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Some Unpublished Correspondence of the Rev. W.B. Clarke

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Abstract: Four previously unpublished letters, with memoranda of Rev. W.B. Clarke to W.S. Macleay, written between 1842 and 1845 clarify the ideas of both about the mode of formation of coal and the age of the stratigraphical succession in the Sydney Basin. Clarke makes the first mention of his discovery of the Lake Macquarie fossil forest, the first identification of the zeolite stilbite in New South Wales and gives details of his study of the volcanic rocks of the Upper Hunter Valley.

Keywords: Clarke, Macleay, coal formation, Sydney Basin, stilbite

INTRODUCTION

When Dr Thomas G. Vallance died in 1993 a considerable amount of his historical jottings and memorabilia on the history of Australian science, and particularly geology, was passed on to me (David Branagan) through his wife, Hilary Vallance. For various reasons, only now have I been able to delve, even tentatively, into this treasure house. The present note concerns four letters of the Reverend W.B. Clarke (1798–1878), together with several additional related memoranda, which Vallance somehow acquired, written to William Sharp MacLeay (1792–1864), Clarke's great friend, and sternest critic, of Elizabeth Bay, Sydney. He transcribed the letters in part, and researched some of the historical and scientific problems which had emerged on reading the letters. I have continued the process.

The four letters were written as follows: Letter 1: 1 July 1842 (with additional memoranda 5 July 1842); Letter 2: 16 July 1842 (Figure 1); Letter 3: 28 May 1843, and Letter 4: 24 January 1845. Letters one and three were written from 'Paramatta' [sic], then Clarke's place of residence, the second from Petty's Hotel, Sydney, where Clarke often stayed when visiting Sydney in that period. The fourth letter was written at Muswellbrook in the upper Hunter Valley. The letters, in Clarke's hand, are here transcribed, but are presented and discussed, not in order of date of writing. The reason for this change of order is that the three later letters are relatively straight-forward, and essentially self-contained, although, of course, almost no letter can stand alone, but depends on the correspondents. Each letter has some importance in dealing with aspects of Clarke's geological work, as will be noted.

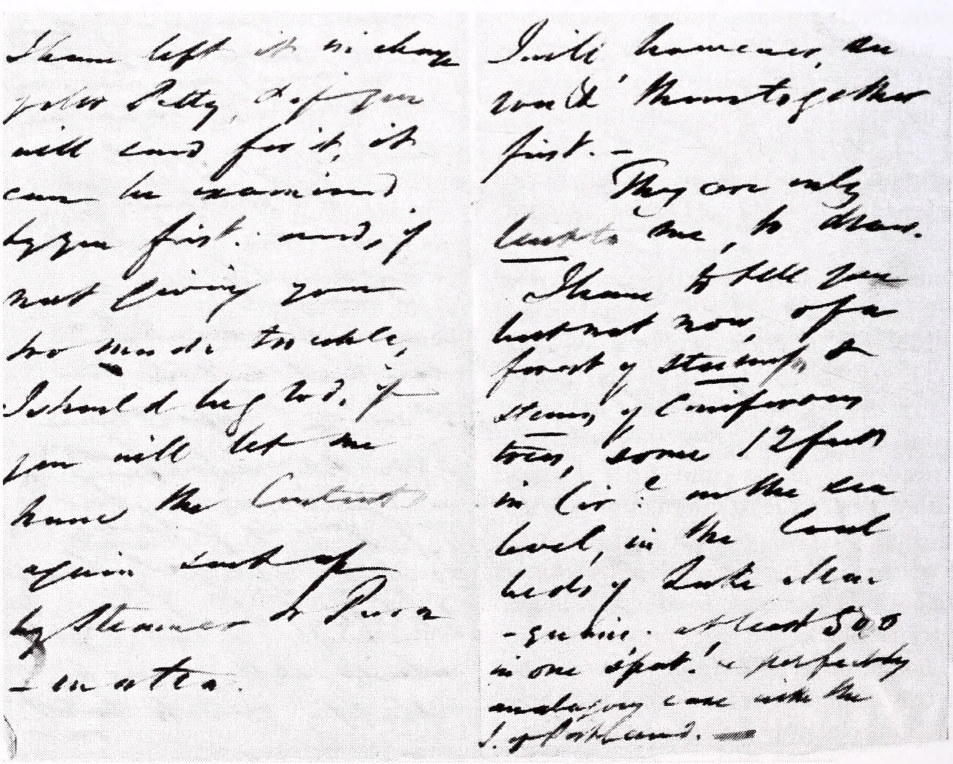
The first and longest letter, which is accompanied by a long series of memoranda and a labelled sketch fits between two letters from MacLeay (28 June & 4 July 1842) to Clarke. Both these MacLeay letters have been reproduced in Moyal (2003), as letters Nos. 30 & 31 (Moyal 2003, vol. 1, pp. 112–120). Part of the earlier MacLeay letter was also quoted by Jervis (1944, pp. 428–429), in which there are slight variations in the transcription from that by Moyal. The two MacLeay letters have been re-transcribed by us herein as there are a few significant, as well as less important, differences from Moyal's transcription, based on our interpretation of the handwriting, the addition of a few lines of postscript (with a sketch), and the advantages of the internet in identifying some doubtful names and historical events. Moyal (2003) in her vol. 1, page 115 footnote 1, reported 'Clarke's reply to MacLeay's previous letter has not survived.' This is the letter which has now turned up, with the previously unreported memoranda and sketch.

While some written words of both Clarke and MacLeay are difficult or impossible to decipher, and a few words are lost through tears, blots etc. the general gist of the letters and memoranda can be readily determined. We have based our interpretation of some words (mainly geological) on the geological literature which was familiar to both writers, and to which they allude quite freely. In addition to mentions of the work of e.g. Lyell (we use a readily accessible work of later date), Murchison, Sedgwick, De la Beche, Adolphe Brongniart we have given attention to other French and German authors, such as Bonnard, Dufrénoy, Thirria and Humboldt, who were involved in sorting out the stratigraphy and palaeontology of both the Palaeozoic and Mesozoic successions in Europe in the 1820s–1830s.

Some allusions in the texts are now less readily understood than they would have been in Clarke's time, and are briefly discussed in footnotes, with leads to more details in references, such as to those researchers mentioned above. For New South Wales locations mentioned in the letters see Figure 2.

The letters deal with aspects of Clarke's studies during his early attempts to sort out the stratigraphy of the Palaeozoic and Mesozoic rocks of New South Wales. They show to a considerable extent how his European (and particularly English) geological background influenced his Australian work, with his attempts to fit the Australian stratigraphy into the 'known' European framework, based largely on supposed palaeontological evidence, which to Clarke's mind, at the time, indicated that the New South Wales coals were considerably younger than the coal deposits of Europe. Thus Clarke's firmly-held attitude at this time was that the Australian (essentially the New South Wales) coals were of Oolitic (i.e. Jurassic) age, whereas MacLeay, perhaps acting in part as 'devil's advocate', kept pushing the coal age back down, although not necessarily to the Carboniferous, the period of the major deposition of coal in the northern hemisphere.

J.D. Dana (1813–1895), during his visit on the Wilkes' Expedition in 1839–40 had agreed with Clarke that the NSW coals did not fit the European system, but he thought them not much younger than Carboniferous, probably Permian, although he was prepared to have them as young as Triassic. However Clarke did not agree at the time. Dana's thoughts, although available in his notes and correspondence, did not become publicly available until the publication of his work on the Geology of the Expedition (Dana 1849).


I have left it in charge
of Mr Petty, & if you
will send for it, it
can be examined
by you first: and, if
not giving you
too much trouble,
I should beg to, if
you will let me
have the Contents
again sent up
by Steamer to Parra
-matta.

I will however, as
would them together
first. —
They are only
lent to me, to draw.
I have to tell you
but not now, of a
forest of stumps &
stems of Coniferous
trees, some 12 feet
in Circ.e on the sea
level, in the Coal
beds of Lake Mac-
-quarie. At least 500
in one spot! a perfectly
analogous case with the
I. of Portland. —

Figure 1. Clarke letter to MacLeay, 16 July 1842

The Australian coal argument, which was very important in the history of the development of Australian geology has been thrashed out by previous authors, particularly Vallance (1981), but see also Organ (1990) and Moyal (2003).

The Clarke Letters 2, 3 & 4 are now transcribed, followed, if appropriate, by a brief comment. Necessary clarifications and additional comments are placed in the footnotes.

Figure 2. Map of localities in New South Wales mentioned in the Letters

CLARKE LETTER 2 – TO W.S. MACLEAY

See Figure 1

[Addressed to] *W.S. Macleay Esq. Elizabeth Bay*
[Postmarked] *General Post Office Sydney, July 18 1842*

[Written at] *Petty's Hotel*[1]
Saturday [July 16, 1842]

My dear Sir,

The weather does not allow me to see you: but I have a box here, containing impressions of ferns etc. etc. from the Coal Shales of Nobby's[2] *and Newcastle which will much gratify you to look over.* [end of first page] *I have left it in charge of Mr. Petty, & if you will send for it, it can be examined by you first: and, if not giving you too much trouble, I should be glad, if you will let me have the contents again sent up by Steamer to Paramatta.* [end of second page]

I will, however, see [? damaged] ... *them together first.* —

They are only lent to me, to draw. I have to tell you but not now, of a forest of stumps & stems of Coniferous trees, some 12 feet in Circ^{e}: on the sea level, in the Coal beds of Lake Macquarie; at least 500! [hole in page] *in one spot! A perfectly analogous case with the I. of Portland*[3] [end of third page]

I have also 2 new shells from the Sandstone (above the Coal) of the Broken Back Range[4].

In haste, faithfully
W.B. Clarke

Comment

This letter is apparently the first mention of Clarke's discovery of the famous Kurrur Kurran Fossil forest, (See Figures 3 and 4), referred to in the letter from Clarke to Adam Sedgwick 29 August 1842, which enclosed Clarke's paper on the topic, for the Geological Society of London.[5] Several specimens were sent separately to Sedgwick.

Although Kurrur Kurran is a designated Geological Heritage site (Percival 1985, pp. 2–3; 88–89), sadly it is only a 'shell' of its condition as first observed by Clarke. Many of the stumps were souvenired over the years, some being used to built fences (still preserved) in the district (Ray 1993, p. 1 and photo) (Figure 5).

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[1] This hotel, owned by Thomas Petty, was at No. 1 York Street, Church Hill. It was earlier the house of the Rev. John Dunmore Lang (1799–1878). It functioned as a hotel into the mid twentieth century.

[2] At that time a small island with a steep cliff marking the entrance to the Hunter River at Newcastle. A project was in progress to link the island with the mainland to the south and prevent ships attempting to enter harbour through the shallow water south of the island.

[3] Clarke is referring to the occurrence of an 'ancient forest' exposed on the so-called Isle of Portland (a peninsula), Dorset, first described by W. Buckland and H. De la Beche (1835), and illustrated by C. Lyell (1878, p. 317).

[4] A range on the southern side of the Hunter Valley near Wollombi Brook. Mitchell (Foster 1985, p. 203), refers to 'Broken Back Mountain' as one of a series of trig points he established in marking the 'Great North Road from Wiseman's Ferry north to the Hunter'. Wells (1848, p. 94) lists it (Brokenback) as 'a mountain of N.S.W., situated in the county of Northumberland, S.W. of Maitland.' We are sure that the bed from which the fossils were collected was stratigraphically below the coal beds.

[5] For this Clarke letter to Sedgwick (August 1842) see Moyal 2003, vol. 1, 121–124. For a follow-up letter, Clarke to Sedgwick (2 February 1843) see Moyal 2003, vol. 1, pp. 130–133. See also J. Jervis 1944, p. 384.

Figure 3. Map of Lake Macquarie annotated by Clarke, probably 1842

Figure 4. Sketch of the Kurrur-Kurran Fossil forest by Clarke

CLARKE LETTER 3 – TO W.S. MACLEAY

Paramatta, 28 May 1843

My dear Sir,

I have just received from Liverpool Plains a small box containing various Bones dug up in making a well, from a depth of 94 feet. They appear to me to belong to some Marsupial animal — but they do not I think all belong to the same individual. I have a part of a jaw — two incisors — a tibia somewhat broken — two metatarsal bones – and several fragments of tibia. It is somewhat curious, that the flat regions west of the Dividing Range appear to abound in these relics, whilst none have been discovered east of it.

I have long been [end of first page of manuscript] *anticipating the pleasure of a call from you, and as I shall be obliged to pack up specimens in a very short time, I should like to shew you them here, if some day this week would suit you. By favoring me with a post to mention, what day you could come up I would take care to be within.*

With compliments to your family, I remain,

My dear Sir,
Very faithfully Yrs.
W.B. Clarke

Comment

We have not located the exact source of the specimens, but see *Sydney Morning Herald* October 1842 – 2 January 1843 (listed in Organ 1994, items 172–178). This letter was not Clarke's first encounter with Australian vertebrate fossils. Clarke had received specimens from J.C. Burnett (1815–1854) in June 1842, which might have been vertebrate fossils. Moyal (2003, vol. 1, p. 112 fn. 2), notes that Clarke wrote 'Mr. Jamison[6] has sent to Mr Macleay a fossil Saurian bone from his station, N.W. of the Liverpool Range far into the interior, – found 35 feet below the surface in mud. Will Mr. B enquire after such things in the wells of New England etc. etc?'.

[6] This is very probably Sir John Jamison (1776–1844) who acquired land on the Namoi River in the 1830s. He was a non-resident member of the Wernerian Natural History Society of Edinburgh (Walsh 1967).

MacLeay had already informed Clarke (16 July 1842)[7] about another supposed saurian bone from the Liverpool Plains obtained from a depth of 35 feet by his friend Alfred Denison. Clarke took up the matter of Australian vertebrate palaeontology with Richard Owen as early as 1847[8], and continued in touch by correspondence until his death.

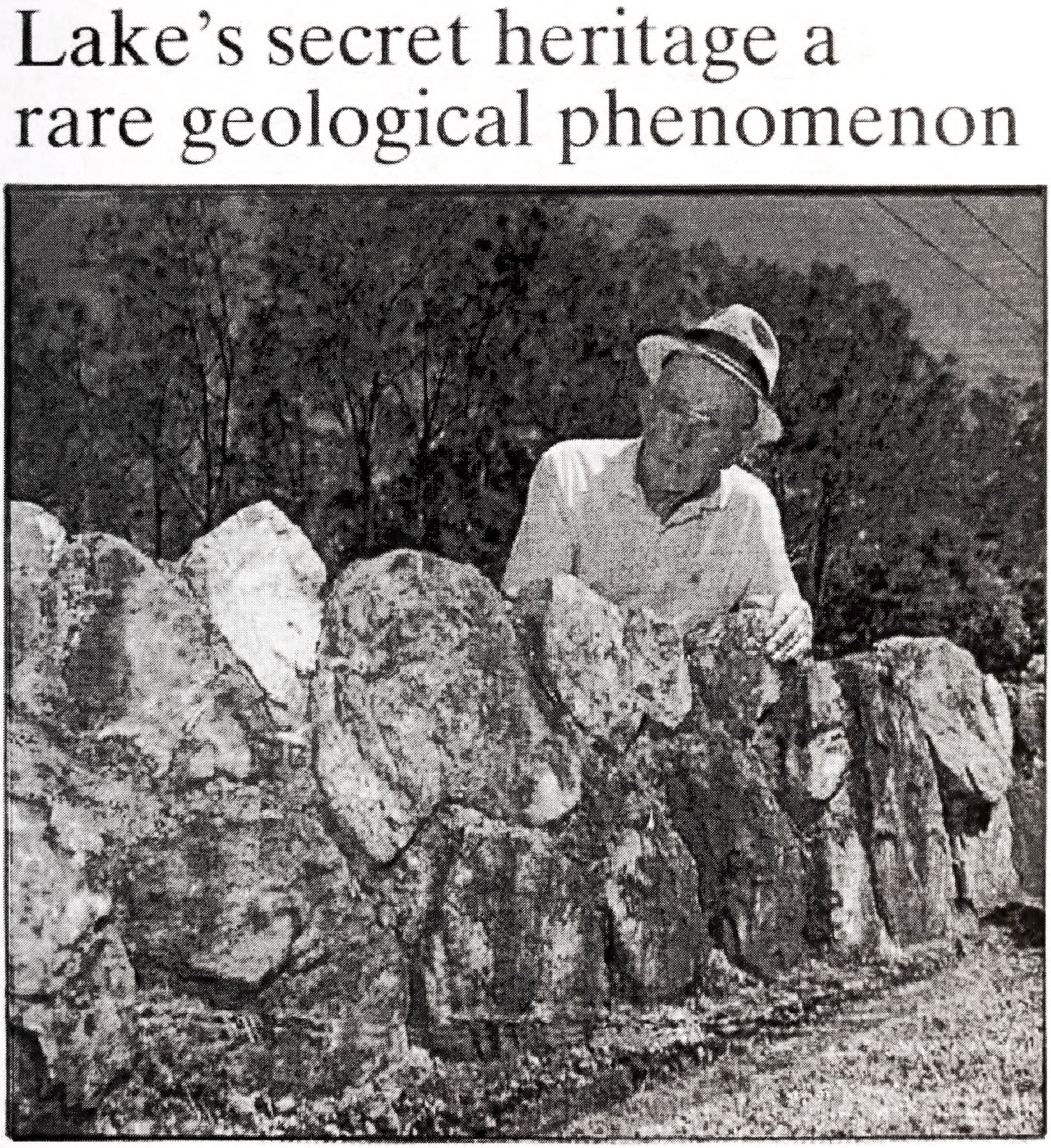

Figure 5. Fossil tree stumps used as a fence.

[7] MacLeay to Clarke 16 July 1842. see Moyal (2003, vol. 1, p. 121).
[8] Clarke to Owen, 30 November 1847 (in Moyal 2003, vol. 1, p. 217). The tone of the letter indicates that the two were already on familiar terms, particularly regarding the topic of fossil vertebrates.

CLARKE LETTER 4 – TO W.S. MACLEAY

Muswellbrook[9]
My dear Sir, *24 Jany 1845*

When I sent you those four wretched little specimens, I was anxious to have your determination of the Trilobite[10]*, with a view to fixing the place of the deposit in which it is found. — Perhaps, if you have not mislaid the paper on which the specimens were fixed, you will kindly look at it & tell me — what genus you put* [it] *in etc. etc.* [end of first page]

I have done some capital work since I have been here. I have examined carefully all the ranges from the Hunter at this place up Dart Brook, Middle Brook & Kingdon Ponds to their junction with the Liverpool Ranges, — I have also explored the ranges on the Page, Hunter & Rouchel to the Isis[11] *— have made out the order of succession of all — and the cause of the disruptions to the limestone mountain on the Page I have passed through, in a gorge which I found dividing it*[12]. [end of second page]

Trap – trap – trap! everywhere: it has cooked, burned and stewed the lower beds, and cleared out the fossils in such a way as to leave only thin coatings [? castings] *of iron. I have seen no more trilobites, but atrypae, leptenae & small delicate spirifers*[13]*, with abundance of crinoidea — much of the marble is composed of small globules — with a nucleus in the heart of radiating fibres. There are myriads of* [? another] *of this size.*  [sketch inserted in letter] *I cannot understand, what they can be: they are quite spherical.*[14]

I have found Coal beds in [end of third page] *all places — always, when that is present, under the spirifer-conglomerate which I now know, or rather believe, to pass into the Sydney Sandstone*[15]*. But in many places, as here, the coal beds have been burnt into brick by basalt, full of stilbite (like the*

[9] From the period of first settlement the town was known as Muscle Brook, because of the abundant shell-fish resembling mussels found in a local creek. This name was formalised in 1833. In 1838 the term Muswellbrook was introduced, and remains, although the original name was never officially altered (Chisholm, 1962, *The Australian Encyclopedia*, vol. 6, pp. 232–233).

[10] Clarke was the first to find and describe Australian trilobites. He defended this claim quite vigorously in the *Tasmanian Journal of Natural Science* in 1846 (Clarke 1849) referring to the specific date, 2 December 1842, when he found specimens at Burragood on the Paterson River. The claim seems to be valid.

[11] These streams are all tributaries of the Hunter River, north of Muswellbrook, see Figure 2.

[12] For the Carboniferous succession in the Glenbawn region, and the faulting see Osborne 1950, Branagan et al. 1970, Oversby & Roberts 1973, Mory 1978.

[13] For identification of the fossils referred to in the letters see some of the standard volumes on palaeontology of the period, e.g. Zittel (1913 et seq.). We have not italicised the fossils species names used in the letters, but left them as written.

[14] These are very probably descriptions of the oolites in the local limestone which occur in the Carboniferous succession in the Glenbawn region. 'Oolite' is not an age term here.

[15] This is perhaps an example of Clarke's rather hurried attempts to correlate the rocks of what later became known as the Sydney Basin. Clarke was already aware (see later, letter of MacLeay) that the Sydney Sandstone (in later years, continuing to the present it became known as the Hawkesbury Sandstone) was essentially un-fossiliferous, in stark contrast with the sandstone he studied in the upper Hunter region, which contained abundant marine fossils. The successions he was studying there, both volcanic and sedimentary, later proved to be of Carboniferous and early Permian age.

Dumbarton rock)[16] *— I have traced these brick beds to Ravensworth — and between that & this occurs a singular case where the volcanic rock is a true lava entangling the burnt glossopteris shales. — My Compts to Mr [&] Mrs Macleay & your Sister*[17]

Yrs. Very faithfully
W.B. Clarke

P.S. Will Mr. Macleay pardon my asking him to send on the enclosed under cover!

Comment

At this time Clarke was apparently thinking only in terms of a *single* coal succession (see Figure 6). Clarke later (before 1867) recognised two separate successions: the lower or older (Anvil Creek or Greta) and the younger (Newcastle coal measures and equivalents). There are in fact three coal successions. The intermediate 'Tomago' Coal measures were not separately identified in Clarke's time (see David 1907). For a general summary of Hunter Valley coal stratigraphy see Branagan & Packham (Branagan & Packham 2000, Table 4, p. 40).

CLARKE LETTER 1 AND THE TWO MACLEAY LETTERS

Introductory Note

Ann Moyal, in her massive two volume collection of Clarke's correspondence to and fro (Moyal 2003) has published a number of letters by William Sharp MacLeay to Clarke. Two that are relevant to the Clarke letter of 1 July 1842 are dated 26 June 1842 (Moyal, vol. 1, pp. 112–115) and 4 July 1842 (Moyal, vol. 1, pp. 115–120). It is clear from these letters that there is a massive argument going on about the mode of formation of coal, various stratigraphic matters and even the relation between geology and theology (or at least aspects of Biblical interpretation).

These MacLeay letters make much more sense if the intervening letter by Clarke is also read. The Clarke letter stands alone to some extent, but it is more easily understood if read with the two MacLeay letters.

Clarke indeed pondered over many of the points raised by MacLeay in his first letter, and there is an interesting set of notes (the accompanying memoranda) he wrote about particular aspects of the correspondence. He summarised, to some extent, his thoughts on the local stratigraphy with his figure (Figure 6). The three letters are now reproduced below in order.

[16] A reference to the then well-known occurrence of stilbite at Kirkaldy, in Dumbartonshire, N.W. of Glasgow (see, e.g. Dana 1932). Chalmers (1979) suggested that the first recognition of stilbite in Australia was made by Samuel Stutchbury at Garrawilla, north of the Liverpool Ranges in 1852 (see also Branagan 1992). The identification by Clarke clearly predates the Stutchbury find.

[17] Clarke is referring to W.S. MacLeay's parents, Alexander (1767–1848) and his wife Elizabeth (née Barclay) (d. 1847), who had completed Elizabeth Bay House (still extant) in 1837. W.S., a bachelor, lived with them from his arrival in Sydney in 1839, together with at least one unmarried sister. W.S. Macleay inherited the mansion on his father's death (MacMillan 1967). Moyal (2003, vol. 1 p. 106) notes that the various MacLeay's chose different spellings of the surname.

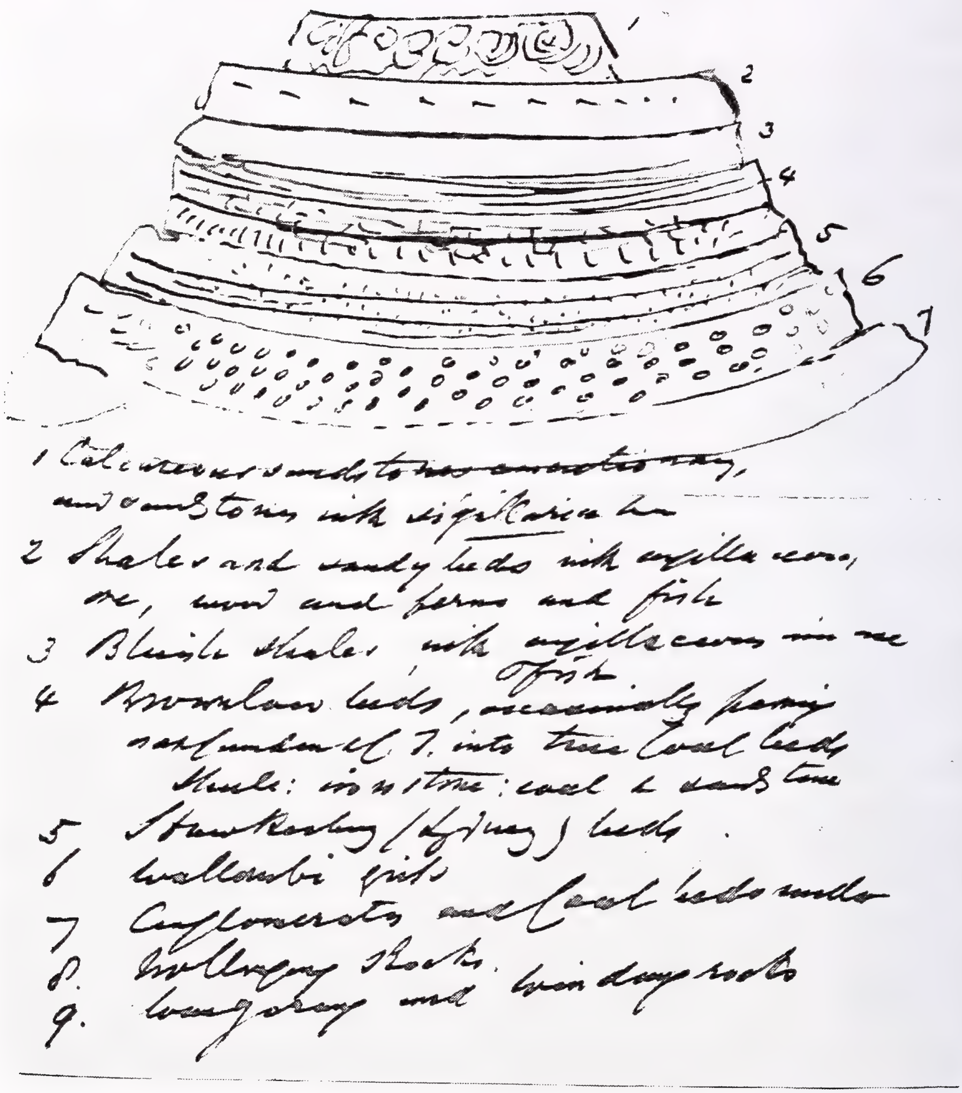

Figure 6. Labelled Sketch by Clarke, July 5 1842, showing the Sydney region stratigraphy as he understood it at the time (see Figure 2 for the named localities).

1. Calcareous sands to [crossed out ‘non concretionary’] and sandstones with sigillaria etc.
2. Shales and sandy beds with argillaceous, [?ore, ?...] and ferns and fish.
3. Bluish shales, with argillaceous [?iron ?ore] & fish.
4. Brownlow beds, occasionally passing, as at Camden [?etc] into true Coal beds

Shale: ironstone: coal & sandstone.

5. Hawkesbury (Sydney) beds.
6. Wollombi grits.
7. Conglomerates and Coal beds [?under].
8. Wollongong Rocks.
9. Burragorang and Windang rocks.

WILLIAM SHARP MACLEAY TO CLARKE

ML MSS 139/42, pp. 381–386
Written from Elizabeth Bay, 26 June 1842

My Dear Sir,

I have considered the subject of your last kind note and I have this evng [evening] *read in the Herald a hint which I suspect comes from a friend whom you are acquainted with intimately*[18]*; and as both of you seem to think that those persons are rather "obstinate" who do not adopt the opinion that the Coal Measures of N.S. Wales belong to the Oolitic age,*[19] *I shall now give you my reasons for thinking your theory is to say the least coram judice*[20]*. Not that I pretend to be the judge myself of this important Geological question, but that I would thank you or any other professed geologist to shew me who am but a dabbler in the Science how far the following crude notions are wrong before I consider the question as absolutely decided in your favour. —*

When the Earth first became habitable by Organized beings it would appear according to geological experience that the Plants and Animals were aquatic and of the lower organizations. When dry land first made its appearance ['. . . in Silurian' inserted on side][21] *which was probably about the Old Red Sandstone epoch, whether this land appeared out of the deep by reason of its own elevation or of the Subsidence of the waters it was apparently in districts comparatively confined on which neither Animal nor plant existed — life being as yet confined to the Sea. These limited portions of land appear in process of time to have become covered by a dense vegetation so dark and vicious that in these days we can form no idea of it except by viewing the enormous thickness of certain Coal beds. To account for this extraordinary large accumulation of vegetable life when the Coal Measures present no trace of terrestrial Animals, Brongniart*[22] *is of opinion, in which by the way he is supported by Phillips*[23] *and other Geologists, that the Atmosphere was at that early epoch charged with an extraordinary dose of Carbonic acid gas which made vegetation flourish while it prevented terrestrial animals from existing. Aquatic animals, Mollusca and Fishes however abounded during this Carboniferous period as well as during the previous Old Red Sandstone and Silurian epochs. Shall we say that the tremendous* [end of original page] *combustion under pressure that converted these ancient uninhabited forests into Coal destroyed nearly all Animal and Vegetable*[24] *life and made the lower new red Sandstone so remarkable for its paucity*[25] *of*

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[18] Macleay's comment was possibly a reference to Ludwig Leichhardt, whom Clarke had befriended. However Aurousseau (1968, vol. 2, p. 495) mentions Leichhardt writing to Gaetano Durando, 23 June 1842, commenting on the poor character of the *Sydney Morning Herald* and the other colonial papers. Using Aurousseau's information it seems unlikely that Leichhardt would have written to the *Herald*, suggesting that MacLeay's idea was probably incorrect, and Clarke's reply indicates the same. Leichhardt had some ideas about correlation of the Newcastle coal measures with the Sydney [i.e. Hawkesbury] Sandstone — an important early example of the idea of horizontal facies change (Branagan 1976, 1994).

[19] Moyal 2003 fn. 1, p. 115 reads 'The position initially advanced by Clarke'.

[20] Coram judice in Latin means 'set out before a judge'

[21] It is not clear whether the insert was made by Macleay or as a comment by Clarke.

[22] Sometimes the name appears written as Brogniart (this miss-spelling also occurred in early writings of Charles Lyell). MacLeay is almost certainly referring to Adolphe Brongniart (1801–1876), although Adolphe's father Alexandre (1778–1847) was also an important geologist. See Moyal 2003 vol. 1, p. 115, fn. 2 for more details.

[23] Possibly William Phillips (1775–1828), whose *Outlines of Mineralogy and Geology*, second edition 1816, remained popular, but more likely John Phillips (1800–1874), William Smith's nephew, whose *Treatise on Geology* (1837) was widely read. John Phillips is later specifically mentioned by MacLeay. See Moyal 2003 vol. 1, p. 115, fn. 3 for more details.

[24] In the right hand margin is an inclined line / crossed out.

[25] In the right hand margin are two vertical long and short lines crossed by a short horizontal line.

Organic remains? At all events an immense quantity of Carbonic acid gas must have been evolved. So we find no trace of true terrestrial Animals in the Poikilitic group of Buckland & Conybeare[26] *the Chirotherium being now understood*[27] *to have been an immense toad or at least a Batrachian*[28] *which we know to be of all the classes of animals the most independent of a pure state of the Atmosphere. Then comes the Grès bigarré* [29] *and the Lias in which other reptiles of a higher order were formed. These reptiles however be it observed were still Amphibious, or even aquatic. Then comes the oolitic and the first appearance of a Mammiferous quadruped in the Stonesfield Marsupial*[30]*. So that we may argue that the formation of Coal from the beginning of the forest to its combustion under pressure poisoned the air for terrestrial animals during a long series of ages; for would not the growth of such a ?dense mass of vegetation as form a Coal bed have required a vast supply of Carbon, and would not the quantity of carbonic acid gas evolved by the combustion of such a mass have rendered the existence of Birds and Mammalia impossible? A Reptile and more particularly a toad or any other batrachian might endure such a state of the air, but nothing higher in the scale of land Animals.*

I have studied carefully the fossil you have returned to my father; and find it to be a new Species of Ulodendron answering to Lindley's[31] *definition of the genus namely "Stem not furrowed but covered with rhomboidal marks the vertical diameter of which is nearly equal to the horizontal". Now Ulodendron is a genus peculiar to the ancient Coal formation. At least I cannot find in Thirria's list*[32] *of the fossils of the "Terrain Jurassique"*[33] *(which is synonymous with what we call the Oolite Series) any mention of those singular Coal genera Sigillaria, Favularia, Megaphyton, Bothrodendron and Ulodendron which Buckland makes so much noise about in his Bridgewater Treatise.*[34]

Again the cycadeous family of plants abound in the Oolitic Series but never have been found in the true Coal Measures; and I would ask if any Cycadeous[35] *or other family of plants peculiarly characterising the Oolitic has been found in N.S. Wales? I am aware of your specimen which you consider*

[26] 'and Conybeare' has been inserted. The term 'Poikilitic' (with its variant 'poecilitic') was introduced about 1836 to refer to the Permian and Triassic rock systems, 'as being composed of variegated rocks' (The *Shorter Oxford Dictionary* Third Edition, revised 1956, p. 1532). The AGI *Glossary of Geology and Related Sciences* (1962, p. 226) attributes the term to Conybeare alone in 1832, who applied it first to the group of rocks – the Magnesian limestone (dolomitic limestone) of middle Permian age, the New Red conglomerates together with the Bunter Sandstone (Triassic) of England. Adolphe Brongniart applied it to the Bunter only, and Buckland to the combined Permian and Triassic systems (Zittel 1901, p. 458). See also Lyell 1865 p. 430.

[27] In the right hand margin are two inclined lines containing 'Br...'?

[28] For this discussion see Lyell 1878, pp. 360, 361.

[29] The French equivalent of the Bunter Sandstone, the oldest of the three units comprising the Triassic of Germany (see Lyell 1878, p. 364). The French term is literally translated as 'multicoloured sandstone'.

[30] See Buckland 1824, *Transactions of the Geological Society* 2nd series 1 (part 2), 390–6. In the right-hand margin are five vertical ink stokes cut by a single horizontal stroke

[31] For information on John Lindley (1799–1865) see Moyal 2003, p. 115 fn. 5.

[32] Although MacLeay's writing is not clear for this word we believe this hard to decipher word is meant to be 'Thirria' for Charles Edouard Thirria (1796–1868), who with Peter Merian (1795–1883), studied the French Jurassic succession in some detail. Thirria published on the geology of the Jurassic ('Terrain Jurassique') of the Haute Saone. (Thirria 1830; see also Zittel 1901, pp. 429, 499), and, using fossils identified by Philippe Louis Voltz (1785–1840), compared this succession with the English sub-divisions (Zittel 1901, p. 458). We have not identified a Knot, the name suggested by Moyal 2003, vol. 1, p. 113

[33] Term given by Brongniart (1829).

[34] Buckland (1836) *Geology and Mineralogy considered in relation to Natural Theology.*

[35] Strictly speaking 'cycadaceous'

to be Cycadeous but may it not have been a voltznamian[36] *or other coal measure plant which had its folioles on the same plane, the only fact by which we deemed it possible that it might be Cycadeous? Have any Marsupial or reptile fossils been found in the Sandstone of New South Wales?*[37] *No. The fossils that have occurred as yet of a higher order than fish have been found in caves and indicate a very recent existence from their identity with existing*[38] *Genera and Species. Again have any Sauroid fishes such as characterize the Coal formations of Gt. Britain and as has been found at Newcastle N.S. Wales*[39] *been ever found in the Oolitic series?*[40] *Thirria's list tells me No.*

You express a wish that I would see what John Phillips says on the Subject of Coal beds in the Oolitic Series. I have consulted him carefully and I find that after alluding to the fact that the Belemnites of the Lias are found both above and below a great number of plants analogous to those of the Ancient Coal Measures, he says "These plants may be viewed as a remainder of the Vegetation of the Era of the Coal deposits transferred to a sea of organic beings of the earliest Oolitic Age"[41]*. By which I understand him to mean that such forests as formed the Coal beds occurring in the Oolitic Series did not grow in the Oolitic* [end of original page] *epoch, but were transferred by some convulsion and accidental cause to the Oolitic Seas. An hypothesis by the way that receives confirmation from the thinness of the seams of Oolitic coal as well as from the rarity of these occurrences and the quantity of fossils that occur immediately above this kind of coal. May not a thin bed of Charcoal formed in the true Carboniferous era but not yet from particular causes heavier than water have been floating about in the early Oolitic waters? By whatever accident or convulsion it got free may not this bed of charcoal have become gradually of greater Specific weight and at last have sunk and taken its anomalous place among the true Oolitic Strata? But however this may be and putting all wild hypotheses aside I must say that I still retain my suspicion that the sandstone of Elizabeth Bay corresponds with the lower New Red Sandstone of England. The Glossopteris Browniana is a fern that singularly characterises the Coal Measures of New South Wales, and no species of the genus so far as I know has ever* ['ever' inserted] *been found in the Oolitic Series.*[42] *Yet it is a curious fact that the same species Glossopteris Browniana occurs in the Coal measures of India. Are the Indian Coal Measures Oolitic? At the same time I beg of you to observe that I do not by this mode*['mode' inserted.] *of reasoning consider myself absolutely to say that the Coal here is of the same Age as the British true Coal measures; for on the one hand it may be stated that the same cause might produce the same effect in different places at different epochs, and again in answer to this it may be urged that Coal, notwithstanding if we believe in Brongniart's hypothesis of a Carbonic Atmosphere*[43], [end of original page] *must have been contemporaneously formed in all places since it is difficult to understand how the atmosphere of the globe should have been impregnated in one place*[44] *with such a strong store of Carbonic acid gas and not in another. — I shall be happy to learn from you how these my difficulties as to the theory of New South Wales Coal being oolitic can be got over. And in the meantime believe me*
My dear Sir,
Yours most faithfully,
W.S. MacLeay

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36 The word is doubtful but could refer to some of the voltz-like fossils described from the 'old' coal measures of Europe, and the Triassic (see Lyell 1878, p. 370).

37 In the left-hand margin are two small vertical lines crossed by two small horizontal lines

38 the word 'the' inked out.

39 Dana (1848) illustrated the fossil fish he was given when visiting the Newcastle Coal mines in 1839–40. Few such have been found in the Australian Permian coal measures, but numerous fossil fish have since been recorded from the Australian Triassic successions.

40 The word 'again' inked out

41 John Phillips *Treatise on Geology* 1837.

42 Moyal (2003, vol. 1, p. 115 fn. 7) indicates that this underlining has been done by Clarke, but we are not sure.

43 Possibly Alexandre Brongniart (1778–1847).

44 word after 'been' crossed out, 'impregnated in one place' inserted.

CLARKE'S REPLY – CLARKE LETTER 1

On the cover of the letter, addressed in Clarke's hand.

W.S. Macleay Esq. etc. etc.
Elizabeth Bay
Sydney
[Post Office Stamps]: *Parramatta Jy 2 1842*
General Post Office Sydney Jy 2 1842

Paramatta 1 July 1842

My dear Sir,

At the present moment I have scarcely time to reply as I would wish to your very interesting & instructive letter of 26 June[45] *, having only returned a few hours from an inspection of the country about Jervis Bay & the Coal Cliffs of Bulli etc.* [Figure 2] *& finding some arrears of correspondence on business matters, with a multiplicity of notes to digest & arrange. I do not like however, to put off to another date my acknowledgment of the favor you have conferred on me in writing so explicitly on the subject of your views, as to the age of the Coal in Australia.*

I must however, beg to say, that you must not hold me responsible for all you read in the Herald – or think me like the Barber in the play Figaro ci Figaro la[46] *– because there may be expressions in the article to which, in consequence of your remark, I have referred, which are perhaps so worded, as to convey more than they mean in strict interpretation: there may be more than one poker in the editorial fire.*

Whether the real Simon Pure[47] *be before you or not,* [end of first handwritten page] *or whether any other Naturforscher*[48] *– (Nature Poker) is engaged in stirring up the coals is little to the purpose. But so far as I read the article to express a doubt, & no more, as to the non-proof of the identity of Australian & Northumberland Coal* [goes! scratched out], *the case seems to me to run neck & neck with your assertion, which is most true, that there is no proof yet that the A.*[ustralian] *Coal is identical with that of the Oolite.*

Your view of the earth's geological progress is one which appears philosophical & true, one which (so to speak of myself in you ear) I have always held, with the exception, that if Combustion under pressure applies to Forests standing, I do not see how the Coal could be, in your plan, produced, & with the addition, that if, as I see no reason to doubt, Carbonic Acid gas was then as common as Soda Water now, it was necessary to be swallowed if there were throats for it to pass through, the wondrous abundance of vegetation, nourished by that gas, was wisely provided, not to [?] *prevent animal existence, but to prepare the earth for it by the invention of oxygen. And it may be said, in reference to this topic, that whilst Lindley's experiments*[49] *shew, that there was probably other veget* [end of second manuscript page of first folded section] *ation than the present Coal plants exhibit, so Moses in Gen. 1.10.11 declares, vegetation followed upon the earth's appearance above the primaeval waters, & preceded even the appearance of the Sun & the creation of the water-creatures.*

Admitting this, & further your idea of the Coal of the Oolitic age being merely emigrant charcoal of a former period (though I confess this is not so clear to me as many of the Q.E.D. in Euclid) though I always have thought all the rocks since the primary ones, save [perhaps] *limestone & some sandstones,*

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45 Moyal (2003, 1, pp. 112–115), reproduced above, but modified by us. In her footnote 1, page 115 Moyal notes 'Clarke's reply to MacLeay's previous letter has not survived.' It has survived and is presented here.

46 *The Barber of Seville* by P.A. Beaumarchais (1732 – 1799).

47 A term made popular in 1815 for the name of a Quaker in a play 'A bold stoke for a wife', impersonated by another actor, meaning a real, genuine or authentic person. See Shorter Oxford Dictionary, Third edition revised 1955, p. 1896

48 See fn. 18 above re Leichhardt.

49 Lindley carried out a number of experiments on the behaviour of plants under varying conditions.

derivative by destructive agency – such as the Old Red from Slates & Granites etc & the New Red from ?; the old – the Plastic Clay Sands from the Hastings & Green Sands etc[50] *& lastly the concretion-invested spirifers & corallines of the Australian, (perhaps) from rocks older than those now entombing them — I cannot see why we are to exclude Vegetation altogether from the Oolitic age, for there must have been trees & plants sufficient to make the small accumulations of oolitic Coal & Lignite: seeing Bush beasts existed,* [end of third manuscript page].

Take the case, however, as it is here – Sandstone & Shales, containing occasionally fossils of the sea land and marshes, & Coal of some sort, with abundance of evidence of fireworks & water frolics in trap dykes & [?] *abraded imbedded fragments – the* [letters crossed out] *problem appears to me to be solved not by the fact, that some of the organic remains abound in the Old Coal Beds of Europe, but by the preponderance of the evidence as to the other fact, that the greater part of these remains are generically oolitic rather than the other way*[51]

Now it was upon this ground, admitting all that can be said as to the presumption in favor of Mountain Limestone [52] *fossils, fish, plants etc that I ventured to surmise, that though in, these things are not of the formations in which they are found of necessity because they are in: your very argument as to Coal Beds.*

If we take mineral character of the rocks here, I am sure all the Books go with me in the supposition. If we take mineral contents, there is as much proof of the one side as the other, e.g. Salt. Salt abounds in the Saliferous deposits of the N. Red.[53] *Be it so. Salt abounds in the* [end of fourth manuscript page, being last page of first folded section] *Alpine oolites; in the Spanish tertiaries, in the Wielickza tertiaries* [54] *& elsewhere in rocks of a later age than the New Red. Again Hydrate of iron & pisolitic Iron etc is abundant in the Oolitic series; they also abound in the rocks of Australia. Alum is another distinguishing mineral, both here & at Alum Bay & Whitby*[55] *& elsewhere.*

Next as to geological structure: Where shall we find so close a parallel to the deep gulleys & abrupt vertical walls of rock so noticeable in the N.S.W. sandstone as in the Jurassic rocks of the Pyrenees?

But to come closer to your objections let us look at the acknowledged fossils – leaving the doubtful ones out of the question. In the Oolitic Period, including the Wealden Rocks, I think we may find nearly all the disputed evidence: & had I taken examples of the features above named, the Wealden Group would supply me with hundreds.

It is only fair to state here, that Mr Bowerbank writing to his friend Kirk[56] *says 'The fossils from Wollongong are the equivalents of the Mountain Limestone'*[57]*, & that* [end of fifth page, labelled 2, being

[50] In the 1840s the Cretaceous rocks were often subdivided into two, the Upper (Younger) Cretaceous consisting largely of 'Chalk' (white earthy limestone and marl), the Lower (older) of greensand. Although Lyell suggested the green colour was caused by the presence of chlorite, the greensands are usually rich in glauconite (hydrous potassium iron silicate, closely related to the micas). However, when examined in detail the rock succession was more varied than this. The Hastings Sands comprised the lower division of the Wealden Formation of Lower Cretaceous age.

[51] The last few words fitted in to the margin.

[52] Limestone of Carboniferous age, underlying the British coal measures.

[53] New Red Sandstone.

[54] This locality, south east of Krakow, Poland, is famous for its salt mines. Stanislaw Staszic (1755–1826) summarised the geology which is now shown at one of the localities in the present tourist mine system.

[55] Alum Bay, at the west end of the Isle of Wight; Whitby in Yorkshire.

[56] Probably James Scott Bowerbank (1797–1877), palaeontologist. Kirk is not identified; he is possibly William King (1809–1886) who studied English Permian fossils (Lyell 1865, p. 456 and Sarjeant 1980, vol. 2, p. 1452). Quote not identified.

[57] Placing the Wollongong fossils in the Mountain Limestone made them stratigraphically well under Clarke's proposed 'Oolitic' coals, rather than over them.

first page of second folded section] *they and the sandstone from Woodford*[58] *lead to the deduction, that there ought to be Coal very near the surface between these localities. Sedgwick also, writing to me*[59] *says that those fossils look like, not are, those of the M. L.*[60] *but that the vegetable remains differ.*

Silicified coniferous plants have been found abundantly in the Portland Oolitic beds [61]. *Almost identical plants, colour character etc agreeing occur not only on the surface in the Hunter District, but in the Illawarra rocks. Equisetums occur not only in our Austral Shale but at Brora*[62] *& in the Yorkshire oolites. Entrochi occur in the inferior oolite of the Haute Saone*[63] *: they occur, at least the branching species, in the fossiliferous rocks of Ja*['r' inserted]*vis Bay* [Fig. 2]. *Spirifers (distinguishing the Coal beds also) are met with in the Lias of Yorkshire, Bath, Lyme, Normandy, South of France, & the Hebrides. Mytili occur in the oolites of the same country. One, if not two, species, occurs in N.S.W. Ammonites occur in the Lias etc. etc. one at least is found here. Your Gryphaea & true oysters shew a great resemblance of* [?] *etc between the oolites &* [End of sixth page, being second page of second folded section] *Australian rocks: one species of oyster I saw at Black Head*[64]. *& I hope ere long, to shew, that they are abundant, as it is, in the sandstone on the range near Jere Wonglo Gap between Jarvis Bay & Argyle* [65]. *I am promised specimens. It may be incorrect, but I believe not.*

You lay much stress on the Glossopteris — Now Alex. Brongniart cites Glossopt. Nilsoniana[66] *from the Gres du Lias of Hör in Scania*[67]. *As to the G. Browniana occurring in India, till recently the Coal beds there were supposed to have been of the Oolitic age: but I have seen somewhere of late an attempt to shew, that they belong to your coal beds.*

Two other plants Pecopteris alata & Phyllotheca australis ("de classe douteux" A.[lex] *B.*[rongniart]*) occur in New Holland*[68]. *Six species of Pecopteris also occur in the oolites.* [several lines inked out here.]

Now, I think, without going further, & not taking into account the Belemnites! & Orthoceratites, species of which latter ['latter' inserted] *occur in the oolitic rocks of Italy, the balance thus* [end of seventh page, being third page of second folded section] *far, setting aside all that is common to the Terrain Houiller*[69] *& the Jurassic formations is in favor of the latter.*

But you ask whether any thing like the Newcastle Fish[70] *occurs in* [? ... not decipherable] *series? I say, I think so: for Mantell says a Lepidosteus (Lacepede) of the Pike Kind, is met with in the Wealden*[71].

There is one other point to which I would allude. Most of the fossils in N.S.W. occur in nodules. Is this the case in the Coal Beds of Northumberland or their congeners? It is the case with some of the Oolitic beds. For the Lias of Lyme contains similar nodules of argillo-calcareous substance, spheroidal &

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58 In the lower Blue Mountains, west of Sydney (Figure 2). A drill hole was sunk there seeking coal in 1888 (see Branagan 2005, p. 47).

59 Probably the letter of Sedgwick (1785–1873) to Clarke, 10 December 1838 (Letter 4 in Moyal 2003, vol. 1, pp. 72–73).

60 The Mountain Limestone (Lower Carboniferous) of Britain overlies Old Red Sandstone, and underlies the Coal Measures.

61 See Lyell 1878, pp. 321–322.

62 See later, fns. 96–98.

63 the eastern French province bordering Switzerland west of Basel.

64 Headland, 40 km south from Wollongong, the furthest point south reached by J.D. Dana on his expedition with Clarke in 1840 (Dana 1849, p. 491).

65 Jerrawongala, see Figure 2.

66 Nilssonia

67 Hör is a small village north of Lund in Scania (part of Sweden), the site of a rich bed of plant fossils in Lias (Cretaceous) sandstones, described first by Sven Nilsson (1787–1883).

68 New Holland, the earlier term for Australia, surprisingly still being used by MacLeay.

69 'Terrain Houillier', French term for the main European coal-bearing sequence. Adolphe Brongniart set up the broad classification of 'Terrains'.

70 see fn. 39.

71 Gideon Mantell (1790–1852) in his *Wonders of Geology* 1838, see also Lyell (1878 p. 301) for this fish, named by Bernard, Comte de Lacépède, (1756–1825).

fracturing in the centre. Again junks of wood occur there: so also much of the fossil wood of N.S.W. is in junks which have been cemented together after having been violently broken. [end of eighth page, being fourth page of second folded section] *I have not touched on a variety of points open to comparison. There are enough for the present, to shew you the grounds on which I have conceived the idea of the possible age of this country's coal.*

Lastly, however, which is the "unkindest cut of all" – I have in my late excursion satisfied myself, of what I before had suspicion, that the Wollongong fossiliferous beds are over, or in, not under the Coal[72]*: and in looking to my notes, I find the same conclusion almost indubitably proved respecting the Harpur's Hill beds*[73] *If this be so, what then becomes of the question?*

My solution would be, that the fossils, even if M.L. fossils, have been intermingled in one common medley with others belonging to a later era, & thus drift fossils are sometimes found in the Crag[74] *beds as well* [end of ninth page, being the first page of the third folded section, and headed 3] *as in the Diluvium*[75] *surmounting it; just as in Bornholm*[76] *Coal occurs with marine beds of all ages from the Silurian to the Chalk.*

When we behold the proofs of great denudating & destructive agencies about us here, and remember, that the original condition of this Continent was most likely an Archipelago, & consider further that the now deep ocean may occupy the place of older sedimentary rocks, such as M.L. Old Red etc it is not wild to suggest, that some of our fossils may be drifted from tracts now buried or submerged, & at a vast distance from us.

In fact, I believe, that it is actually necessary to take in to the account physical as well as fossilif – [end of tenth page, being second page of third folded section] *erous geology before we can come at the truth of the latter.*

These are my notions, wild, crude, & undigested they may be: but I place them before you, without hesitation, believing that though I am in your hands as a fly in that of a giant, you have gentleness of nature enough about you to use the giant's strength with delicacy & to crush my theory as Walton says of the frog on the hook[77]*, as "if you loved" me.*

I have seen a good deal in my late excursions, & know more than I did about the succession of beds.

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72 This is incorrect and is a somewhat surprising statement by Clarke, as while the coal measures are exposed at sea-level a few kilometres north of Wollongong the seams had risen towards the south, and at Wollongong were exposed below the cliff line of Mounts Keira and Kembla, west from Wollongong . The marine fossils were both topographically and stratigraphically lower than the coal measures (see also Dana 1849, p. 491). Clarke's statement seems to be contradicted by his Table (Figure 6), in which the Wollongong beds are shown below coal.

73 A fossiliferous succession exposed on the road to Muswellbrook (near Singleton) in the Hunter Valley, the hill being apparently named for Charles Harpur (1813–1868), poet. It is sometimes written as 'Harper'. The fossil occurrences were commented upon by various authors, such as the Rev. Richard Taylor 1838, p. 282; Dana 1849, p. 493, and his Appendix 1 pp. 681–720.

74 Beds of shelly sand occurring in the Pliocene (Mid to Late Tertiary) beds of Eastern England (Lyell, 1878, p. 172).

75 What is now known as glacial drift. The term was originally used to explain the extensive occurrences of unconsolidated material thought to have been left by the withdrawal of Noah's Flood. This idea lingered with some 'biblical' geologists, when evidence of continental glaciation became generally accepted from the 1840s. However the word continued as a useful term for these deposits.

76 Bornholm, Danish island in the Baltic Sea, SE of Denmark.

77 Isaac Walton's *The Compleat Angler*, chapter eight in the 1932 edition.

When I can spare time I am going to Lake Macquarie. Threlkeld has sent me a box of specimens[78]
The Maughan[79] *fossil I had marked down before I had your letter as Ulodendron or*[?] *Favularia. I* [?] *I was not far out. That remember was not in situ – but drifted – black fellow carried!*
Pardon the length & cacography[80] *of this scrawl & believe me*

Faithfully yours
I beg my compliments to the family *W.B. Clarke*

MANUSCRIPT MEMORANDA

This relates to the discussion in Letter 1 (Clarke to Macleay, 1 July 1842)
Dated at the end: Midnight 5 July 1842.

Mem:
Combustion. No proof such was the case. Charcoal, I believe, may be produced without combustion — & wood may be bituminised without fire — though perhaps not without heat whether derived from pressure or otherwise. Quere![81]
Moses. The word "appeared" was marked [?]. *I admitted the existence of the Sun before that time: his appearance could not take place till the fog & the darkness over the great deep was cleared off. I allow all that is said about the introduction of Scriptural Geology. & I have finished some forty or fifty pages against it*[82]. *My allusion to the subject was merely to point out a curious coincidence. I believe the days of Genesis to have been 24 hours long, & all fossiliferous rocks older than the history of the preparation, for the use of man, of the Earth after having been flooded & so to speak destroyed. Created in the indefinite Beginning (When ? – who knows. See Joh.1.1 –* [?]*)*[83] *it had been peopled — was destroyed & was again to be peopled.* ['granted' written along left-hand edge of this text] — [End of page 1 of Memorandum, the next page is headed '2']
Carbonic Acid Gas.
Is not the argument for this idea derived from the Limestones of the Silurian & Carboniferous eras? No[84] *Where are these limestones in Australia? All I have seen are plutonic*[85], *& for ought I know more recent than the Coal. I believe some are. Quere*
Preponderance of Species. By this I meant not that more or as many species of any one Genus were found in the oolites rather than in the M.L. & Coal beds: but that there were of species found in Australia more that could be referred, of all genera to the O. rather than to the M.L. & C. This is not the case
Conglomerates. The oolitic series contains such "Quartzose Conglomerates" in the Vallorsine, Trient, etc etc & are not confined to Savoy & the French Alps, but in the shores of Como & La Spezia abound (see De la Beche)[86]. *Quere*

[78] Lancelot Threlkeld (1788–1859), Congregational minister who opened a coal mine at Coal Point on the west side of Lake Macquarie in 1840 in opposition to the Australian Agricultural Company's supposed monopoly (Branagan 1972, pp. 65–66; see also Champion 1939).
[79] Not identified. It is apparent that both writers were familiar with the specimen and its origin. We have not identified either a place or person, and there are no Clarke or MacLeay letters of earlier date presently extant. We may have misread the word.
[80] 'bad writing' or 'incorrect spelling' (*Shorter Oxford Dictionary*, p. 245).
[81] Words such as 'Quere' etc at the end of each section are in pencil and apparently indicate MacLeay's reaction to the section.
[82] Clarke apparently never published these notes on Scriptural Geology.
[83] Probably referring to The Gospel according to John.
[84] See fn. 83.
[85] possibly meaning metamorphic, i.e. marble.
[86] De la Beche 1836.

The latter conglomerates separate the gneiss and mica slate of the higher Alps from the calcareous beds: they are composed of "rounded pieces of quartz [End of page 2 of Memorandum] *and porphyry & other rocks associated* [partly torn] *with beds of sandstone."* –

This is identically the case in the Blue Mountains (Hassan's Walls) & in Argyle (Gibraltar Rocks)[87] *may be so*

Rocks behind Eliz. Bay

They appear to me as much like the P. clay beds[88] *of Dorsetshire, or older: but I admit if for Shale with lignite we read 'Marl with gypsum' they might pass for a yellow variety of New Red. If the Sydney Sandstone be New Red, where are the red & green marls — & the gypsum?* *not necessary*

abrupt character of gulleys etc

Take the case of Normandy, where the oolitic series rests on the old rocks & the rivers have been cut down to the latter. *not to the point*

Grès des Vosges M. Bonnard[89] *says that what he calls 'Arkose', represent* ['ing' crossed out] *the ar*['a' crossed out] *enaceous beds of the lowest part of this ?unit of the Vosges; & Dufrénoy*[90] *says this arkose exists in S.W. France. This arkose (a sandstone – baked?) made up of felspar, quartz grains & cemented by siliceous or marly matter* [End of page 3 of Memorandum] *separates the* [damaged] *& oolites f* [inserted 'r']*om each other near Chatre* [sic]. *farfetched*

"This arkose seems to pass into lias limestone." Now if I interpret all this aright such arkose exists in the lower beds of the sandstone of N.S.W. a specimen of it, or rather a variety, goes to you with this.

Mica. I admit, generally, want of mica distinguishes the Oolitic rocks. Yet micaceous marls rest on lias in S.W. France: & micaceous brown sandstone [underwritten 'like greywacke'] *occurs in the Gulf of Spezia in ool. Series. (Salt encore. Mines of Halle in Austria*[91] *— oolitic. —) Silicified wood. If this lies in beds of sandstone above the Coal: it bears on the argument, presuming that of the Illawarra etc to be of same era as the Portland. Now such does lie in beds above Australian Coal. valeat consequentur*[92] *Gryphites. Two species occur in the great arenaceous formation of* [the] *Western Islands*[93]*. Six others in Lias.* [End of page 4 of Memorandum]. *Murchison & Sedgwick class the great sand & sandstone formation above the Brora Coal as the equivalents of the Great & Inferior Oolites. — the upper part sand & sandstone, the lower carboniferous shales & sandstones*[94]*. These are Murchison's words "with respect to Brora Coal, the purer part of it differs in no respect from the coal of the carboniferous series when subjected to chemical analysis: but it offers a mineralogical distinction upon being pulverised, assuming like all*[95] *lignites a red*

87 See Figure 2 for locations. Clarke is apparently referring to the Gibraltar Rocks, on the northside of the Wollondilly River, County Argyle, GR745651 in the far southeast corner of Chatsbury 8828-I-N 1:25 000 topographic Map, rather than the better-known 'The Gib' (Mt. Gibraltar) at Mittagong (Wells 1848, p. 179), which is in the adjacent county, Camden, close to the boundary with Argyle, and which consists of igneous rock, while the Gibraltar Rocks are of Permian conglomerate.

88 Plastic Clay sands.

89 Augustin Henri de Bonnard (1781–1857), a Freiberg graduate, author of Apercu géognostique des Terrains, *Annales de Minéralogie*, 1819.

90 Pierre Armand Dufrénoy (1792–1857), who carried out stratigraphical work in the Pyrenees (Zittel 1901, p. 501).

91 NW of Leipzig, now Germany.

92 'It is a logical consequence'.

93 Of Scotland.

94 Murchison & Sedgwick first worked together in Scotland in 1827 (Geikie, 1875, vol. 1. pp. 139–145). Zittel (1901, p. 432 incorrectly says 1826).

95 There is no underline in the original (Murchison 1829A, p. 301)

ferruginous tinge, and thus differing from the true coal which works into a black powder."[96] *In my idea the Brora coal is the best type of the Australian: if it is not*[97] *rather to be found in the Brown Coal of the Rhine.*[98] — [End of page 5 of Memorandum] [New page: top right hand corner '6'] *Unkind Cut. Not to Mr M^{c}Leay, but to old Dawson* [99] *and the Mountain Limestone folks. And how. If as Mr M^{c} Leay says – the beds containing the fossils be Recent — and they are all the "old Coal" people rely on — eadit questio*[100] *But since these beds are part of the Coal & Sydney sandstone series, for all are one, (I can prove it,) — if they in the middle be recent, what are the upper. — (recent i.e. comparatively so). —*

Limestone. 1. What is the age of the Aust^{n}. Limestone of Wellington etc Pentland says that of the Cave limestone of Yorkshire i.e. — Kirkdale ?etc i.e. Jurassic — or Ooltic[101] *—*
2. Where is there any, of the equivalents of any M.L. [102] *in N.S.W.? —*

Fullers' Earth. abundant near Newcastle, where I have seen a bed of it. Sulphate of Lime. in small portions, in the ['shape' crossed out] *form of fibrous gypsum, Bullai* [sic] *"Coal" Cliffs.* [End of page 6 of Memorandum]

Porphyry of P. Stephens [Port Stephens, Figure 2] [inserted 'Some', then several words lost as page is torn] *it is decidedly older than the sandstone* [inserted '& grit'] *which overlies it, & which are composed of pebbles & grains of porphyry — yet contain impressions of Newcastle Coal plants & casts of the Harpur's Hill fossils. The P. of P.S. is not all of one age — dykes of a later kind — later than the grit etc pass through the older, & tilt up the sandstone thus in one of the little islands.*[103]

[96] The quote is from Murchison *Transactions of the Geological Society of London* 1829, 2nd series II, pp. 293–353. Brora Coal refers to an 'anomalous patch of coal-bearing strata in the Brora district' in the eastern Highlands of Scotland, near where Roderick Murchison was born. Murchison carried out some of his earliest fieldwork on these rocks trying to see where they fitted into the stratigraphic column. Murchison thought the fossil evidence fitted with Oolitic rocks he had been shown in Yorkshire by William Smith and his nephew John Phillips, so that the Brora Coal did not belong to the 'true' British coals measures, of Carboniferous age. (Rudwick 1985, p. 68; Murchison 1829a; 1829b; Oldroyd 1990, p. 32 note 28; p. 47 note 64).

[97] Here the text is interrupted by two 'blots' separated by a rough near-vertical line. The blot on the left is identified as: '1 ?wet powder of Illawarra 'Coal' with an additional note stating 'there are redder varieties than this'. The blot on the right: '2 Cake of best Cologne Earth from Paint Box' (Figure 7)

[98] The German brown coals are about the equivalent of the Tertiary brown coals of the Latrobe Valley, Victoria. Their existence was virtually unknown in Clarke's day.

[99] The comment possibly refers to Robert Dawson (1782–1866), first 'Superintendent' of the Australian Agicultural Company (A.A.Co.), between 1825 and 1829, who exhibited (Friday Sept 15, 1837), a collection of fossils from New South Wales at the 7th meeting of the British Association for the Advancement of Science (Liverpool).

[100] 'likewise this is questioned'.

[101] Joseph Barclay Pentland (1797 – 1873), Baron Georges Cuvier's assistant, described the Wellington fossils following Cuvier's death. He is shown in the titles of these papers on the fossils (Pentland, 1832, 1833) as W. Pentland, possibly a misidentification of M. (for Monsieur). The Kirkdale occurrence was made famous by Buckland's exploration of 'a hyena's den' (Buckland *Reliquae Diluvianae* 1823). The Wellington limestones are Silurian.

[102] Mountain Limestone, essentially Early Carboniferous, underlying the European Coal Measures.

[103] The tilting has not been caused by the dyke intrusions, but is the result of regional folding, which Clarke might not, at that time, have seen in the region.

It also forms true prismatic columns on One Hill No. 1, 500 feet high, behind Tahlee House[104] *— This second porphyry is decidedly trappean & changes into, or ?intercalates with the Basaltic & Trappean rocks of Stroud. The "Coal" beds of Booral*[105] *also lie highly inclined in consequence — some also fossiliferous having casts in them of Spirifers: which I discovered when there in April.*

Porphyry of Oolitic ?age Humboldt says: "Dans la partie meridionale du Tyrol des masses de granite & et de porphyre syénitic qui (i.e. spec. Australas [?]) semblent même déborder du grés rouge dans le [End of page 7 of Memorandum] *calcaire alpin, et ces phénomènes curieux d'alternance, liés à tant d'autres plus anciennement connues, semblent condamner à la fois et la séparation du grès houiller des porphyres du terrain intermèdiaire et la denomination historique et trop exclusive de terrains pyrogènes." (Gisements des Roches p. 190)*[106]

He also mentions a porphyry in the Southern Hemisphere in the Andes cov'd by a "calcaire (alpin?)" with fossils etc He further names the porp[y][107] *associated with rocks younger than the "calcaire alpin" in another part of the country. But so far as Australia is cond*[108]*, the question is solved — Mount Hay & Mount George in the Blue Mountains are crested with overflowing masses of porphyry which have passed up from below*[109]

WBC *Midnight 5 July 1842*

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104 The main site of the Australian Agricultural Co. on the north side of Port Stephens, occupied by the Australian managers of the company, including P.P. King, and later his son P.G. King. The building is still extant. The nearest hill to the house is some 130 m high.

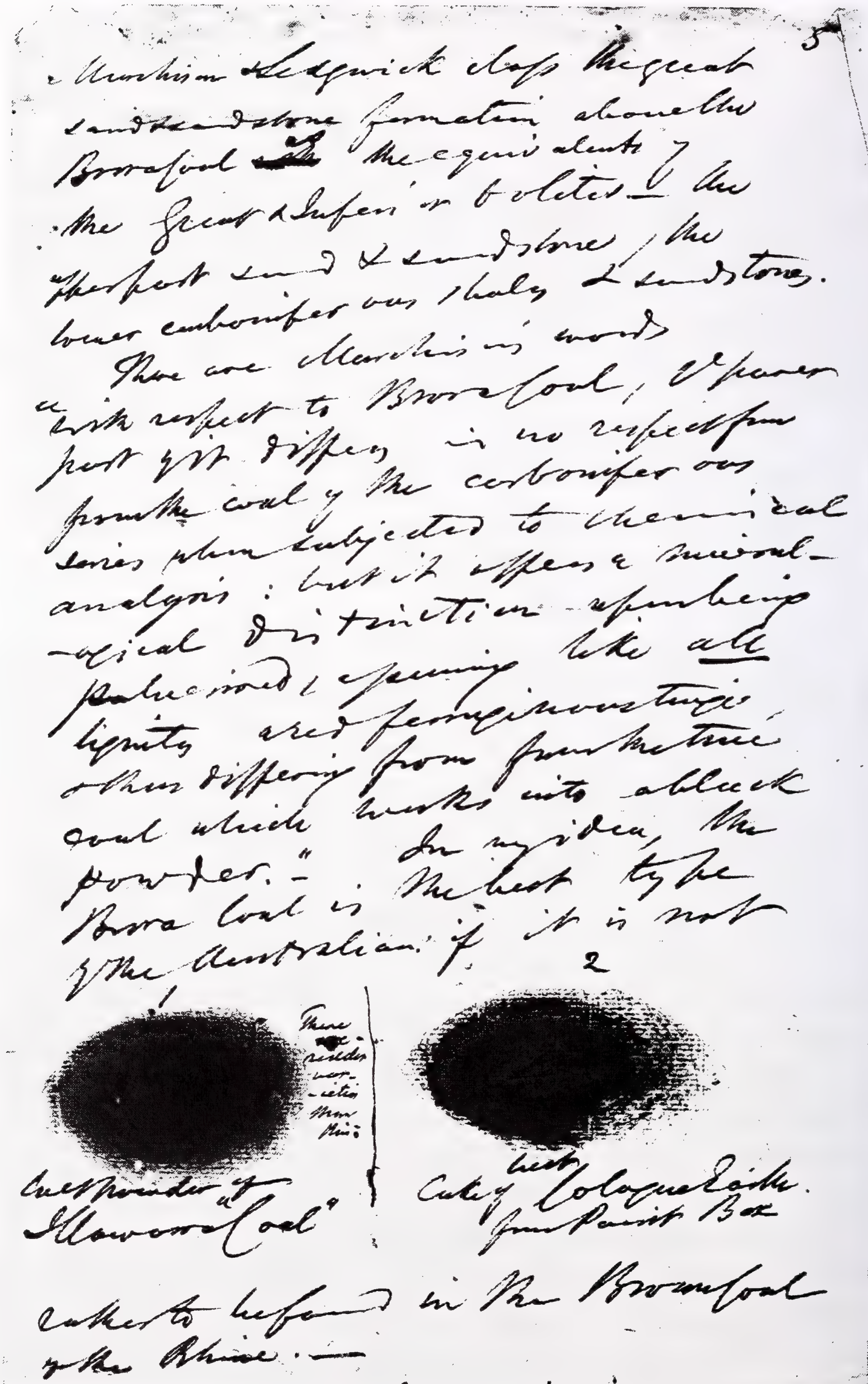
105 The coal beds of Booral are in the later-named 'Stroud-Gloucester Trough', and were first described in any detail by Ferdinand Odernheimer (1808–1885) a consultant brought (with his assistant Ernest Herborn, (?1827–1909)) to New South Wales to advise the A.A. Co.

106 'In the central region of the Tyrol are masses of granite and syenitic porphyry which seem even to extend beyond the red sandstone onto the alpine limestone, and these curious alternating phenomena linking up with many others, known to be much older, seems to assign [them] to the period of the separation of the sandstones of the coal succession from the porphyries of the intermediate succession, and to the historic and unique episode of the [formation of] the pyrogene [i.e. igneous] terrains.' Translation by Branagan 2008.

107 Porphyry.

108 Possibly abbreviation of 'concerned'.

109 These two mounts are capped by basalt of Tertiary age (mid-Miocene), between 14.6 and 17.7 million years old (Pickett & Alder, 1997). The name Mount [King] George has been replaced by Mt. Banks.


Murchison & Sedgwick class the great
sandstone formation above the
Browncoal with the equivalents of
the Great & Inferior Oolites & the
Upper sand & sandstone / the
lower carboniferous shales & sandstones.
These are Murchison's words
"with respect to Browncoal, I have
not yet differed in no respect from
from the coal of the carboniferous
series when subjected to chemical
analysis: but it offers a mineral-
-ogical distinction upon being
pulverised & exposing like all
lignites a red ferruginous tinge
otherwise differing from from the true
coal which breaks into a black
powder." In my idea, the
Browncoal is the best type
of the Australian. if it is not

1 | There are redder varieties than this | 2

Coal powder of Illawarra Coal | Cake of best Cologne Earth from Paint Box

rather to be found in the Browncoal
of the Rhine.—

Figure 7. Page from Clarke's memoranda (5 July 1842) showing his comparison of the two colours of powdered coal specimens.

MACLEAY'S REPLY

Eliz. Bay 4 July 1842

My dear Sir,

Mille choses! by which magic words I hope, a thousand thanks, Compliments etc are safely got over and perfectly understood by you. Our grand business is the Search after Geological truth, and therefore let us proceed to work not like two rustic bruisers in order to ascertain which is "the better man" nor yet roaring out like MacBeth "c—d be he who first cries hold enough" Rather like two peaceable warriors on a melodramatic stage let us be content with eliciting a few sparks of light from the collision of our respective weapons.

1. *You begin by questioning the accuracy of my expression "combustion under pressure" as applied to the Great Coal Bed. Perhaps the expression may be loose, but my idea of the formation of coal is this. Vast quantities of wood were carried down by the ancient torrents and deposited* ['on deltas or otherwise' inserted] *at the mouths of rivers whether these were clothed with standing trees or not. Here piled up, these masses of vegetation were covered by a Sea which seems gradually and quietly to have deposited its sediments around and over them whether the trees were standing or prostrate. Then again all was covered by a Sea which deposited beds of Sand over the mud. Then followed that tremendous fire which I think must have acted from without, burning the beds of sand that lay on the Coal, cementing them with iron and the carbonic acid of the shells they contained so as to form the lower New Red Sandstone while the mass of vegetables in the mud bed below was converted into Coal. My reason for supposing the fire that made the coal to have come from without is that the fossils of the several lower limestone formations would have been all melted down into marble and have disappeared had this great Conflagration proceeded from the centre of the earth. By combustion under pressure therefore, I merely meant the conversion by heat of the wood into coal under the pressure of the superincumbent Mud and Sand.*[110]

2. *As to what Moses says in Genesis of the Creation I have long thought the safest way <u>for me</u> would be to consider that if this lawgiver had adapted his lessons to the discoveries made by modern Philosophy instead of adapting* [end of original page] *to the state of knowledge of those he governed he would not have been understood by the Israelites. It is possible that as a clergyman you think you have a right to a more distinct exposition of my <u>belief</u> than this, and I am not the person to shrink from giving it. Thus I <u>believe</u> that terrestrial vegetation (for fucoids existed before in the waters) followed upon the earth's appearance out of the primaeval deep; but I doubt <u>(nay I will go further) I do not believe</u> that vegetation preceded the appearance of the Sun and of every kind of Aquatic Animal. I must disbelieve my senses or put faith in the Geological evidence* [several words inked out] *against such an antiquity of grass, herbs and trees. Nevertheless, I do not think I am placed in the sad predicament of conceiving the statements of Moses inconsistent with the truth.*[111] *On "the first day" the Creator said "let there be light" and he called this light day and the darkness he called night and he then divided that light <u>that is</u> day from the darkness <u>i.e.</u> night. It was on this "first day" then that the Sun was created; for on "the fourth day" if the Almighty said "let there be lights in the heaven to divide the day from the night" these clearly* ['were' crossed out] *had been already divided on the first day, and I therefore understand that by this apparently second division of the day and night is meant the division into the Seasons, day and year nearly as these periods of time at present exist. Nor do I imagine that there is any improbability in some great Astronomical Change of this kind having taken place long prior to the existence of Man. In short my interpretation of the Bible is that the Sun existed before the fourth day, but the Creator at that epoch* [end of original page] *made it to regulate the day and year as they at*

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[110] MacLeay's hypothesis on the formation of coal by fire is no longer accepted. Pressure and heat, together with chemical changes, caused largely by the pressure of cover of overlying sedimentary layers, interaction with underground water, intrusions and tectonic movements are known to be sufficient. See for example Dulhunty (1954).

[111] See Moyal (2003, vol. 1, p. 120 fn. 2), where she discusses Clarke's earlier comments and work on Biblical geology.

present exist. There is every reason to believe that there was no dry land until after the Silurian age; and yet during the Silurian age and consequently before terrestrial vegetation Fishes and trilobites lived in possession of eyes having a structure such as to show us that they were formed to meet light of much the same kind as fishes and Crustacea enjoy at present.

3. *As to the time of creation of the Aquatic Animals, I believe Infusoria to have been almost contemporaneous with the precipitation of water; that is, with the formation of the earliest primitive Strata. Reade discovered them in mica Slate*[112] *and Ehrenberg*[113] *has discovered infusoria living in hot springs and has shewn that the ancient fossil species are almost identical with those now existing. Indeed Infusoria must have lived to supply food to the Annelida of the Cambrian System and to the Polyps Mollusca and trilobites of the Silurian System. All these animals with the Crinoidea and Fishes of the same epoch must according to Geological evidence have existed before dry land. Do I then dare to contradict, – you will ask – the 20*th *verse of Gen.* [Genesis] *c.1. No, I believe that on the fifth day (which may have been for all that I know the Oolitic epoch) "moving creatures were created abundantly in the waters" although many Species existed in the deep during the previous epochs. That was the time when Ichthyosauri Plesiosauri and other Leviathans made their appearance. The word "whales" in our translation, is said to signify* [inserted 'in the original'] *any kind of large Aquatic Animals, and this to me is the more probable as I am not aware that there is any well authenticated fossil of Cetaceae prior to the Miocene tertiary formation. – So much for Mosaic Geology – But to say the truth I am no Hutchinsonian nor Granville-Pennite nor Dean Cockburnite*[114]*. I cannot* [end of original page] *consider the Bible as a Scientific book according to the vulgar meaning of the word Scientific; and although I do not conceive that Moses wrote anything inconsistent with the truth, I confess I have as much confidence in his opinion of the binomial theorem as I have in his dictum on Geology. If therefore you as a Hebrew scholar tell me that my interpretation of the Mosaic Cosmogony is not borne out by the original, however it may square with the translation, I shall not much care, as on this head at least my Conscience is void of offence. I say this however with all the respect which is due to such a subject and to the profession of the person I am addressing.*

4. *I surely made a gross mistake if by any expression in my letter I seem to you to exclude vegetation from the Oolitic age. The Cycadea and other plants of the Oolitic and the Herbivorous Iguanadon as of the Wealden* [115] *would contradict me at once if I had been so absurd. But I never meant this whatever I may have written. All I said or at least all I meant to say was that in the Oolitic epoch there were no such enormous masses of vegetation as to require the extraordinary dose of Carbonic acid gas which Brogniart* [sic] *deems to have been necessary for the Great Coal bed vegetation.*

5. *The Problem as to the age of the Australian Coal appears to you to be solved not so much by the fact that some of the organic remain(s) abound in the Old Coal Beds of Europe as by the predominance of the evidence* [end of original page] *in support of the other fact namely that the greater part of these remains are oolitic rather than otherwise.* [see Figure 8] *For the "sake of peace and quietness", I shall grant that the problem is to be thus solved; and now I ask does the evidence so preponderate? I shall venture to discuss seriatim*[116] *the evidence which you give as to this point. In the first place you acknowledge yourself that as to mineral contents there is as much proof on the one side as on the other; but* [inserted 'you'] *refer to the mineral characters. I am not sure that I rightly comprehend your reference, but my notion as to "the Mineral Character" of these rocks is, that the Sandstone and Quartzose Conglomerate which characterizes the neighbourhood of Sydney agrees with the character of the Millstone Grit that lies under the old Coal Measures and also with the character of the Grès*

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[112] Reverend Joseph Bancroft Reade (1801–1870) microscopist and photographer (Serjeant 1982).

[113] Christian Gottfried Ehrenberg (1795–1876), microscopist (Serjeant 1980 , pp. 948–950).

[114] See Moyal 2003, vol. 1, p. 120, fn. 3,for further on Hutchinson, Granville Penn and Cockburn, defenders of the Mosaic story.

[115] Moyal (2003, vol. 1, p. 117) notes here several words blurred. We read them as 'of the Wealden'.

[116] 'one by one in succession'.

bigarré of the New Red that lies above them; but where is there any [inserted 'sandstone'] *rock bearing the character of a Quartzose Conglomerate in the Oolitic Series? Again I am ignorant of any place in the Oolitic where you will find the layers of sandstone separated by micaceous lamning* [117] *although it is a character common in the sandstone of the Poecilitic Formation* [118] *and in* [inserted 'the'] *Rock behind this house. With respect to Geological Structure you ask where we shall find so close a parallel to the deep gullies and abrupt vertical walls of rock so noticeable in the NSW Sandstone as in the Jurassic Rocks of the Pyrenees? I answer that I find a much better parallel in the precipices of the Pays des Vosges; for in addition to its like abrupt structure the Grès des Vosges is a micaceous sandstone free from fossils like the Sydney rocks whereas the* [end of original page] *precipices of Jura are Calcareous and abound with fossils of the genera Pteroceras Nerinaea etc.. In short, it may possibly be my ignorance, but I would say that in general Limestone and Clay are the prevailing constituents of the Oolitic Series, Sandstone being the exception, whereas Dolomite and Marles*[119] [sic] *form the exceptions in the New Red System of Sandstone.* [see Figure 8]

6. *You say that the Silicified Coniferous plants of the Hunter River district and Illawarra rocks are almost identical with those of the Portland oolitic beds. For my part I have never seen and know nothing of the coniferous plants of the Portland and Illawarra beds; but supposing the silicified plants of the Upper Hunter and Illawarra districts to be of the oolitic epoch I do not see how this can affect my arguments with respect to the* [inserted 'age of the'] *Sydney Sandstone which lies immediately over our Australian coal. Equisetums you mention as occurring not only at Brora but in the Yorkshire Oolite; and on examining this matter I find that the Equisetum Columnare ie. one solitary species does indeed occur at both these places and is the known* [inserted 'Oolitic'] *species; whereas twenty species and two different genera of* [several words inked out here] *Equisetaceae are described from the old Coal measures. By the way the Australian genus appears to be "Calamites" – a genus that has never yet occurred in Europe but in the Old Coal strata where 17 species are known. I confess I respect the whole family of Sauroid fishes so abundant* [end of original page] *in the Coal measures more than the solitary individual which you mention as having occurred in the location. And as to the Entrochites which you mention from the inferior Oolite of the Haute Saone, I will add to them those that are found in the Oolite of various other parts of France of Germany and Switzerland together with the Pentacrinites vulgaris*[120] *of the Yorkshire Oolite; but at the same time I must beg attention to this fact namely that Crinoidea first made their appearance as early as the Cambrian System, (see note p. 710 of Murchison's Sil^n. System) and are abundant in every System between it and the Oolitic not even excepting the old Coal Measures; therefore valeat quantumide*[121]. *So also Spirifer is a genus which you acknowledge in the Carboniferous Series, but they are most abundant in the Silurian system. Mytilus is a genus common in the New Red and one species of it occurs in the Old Coal. Six species of ammonites are described from the true coal beds, and according to Thirria's*[122] *list the genera Ostrea and Gryphaea occur in the Silurian System (or what the French call 'Le Terrain Schisteux'), but I confess I have my strong doubts of these two last* [?] *genera being so old since Murchison makes no mention of them. Ostrea, however, is to be found in the lists of the New Red Sandstone, Gryphaea is not. And I therefore hold your Gryphaea to be a most interesting specimen*[123]. *The abundance of this genus is no doubt a marked characteristic of the Oolite, but what is singular, it appears never yet to have been found in Europe in the grès du Lias which I imagine to*

[117] Laminations.
[118] = Poikilitic, as previously (fn. 26).
[119] This alternative spelling of 'marl' was apparently widespread at the time. The term, although widely used, was never firmly defined, being applied most often to lime-rich clays
[120] This species does not appear in the list in De la Beche, 1836.
[121] valeat quantumide means 'cancels out'
[122] See fn. 31, re Thirria.
[123] Moyal (2003, vol. 1, p. 120 fn. 5) suggests this underline is by Clarke. We are not sure if this idea is substantiated.

be the French name for the Oolitic Sandstone. But granting that curious Corinda [124] *bed from which you obtained your Gryphaea* [end of original page] *to be oolitic – of which by the way there is as yet no proof – even this would not affect the validity of my side of the question which relates merely to the age of the Australian Coal and Sydney Sandstone.*

7. *As to "the unkindest cut of all" namely your discovery of the Wollongong and Harpur Hill fossiliferous beds being over the Coal, I imagine it would be a still more unkind cut for me than "the unkindest" if you had happened to have ascertained such recent formations to be under the Coal; for I never have imagined these formations to be Mountain Limestone but think them to be an ancient volcanic detritus washed down and forming a Sediment enclosing various ancient and more modern shells, which Sediment has afterwards become a concrete, fossiliferous Rock by means of Carbonic gas or iron, the two great causes of Rock concretion.*

8. *And now*[125] *with respect to the Sandstone fossil in your possession which in consequence of its leaves being in one plane we fancied might be Cycadeous. I have considered the matter and have no doubt of its proving a new Species of Brongniart's coniferous genus Voltzia which characterizes the Grès bigarré. I have an undescribed coniferous living tree from Moreton Bay allied to this New Red Sandstone genus and like it having its leaves in the same plane. You will find a figure of two species of Voltzia*[126] *in Mantell's "Wonders of Geology".*[127] *This Voltzia may have drifted like the Ulodendron but you will grant that the Old Coal cannot be far off from the place where they were found, more particularly if "drifted by blackfellow".*[128] *So you see my dear Sir that I do not get to say ?"proven"*[129]*, and will died hard, not confessing anything more than it is no joke and requires a long wind to contend with you.*[130]

For [end of original page] *a little time therefore I leave the subject in order to take breath, since he that fights and runs away may live to fight another day,*
Believe me
Yours very obediently
But sincerely
W.S. MacLeay

Have you ever heard of the occurrence of Selenite (or some other form of Sulphate of Lime) and also Fullers earth[131] *in Australia?*

I believe you will ?find an expression in my last letter by which it would appear that I had forgotten Professor Hitchock's discovery of a trace of a phalangeal[132] *Bird* [word obscure] *in Grès bigarré*[133] *beds of Connecticut N. America. I sit corrected in this respect, but there is nothing of it in the lower Red*

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[124] Corinda possibly refers to the property of Archibald Bell (1804 – 1883) near Singleton, on the Hunter River (Wells 1848, p. 135), which he established in the mid 1820s (Heydon 1966, p. 80). The rocks from this area are largely Permian or Carboniferous, but might possibly be as young as Triassic. Clarke (1878, pp. 137, 139) refers to a number of fossils from 'Korinda'. These beds are Permian, older than the Coal succession.
[125] word crossed out 'with respect' written above those crossed out.
[126] 'of Voltzia' inserted. Named for the palaeontologist M. Voltz of Strasbourg d. ca 1849
[127] Mantell's *Wonders of Geology*, published 1838.
[128] An interesting recognition of the transportation/trade of stone by the Aborigines.
[129] It is not clearly the word 'proven'.
[130] See Moyal (2003, vol. 1, p. 120 fn. 6) for more on the MacLeay/Clarke relationships on these matters.
[131] Clarke mentions it in his memoranda (see above) as occurring at Newcastle.
[132] This word is uncertain. The word might possibly just be 'prehistorical'. However MacLeay is referring to the discovery by Edward Hitchcock (1793–1864) of Amherst College, of footprints of what he thought were made by web-footed birds in the Triassic sandstones of Connecticut (Hitchcock 1837). We now recognise them as reptile and dinosaur tracks. For Hitchcock see Sarjeant 1980, 1267–1268.
[133] Words inked out, replaced by 'Grès bigarré'.

Sandstone. Pray remember that I do not say that there is no member of the oolitic series to be found [?] in Australia. I am only arguing for the Antiquity of the Sydney Sandstone and[?] Coal. On reading over your letter I find I have omitted to notice your mention of the species of pecopteris found in the Oolite. On this head all I can say is that no less than 75 species of pecopteris have been described from the the Carboniferous Series !!! The occurrence of the Orthoceratite[134] *at Lyme Regis is doubted. Dechen considers it 'ie alveoloe de Belemnite'.*[135] *At all events this is the only existence of an Orthoceratite in Oolite. If indeed you have found a true Belemnite in NSW the matter would be worthy of some attention. I am not yet in a state to answer your question as to the fossiliferous nodules. Another question occurs to me namely does not Porphyry of Port Stephens shew the immediate vicinity of Old Coal instead [of] the vicinity of oolite? When does a Porphyritic dyke traverse Oolite? I suspect the Port Stephens Porphyry to be a Plutonic Rock*[136] *older than the oolitic rock. But there is no end to my novissima verba.*[137]

[Additional Notes, possibly by Clarke]
Glossopteris Nilsonni Hörn ? Coal was considered oolitic Limestone of Wellington by Pentland and oolitic same as that of the [?] Hersian[138] *cavern*

See De la Beche p. 332 Plants of the Pine [?] Tribe identical with those of Pentland.

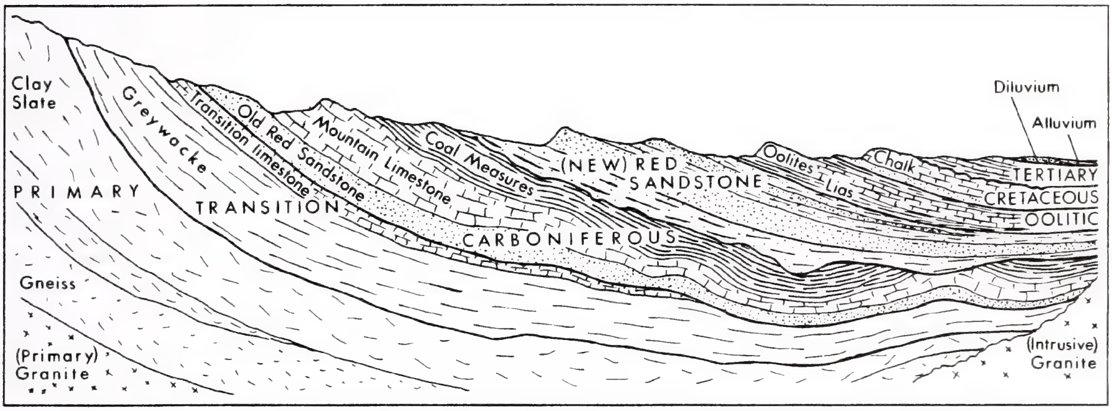

Figure 8. Generally accepted British and comparative Continental European stratigraphic terms of the early 1840s, as used in the letters (Buckland, 1823).

134 A cephalopod.
135 Heinrich [Ernst Heinrich Karl von] Dechen (1800–1889), geologist and explorer thought the supposed cephalopod was the 'conical chamber of a Belemnite'. Source of the original quotation not located.
136 The Port Stephens rocks are not plutonic, but flows or explosive eruptive rocks.
137 My last words.
138 Not identified

The original Clarke letters have now been deposited in the Mitchell Library, and will presumably be added to the Clarke Papers: ML MSS 139 Collection.

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The authors are grateful to Professor Hugh Torrens (Keele Uiversity, UK) for advice on some 19th century British geological terminology, the Mitchell and Fisher Libraries in Sydney and the enthusiastic editorial staff of this journal (Bruce Welch and Mike Lake) for ensuring effective presentation of the historical material.

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Searching for ETI

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Abstract: The search for extraterrestrial intelligence is a scientific experiment which has been pursued for the last forty-five years. Over one hundred searches (ranging from one-off to sporadic and continuous) in both the microwave and optical regions of the electromagnetic spectrum have been carried out during this time. To date no ETI signals with the required signature have been discovered. This paper discusses some of the most significant searches and future directions in the search for extraterrestrial intelligence.

Keywords: ETI search strategies; ETI radio searches, Nanosecond pulses.

INTRODUCTION

The scientific search for extraterrestrial intelligence or SETI for short had its beginnings in the second half of the 20th century. In its early years the SETI program was plagued by questions of its validity as a scientific discipline. In fact, several members of the IAU Commission 51 were extremely critical of it. However, this has not stopped astronomers and astrobiologists from continuing the search for ETI in the electromagnetic spectrum.

GENESIS AND RADIO SEARCHES

The genesis of the modern SETI experiment was a seminal paper published by Cocconi and Morrison in 1959 (Cocconi and Morrison 1959) which suggested that radio telescopes should be used to look for signals at 1420 MHz (21 cm line) from seven sun-like stars within 15 light-years from the Sun. Within five years of the publication of this paper in the scientific press several lines of inquiry were established, viz: radio, optical, probes and biospheres. The emphasis placed on each of these methods was different.

The first radio search was conducted in 1960 by Drake in his now famous Project Ozma experiment (Drake 1961). The search failed to detect any signals from ETI civilisations

Four search strategies emerged (brief directed searches on available telescopes, piggyback searches which operated on telescopes being used for mainstream astronomy programs, dedicated searches and distributed searches by amateur SETI astronomers worldwide) after Drake's historic search. Both targeted and sky survey techniques have been used. The microwave searches have mainly been carried out on so called 'magic' frequencies (the 21 cm hydrogen line) with frequency resolutions varying from Megahertz to a few hundredths of a Hertz. The size of the radio telescopes has ranged from a few metres in diameter to the giant 305 metres instrument at Arecebo, the world's most sensitive and largest radio telescope.

About ten years after Project Ozma the first dedicated search in the USA for ETI signals was carried out under the direction of J. Kraus and R. Dixon at the University of Ohio. Although a number of candidate signals were detected during the course of the program, including the now famous Wow! signature, however, none of them were reconfirmed. The Ohio SETI group is now engaged in the design and construction of the Argus radio telescope. The Argus telescope which is designed to cover most of the sky at L-band consists of a planar array of mass produced omnidirectional antennas which are capable of 'seeing' in all directions of the sky at once. (Ellingsen et al. 2008).

The Harvard University group began their SETI searches with suitcase SETI which was later reconfigured as Project Sentinel in 1983. Suitcase SETI was a portable high-resolution spectrometer developed in 1978–82 and connected to the Arecibo radio telescope in March 1982. It was further developed into META (Megachannel Extraterrestrial Assay), META II and BETA. All these instruments were used to carry out all-sky surveys. The Harvard BETA instrument scanned the waterhole region with a 250 million channel receiver, each channel being 0.5 Hz wide. It used a 26 metre dish and scanned 68 per cent of the celestial sphere four times from October 1995 until March 1999 when the antenna's mounting broke in a windstorm. The telescope was dismantled in May 2007.

The negative results of the BETA search has allowed the Harvard group to set some limits on the prevalence of transmitting civilisations albeit with certain qualifications (Leigh and Horowitz 2000). None of the archived candidates had the characteristics of an extraterrestrial signal.

The SERENDIP (acronym for the Search for Extraterrestrial Radio Emissions from Nearby Developed Intelligent Populations) program has its home at the University of California and began operations in the 1970s. It was designed for use in piggy back mode. This was to get around the difficulty of not being able to get telescope time on major radio telescopes. The SERENDIP equipment at the University of California has undergone a number of evolutions, viz: SERENDIP I, SERENDIP II, SERENDIP III, SERENDIP IV and SERENDIP V. Each stage in the evolution has been more complex and sensitive than the previous one. The number of channels has increased at each stage of its development. SERENDIP IV was designed and run by Werthimer, et al. (1997) in piggyback mode as an all-sky survey on the Arecibo telescope. The survey used a 168 million channel FFT spectrum analyser to search for narrow band radio signals in a 100 MHz band centred at the 21 cm hydrogen line. The system had a 1.7 second integration time, 0.6 Hz resolution and a sensitivity of $10^{-24}\,\mathrm{W/m^2}$. The latest SERENDIP V is much more sensitive and it can listen to 300 MHz of radio channels at once instead of 100 MHz. It piggy-backs on the Arecibo telescope and takes advantage of its 7-beam focal plane array. It uses coincident detections to discriminate against interference.

Project Phoenix is the flagship of the SETI Institute in California. It was the largest, most sensitive targeted search program. Project Phoenix's first major search program was carried out at the Parkes radio telescope in Australia from 2nd February to 6th June 1995 (Tarter 1997). The Parkes and Mopra antennas were used as a pseudo-interferometer to search for ETI signals from 209 solar-type stars in the Southern Hemisphere over the frequency range 1,200 to 3,000 MHz. The sensitivity of the observations was sufficient to rule out any narrow band transmitters stronger than 5×10^{12} Watts broadcasting during their observations.

Although no ETI signals were found the strategy of using two widely separated antennas linked together as a pseudo-interferometer proved to be an extremely effective way to discriminate against RFI.

After the Parkes survey, Project Phoenix used the Arecibo telescope to search for ETI signals from a list of 1000 promising stars within 200 light years of the Sun. The Arecibo telescope was paired with the Jodrell Bank telescope in the UK. The search frequency spanned the range 1,200 to 3,000 MHz and surveyed about 500 nearby stars. It concluded its nine year search in 2004. Project Phoenix has been replaced by a new program based on the Allen Telescope Array (ATA). It will use 350 mass-produced small dishes (6 m in diameter) to form a collecting area of 10,000 square metres and target 100,000 candidate stars for intensive SETI observations (Tarter 2001). In October 2007 the first 42 dishes began science observations.

Still in the planning stages is the development of the multinational Square Kilometre Array (SKA) which will be used for mainstream astronomical research and also for the cradle of life program which will have the SETI search as one of its components (Tingay 2008, Bhathal 2005). The main scientific thrust of the array is to study the structure of the early universe prior to the formation of galaxies with the use of highly red-shifted HI. It will also have the ability to synthesize up to 100 pencil beams simultaneously. Even if just ten beams were used for the SETI program it will be able to cover a million stars in a targeted search over a period of about ten years.

OPTICAL SETI

A quick calculation shows that the apparent magnitudes of the ETI star and the ETI CW laser at a distance of 10 light years from us would be 2 and 21. The laser source would just be picked up by the 200 inch telescope at Mt Palomar Observatory. However, it must be pointed out that in this scenario the host star would swamp the light from the laser. For the experiment to work we need to have more powerful lasers. Pulsed solid-state lasers have achieved terawatts, albeit for a few nanoseconds. The National Ignition Facility at the Lawrence Livermore National Laboratory could deliver 500 TW pulses lasting 3 to 5 ns.

These developments in laser power have opened the way for a consideration of the optical SETI search strategy as a viable search strategy (Bhathal 2000). However, the breakthrough came with the discovery a few years back of a long forgotten paper by Monte Ross who had been working on laser communications for the Research and Development Department at Hallicrafters Co., Chicago. In his now classic 1965 paper (Ross 1965), he noted that information theory shows that at optical frequencies, narrow pulse, low-duty cycle systems can convey more information per received signal photon than radio waves. Calculations show that a pulsed laser beacon will outshine its host star by four to seven orders of magnitude depending on the output of the laser. For example, for a pulsed laser beacon system with a 1 Hz repetition rate and a peak power of 10^{18} W it can be shown that the magnitude of the ETI laser and the ETI star at a distance of 10 light years would be -15 and 2. Sources of these magnitudes can be easily picked up even by small telescopes.

Over the last seven years four new optical SETI projects have come on line, viz: the University of California's SEVENDIP (acronym for Search for Extraterrestrial Visible Emissions from Nearby Developed Populations) project, the Harvard University optical SETI project, the Lick Observatory optical SETI project and the University of Western Sydney's Australian Optical SETI (or OZ OSETI for short) project. All projects are based either on very fast photomultiplier tubes or avalanche photodiodes. The equipment uses a beam splitter to feed the light from the telescope onto a pair of very fast photomultiplier tubes or avalanche photodiodes. The signals are fed to a pair of high speed amplifiers, a pair of fast discriminators and a coincidence detector. All are searching for nanosecond pulses with specially built coincidence circuits to eliminate false signals and noise which can be attributed to scintillation in the photomultiplier glass from cosmic rays, ion feedback and radioactive decay of potassium (K40) located in the PMT glass. Background noise and interference from astrophysical phenomena and atmospheric and terrestrial sources have been found to be negligible in the optical SETI experiments conducted to date. Most of the interference has come from detector pathologies. In general, this has been eliminated by the use of two or three detector systems with coincident circuits or two telescopes with detectors wired up in coincident mode.

The University of California is searching in the 300–650 nm wavelength range with a 0.8 m automated telescope at Leuschner Observatory. Fast PMTs with a rise time of 0.7 ns are wired up in coincident mode. They are searching for signals from F, G, K and M stars, a few globular clusters and galaxies (Werthimer et al. 2001). The pulse search has examined about 700 stars with a dwell time of about two minutes a star. The experiment's sensitivity is 1.5E-17 W/m^2 for a one nanosecond pulse. To date they have found no ETI signals.

The Harvard University project was searching in the 160–850 nm wavelength range but centred on 420 nm. They were also targeting F, G, and K stars. Their detector system rode in piggyback mode on a radial velocity survey. They synchronized their observations with a group at Princeton University located about 200 km away with the use of GPS receivers to synchronize the detection of pulses within a microsecond over the millisecond delay between the two observatories. By 2004 they had made observations of over 6,000 stars but they did not find any ETI signals of the nanosecond pulsed variety (Howard, et al. 2004). The Harvard group has built a 1.8 m dedicated wide-field optical telescope with a fast pixelated photodetector for an all-sky survey. The telescope is essentially used as a photon bucket.

The Lick Observatory project uses a three detector system which has been designed to eliminate the incidence of false positive signals that have been observed on the University of California and Harvard University two detector optical SETI systems. The system uses fast PMTs with a spectral response from 300-850 nm. The device is mounted at the f/17 Cassegrain focus of the Lick Observatory's 1 m Nickel telescope.

The OZ OSETI project was built mainly with private sector funding. It is searching for signals from transmitters with peak instantaneous power greater than 10^{18} W. The search is conducted in the 300–700 nm range but centred on 550 nm. The equipment is wired up in coincidence mode to eliminate false signals. The OZ OSETI project is the only dedicated optical search in the Southern Hemisphere. To date 2,000 stars and 30 globular clusters have been searched for ETI signals. A FFT analysis of all the observations with MATLAB has provided negative results to date.

THE FUTURE

Over the last few years a number of strategies have not only been revisited and refined but new search strategies have been developed. All of them are in various stages of development.

Major developments in detector technology could enable pulsed IR searches. From the point of view of the transmitter, pulsed infrared SETI has a number of advantages, such as, greater signaling range, lower energy cost per photon and decreased stellar background. This search strategy will become feasible when affordable fast detectors become available.

Ross and Kingsley (2001) are planning the PhotonStar project which will be an optical version of the SETI@home project but with a difference. The project is aimed at 'amateur' optical astronomers who already posses a well equipped observatory. GPS technology will be used to obtain precise location and time information for the observatories located across the USA. Each observatory will have a turnkey detector module and the data from each observatory will be collected and integrated over the internet.

The OZ OSETI project is planning to build a dedicated one metre optical telescope to be financed mainly by the private sector. The initial design plans have been drawn up. The telescope will be used as a light bucket in transit mode and will be able to complete a survey of the southern sky in about 250 nights. The detector will be based on Hamamatsu's recently released multi-pixel photomultiplier tubes which have a quantum efficiency between 10 and 20% for 300–550 nm, a gain of 10^6 and a rise time of about 1 ns and FWHM of about 3 ns.

Over the next few decades a number of space telescopes will be launched by ESA and NASA. The space telescope programs offer a tremendous opportunity of carrying out an optical SETI search along with other astronomical programs. The Terrestrial Planet Finder is planned for launch in 2015. It will look for traces of early life in the infrared spectra of extrasolar planets. As currently envisioned it will also be sensitive to deliberate laser transmissions from technologically advanced civilisations. A kilowatt class laser with a 10 m beam director would produce a signal visible to TPF at a range of 15 pc that is distinguishable from astrophysical phenomena and noise (Howard and Horowitz 2001).

Far into the future is a proposal for a SETISAIL project proposed by Jean Heidmann and Claudio Maccone (1994). They based their arguments on the gravitational lens effect of the Sun, solar sail technology and the galactic belt of advanced life to launch an inflatable combined sail/radio telescope system at a 550 AU distance outside the solar system. The sail would be focused at Balaz's maximum where it will go through a 7000 light years long section of the belt of life. They even propose a launch direction at galactic longitude of 270 degrees and galactic latitude of 0 degrees. Because of rising radio interference it is envisaged that sensitive SETI observations will be difficult to be conducted from Earth within the next ten to twenty years. Thus, Heidmann (2000) has proposed the establishment of an observatory on the far side of the Moon. He has suggested that the observatory be located at the Saha crater because no Earth or geostationary orbit based radio emission can reach this site.

CONCLUSION

For SETI to succeed it is imperative the search strategies be broad and varied. The reason for this is that no one really knows what type of communicating device ETI civilisations will use to contact us. Although forty-five years of searching have been conducted it would appear that we have barely begun the search.

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Antarctic Astronomy

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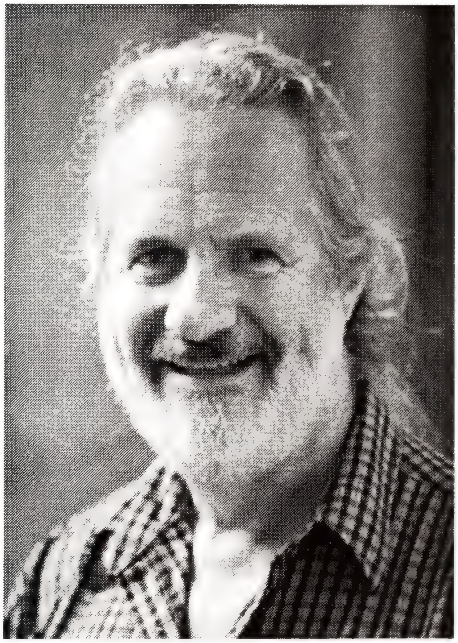
Abstract: John Storey is a Professor of Physics at the University of New South Wales. He was awarded the Pawsey Medal by the Australian Academy of Science and the Antarctic Service Medal of the US Congress. His research interests include Antarctic astronomy, infrared astronomy and millimetre wave astronomy and energy-efficient vehicles. He is Chairman of the Antarctic Astronomy and Astrophysics Expert Group of SCAR which helps to coordinate international astronomical research in Antarctica.

Keywords: Bio-astronomy, Infrared astronomy, Large telescopes

INTRODUCTION

John Storey's parents were both school teachers and as a result of that profession they moved around various towns during his early childhood. 'So we never spent more than a few years in any one place.' He had a varied and interesting childhood and perhaps because his parents moved from one place to another he did not have a large number of friends. So he spent a lot of his childhood in building things and playing with mechanical and electrical things. At about the age of ten he was given an OC71 germanium transistor which he built into his first crystal set. He remembers he said, 'listening to my one-transistor radio and hearing the announcement that President Kennedy had been shot. I went and told my parents who were shocked by the news.' That hobby evolved into amateur radio and at the age of fifteen he obtained an amateur radio license but was not able to legally operate a transmitter until he turned sixteen. These early experiments with things scientific and technical sparked in him a desire to be a scientist and later in life it showed up in his interest in building scientific equipment. It is rather surprising that his interest in astronomy came much later.

He was always near the top of his class and won a scholarship to study at Melbourne Grammar School. 'I was very lucky to have outstanding teachers in physics and chemistry. I also fondly remember the history and language teachers and I always enjoyed languages and history as much as I enjoyed science.' His father was 'probably the main person who motivated him into a physics-type discipline.'



LA TROBE AND THE UNIVERSITY OF CALIFORNIA

For his undergraduate studies he went to La Trobe University which happened to be close to his home. It was the time of the Vietnam War and like many socially conscious students he got 'into student politics and anti-war demonstrations.' At La Trobe he came under the influence of Keith Cole a well known ionospheric physicist and a great advocate of space science in Australia. From Cole he learnt 'that we should never worry about getting a job. That what we should do is what we were interested in.' 'I think it was very good advice', he told me.

After completing his Honours degree he joined the Chemistry Department at Monash University rather than the Physics Department to do his PhD under the supervision of Ronald Brown, an internationally recognized astrochemist. 'I saw this as an opportunity to do laboratory spectroscopy at microwave frequencies of molecules that had just been detected, or additional molecules that might be detected in interstellar space.' His PhD topic was on microwave spectroscopy and radio astronomy of biologically interesting molecules. 'For many years people believed that molecules could not exist in interstellar space because of the ultra-violet radiation field. I think the OH radical had been known since World War II from optical observations but it was not until 1968 that Charles Townes and Al Cheung discovered ammonia that it was realized that quite complicated molecules could exist. In the years immediately after 1968 I guess a dozen or more molecules were detected at radio telescopes including Parkes.' In searching for biological molecules he succeeded in 'getting a microwave spectrum of urea.' According to him, 'our ability to measure the microwave spectrum of urea was something of a breakthrough because that was the first biological molecule for which a microwave spectrum had been achieved.'

He went to Kitt Peak with Brown and Peter Godfrey to search for glycine with the 36 foot diameter radio telescope. While there 'we were able to look for the carbon 13 line of HNC and the fact that we were able to detect this meant that the identification of HNC was then assured (Brown, et al., 1976)'. The search for glycine was not successful (Brown, et al., 1979). In fact, over the years several astronomers have been trying to search for glycine in space but to date have not been able to detect it. Storey believes that 'there are tantalizing indications that glycine is there. I think it will eventually be detected. It is a surprisingly difficult molecule to find and in fact if you calculate how abundant you think it should be, just on the basis of how many atoms it has, at that abundance level it is extremely hard to find. The problem with it is that it is a completely asymmetric molecule.' There is much interest in the search for biomolecules in space because some astronomers and astrobiologists believe that life on Earth may have been seeded by biomolecules from outer space rather than having to start from scratch in Darwin's small warm pond on Earth.

For his post-doctoral fellowship he went to the University of California at Berkeley in the late 1970s and joined Charles Townes' group. Townes was a Nobel prize winner and the inventor of the laser. According to Storey, 'Townes was an absolute delight to work with. He was very much a renaissance man, interested in not just physics but also philosophy, religion, history and languages. He was extraordinarily kind and generous and very much engaged with his students. Townes was a great inspiration to me.' Storey spent four and a half years at Berkeley.

He said his time at Berkeley was one of his most creative periods. He was involved in 'developments there of infrared interferometry, and airborne astronomy on the Kuiper Airborne Observatory (KAO).' The interferometer had been built by Townes and his students Michael Johnson, Al Betz and Ed Sutton. With the 'two-telescope interferometer they were able to look at objects with much greater spatial resolution than had been possible before. But the main result at that time was looking at dust shells around stars. We were able to measure the diameter of those dust shells and measure the inner radius of that dust shell (Sutton, et al., 1977)'. He developed his own spectrometer (Storey, et al., 1981), a Fabry-Perot scanning spectrometer with a helium cooled detector and this 'flew on about eighty flights with the KAO.' They were able to detect molecules and characterize the warm gas component of interstellar gas clouds. They were also able to detect fine structure lines of various ionic species like [OI], [OIII] and [NIII]. When he returned to Australia he tried to arrange regular flights for the KAO in Australia. He succeeded in getting it once to Sydney at the Richmond Air Force Base. Due to some administrative and financial problems with the Richmond Air Force Base the KAO subsequently went instead to New Zealand and 'flew out of Christchurch.' KAO ceased flying in the late nineteen-eighties to make way for SOFIA and an Australian woman astronomer Jackie Davidson is one of its leading lights. SOFIA will be a tremendously powerful probe of the far infrared universe.

He wrote a review on infrared astronomical spectrometers which was a summary of the major developments in the field (Storey, 1985). 'It was a very exciting in around 1985 because we were opening up this new spectral region. And part of the debate at the time and in fact is still ongoing is that at radio wavelengths it's very clear what techniques to use. You use heterodyne techniques where you mix the incoming signal with a local oscillator and as soon as possible convert the signal into an electrical signal you can then process digitally. At optical wavelengths again it is clear you use a grating spectrometer or a Fabry-Perot spectrometer and do all the processing optically. And at the very last part of the instrument is the detector where you turn it into an electrical signal.' 'So it's two completely different approaches,' he said. 'Now clearly these two techniques meet in the middle and they meet in the far infrared. And it's in the far infrared that you really have to understand what the benefits are of using one technique or the other.' The technology has changed very rapidly and according to Storey, 'we are getting very close to the quantum limits of detection across the entire electromagnetic spectrum from low frequencies to X-rays. And so there is no longer really any debate. You simply look at what it is that you are trying to measure and it becomes very clear whether you use an optical technique or a radio type technique.' In the far infrared both techniques have their place and he believes that the Herschel satellite will carry some radio-type heterodyne instruments and also some optical-type direct detectors.

UNIVERSITY OF NEW SOUTH WALES

He returned to Australia in 1981 and joined the Anglo-Australian Observatory which at that time 'had been going for five or six years and was riding the crest of a wave as one of the most productive of the new generation of four-metre telescopes' under the directorship of Donald Morton. He came back to a five-year position at the Anglo-Australian Observatory but a year later he joined the Physics Department at the University of New South Wales as a lecturer because they 'offered him a permanent job.' Five years later he was appointed to a new position as Professor of Physics. He was thirty-six and probably one of a very few academics in Australia to get a professorship at that age. Most Australian academics get a professorship in their late forties or fifties.

At the time he joined the School of Physics he said, 'it was a lumbering kind of school. I think there were forty-two academics, most of them approaching retirement age so there were a lot of resources available.' With Louise Turtle and colleagues he built the Astronomy Department which he said, 'became the second highest cited Astronomy Department in the country.' Turtle was also responsible for nominating him for the Pawsey Medal.

He was involved in the acquisition of a satellite-tracking optical telescope from NASA when NASA closed down their satellite tracking station at Orroral Valley. With Jack Cochrane, Louise Turtle and Peter Mitchell he heavily modified it for use as an astronomical facility and relocated it to Siding Spring to become the Automated Patrol Telescope. 'It is now being operated by Michael Ashley and used for searching for extra-solar planets, gamma ray burst sources and for all kinds of transient sources. It is now a very successful and very productive facility and they are churning out several papers a year', he said. With Michael Burton he was instrumental in fitting out the Mopra radio telescope with millimetre-quality panels over the entire surface. 'So we basically turned Mopra into a millimetre telescope and then using ARC LIEF funding we are providing a very wide bandwidth receiver for the back end.' Millimetre wave astronomy is a rapidly growing field. At the moment Mopra is the only big millimetre wave telescope in the southern hemisphere but that window of opportunity will be lost when ALMA (Atacama Large Millimetre Array) comes on line in South America.

ANTARCTIC ASTRONOMY

His major interest now is in Antarctic astronomy (Aitken, et al., 1994; Burton, et al., 2004). According to him, 'Antarctica offers several advantages. One is of course it's very cold and it's very high on the Antarctic plateau. Because the atmosphere is very dry you have got much better atmospheric transparency. In addition of course the infrared background is very much lower because it's colder and the skies are effectively twenty to fifty times darker across the infrared and so at infrared wavelengths you get a sensitivity gain of up to seven or ten. In addition to that the atmosphere's also extremely stable and so the image quality is much better than you get at any other site.' He believes that the high plateau sites are by far and away the best Earth-based sites for a lot of infrared and optical astronomy as well as submillimetre and millimetre wave astronomy. The other advantages, he said, 'of constructing there are the very low wind speeds and lack of earthquakes. So potentially you can build extremely large telescopes there, probably cheaper than they could be built at other sites.'

His ultimate ambition would be to build a 25 metre extremely large telescope. He has written a paper with Roger Angel from Arizona. But to get to that stage they are planning to firstly build a 2.4 metre optical infrared telescope. Called PILOT, he said, 'we would like to get on with that straight away (Burton, et al., 2005)'. The cost is about ten million dollars. The reason for building this first is to demonstrate that there are no insurmountable problems. The next stage after that is to build an eight metre telescope. He has in mind a proposal called 'LAPCAT' for that. The final step is to build the 25 metre telescope which would effectively be derived from the Giant Magellan Telescope.

They have done enough site testing at the moment to show that 'one can sensibly talk about building a big telescope. Furthermore the site conditions are so favourable that it is worth building a big telescope.' They have also done a great deal of technology development so that they know how to make things work in Antarctic conditions. They have, he said, 'built a robotic observatory that's worked for months with nobody around in Antarctica under the harshest conditions (Ashley, et al., 2004). We know how to do it and it is just a question of putting the pieces together.'

ACHIEVEMENTS

He has supervised about a dozen postgraduate students who have gone in different directions. Some of these are Kate Brooks who is now at the CSIRO Australia Telescope National Facility, Tony Travouillon is at Caltech while Paolo Calisse is at Cardiff University.

He has a very active research profile. He attributes this to Townes' influence which is 'not to do what is necessarily the obvious thing to do. That if it's clear what the next step is going to be in some field then why not let someone else do that because if it really is obvious then other people are going to come along and do it. So what's the point of you going in there and competing with them. It's much better to do something which otherwise wouldn't happen and to try and be creative and actually make a difference to the way science develops. So I guess throughout my career I've tried to do things that will actually make a difference rather than doing things that are perhaps easy.'

As to his achievements to date he said, 'I think putting UNSW physics and astronomy on the map. I think the other achievement of effectively launching the field of bio-astronomy has been something I can take some pride in although clearly I was only a PhD student at the time and so most of the credit should go to my supervisors. Opening up the far infrared spectroscopy through the work I did at Berkeley. But I would say that Antarctica would have to be the most important thing I've done. I thank the group here and it's been very much of a team effort with Michael Ashley and Michael Burton. Peter Gillingham at the Anglo-Australian Observatory I think should take a lot of the credit for stimulating the work that we've done and contributing to it. What we have shown is that Antarctica does offer enormous advantages for optical/IR astronomy and for other fields as well. And I think we've shown that this is an opportunity for Australia and I think if Australia does take the opportunity up then that will be the thing that saves optical/IR astronomy in Australia.'

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On an f(R) Theory of Gravity

S. N. PANDEY

Abstract: We attempted to develop a higher-order theory of gravitation based on a Lagrangian density consisting of a polynomial of scalar curvature, R to obtain gravitational wave equations conformally flat. In this theory, it is desirable to study the gravitational field of a spherically symmetric mass distribution and the motion of particle to bring out the effect of modification of general relativity. In the context it is found that the spherically symmetric metric is not asymptotically flat as r tends to infinity and, in case of orbital motion of the planet, it turns out that it differs from Einstein case by having an additional term, though of small magnitude, in the equation. This term does not contribute to produce observable effect as such the precession of the perihelion is consistent with observation.

Keywords: General Relativity

INTRODUCTION

We investigated an f(R) theory of gravity in the context of general relativity. However, this theory in the framework of Palatini approach as solution to the problem of the observed accelerated expansion of the universe is discussed in Capozziello et al. by considering two physically motivated popular choices for f(R), that is, power law, $f(R) = \beta R^N$ and logarithmic, $f(R) = \alpha \log R$. This give rise to cosmological models comprising only standard matter and undergoing a present phase of accelerated expansion but the deceleration parameter is higher than what is measured in the concordance ΛCDM model. The ΛCDM model is also plagued by many problems on different scales. If interpreted as vacuum energy, Λ is up to 120 orders of magnitude smaller than the predicted value.

In this framework, there is also the attractive possibility to consider the Einstein general relativity as a particular case of a more fundamental theory. This is the underlying philosophy of what are referred to as f(R) theories. In this case, Friedmann equations have to be given away in favour of a modified set of cosmological equations that are obtained by varying a generalized gravity Lagrangian where the scalar curvature R has been replaced by a generic function f(R). The usual general relativity is recovered in the limit f(R) = R, while completely different results may be obtained for other choices of f(R). While in the weak field limit the theory should give the usual Newtonian gravity, at cosmological scales there is an almost complete freedom in the choice of f(R). This leaves open the way to a wide range of models.

On the other hand, the non-conformal invariance of gravitational waves which are an inevitable consequence of Einstein theory of gravitation motivated us Pandey 1983, Pandey 1988, Grishchuk 1977 to modify the Einstein theory by choosing f(R) as a polynomial in R of a finite number of terms without associating any other field except gravitation. Therefore, we took the Lagrangian in the form

$$\mathcal{L} = R + \sum_{n=2}^{N} Cn\{(l^2 R)^n / 6l^2\}$$

$$\text{or equivalently} \quad \mathcal{L} = R + \sum_{n=2}^{N} a_n R^n \tag{1}$$

where l is the characteristic length and C_n are the dimensionless coefficients corresponding to n introduced to nullify the manifestation of gravitation. The values of $n = 0$ and 1 result in Hilbert Lagrangian, that is, Einstein theory. Therefore n begins from $n = 2$ onwards.

This choice of f(R) should not be disturbing because it is an observational fact that our universe is not asymptotically flat. There is enough matter on our past light cone to cause it to refocus. The total energy of the universe is exactly zero, the positive energy of gravitation and the matter particle being exactly compensated by the negative gravitational potential energy. That is why the universe is expanding. Also the unitarity is not well defined except in scattering calculations in asymptotically flat spaces.

Therefore, the paper is organised as follows. The field equations of this f(R) theory under consideration are given in section 2. Section 3 deals with an attempt to find the gravitational field surrounding a spherically symmetric mass distribution at rest while the equation of motion of a particle in this field is the subject matter of section 4. In the last section we give concluding remarks on the results of this f(R) theory.

FIELD EQUATIONS

A quite interesting and fascinating scenario predicts that standard matter is the only ingredient of the cosmic pie as it is indeed observed, but the Einsteinian general relativity breaks down at the present small curvature scale. As a result we generalize the action as Pandey 1983, Grishchuk 1977, Pandey 2001

$$A = \int (\mathcal{L}/\kappa + \mathcal{L}_s)\,\mathrm{d}^4x \qquad (2)$$

with $\mathcal{L}_s$ standing for the source Lagrangian density to obtain the graviton equations in the background of Friedmann universe having scale factor $a(\eta)$ as:

$$\mu'' + \mu[n^2 - a''/a] = 0 \qquad (3)$$

An application of variational principle to this action yields the field equations as:

$$\begin{aligned} R^{uv} - \frac{g_{uv}R}{2} + \sum_{n=2}^{N} n a_n R^{n-1}\Bigg[R_{uv} - \frac{Rg_{uv}}{2n} \\ - \frac{n(n-1)}{R}(R_{;u;v} - g_{uv}\Box R) \\ - \frac{(n-1)(n-2)}{R^2}(R_{;u}R_{;v} - g_{uv}R_{;\alpha}R^{;\alpha})\Bigg] \\ = \kappa T_{uv} \qquad (4) \end{aligned}$$

Here $rT_{uv} = \sqrt{(-g)}(\delta\mathcal{L}_s/\delta g^{uv})$ (eqn. 5) stands for the energy-momentum tensor responsible for the production of the gravitational potential g_{uv}. It can easily be seen that $T^v_{u;v} = 0$ (eqn. 6) holds for these field equations as it is in case of Einstein general relativity. Again it should be noted that $1 + na_nR^{n-1} \neq 0$ or equivalently,

$$\begin{aligned} 1 + 2a_2R + 3a_3R^2 + 4a_4R^3 + \dots \\ + Na_nR^{N-1} \neq 0 \qquad (7) \end{aligned}$$

because of the Cauchy problem. This fact is important in studying the completeness of geodesic in higher-order theory of gravitation.

SPHERICALLY SYMMETRIC FIELD

It is interesting to know in this theory of gravity the gravitational field surrounding a spherically symmetric mass distribution at rest. Obviously the gravitational field would have spherical symmetry. We require the field to be static, that is, it should be both time independent and unchanged by time reversal. So, we consider

$$\begin{aligned} \mathrm{d}s^2 = e^{N(r)}\,\mathrm{d}t^2 - e^{L(r)}\,\mathrm{d}r^2 - r^2\,\mathrm{d}\theta^2 \\ - r^2\sin^2\theta\,\mathrm{d}\phi^2 \qquad (8) \end{aligned}$$

where functions $N(r)$ and $L(r)$ are to be determined by using the field equations of f(R) gravity. In vacuum where $T_{uv} = 0$, we get

$$\begin{aligned} R^0_0 - R/2 = R^1_1 - R/2 = R^2_2 - R/2 \\ = R^3_3 - R/2 = \Psi(r) \qquad (9) \end{aligned}$$

$$\text{where} \quad \Psi(r) = \frac{\sum_{n=2}^{N} a_n(2 - n/2)R^n}{1 + \sum_{n=2}^{N} na_nR^{n-1}} \qquad (10)$$

The functions $N(r)$ and $L(r)$ are seen to satisfy from $R^0_0 - R/2 = R^1_1 - R/2$ $N(r) = -L(r)$ (eqn. 11). Again $R^0_0 - R/2 = \Psi(r)$ (eqn. 12). So we find

$$e^{-L} = 1 + \frac{k}{r} + \frac{1}{r}\int r^2\Psi(r)\,\mathrm{d}r \qquad (13)$$

where k is a constant which can be determined from the fact that at large distances the g_{00} component of the metric must conform to Newtonian potential, that is $1 - 2\varphi$. If M is the central mass then $k = -2MG$ (eqn. 14). leading to

$$ds^2 = \left(1 - \frac{2MG}{r} + \frac{1}{r}\int r^2 \Psi(r)\,dr\right) dt^2 - dr^2 \Big/ \left(1 - \frac{2MG}{r} + \frac{1}{r}\int r^2\Psi(r)\,dr\right) - r^2\,d\theta^2 - r^2\sin^2\theta\,d\phi^2 \quad (15)$$

It is to be noted that M is the total mass of the system. The mass energy contributed by the gravitational field is to be included in M. Clearly, in view of the principle of equivalence, the gravitational mass of the system which produces the field (15) is, in fact, equal to the inertial mass of the system The other equations in (9) are satisfied by equations (11) and (13).

Now we turn our attention towards equation (10). The denominator of equation (10) is non-vanishing due to equation (7) and can, therefore, be expanded in powers of r. Thus

$$\Psi(r) = b_0 + b_1 r + b_2 r^2 + b_3 r^3 + \ldots \quad (16)$$

Since the contribution of $\Psi(r)$ is very small, then

$$\frac{1}{r}\int r^2\Psi(r)\,dr = \frac{b_0 r^2}{3} + \frac{b_1 r^3}{4} + \frac{b_2 r^4}{5} + \ldots \quad (17)$$

$$\text{yields} \quad e^N = e^{-L} \approx 1 - \frac{2MG}{r} + \frac{b_0 r^2}{3} \quad (18)$$

by retaining only the first term in equation (17). Therefore the metric (8) becomes

$$ds^2 = \left(1 - \frac{2MG}{r} + \frac{b_0 r^2}{3}\right) dt^2 - dr^2 \Big/ \left(1 - \frac{2MG}{r} + \frac{b_0 r^2}{3}\right) - r^2\,d\theta^2 - r^2\sin^2\theta\,d\phi^2 \quad (19)$$

It can easily be seen that the metric (19) is not asymptotically flat due to the presence of term $b_0 r^2/3$. Again, it can be seen that in this f(R) theory of gravitation the space-time, by virtue of equation (7), will no longer be asymptotically flat at larger distances. Again the appearance of term $b_0 r^2/3$ is worth comparing with the Schwarzschild solution, that is,

$$ds^2 = \left(1 - \frac{2MG}{r} - \frac{\lambda r^2}{3}\right) dt^2 - dr^2 \Big/ \left(1 - \frac{2MG}{r} - \frac{\lambda r^2}{3}\right) - r^2\,d\theta^2 - r^2\sin^2\theta\,d\phi^2 \quad (19a)$$

of the Einstein field equation with cosmological constant, that is, $R^v_u - (1/2)\delta^v_u R = -\Lambda\delta^v_u$. As such the contribution due to modification is behaving as a cosmological constant which is very small and can be taken to correspond to a cosmological correction to the Newtonian potential. For the motion of planets the cosmological correction is completely insignificant. Further, even if we include the second term or more of equation (17), the qualitative picture, for instance the asymptotic flatness, remains unchanged. Quantitatively however the values of the metric potentials will differ.

EQUATION OF MOTION

The equation of motion of a particle in a gravitational field is

$$\frac{d^2x^\mu}{d\tau^2} + \Gamma^\mu_{\alpha\beta}\frac{dx^\alpha}{d\tau}\frac{dx^\beta}{d\tau} = 0 \quad (20)$$

and the quantity

$$g_{ik}\frac{dx^i}{d\tau}\frac{dx^k}{d\tau} = \text{constant} = 1 \quad (21)$$

is a constant of motion. Therefore it can be regarded as a first integral of the equation of motion.

Now we consider the equation of motion of a particle or planet in the gravitational field of (8). They are:

$$\ddot{t} + N'\dot{r}\dot{t} = 0 \quad (22)$$

$$\ddot{r} + \frac{1}{2}N'e^{N-L}\dot{t}^2 + \frac{1}{2}L'\dot{r}^2 - re^{-L}\dot{\theta}^2 - r^2\sin^2\theta e^{-L}\dot{\phi}^2 = 0 \quad (23)$$

$$\ddot{\theta} + \frac{2\dot{r}\dot{\theta}}{r} - (\sin\theta\,\cos\theta)\dot{\phi}^2 = 0 \quad (24)$$

$$\ddot{\theta} + \frac{2\dot{r}\dot{\theta}}{r} + 2(\cot\theta)\dot{\theta}\dot{\phi} = 0 \quad (25)$$

where $\dot{r} = dr/d\tau$ and $N' = dN/dr$.

Now we assume that orbit is in the $\theta = \pi/2$ plane. So, initially $\dot{\theta} = 0$ and equation (24) yields $\ddot{\theta} = 0$ This means that the orbit remains in this plane. Further equations (22) and (25) lead to

$$\dot{\phi} = A/r^2 \quad (26)$$

and

$$\dot{t} = Be^{-N} \quad (27)$$

where A and B are constants. As pointed out earlier, the equation (21) is the first integral, we take it and ignore equation (23). Therefore

$$e^N\dot{t}^2 - e^L\dot{r}^2 - r^2\dot{\theta}^2 - r^2\sin^2\theta\dot{\phi}^2 = 1 \quad (28)$$

which with $\theta = \pi/2$ and $\dot{\theta} = 0$ gives

$$\frac{B^2}{e^N} - \frac{\dot{r}^2}{e^{-L}} - \frac{A^2}{r^2} = 1 \quad (29)$$

by virtue of equations (26) and (27). Now, changing $r = 1/u$ and making use of equation (15), the equation (29) reduces to

$$\frac{\mathrm{d}^2u}{\mathrm{d}\phi^2} + u - \frac{GM}{A^2} - 3GMu^2 - \Phi(u) = 0 \quad (30)$$

where

$$\Phi(u) = \left\{(1 + A^2u^2)\frac{\mathrm{d}}{\mathrm{d}\phi}[u\int\frac{\Phi(u)}{u^4}\,\mathrm{d}u] + u\int\frac{\Phi(u)}{u^4}\,\mathrm{d}u\right\}/2A^2\frac{\mathrm{d}u}{\mathrm{d}\phi} \quad (31)$$

This is a second order differential equation for the orbit. Here it is interesting to recall that corresponding orbital equation in Newtonian theory is

$$\frac{\mathrm{d}u^2}{\mathrm{d}\phi^2} + u - \frac{GM}{A^2} = 0 \quad (32)$$

and the one in case of Schwartzschild metric (Einstein theory) is

$$\frac{\mathrm{d}^2u}{\mathrm{d}\phi^2} + u - \frac{GM}{A^2} - 3GMu^2 = 0 \quad (33)$$

Comparing equations (30) and (33) we get an additional term in the orbital motion of the planet in this theory of gravity. This is absent in Einstein's theory. However, it is very small in magnitude.

CONCLUDING REMARKS

Assuming the Lagrangian approach is the correct way to treat f(R) theories, we have investigated the gravitational field surrounding a spherically symmetric mass distribution and the motion of a particle in this gravitational field.

In the former case the appearance of $b_0r^2/3$ in space-time metric does not allow it to be asymptotically flat when r approaches infinity. Therefore, it behaves like a contribution that comes from a cosmological constant. This is as if Einstein theory is considered with cosmological constant, that is, $R^v_u - (1/2)\delta^v_uR = -\Lambda\delta^v_u$, where Λ is the cosmological constant. This contribution is small. If $1/\sqrt{b_0} \gg r \gg GM$, the metric (19) is nearly flat. The effect of mass term M dominates for the values of r below this range and the effect of this term, $b_0r^2/3$ dominates for the values of r above this range. However, in this situation, the Newtonian potential gets modified to $\phi = -GM/r + b_0r^2/6$. The second term here appears due to the correction in the Hilbert Lagrangian, R.

It is interesting to look at the scalar curvature in an f(R) theory of gravity. For instance, equation (4) in vacuum and for $n = 2$ gives trace $\Box R - R/6a_2 = 0$. This is a wave equation and is comparable with massless scalar field equation $\Box\phi + R\phi/6 = 0$. $\Box R$ is non-vanishing for all values of $n \geq 2$. This means that scalar curvature is of wave nature in f(R) theories of gravitation.

In case f(R) is zero or constant, the metric (15) will correspond to the Schwarzschild solution of Einstein theory with or without cosmological constant.

Now we consider the motion part. The differential equation for the orbit in Einstein theory differs from the corresponding orbital equation of Newtonian theory by the term $3GMu^2$ and that of this f(R) theory differs from the corresponding orbital equation of Einstein theory by the term $\Phi(u)$. Thus the equation in this theory differs from the Newtonian theory by the terms $3GMu^2 + \Phi(u)$. The relativistic correction to planetary motion is extremely small. This can be seen by comparing second and fourth terms in equation (30). These terms differ by an order of GMu or GM/rc^2 in c.g.s. units. For Mercury $GM/rc^2 \approx 3\times10^{-8}$ because $M = M_\oplus = 2\times10^{33}$ gm and $r = 5.5\times10^{12}$ cm.

Since it is having the effect similar to that of a cosmological constant the change in constant GM/A^2 in equation (30) is not producing any interesting observable effect in planetary motion. However $3GMu^2$ is small compared to other terms, it is sufficient to use the method of successive approximation. We consider the solution of Newtonian equation (32) as

$$u = \frac{GM}{A^2}\{1+\epsilon\cos(\phi-\phi_0)\} \tag{34}$$

where ϵ and ϕ are constants. Equation (34) represents an ellipse with ϵ as eccentricity and a perihelion located at $\phi = \phi_0$. Replacing small terms $3GMu^2$ by its Newtonian approximation (34) we obtain:

$$\begin{aligned}\frac{d^2u}{d\phi^2} + u - \frac{GM}{A^2} - \frac{3(GM)^3}{A^4}\\ - \frac{6\epsilon(GM)^3}{A^4}\cos(\phi-\phi_0)\\ - \frac{3(GM)^3}{A^4}\epsilon^2\cos^2(\phi-\phi_0) - \bar{\Phi} = 0\end{aligned} \tag{35}$$

where

$$\bar{\Phi} = \Phi\frac{GM}{A^2}[1+\epsilon\cos(\phi-\phi_0)] \tag{36}$$

For a nearly circular orbit, ϵ is small. We neglect the term proportional to ϵ^2. The term $3(GM)^3/A^4$ can also be neglected as it is proportional to or equivalent to the change in the constant GM/A^2 and produces no observable effects. Also $\bar{\Phi}$ can be ignored because:

$$\begin{aligned}\bar{\Phi} \approx \Phi\frac{GM}{A^2}\\ + \phi'\frac{GM}{A^2}\left[-\frac{\epsilon GM}{A^2}\cos(\phi-\phi_0) + \frac{GM}{A^2}\right]\end{aligned} \tag{37}$$

The first term in (37) corresponds to the changes in constant GM/A^2 due to modified theory other than that of Einstein and is of little significance in observation. The second term in (37) vanishes at the perihelion. Therefore, the contributions from $\bar{\Phi}$ can be ignored. Thus, we have

$$\frac{d^2u}{d\phi^2} + u - \frac{GM}{A^2} - \frac{6\epsilon(GM)^3}{A^4}\cos(\phi-\phi_0) = 0 \tag{38}$$

of which the solution is

$$\begin{aligned}u = \frac{GM}{A^2}[1+\epsilon\cos(\phi-\phi_0)]\\ + \frac{3\epsilon(GM)^3}{A^4}\phi\sin(\phi-\phi_0)\end{aligned} \tag{39}$$

or it can be written as

$$u = \frac{GM}{A^2}\left[1+\epsilon\cos\{\phi-\phi_0 - 3\frac{G^2M^2}{A^2}\phi\}\right] \tag{40}$$

Equation (40) represents a precessing elliptical orbit. If ϕ changes by

$$\begin{aligned}\Delta\phi &= 2\pi\left[1-\frac{3G^2M^2}{A^2}\right]^{-1}\\ &\approx 2\pi\left[1+\frac{3G^2M^2}{A^2}\right]\end{aligned} \tag{41}$$

the arguments of cosine changes by 2π. This shows that the angular distance between one perihelion and the next is larger than 2π by $6\pi G^2M^2/A^2$. This quantity gives the angular precession of the perihelion per revolution showing that the perihelion advances $\Delta\phi > 2\pi$ in the direction of motion. There is no further need to proceed for approximation.

For a nearly circular orbit, equation (34) gives $GM/A^2 = 1/r$ where r is the radius of the orbit. The angular advance of the perihelion per revolution in c.g.s. unit is $6\pi GM/rc^2$ (42)

Thus, in this f(R) theory of gravity observable effects are similar to that of Einstein theory as the term $\Phi(u)$ has nothing to contribute even in successive approximations. Therefore, the precession of the perihelion is consistence with observation. One of the possible reasons for this can be seen in the fact that in this choice of f(R), the resulting field equation (4) is based only on the scalar curvature and is not associated with any other field like scalar field or meson field.

It is interesting to note that the precession of the orbit can be quite large in case of close binary star systems. For a system consisting of two white dwarfs or two neutron stars of mass $1M_\oplus$ separated by a distance of 10^{11} cm, equation (42) gives a periastron advance of 3×10^{-5} radians per revolution which means $\approx$ $2°$per year.

We have considered a choice of f(R) assuming that Einstein general relativity is the correct theory of gravity. On the contrary, if f(R) theories are indeed able to explain the accelerated expansion the right choice for the function f(R) and how the variation has to be performed (higher order metric or Palatini approach) should be investigated. One can expect that the functional expression of f(R) is not changing during evolution of the universe, even if R evolves with cosmic time. If this is the case then f(R) theory should reproduce the phenomenology we observe to day but also give rise to an inflationary period in the early universe. Then, the logarithmic Lagrangian can be ignored because it does not predict any inflationary period, whereas the choice $f(R) = \beta R^n$ is able to explain inflation provided one sets $n = 2$.

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Thesis Abstract: Integration of Sensory Feedback when Adapting to Novel Visuomotor Environments

DR MARK HINDER

Abstract of a Thesis submitted for Doctor of Philosophy
The University of Queensland, August 2007

This thesis investigated how the central nervous system integrates feedback information from different sensory modalities to permit skill acquisition, and the subsequent consolidation of that skill, when exposed to novel *visuomotor* environments. By manipulating the sensory feedback from the visual and proprioceptive systems during learning, it was possible to determine those facets of the feedback that are essential for adaptation.

The first two chapters provide a conceptual basis for the thesis and a review of current research, while the final chapter provides an overall discussion. Chapter 3 investigated interference and consolidation in an isometric target acquisition task. Exposure to a 30° counter-clockwise (CCW) rotation was followed by a period of rest, trials with no rotation, or trials with a 60° clockwise (CW) rotation. Retention of the initial adaptation was assessed 5 hours later. Full interference was manifested in circumstances in which either counter-rotated *or* non-rotated trials were encountered following the initial learning. Results suggest that the observed interference is anterograde in nature, and highlight differences in the mechanisms employed by the CNS when compensating for novel kinematics (e.g. visuomotor rotations) compared with adapting to novel dynamics (e.g. external forces).

Chapter 4 investigated the role of visual feedback in an isometric target acquisition task. Following trials with no rotation, participants adapted to a 60° CCW rotation before returning to the non-rotated condition. Separate groups received continuous visual feedback (CF) during task execution *or* post-trial visual feedback (PF), both indicating task performance. One CF group were instructed to make any (feedback) modifications necessary to acquire the target, while another CF group were instructed to make uncorrected movements. Colour cues permitted the identification of the task environment on every trial. Results indicate that an automatic recalibration of the visuomotor mapping occurs when CF is provided, but that performance improvements with PF are mediated by a cognitive strategy. Furthermore, execution of feedback motor commands to correct errors *did not* enhance the adaptation that occurred when CF was provided, indicating that the perception of sensory errors (and not feedback commands that may be applied to reduce those errors) drives feedforward visuomotor adaptation.

To investigate whether additional proprioceptive feedback associated with movement altered the adaptation patterns observed in chapter 4, in chapter 5 we conducted a similar study to that reported above but a discrete, goal-directed, *movement* task replaced the isometric task. Subjects were deprived of vision of their arm, but were provided with PF or CF indicating task performance. The patterns of adaptation noted in the isometric task were also exhibited in this dynamic task, indicating that the *timing* of the visual feedback of task performance has a profound effect on how performance improvements in a novel visuomotor rotation occur.

Chapter 6 assessed the ability to adapt to two conflicting visuomotor rotations interleaved within the same training period, when each task rotation could be identified by a colour cue. While full dual adaptation was not observed, results suggest that the colour cues were used to select distinct motor commands for each task rotation.

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Thesis Abstract: Experimental and Numerical Studies for Evaluating Dynamic Behaviour of Pre-stressed Concrete Sleepers Subject to Severe Impact Loading

DR SAKDIRAT KAEWUNRUEN

Abstract of a Thesis submitted for Doctor of Philosophy
(Civil Engineering), University of Wollongong, 2007

Rail operators are consistently demanding higher axle loads to compete effectively with other modes of transport, particularly for heavy haul freight of minerals. However, high axle loads can only be achieved by ensuring that the existing rail infrastructure can cope with the greater static and dynamic loads associated with the wheel-rail interactions. Premature cracking of pre-stressed concrete sleepers is often the result of high-intensity dynamic loading caused by wheel or rail irregularities. The high-magnitude wheel loads produced by a small percentage of 'bad' wheels or rail head surface defects are crudely accounted for in the Australian Standard AS 1085.14 by a single load amplification factor. In addition, there is a widespread perception within the railway engineering community that the carrying capacity of the existing track infrastructure is not fully utilised, and concrete sleepers possess significant amounts of untapped reserve strength. This can be attributed to the current design philosophy for concrete sleepers, outlined in AS 1085.14. This is based on the assessment of permissible stresses resulting from quasi-static wheel loads and essentially the static response of concrete sleepers, making it unduly conservative and very costly for the railway organisations. This thesis addresses the identified deficiencies of the current design method through an in-depth analysis of the dynamic response of concrete sleepers under realistic loading conditions and proposes a more rational design procedure.

In order to shift the conventional methodology to a more rational design method that involves more realistic dynamic response of concrete sleepers and performance-based design methodology, a significant research effort within the framework of the Cooperative Research Centre (CRC) for Railway Engineering and Technologies has been carried out to perform comprehensive studies of the loading conditions, the dynamic response, and the dynamic resistance of pre-stressed concrete sleepers. The collaborative research between the University of Wollongong (UoW) and Queensland University of Technology (QUT) has addressed such important issues as the spectrum and amplitudes of dynamic forces applied to the railway track, evaluation of the reserve capacity of typical pre-stressed concrete sleepers designed to the current code AS 1085.14, and the development of a new limit states design concept.

The comprehensive literature review highlighted the extremely limited research work that previously had been done in this field of research. In order to enhance an understanding of the dynamic performance of railway tracks, the first part of this thesis investigates the dynamic characteristics of the global railway track and its individual components with particular reference to rail pads and pre-stressed concrete (PC) sleepers. The experimental techniques for extracting dynamic properties of track components, developed in the laboratory, have been successfully applied in field trials. Moreover, this thesis provides an intensive review aimed at predicting wheel impact loads due to the wheel/rail irregularities at different return periods (based on the field data from wheel impact detectors).

The experimental and numerical investigations into the dynamic behaviour of pre-stressed concrete sleepers subjected to severe impact loading are then presented. The impact tests were carried out using the pre-stressed concrete sleepers manufactured in Australia. A track test bed was simulated in the laboratory and calibrated against the frequency response functions obtained for real tracks. A series of incremental impact loading tests for the pre-stressed concrete sleepers was performed, ranging from a typical design load to a severe wheel load. The cumulative impact damage and crack propagation in concrete sleepers were identified. The effects of track environment together with the relationship between the bending moment of pre-stressed concrete sleepers and the applied impact force are also presented.

The later part of this thesis identifies the responses of pre-stressed concrete sleepers in railway track structures under both single and repeated impact loads associated with different probabilities of occurrence. The residual capacities of the damaged pre-stressed concrete sleepers are studied in order to clarify the notion about the reserve strength of the concrete sleepers. The numerical investigations of the static and impact behaviours of railway pre-stressed concrete sleepers under static and dynamic loads were also undertaken to supplement the experimental findings in this thesis.

A proposal for the reliability-based design concepts and rationales associated with the development of limit states design procedures for the conversion of AS 1085.14 to a limit states design format is one of the key outcomes of this thesis. The new limit states design concepts and procedures for railway pre-stressed concrete sleepers are presented as the design guidelines for the railway engineers. The new methodology is aimed not only to save the material resources to achieve financial gains, but also to reduce the amount of cement production which would otherwise emit carbon dioxide as a contributing factor towards global warming.

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Biographical Memoir

LAWRENCE DRAKE, S.J.

1931 – 2007

Lawrie Drake was born on 29 October 1931, and spent his childhood years at Lorne on the coast of Victoria. A student at the Jesuit school, Xavier College, Melbourne, he went on to obtain bachelor degrees in Science and Arts at the University of Melbourne, having already joined the Jesuit order. Later he gained a doctorate in geophysics at the Berkeley campus of the University of California.

In 1952 he was appointed Director of the Jesuit-operated observatory at Riverview College, Sydney, founded in 1907 by a former member of the Society, Fr. E. Pigot, and following in the footsteps of Fr. T.N. Burke-Gaffney S.J, also a member. Dr Drake published two papers in the Society's journal, on the Seismicity of New South Wales, and on Seismic Risk, as well as contributing the obituary of the eminent geophysicist, Professor Keith Bullen, and was awarded the Archibald Ollé Prize in 1976.

He was often called on by the media concerning earthquakes, providing clear and precise analyses of data from the observatory's sensitive equipment which detected storm waves and occasionally nuclear test explosions.

In addition to his observatory duties, for nearly twenty years from about 1973 to 1992 Lawrie Drake was a popular member of staff of the School of Earth Sciences at Macquarie University. In his maiden speech, Federal Parliamentarian, Barnaby Joyce mentioned Lawrie Drake as one of his most important influences.

In 1992 Dr Drake resigned as Director of the Riverview observatory, which subsequently ceased to function as a fully-fledged observatory, and took up the challenge of the directorship of the astronomical and seismographic observatory at San Calixto, near La Paz, Bolivia. When diagnosed with cancer he moved back to Melbourne in 2002.

There, although increasingly ill, he translated Spanish papers for his South American colleagues and became involved in debunking so-called 'creation science'. I last met him in the Jesuit archives, Melbourne, where he was working on the archives of Jesuit scientists.

Blest with a great sense of humour and particularly fond of 'Irish' jokes Dr Drake was nevertheless what one might regard as a conservative theologian, holding firmly to Church pronouncements on liturgy and other matters. His fellow Jesuit, Fr. Lake-Smith, wrote of Dr Drake 'For Lawrie rules were a help for our human weakness, there for a common good, a stimulus to our responsibility. Truth was important and to be followed.' He died on 29 April, 2007.

Compiled by David Branagan from personal acquaintance; obituary by Michael Head, *The Age*, 11 May 2007, p. 6; eulogy by T. Lake-Smith (Jesuit Archives, Melbourne); Article, 'Seismologist Jumps at Bolivian Job' *Sydney Morning Herald*, 17 August 1992; Article 'Design in the Universe' *AD 2000*, November 1988, p. 13–14, and generous advice from Alan Day.

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Biographical Memoir

EDMUND C. POTTER

PhD (London), FRSC, FRACI, CCHEM
1923 – 2005

Edmund Potter was born on 14 March 1923 in England. His university studies were carried out at London University where he obtained a PhD in physical chemistry. After graduation he began work for the British Electricity Authority in 1951 to work on the corrosion of steel, a major problem in the maintenance of power generation.

Although trained essentially in physical chemistry Dr Potter found himself investigating electro-chemical problems and moving from an applied field on the behaviour of boilers into fundamental aspects of the properties of steel, particularly the behaviour of magnetite. In the ten years from 1955 he published at least six important papers on Internal boiler Tube Corrosion, three singly and three jointly with colleagues.

In 1968 Dr Potter, his wife Marion and family, relocated to Sydney, at the invitation of CSIRO, to work on another applied problem, that of the combustion of pulverised flue ash in furnaces closely adjacent to the boilers. He found himself again moving into fundamental research on electrostatic precipitation. At least one paper resulted from his study of the composition of dissolved oxygen in water, an important factor in electrostatic precipitation, the latter resulting in at least four papers (one joint).

Edmund Potter joined the Royal Society in 1988, and was quickly elected to the Council. He served two terms as President, 1991–92, and 1997–1998. He remained on the Council in the intervening years and until 2003. His attention to detail and charm helped to soothe some occasional difficult meetings in the later period.

His two Presidential addresses provide a fine summary of his interests over almost fifty years in physical chemistry and science in general. He suggested that his work fell into two separate, but related, fields 'keeping boilers intact and cleaning smoky chimneys', but there was much more to it than that. Edmund evinced rare slices of pessimism in his feeling that 'applied science was alive, but unwell', and regretted that present researchers not infrequently skimped on literature reviews, resulting in a considerable duplication of research and 're-invention of the wheel'.

His broader interests are shown in his first Presidential address 'On being interested in the extreme', where he paid compliment to one of his favourite reading, The Guinness Book of Records, to which he had been delighted to contribute!

Edmund Potter gave a great deal to the Royal Society of New South Wales, in its difficult years in the late nineties into the twenty-first century, when the society was in a parlous state, due to falling membership and forced moves from a relatively roomy space into very cramped quarters at Macquarie University.

Edmund's dedication to the Society's monthly meetings was shown by his regular attendance, coming from Kariong near Gosford, with his wife, Marion, and presenting for the newsletter a fine readable summary of each presentation, spiced with his light-hearted humour.

Edmund Potter's wise council, his pleasant, gentlemanly manner (we cannot remember him ever having a temperamental outburst, although no doubt there were plenty of temptations) contributed greatly to this Society. His philosophy is summed up in his comment: 'Well, for better or worse, I prefer to call myself an applied researcher with a broad scientific base and an eye for a deficiency in fundamentals that has to be remembered if development is to proceed on sound principles and persistent problems are to be overcome'.

Edmund C. Potter, PhD (London), FRSC, FRACI, CCHEM died on 27/7/2005, and was farewelled by family, close friends and Society members at a moving celebration Mass at Gosford.

David Branagan & Daniel O'Connor

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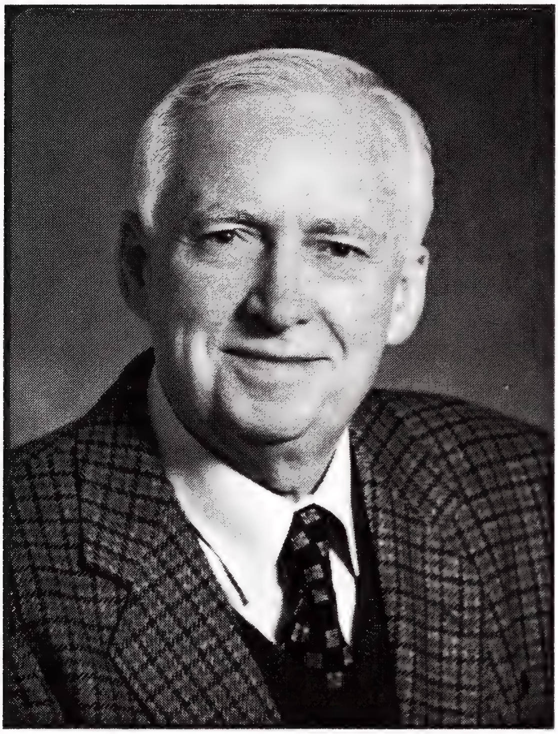
Biographical Memoir

VIVIAN WHITTAKER

1930 – 2008



Vivian Whittaker, a medical doctor, research scientist and retired Senior Lecturer in Biochemistry at the University of Sydney died in Sydney at the age of 78 on 16 September 2008.

He was born in Namatanai, New Ireland, where his father, trained as a Medical Assistant in Rabaul, ran the hospital. Viv's parents, and Viv himself, were deeply affected by the Japanese invasion of New Guinea and Viv would tell of how he and his mother returned to Cairns and moved down the coast to Bundaberg which was considered safe from any invasion. He went to secondary school in Brisbane and trained as a doctor in that city. Viv had a deep love of Papua New Guinea; his childhood and the two years he spent there running the TB hospital in Finschhafen and as medical officer at Mt Hagen provided him with an endless fund of stories. A born raconteur, he loved to tell these stories in Pidgin or in English, and, in his own words, lived off those two years for the rest of his life. He competed a PhD at the John Curtin School of Medical Research in Canberra and then spent two years at the University of California at Berkeley. He was appointed to the University of Sydney in 1964 where he worked until his official retirement in 1995, although he continued his research on glycoproteins until shortly before his death.

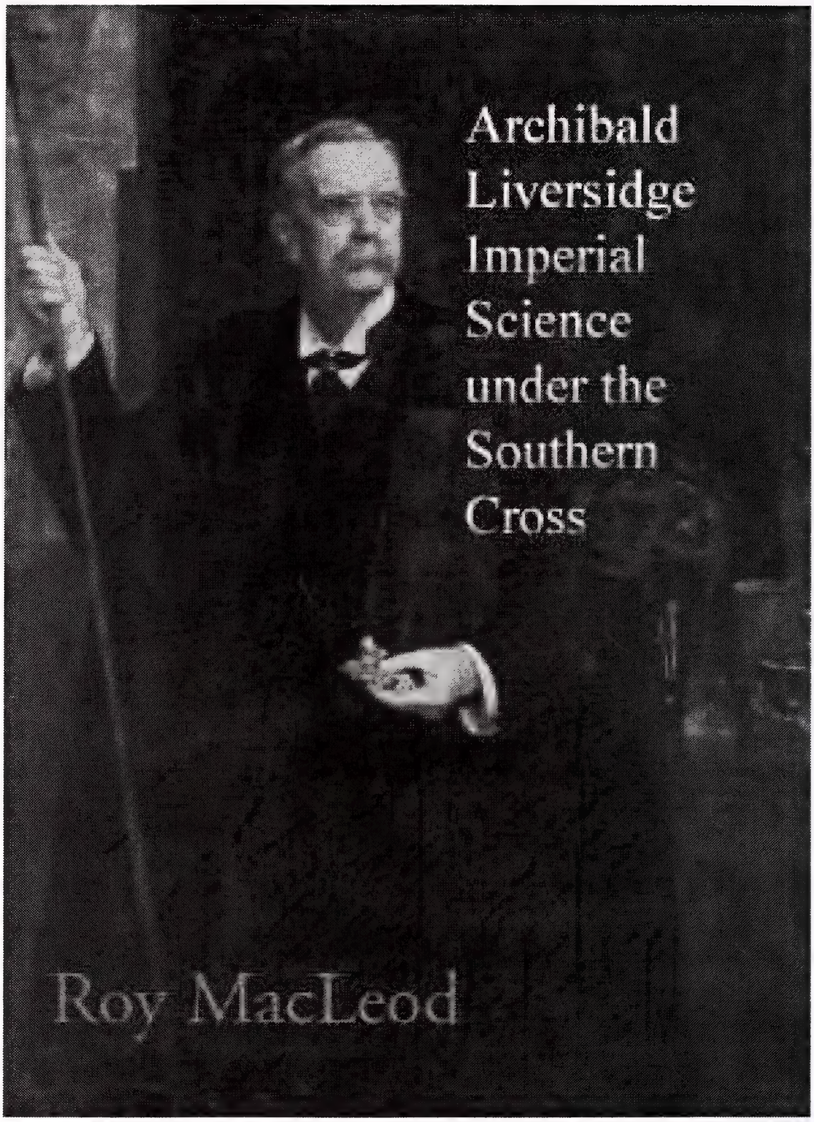
Viv Whittaker was a gentle and a wise man, much loved and admired by family, friends and students. A man of wide-ranging intellectual interests, he was initially torn between a career in medicine or one in music. He was an outstanding pianist and a composer with a melodic gift which he used to write four amusing intellectual musicals which were successfully (artistically and financially) produced whilst he was a PhD student. For many years he researched the life of Governor William Bligh for another musical, Goodbye Governor Bligh, which was incomplete at his death. Bligh held another fascination for him: the epic voyage to Timor in a long boat after the mutiny on the Bounty without a single loss of life was turned into a lecture on starvation, one of Viv's most successful undergraduate lectures.

For the last 20 years of his life, he was increasingly disabled by arthritis and other medical conditions which restricted his mobility. At this stage he decided to learn all the sonnets of Shakespeare. A gifted Latin scholar – he read Horace every day for pleasure – he taught himself ancient Greek and started learning hieroglyphics and Egyptian grammar. Always fascinated by languages, he decided to increase his knowledge of European languages by reading Gabriel Garcia Márquez's The Autumn of the Patriarch (El otoño del patriarca) in all the available translations. He was a passionate collector of books, porcelain, glass and cloisonné.

Viv had a strong sense of theatre in everything he did from playing the piano, to writing musicals, giving after-dinner speeches or undergraduate lectures in biochemistry, one of the more difficult of the pre-clinical subjects. During his long career at Sydney University, he taught over 7,000 medical students. His enthusiasm, intelligence and wit enabled him to impart a sound understanding of biochemistry to a whole generation of future doctors. His combined background in science and medicine made him ideally suited to this task. His most famous lecture was on porphyria, the disease associated with the madness of King George III. His deep knowledge and love of history had much to do with the success of this lecture in which he searched for symptoms of the malady through the royal families of Europe, the forebears of King George III. He attached great importance to his undergraduate teaching and often said he regarded the undergraduates he taught as his surrogate family, a family which he never had to feed or clothe but to whom he always had time to listen. His deep commitment to teaching was not at the expense of his research, which he regarded as his greatest intellectual achievement.

The area in which he chose to work is amongst the most difficult in biochemistry, that is, the synthesis and role of the sugar chains which are attached to the surface of glycoproteins. The sugar chains are known to have an important role in regulating the social interactions of cells but the precise mechanism by which the sugar chains exert their effects is obscure. Viv Whittaker believed that the enzyme phosphodiesterase I was involved in the synthesis of retinoic acid nucleotides which act as sugar donors or as modulators of protein function. From careful reading of the scientific literature, particularly in the years following his retirement, he became convinced that he could explain many of the widely reported, but to his mind, wrongly interpreted, findings in the field. He believed that his research would lead to a greater understanding of diseases such as Alzheimer's and Parkinsonism. Most of the results obtained in his laboratory, the work of 32 research students and two assistants over nearly 30 years, are preliminary and will, in the near future, be rigorously tested, with funding provided by his bequest, in honour of his parents, to the University of Sydney.

Michael Slaytor and William Sewell



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Archibald Liversidge
Imperial Science under the Southern Cross

by Professor Roy MacLeod


Professor Roy MacLeod

Roy MacLeod is Professor Emeritus of (Modern) History at the University of Sydney, and an Honorary Associate in the History and Philosophy of Science. He was educated in history, the biochemical sciences, and the history of science at Harvard University (summa cum laude), in sociology at the London School of Economics, and in history and the history of science at Cambridge, where he took the PhD degree in 1967.

He is the author or editor of 22 books and about 120 articles in the social history of science, medicine and technology; military history, museum history, Australian and American history, European history; research policy, and the history of higher education.

Roy MacLeod's most recent book, *Archibald Liversidge: Imperial Science under the Southern Cross* is about to be published by the Royal Society of NSW and Sydney University Press. Liversidge was renowned for his remarkable service to Australian science in the early days of the University of Sydney, where in 1872 he became demonstrator in chemistry and then 'Reader in Geology and Assistant in the Laboratory' and professor of geology and mineralogy in 1874.

One of his greatest contributions was to science education. He worked tirelessly to secure proper recognition of science in both secondary and tertiary education. In the Preface of his book, Professor MacLeod comments: "Liversidge remained confident that Australia's path would follow the route of the 'moving metropolis', strengthened by the bonds that tied Australia to its British heritage. In that heritage lay his life, and through that heritage, flowed the genius of imperial science in New South Wales."

NOTICE TO AUTHORS

Manuscripts should be addressed to The Honorary Secretary, Royal Society of New South Wales, Building H47 University of Sydney NSW 2006.

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Papers, other than those specially invited by the Editorial Board on behalf of Council, will only be considered if the content is substantially new material which has not been published previously, has not been submitted concurrently elsewhere nor is likely to be published substantially in the same form elsewhere. Letters to the Editor and short notes may also be submitted for publication.

Three, single sided, typed copies of the manuscript (double spacing) should be submitted on A4 paper.

Spelling should conform with 'The Concise Oxford Dictionary' or 'The Macquarie Dictionary'. The Systéme International d'Unites (SI) is to be used, with the abbreviations and symbols set out in Australian Standard AS1000.

All stratigraphic names must conform with the International Stratigraphic Guide and new names must first be cleared with the Central Register of Australian Stratigraphic Names, Australian Geological Survey Organisation, Canberra, ACT 2601, Australia. The codes of Botanical and Zoological Nomenclature must also be adhered to as neccessary.

The Abstract should be brief and informative.

Tables and Illustrations should be in the form and size intended for insertion in the master manuscript – 150 mm x 200 mm. If this is not readily possible then an indication of the required reduction (such as 'reduce to 1/2 size') must be clearly stated. Tables and illustrations should be numbered consecutively with Arabic numerals in a single sequence and each must have a caption.

Half-tone illustrations (photographs) should be included only when essential and should be presented on glossy paper.

Maps, diagrams and graphs should generally not be larger than a single page. However, larger figures may be split and printed across two opposite pages. The scale of maps or diagrams must be given in bar form.

References are to be cited in the text by giving the author's name and year of publication. References in the Reference List should be listed alphabetically by author and then chronologically by date. Titles of journals should be cited in full – not abbreviated.

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