch of clayey calcined coal at 2,829 feet 6 inches; one foot two inches of dirty splint coal at 2,898 feet 3 inches; one foot of coal at 2,941 feet 2 inches; five feet of carbonaceous clay shale passing downwards into about one foot of clayey coal at 2,947 feet 2 inches; two feet four inches of coal at 3,020 feet 2 inches; one foot four inches of coal and bands at 3,030 feet; five inches of coal at 3,054 feet 11 inches.

* Annual Report, Department of Mines for 1883, p. 197.
The chocolate shales were struck at a depth of 943 feet 4 inches. The surface level at this bore was fifty-four feet above the sea.

(11.) Second Cremorne Bore.—In consequence of the coal in the seam struck at the first bore having been damaged by the dolerite dyke, the syndicate resolved to put down a second bore, and with a view of avoiding the dykes in the second bore, applied for a geological survey of the neighbourhood with the object of determining the exact trend of the dykes. An examination was accordingly made by the Geological Survey, and it was found by the authors that a dyke of dolerite about five feet wide outcropped near the first bore, dipping towards the borehole at a rate which would make it approximately intersect the bore at the depth at which the dolerite dyke was actually encountered in the bore. A subsequent examination by one of the authors led to the discovery of a second dyke, trending so as to almost exactly intersect the spot where the bore was commenced.*

The site for the second bore was accordingly placed as far as possible from the outcrops of these two dykes, though the boundaries of the Syndicate’s property did not admit of its being distant more than a quarter of a mile from either outcrop. At a depth of 2,917 feet a seam of coal was struck, which proved to be ten feet three inches in thickness. The upper eight inches of this seam was slightly damaged through the action of superheated water carrying mineral matter in solution from the dyke, but the remainder of the seam proved to have been quite unaffected by the dyke, and the analysis of the coal shows it to be a steam coal of very good quality. The following is a section of the seam:

Roof, clay shale.

<table>
<thead>
<tr>
<th>Feet</th>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>

Feet. Inches.

0  0\(\frac{1}{4}\) band dark brown clay shale, adhering firmly to coal.
6  4\(\frac{1}{4}\) coal, splint and bituminous of good quality, the last three inches rather soft and bituminous.
0  3\(\frac{3}{4}\) coal, soft bituminous, a trifle clayey.

Total 10  3

Floor black carbonaceous clay shale passing downwards into a hard mudstone. This bore was carried to a depth of 2,929 feet.

The quality of the coal in this seam is shown by the following analyses by Mr. J. C. H. Mingaye, F.C.S., Analyst and Assayer to the Department of Mines:—

2572 No. 1. Average sample from the first eighteen inches of coal next below the eight inches of coal with calcite veins at the top of the seam:

\[
\begin{align*}
\text{Hygroscopic moisture} & : 0.65 \\
\text{Volatile hydrocarbons} & : 17.30 \\
\text{Fixed carbon} & : 71.75 \\
\text{Ash} & : 10.30 \\
\end{align*}
\]

\[
\text{Coke } 82.05\%
\]

Sulphur in coal 7.95\%. Specific gravity 1.207. Ash, reddish tinge, flocculent.

One pound of this coal by experiment in a Thompson's calorimeter will convert 12.7 lbs. of water into steam.

2573 No. 2. Average sample from the next eighteen inches of coal:

\[
\begin{align*}
\text{Hygroscopic moisture} & : 0.70 \\
\text{Volatile hydrocarbons} & : 17.80 \\
\text{Fixed carbon} & : 71.60 \\
\text{Ash} & : 9.90 \\
\end{align*}
\]

\[
\text{Coke } 81.50\%
\]

100.00

2574 No. 3. Average sample from the next fourteen inches of coal:

\[
\begin{align*}
\text{Hygroscopic moisture} & : 0.80 \\
\text{Volatile hydrocarbons} & : 16.90
\end{align*}
\]
**NOTES ON THE CREMORNE BORE.**

<table>
<thead>
<tr>
<th>Coal Type</th>
<th>Hygroscopic Moisture</th>
<th>Volatile Hydrocarbons</th>
<th>Fixed Carbon</th>
<th>Ash</th>
<th>Coke</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. 4</strong></td>
<td></td>
<td></td>
<td>71.05%</td>
<td>11.25%</td>
<td>82.30%</td>
</tr>
<tr>
<td><strong>No. 5</strong></td>
<td></td>
<td></td>
<td>71.25%</td>
<td>11.00%</td>
<td>82.25%</td>
</tr>
<tr>
<td><strong>No. 6</strong></td>
<td></td>
<td></td>
<td>71.75%</td>
<td>9.35%</td>
<td>81.10%</td>
</tr>
</tbody>
</table>


One pound of this coal will convert 12.9 lbs. of water into steam.

**2575** No. 4. Average sample from the next fourteen inches of coal:

- Hygroscopic moisture: 70%
- Volatile hydrocarbons: 17.05%
- Fixed carbon: 71.25%
- Coke: 82.25%

Sulphur in coal 8.09%. Specific gravity 1.374. Ash, reddish tinge, flocculent.

One pound of this coal will convert 12.9 lbs. of water into steam.

**2576** No. 5. Average sample from the next fourteen inches of coal:

- Hygroscopic moisture: 65%
- Volatile hydrocarbons: 17.95%
- Fixed carbon: 70.15%
- Coke: 81.40%

Sulphur in coal 8.78%. Specific gravity 1.373. Ash, reddish tinge, flocculent.

One pound of this coal will convert 13.1 lbs. of water into steam.

**2577** No. 6. Average sample of the last fourteen inches of coal:

- Hygroscopic moisture: 45%
- Volatile hydrocarbon: 18.45%
- Fixed carbon: 71.75%
- Coke: 81.10%

100.00
Sulphur in coal -686%. Specific gravity 1·362. Ash, reddish tinge, flocculent.

One pound of this coal will convert 13·2 lbs. of water into steam.

Mean analysis of the six samples:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hygroscopic moisture</td>
<td>66</td>
</tr>
<tr>
<td>Volatile hydrocarbons</td>
<td>17·57</td>
</tr>
<tr>
<td>Fixed carbon</td>
<td>71·09</td>
</tr>
<tr>
<td>Ash</td>
<td>10·68</td>
</tr>
</tbody>
</table>

\[
\text{Coke} = 81·77
\]

100·00

Mean sulphur -724%. Mean specific gravity 1·346. Mean calorimetric value 13·0.

The above analyses prove the coal to be a steam coal of good quality, slightly superior to the Bulli coal, but resembling it in general physical characters, as might have been expected, seeing that it belongs to the same seam. The Bulli coal however, contains at least two per cent. more ash than that from Cremorne.

Mr. Mingaye adds that the Cremorne coal forms an excellent coke. The mean percentage of ash in the coke would be 13·06.

**General character of the Coke of the Bulli Seam.**—The coke hitherto made from coal taken from the Bulli Seam contains a rather higher percentage of ash than that made from the Northern or Newcastle coal, and although at the Bulli Colliery Coke Works the coal was passed through a Sheppard Coal Washing Machine prior to its introduction to the coke ovens, the percentage of ash in the resulting coke amounted to 13·4.* This is said to be due to the fact that the dirt or ash-forming material is intimately mixed with or distributed through the Bulli coal in a very fine state of division. Nevertheless it appears probable that if the washing were preceded by sufficiently fine crushing, a very material reduction in the percentage of ash would result. One distinct advantage possessed by coke made from the Bulli Seam is its capacity for resisting crushing strain, or in other words, its

excellence for smelting purposes in those cases where it has to resist a heavy furnace burden. It will be seen by reference to the report last quoted, that in some tests made by Professor Warren, samples of the Bulli coke resisted a pressure of from 2,400 to 3,100 lbs. per square inch—a pressure which was largely in excess of that withstood by any of the other specimens of foreign or colonial coke experimented with.

Gas.—Coal gas was given off abundantly from the coal core for over two hours after it had been drawn to the surface. The coal dust floated up in the water which was being circulated in the borehole by the force pump in the process of drilling, discharged coal gas so copiously that it bubbled up strongly through the water, and was readily ignited, burning with a bluish flame six to eight inches in length. It will be recollected that gas, probably coal gas mixed with atmospheric air, was given off from both the bores for coal at Narrabeen. It was probably derived from the same seam as that struck at Cremorne, and was conducted into the Narrabeen bores possibly by an oblique joint in the strata, which intersected one bore at a depth of 1,200 feet, and the other at 1,560 feet.

IV. (a) Details of No. 2 Cremorne Bore.—The following is a generalised section of the strata penetrated in this bore from the surface down to the total depth 2,929 feet:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawkesbury Sandstone ...</td>
<td>1,020</td>
<td>6</td>
</tr>
<tr>
<td>(a) Chocolate shales...</td>
<td>163</td>
<td>6</td>
</tr>
<tr>
<td>(b) Sandstones, shales and conglomerates, with Thinnfeldia, Sphenopteris, Sagenopteris, Macrotenopteris, Odontopteris, Schizoneura, and Estheria.</td>
<td>1,112</td>
<td>6</td>
</tr>
<tr>
<td>Narrabeen Beds.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) Tuffaceous dark green gritty shales—horizon of the Cupriforous tuff of the Holt, Sutherland and Heathcote bores.</td>
<td>60</td>
<td>6</td>
</tr>
<tr>
<td>(d) Sandstones, shales and conglomerates</td>
<td>560</td>
<td>0</td>
</tr>
</tbody>
</table>
The line of division between the Mesozoic and Palæozoic rocks has been drawn at the top of the coal seam for the reason that the horizon of the ironstone nodules, which is well marked as forming the basal bed of the Hawkesbury Series, was found to descend at this bore to within a few feet of the coal seam.

(b) Dip of the Seam.—At the No. 1 Cremorne Bore the surface level was fifty-four feet above the sea, and at the No. 2 Bore one hundred and forty-three feet above sea-level. At the No. 1 Bore, the coal was struck at 2,801 feet 9 inches, and at the No. 2 Bore at 2,917 feet. Consequently the seam at the No. 2 Bore was one hundred and fifteen feet deeper (in round numbers) than at the No. 1 Bore, whereas there was a difference in the surface levels of only about eighty-nine feet. The seam has therefore dipped from the No. 1 Bore towards the No. 2 Bore twenty-six feet in a distance of forty chains in a direction of North 34° West.

At the Narrabeen Bores the chocolate shales were struck at a depth of three hundred and seventy-nine feet six inches, the distance from the No. 2 Cremorne Bore being nine and a-half miles and the bearing North 5° 45' East. The surface level being about four feet above the sea.

At Holt Sutherland, the surface level being one hundred and thirty-two feet above the sea, the depth to the first seam of coal was 2,228 feet, and to the second seam 2,296 feet. If the authors' opinion be right that these two seams come together and become united to form the single ten feet three inches seam at Cremorne, the depth to the top of the lower seam with the thickness of the upper seam subtracted from it should be taken as the level from which to measure the dip of the seam from Holt Sutherland towards Cremorne, that is 2296 feet — 4 feet 2 inches = 2,292 feet in round numbers. The total dip therefore from the Holt Sutherland Bore to the No. 2 Bore at Cremorne has been six hundred
and fourteen feet, the bearing being N. 21° 30' E. and the distance sixteen and a-half miles. The chocolate shales at the Holt Sutherland Bore were struck at a depth of seven hundred and eighty-seven feet,* whereas at the No. 2 Bore at Cremorne they were struck at 1,020 feet, a total dip of two hundred and twenty-two feet, so that, whereas the coal measures dip six hundred and fourteen feet, the top of the Narrabeen beds and base of the Hawkesbury Sandstone has dipped only two hundred and twenty-two feet, which proves that the Narrabeen Beds thicken between Holt Sutherland and Cremorne three hundred and ninety-two feet in a distance of sixteen and a-half miles.

The surface level at the Liverpool Bore is about forty feet, and the depth to the top of the main seam 2,584 feet 10 inches, so that the main seam dips from Liverpool towards the No. 2 Bore, Cremorne, two hundred and twenty-nine feet, the bearing being N. 53° E., and the distance twenty miles.

These data are not sufficient to admit of the exact amount and direction of dip of the coal measures at Cremorne being calculated. From Coal Cliff to Holt Sutherland the dip is northerly at about one hundred and thirty feet per mile; from Lithgow to Liverpool it is easterly at about sixty feet per mile without allowing for the downthrow fault and sharp monoclinal fold at Lapstone Hill, which amounts to perhaps about six hundred feet. If this six hundred feet be added, the dip from Lithgow to Liverpool would be about sixty-seven feet per mile.

The general dip from the coast towards the No. 2 Cremorne Bore is westerly at one hundred and ten feet per mile. At Wyong, about forty miles northerly from Cremorne, the same chocolate shales which are about eight hundred and seventy-seven feet below sea-level at Cremorne, are at sea-level, dipping in a southerly direction. It is obvious from these facts that Sydney cannot be far from the centre of the great coal-field, which extends from near Ulladulla to Port Stephens, and from the sea coast to

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* Annual Report, Department of Mines, 1883, p. 197.
beyond Lithgow. The westerly dip at Cremorne proves that the bore is situated on the eastern half of this coal basin, and as the seam is rising in an easterly direction at Cremorne at the rate of about one hundred and ten feet per mile, it should outcrop at sea level at a point about twenty-four and three-quarter miles from the coast eastwards from the bore. The ocean however here is about one hundred fathoms deep, so that the submarine outcrop of this seam should lie approximately nineteen and a-quarter miles easterly from the entrance to Port Jackson.

It may be safely predicted that in the near future the coal seam at Cremorne will be worked far under the ocean, and already a company "The Sydney and Port Hacking Coal Company Ltd.," name since changed to "The Sydney Harbour Collieries, Limited," has acquired the right to mine for coal under an area of about 8,000 acres of Port Jackson, Middle Harbour, and Manly Cove.

V. Temperature.—With a view of ascertaining the temperature as accurately as was practicable in the short space of time available for the experiment, by the advice of Professor Threlfall and Mr. H. C. Russell, the Government Astronomer, some maximum-register thermometers were hermetically sealed in a strong piece of wrought iron water pipe about two feet three inches in length. A cap piece was "sweated on" to the lower end of this tube, the threads of the screw in the cap piece and pipe being filled with molten solder and the cap piece being screwed on, while the solder was still molten. By this means a joint was formed capable of withstanding the great pressure to which it would be subjected, when lowered to the bottom of the bore, the bore being full of water from a level of 2,900 feet to within about three hundred feet of the surface, and it being necessary therefore to protect the bulbs of the thermometers against this water pressure, in order to preclude the possibility of their registration being unduly high from that cause. The lower end of the pipe was then filled to a depth of about two inches with brass turnings. The thermometers were next carefully lowered into the tube. Three of these were maximum registering overflow thermometers, made by Negretti
and Zambra, two of them kindly lent for the purpose by Mr. H. C. Russell, and being Kew-certificated. A fourth was a combined spirit and mercury thermometer registering both maximum and minimum temperatures by means of small steel pistons washered with vulcanite.

The three overflow thermometers were placed with their bulbs uppermost to facilitate the breaking of the mercury column when the maximum temperature had been reached. Brass turnings were then packed around them in order that the heat might be conducted rapidly to their bulbs from the water in the bore. Strings were fastened to the bulbs to facilitate the withdrawal of the thermometers from the tube after the experiment of taking the temperature had been completed. The ends of these strings were carried close up to the top of the pipe, the brass turnings being packed around them like tamping around a fuse in a shot-hole. A few card-board wads and a layer of loose paper two inches in thickness were inserted in the upper portion of the tube to prevent the conduction downwards of the artificial heat, which would otherwise travel down to the thermometers from the upper end of the tube when it was dipped in the molten solder, previous to the upper cap-piece being "sweated on." A ring-bolt for attaching the lowering cord was screwed into the upper cap-piece with molten solder sweated into it; and the whole cap-piece was then screwed and sweated on to the upper end of the tube in the same manner as the lower cap-piece.

The tube carrying the thermometers was then lowered down the borehole by means of about five hundred feet of piano wire attached to two thousand five hundred feet of tarred rope. Owing however, to the fact that the bulbs of the two Kew thermometers (these two alone were used on the occasion of the first experiment) having a few thicknesses of soft paper around their bulbs it was found on raising the tube after it had remained near the bottom of the bore for about an hour, that no sensible alteration had taken place in the level of the mercury. Considerable delay however had occurred between the time that the thermometers
reached the surface and the time that the reading was taken, as it was necessary to convey the tube from the site of the bore back to the plumber's in order to have the upper cap-piece removed. It is just possible therefore that as both thermometers were in a vertical position in the tube, the mercury may have become gradually sucked back into the bulbs after having been forced up the graduated tube to the temperature of the water near the the bottom of the bore.

On the occasion of the second experiment all the four thermometers previously described, were employed, no paper being wrapped around the bulbs, but the brass dust being continuous from the bulbs to the side of the iron pipe. On that occasion, however, owing to an obstruction in the bore at a depth of 2,733 feet, the piano wire became slackened, as the lowering was continued until it was estimated that the tube with the thermometers had reached a depth of about 2,880 feet. Consequently about one hundred and sixty-seven feet of rope was paid out after the tube had reached the depth of 2,733 feet, the reduction in weight on the rope consequent on the tube becoming lodged at that level not being sufficiently perceptible to apprise those in charge of the lowering that the bore had become blocked. When, therefore, after the tube had remained down the bore for over an hour, the work of winding up was commenced, the slackened coils of piano wire kinked, and the wire snapped, and the tube was left remaining in the bore at the depth above mentioned. After an immersion of about twenty-seven hours, the tube together with over a hundred feet of tangled wire was brought to the surface by the Superintendent of Drills, Mr. W. H. J. Slee, with the assistance of his foreman, Mr. Ayles, who succeeded in grappling the wire with an improvised recovering tool in the shape of a heavy iron coupling, terminating downwards in an iron prong about a foot long, armed at the sides with stiff springs riveted on to the prong at one end, and with the free ends pointing outwards and upwards, like the barbs of a harpoon.

The upper cap-piece was then rapidly heated in a chafing dish of charcoal made of an old nail can with a hole cut out of the
bottom just sufficiently large to admit of the upper end of the tube being passed up it, and oxygen gas from a compressed cylinder was blown through a Fletcher's Blowpipe on to the charcoal, so that in less than half a minute the solder in the threads of the cap-piece was melted—the lower portion of the tube containing the thermometers being meanwhile wrapped in wet cloths to prevent the heat travelling downwards. The cap-piece having been unscrewed and the thermometers withdrawn, the highest temperature registered was found to be 97° Fah.

In spite of the tube having remained for twenty-seven hours under the great hydrostatic pressure it must have sustained at a depth of 2,733 feet, not a drop of water had found its way into the tube, a fact, which speaks for itself as to the excellence of the work done by the plumber, Mr. James Gilchrist, of 174a Pitt Street, Sydney.

On the following day the experiment was repeated, the tarred rope alone being used with a weight of only about thirty pounds, including that of the tube. This time the tube was withdrawn after it had remained down the bore one hour. The stoppage of the tube in the bore at a depth of 2,733 feet, was this time distinctly perceptible, and so the cause of the kinking of the piano wire on the previous occasion was explained.

The maximum temperature registered by the three overflow thermometers was 96° Fah. The maximum and minimum thermometer was found to have been shattered, probably through the jarring of the tube against the sides of the borehole. The lower temperature recorded on the occasion of the third experiment as compared with that of the second, was probably due to the tube carrying the thermometers and the sheet lead wrapped round it, (in order to increase its weight) having slightly chilled the water at the point where the temperature was taken, and the time allowed (one hour), before the tube was withdrawn having been too short to admit of the water around the tube in the bore resuming the normal temperature of the surrounding rock.
The above experiments were conducted without any special precautions having been taken against convection currents. It is impossible, however, that convection currents would obtain to such an extent as to materially alter the temperature in a bore-hole only four inches in diameter from 2,400 feet to 2,929 feet, and five inches in diameter from 2,400 feet to the surface. If therefore 97° Fah. be assumed to be the correct temperature of the earth's crust at Port Jackson at a depth of 2,733 feet, (and the authors do not think there is likely to be an error of more than half a degree in the temperature above quoted), the mean surface temperature being 63° Fah., as determined by Mr. H. C. Russell, the rate of increase in temperature down to a level of 2,733 feet would be 1° Fahr. for every eighty feet, after the zone of mean temperature, at about thirteen feet below the surface, has been passed. The temperature therefore at the depth at which the coal seam was struck, 2,917 feet, should be 2·3° Fahr. higher than that registered at 2,733 feet, that is 99·3° Fahr.

At the Metropolitan Colliery near Sydney, the rate of increase of temperature was found to be approximately 1° Fahr. for every seventy-eight feet. This result however, can be considered as only approximate. Experiments were also made with a view of ascertaining whether the water in the deeper portions of the harbour may have had any chilling effect locally on that portion of the earth's crust nearest the bore, so as to depress the isogeotherms. The temperature however of the water in the harbour at the greatest depths near Cremorne, varying from forty-five feet to sixty-three feet, was uniform at 68° Fah. The experiment was made on December 6th, 1893. The abnormally low rate of increase in temperature in the earth's crust downwards at Cremorne cannot therefore be attributed to any chilling effect of the water in the harbour. More observations will be needed before any definite conclusions can be arrived at. The comparatively low temperature at the horizon of the coal seam will obviously materially lessen the cost of ventilation, as compared with what it would have been, had the rate been 1° for every sixty-three
feet, as has so often been experienced in other countries under somewhat similar conditions.

VI. Possibility of Working the Seam,—With the efficient ventilation which can be secured by means of the most modern ventilating fans, there does not appear to be any reason to doubt that the temperature of the mine workings under the harbour at Sydney, can be reduced to 80° or even less. At the Metropolitan Colliery, Helensburgh, with a Schiele fan twenty feet in diameter working at the top of the upcast shaft, a ventilation of about 350,000 cubic feet per minute is said to be obtained, and the condition of the air in the mine is very satisfactory. The depth of the coal below high watermark at Cremorne—about 2,774 feet is undoubtedly great, but it is not by any means the greatest depth at which coal has been worked. Thus in England at the Ashton Moss pit, at Dukinfield, the workings were carried to a depth of 2,850 feet, while in Belgium at a Colliery near Charleroi a depth of 3,411 feet was attained.*

It may therefore be reasonably expected that the difficulties of working the coal under Sydney harbour can all be overcome with the aid of the most improved appliances for ventilating and hoisting. The only other question to be considered, viz., whether the trade that may be looked for in the near future will be sufficient to pay interest on the capital required to develop the mine, is a commercial rather than a scientific one, and is therefore outside the limits of this paper.