On the Discovery of Marine Deposits of Pliocene Age in Australia.

By Professor Ralph Tate, F.G.S., F.L.S., &c.

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Towards the end of last year a deep bore in search of water was successfully completed at the Australian Smelting Company's Works at Dry Creek, Adelaide. A summary of the beds passed through, which here follows, has been furnished me by Mr. John Provis, the Company's General Manager:—

"The bore was commenced with an auger big enough to take an eight-inch tube, and was sunk 120 feet through clay; after 100 feet had been reached, occasionally thin seams of sand occurred which carried a little water. At 120 feet the tube reached the sand, and a good supply of water was struck, estimated at about 30,000 gallons per day. The sand rose so rapidly, however, that it was impossible to keep it out, and the tube was constantly choked. Owing to the bore being suspended as soon as water was struck, the sand and clay packed so tightly round the tube that it was impossible to drive it, and another tube had to be inserted; this was put down a considerable distance further, in a very fine sand, but eventually shared the same fate. As a last resource, a third tube was inserted, and arrangements were made to carry on the work night and day without intermission.

"A little water began to flow below 300 feet. At about 320 feet we came on to the marine shells, and these continued down to about 400 feet. At 400 feet to 410 feet very few shells occurred, and a little clay was mixed with the sand. There were also occasional pebbles of quartzite and schist. At 400 feet water commenced to flow very freely, and at 410 feet the flow increased to a quantity estimated at 100,000 gallons per day, and continues to-day (July 5, 1890) as strong as when first struck. There is also a marked improvement of the quality of water* now flowing."

The site of the bore is about 14 feet above sea-level, and is at the margin of the Recent Marine silts overlapping the red loams of the Adelaide Plain. The upper 120 feet of the bore-section doubtlessly belong to the Pliocene or Mammaliferous Drift, but until the fossiliferous bed at 320 feet was reached I had not

* See Appendix.

visited the bore. I am, therefore, unable to express an opinion as to the nature and probable age of the intervening portion of the section; moreover, I had not the opportunity of examining any of the extracted material. Particular interest, as regards this geological section, belongs to the fossiliferous sands extending in depth from 320 to 410 feet; because, if I have rightly correlated the fauna here brought to light, we have now knowledge of a marine deposit of Pliocene age, which partially fills the hiatus separating our Older Tertiary series from the Pleistocene and Recent Marine formations.

The sand is very sharp and somewhat coarse; it resembles broken quartz-crystals, and shows little or no attrition. With it there is freely mingled dark-brown or blackish carbonaceous chips, apparently belonging to stout stalks of sea-weed; the dissolved sulphurretted hydrogen in the outflowing water may have originated partly from the chemical action of the decomposing vegetable matter on the alkaline sulphates, whilst some of the animal tissues, which in the form of the ligamental union of bivalve-shells is still preserved in some of the larger species, may have contributed in a like manner. The organic debris consists largely of broken shell-substance; whilst the more or less perfect shells, which also show no signs of extensive rolling, have lost their original lustre; though in one species of *Phasianella* traces of colour are not infrequently clearly discernible, though the original polish has been wholly obliterated. The presence of quartzite-pebbles at from 400 to 410 feet would indicate an approach to the base of the Tertiary series; the pebbles range to about one inch in diameter, and are only slightly eroded.

The fauna comprises 10 species of foraminifera, a coral (*Cyclicia rubeola*, Q. & G.), a few species each of crustacea (*Eliminius simplex*, Darwin, &c.), echinoids (*Goniocidaris*, sp., *Stronglyocentrotus*, sp.), and polyzoa, 60 species of lammellibranchs and 150 gastropods. The species have been carefully compared with Recent and Tertiary forms belonging to Australasia, and less exhaustively with Recent and Tertiary faunas of exotic areas; with the general result that about one-half of the species is peculiar, about 30 per cent. common to the Miocene fauna as known at Hallett's Cove and southward to Aldinga Bay, at Muddy Creek and at the Gippsland Lakes, whilst about 20 per cent. belongs to the recent fauna of Southern Australia. This result would not be anticipated from a cursory survey of the collection, which has a strong modern facies, though the majority of the species after careful comparison prove to be distinct.

Details of the result of a comparison of the Lamellibranchiate fauna with those of the Recent and Tertiary Epochs I am able

to submit, as follows; whilst as regards the Gastropod-fauna, the comparisons are not completed—the magnitude of the task being disproportionately great, though estimated by so much as has been determined, there are fewer species represented in living creation or in older Tertiary deposits, and a larger number peculiar to the fauna.

Table of the Genera of Lamellibranchiata, with the number of their species belonging to the Pliocene.

Family Gastrochænidæ—			Family Carditidæ—		
Humphreyia		1	Cardita		2
Family Saxicavidæ—			Carditella		1
Saxicava		1	Family Nuculidæ—		
Family Corbulidæ—			Nucula		1
Corbula	...	1	Leda		1
Family Anatinidæ—			Family Crassatellidæ—		
Myodora		2	Crassatella		1
Myochama		1	Family Arcidæ—		
Family Mactridæ—			Limopsis		1
Mactra		1	Pectunculus		2
Hemimactra		1	Cucullæa		1
Family Tellinidæ—			Arca		1
Tellina	...	3	Barbatia		1
Family Veneridæ—			Family Aviculidæ—		
Chione		6	Meleagrina		1
Cytherea		2	Family Spondylidæ—		
Rupellaria		1	Spondylus		1
Family Cardiidæ—			Family Limidæ—		
Cardium	...	2	Lima		1
Family Lucinidæ—			Limatula		1
Lucina	...	7	Family Pectinidæ—		
Divaricella	...	1	Pecten		3
Miltha	...	1	Pleuronectes		1
Loripes	...	1	Family Anomiidæ—		
Family Erycinidæ—			Placunanomia		1
Lepton	...	3	Family Ostreidæ—		
Pythina	...	1	Ostrea		1
Mysella	...	1			—
Cyamium	...	1	Total species		60

TABLE of the DEFINED SPECIES of LAMELLIBRANCHIATA, occurring in the Pliocene Sands, showing their DISTRIBUTION IN TIME within the AUSTRALIAN AREA.

The sign xx before the name indicates that the species is abunbant; x that it is not uncommon. The asterisks in the columns showing distribution indicate that the species are characteristic.

	Eocene.	Miocene.	Pleistocene.	Recent.
Humphreyia Strangei, *Adams* ...	.	.	.	x
x Saxicava arctica, *Linn.* ...	x	x	.	x
Corbula ephamilla, *Tate* ...	*	x	.	.
Myodora brevis, *Sow.* ...	x	x	.	x
Mactra Hamiltonensis, *Tate* ...	.	*	.	.

	Eocene.	Miocene.	Pleistocene.	Recent.
xx Hemimactra Howchiniana, *Tate* ...	.	x	.	.
Tellina albinelloides, *Tate*	.	x	.	.
xx Chione striatissima, *Sowerby* ...	.	.	.	x
propinqua, *T.-Woods*, var....	x	x	.	.
subroborata, *Tate*	.	*	.	.
Cytherea submultistriata, *Tate* ...	.	x	.	.
Rupellaria pauperita, *Tate*... ...	.	x	.	.
Cardium tenuicostatum, *Lamk.* ...	.	.	.	x
cygnorum, *Desh.*	.	.	.	x
xx Lucina nuciformis, *Tate*	.	*	.	.
xx leucocomorpha, *Tate* ...	x	.	.	.
fabuloides, *Tate*	.	x	.	.
affinis, *Tate*	.	x	.	.
Tatei, *Angas*...	.	.	.	x
quadrisulcata, *D'Orb.* ...	.	x	x	x
Loripes simulans, *Tate*	.	x	.	.
xx Lepton trigonale, *Tate*	.	.	.	x
Mysella anomala, *Angas*	.	.	.	x
Crassatella oblonga, *T.-Woods* ...	x	*	.	.
Cardita Preissii, *Menke.*	.	x	.	x
x Nucula tumida, *T.-Woods*	x	*	.	.
x Limopsis Belcheri *Adams & Rv.* ...	*	*	x	x
xx Pectunculus obliquus, *Reeve* ...	.	.	x	x
x convexus, *Tate*, var. ...	.	*	.	.
Cucullæa Corioensis, *McCoy* ...	*	x	x	.
Arca navicularis, *Brug.*	.	.	.	x
Meleagrina crassicardia, *Tate* ...	x	x	.	.
Lima Bassii, *T.-Woods*	x	.	.	.
Limatula Jeffreysiana, *Tate* ...	x	.	.	.
xx Pecten anti-australis, *Tate*... ...	.	*	.	.
spondyloides, *Tate*... ...	.	x	.	.
subbifrons, *Tate*	.	*	.	.
Pleuronectes lucens, *Tate*	.	x	.	.
Placunanomia Ione, *Gray*	.	x	x	x
Ostrea Angasi, *Sowerby*	.	.	x	x
Total species, 40.	12	27	6	16

A summary of the distribution of the 60 Pliocene species is as follows :—

Living species	16 or 27 per cent. nearly
Extinct species of the Eocene and Miocene fauna ...	24
Restricted Pliocene species	20
Total	60

Table of the Genera of Gasteropoda, with the Number of their Species belonging to the Pliocene :—

Murex (Chicoreus)	1	Vitularia	1
(Ocinebra)	2	Trophon	1
(Rhinacantha)	1	Fusus	1
(Pteronotus)	1	Sipho	1

Fasciolaria	...	2	Odostomia	...	2
Triton	...	2	Turbonilla	...	3
Ricinula	...	1	Alaba	...	1
Nassa	...	3	Lacuna	...	1
Cominella	...	1	Rissoina	...	4
Phos	...	1	Rissoia	...	3
Voluta	...	2	Hydrobia	...	2
Ancillaria	...	2	Phasianella	...	2
Mitra	...	3	Eucosmia	...	1
Costellaria	...	3	Astralium	...	2
Columbella	...	9	Cyclostrema	...	5
Cassis	...	1	Teinostoma	...	1
Pelicaria	...	1	Liotia	...	1
Terebra	...	1	Cantharidus	...	3
Cancellaria	...	2	Calliostoma	...	1
Marginella	...	3	Clanculus	...	2
Pleurotoma	...	1	Elenchus	...	2
Bela	...	1	Diloma	...	1
Surcula	...	1	Solariella	...	1
Cithara	...	1	Euchelus	...	1
Drillia	...	1	Haliotis	...	1
Clathurella		5	Nacella	...	1
Cypræa	...	1	Fissurellidæa	...	1
Crepidula	...	2	Fissurella	...	1
Trochita	...	1	Emarginula	...	1
Amalthea	...	1	Ringicula	...	1
Natica	...	5	Tornatella	...	2
Sigaretus	...	1	Atys	...	1
Vermetus	...	1	Volvula	...	1
Siliquaria	...	1	Tornatina	...	1
Turritella	...	1	Utriculus	...	1
Mesalia	...	1	Cylichna	...	4
Cerithium	...	3	Ischnochiton	...	1
Campanile	...	1	Schizochiton	...	1
Bittium	...	3	Chitonellus	...	1
Triforis	...	2	Entalis	...	1
Cerithiopsis	...	3	Dentalium	...	3
Eulima	...	1	Cadulus	...	1
Syrnola	...	3			

Table showing the Vertical Distribution of some Gastropoda occurring in the Pliocene Sands. (Explanations as before).

	Eoc.	Mioc.	Pleist.	Rec.
Nassa Jacksoniana, *Quoy & G.* ...	.	.	.	x
Nassa Tatei, *T. Woods*	*	x	.	.
Cominella subfilicea, *Tate*	.	x	.	.
Triton armatum, *Tate*	x ?	x ?	.	.
xx sexcostatum, *Tate*	.	x	.	.
Ancillaria orycta, *Tate*	.	*	.	.
xx pseudaustralis, *Tate* (dwarfed)	*	.	.	.
Columbella exoptata, *n. sp.*... ...	.	x	.	.
Cassis fimbriatus, *Quoy & G.* ...	.	.	.	x
Pelicaria coronata, *Tate*	.	*	.	.
Cancellaria Wannonensis, *Tate* ...	.	*	.	.
Cypraea Jonesiana, *Tate* ...	.	x	.	.
Crepidula monoxylon, *Lesson* ...	.	x	x	x
immersa, *Angas*	.	.	.	x

		Eoc.	Mioc.	Pleist.	Rec
	Amalthea conica, *Lamk.*	.	x	x	x
	Natica aurantia, *Lamk.*	.	.	.	x
xx	ovata, *Hutton*	.	*	.	.
xx	gibbosa, *Hutton*	.	*	.	.
	sagittata, *Menke*	.	.	.	x
xx	Mesalia Provisi, *n. sp.*	.	x	.	.
xx	Cerithium tenue, *Sow*	.	.	.	x
xx	Potamides dubium, *Sow.*	.	.	.	x
	Rissoina lirata, *Angas* ...	.	.	.	x
	Rissoina elegantula, *Angas*	.	.	.	x
	Cyclostrema micra, *T. Woods* ...	.	.	.	x
	Liotia Angasi, *Crosse*	.	.	.	x
	Elenchus irisodontes, *Quoy & G.* ...	.	.	.	x
	Euchelus Tasmanicus, *T. Woods* ...	.	.	.	x
	Haliotis nævosa, *Reeve*	.	.	.	x
	Fissurella scutella, *Gray*	.	.	.	x
	Emarginula candida, *Reeve*	.	.	.	x
	Utriculus eumicrus, *Crosse*	.	.	.	x
	Volvula rostrata, *A. Adams* ...	.	.	.	x
	Cylichna pygmaea, *A. Adams* ...	.	.	.	x
	Dentalium elephantinum, *Lin.* ...	.	.	.	x
	octogonum, *Lamk.* ...	.	.	.	x
x	Entalis sectum, *Deshayes*	.	.	.	x
	Cadulus acuminatus, *Deshayes* ...	.	x	.	x

LIST OF SPECIES OF FORAMINIFERA FROM THE DRY CREEK-BORE, determined by Mr. W. Howchin, F.G.S.

Rotalia Beccarii, *Linn.* Common; fine examples.
Polystomella crispa, *Linn.* Rather scarce and small.
subnodosa, *Münst.* Common; fine examples, carinate and conspicuously umbonate.
Discorbina turbo, *D'Orb.* Rather scarce.
rosacea, *D'Orb.* Rather scarce.
Truncatulina lobatula, *W.* and *J.* Very rare.
Miliolina Ferussacii, *D'Orb.* Very rare.
oblonga, *Montag.* Very rare.
(Triloculina) tricarinata, *D'Orb.* Rare.
Biloculina bulloides, *D'Orb.* Very rare.

The above are all shallow-water species, and each has been noted in one or other of the Muddy Creek-beds; but the list is much more characteristic of the Upper Bed (Miocene) than the Lower (Eocene).—W. H.

I have already stated that the fauna has a strong modern facies, but at the same time it does not materially differ in its generic grouping from that of our Miocene, which presents so many points of contrast with the Eocene. The only genera of special interest are *Lacuna* and *Cyamium*, both now known for the first time as constituents of a Tertiary fauna in Australia, and as yet unknown in its recent one. The former belongs to

the Palæarctic fauna, though well represented in the Parisian Eocene. It is remarkable that it is here represented by a species so closely near to *L. pallidula* as to cause hesitation to inscribe it under a different denomination. One is almost tempted to place it in the same category as *Saxicava arctica*, *Lasaea rubra*, and a few others which are common to the temperate seas of both hemispheres. *Cyamium* is Palæo- and Neo-arctic, though known by one species in the Paris-Basin.

A fact of some significance, suggestive of a colder climate prevailing during this life-epoch, as compared with the Miocene on the one hand and the Recent Period on the other, over the same areas, is the large proportion of diminutive shells, either in regard to the genera to which the species belong, or in regard to identical species of older or recent date. This is very conspicuous in the genera *Columbella*, *Phasianella*, and *Chione*, and exemplified by the species *Corbula ephamilla*, *Arca navicularis*, *Hemimactra Howchiniana*, *Cucullæa Corioensis*, *Ancillaria pseudaustralis*, *Pelicaria coronata*, &c., whilst on the other hand *Saxicava arctica* attains to large dimensions, as in forma *Angasi*.

The fauna is certainly distinct from the Older Miocene, as known at the localities previously named, and is a new one for Australia. In its higher percentage of living species it occupies an intermediate place in the scheme of geological periods between the Miocene and the Recent; and though I provisionally employ the stratigraphical designation of Older Pliocene for it, I am fully aware that the proportion of living species is too low to justify its employment as measured by the European standard; yet in this case the percentage-principle of classification does not adequately express the modern complexus of the whole fauna.

The majority of the living species range from low-water mark to five or six fathoms in depth. Most certainly the fauna belongs to the shallow water. The sharp sands and the fragmentary and unrolled condition of the fossils are rather suggestive of shallow-water material having been swept into a depression of the sea bed, or perhaps indicative of rapid accumulation on a sinking bottom.

The general elevation of the fossiliferous Miocene skirting the east coast of Gulf St. Vincent is about 80 feet above sea level; so that there is a difference of level of about 500 feet between the marine equivalents of the Miocene and Older Pliocene. The Older Pliocene fossil-bed is at from 320 to 410 feet in the Dry Creek bore, which is equal to 306 to 396 feet below sea level, and if we deduct 36 feet as the probable depth at which the species lived, then there has been a general depression of the coast-line

since the Older Pliocene period of 360 feet. The opinion that this deposit has been thrown by a fault is hardly worthy of consideration; though it is absolutely demanded if the extreme view is held that the Dry Creek deposit is synchronous with the Miocene, the nearest site to which is in the city of Adelaide, five miles distant, at an elevation of 110 feet above sea-level.

The above estimate of movement closely accords with those founded on other data, namely, the extension of the Mammaliferous Drift below sea-level, to which I have appealed as some warranty for the opinion that elevation was a factor in climatic change during the time when glaciers existed in the southern part of Australia. The following quotation is significantly applicable:—"I am unacquainted with marine Pliocene beds in South Australia, or even in Australia, ... therefore the marine equivalents to the Pliocene [Mammaliferous] Drift, if extant, are submarine." Arguing on the lacustrine origin of the Pliocene Drift, and its extension below sea-level, as evidence of the depression of the land since then, reference is made to the Pliocene Drift at Port Wakefield extending to 312 feet below sea-level, and overlying Cambrian or Pre-Cambrian strata; at Port Augusta to 356 feet below sea-level (but the base not reached). R. T., in Trans. Roy. Soc., S. Aust., vol.

Appendix.

Analysis of water from the Dry Creek-Bore. By Professor Rennie, D.Sc., &c.

In parts per 100·000.

Total solids dried at 180 deg. C.	321·
After ignition and restoration of carbonates ...	302·50
Sodium	83·90
Potassium	3·06
Calcium	16·28
Magnesium	10·85
Iron	·23
Aluminium	·21
Silica (SiO_2)	2·7
Chlorine	119·15
Sulphuric acid (SO_4)	48·45
Phosphoric acid (PO_4)	*nil*
Total carbon dioxide (CO_2)	40·00
*(Free or semi-combined CO_2)	16·27
Sulphurretted hydrogen (SH_2)	·80

* Calculated.

These may conveniently be supposed to be combined as follows, but it must be clearly understood that such combinations are to a large extent arbitrary, there being no known method of ascer-

taining with certainty how the acids and bases are combined in the original water :—

Parts per 100·000.

Potassium chloride	5·845
Sodium chloride	191·758
Sodium sulphate	26·276
Magnesium sulphate	38·357
Magnesium carbonate... ...	11·126
Calcium carbonate	40·700
Oxide of iron (Fe_2O_3) ...	·335
Alumina	·315
Silica	2·700
	317·407

This takes no account of organic matter, which is present in sufficient quantity to blacken the residue on ignition.