ON THE SUCCESSION AND HOMOTAXIAL RELATIONSHIPS OF THE AUSTRALIAN CAINOZOIC SYSTEM.

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Previous Opinions of Time Equivalents.

In the earlier days of palæontological work in Victoria, the conclusions as to the age of the rich Tertiary faunas of southern Australia* were necessarily founded on limited evidence, derived from an imperfectly-known series of fossils. The palæontology of these beds had then been scarcely touched by systematic workers, so that the small number of species available for purposes of comparison, both in relation to the question of local stratigraphical sequence and the wider one of correlating them with the well-studied Tertiary faunas of Europe, rendered a solution of the problem one of great difficulty.

The first effort at correlation was made by Sir A. R. C. Selwyn in 1854, who, in a "Report on the Geology, Palæontology, and Mineralogy of the Country situated between Melbourne, Western Port Bay, Cape Schanck, and Point Nepean,"† stated, "Both the clay and limestone" [of the Mornington beds = Balcombian] "are very rich in fossil remains, and both in general lithological character,

* By southern Australia it is intended to include the States of South Australia and Victoria, which have a community of facies in Tertiary stratigraphy. This explanation is necessary from the fact that localities in Victoria have often been erroneously referred by European palæontologists to South Australia.

† Parl. Papers, 1854–55, vol. i.

mineral and organic contents, bear a striking resemblance to the clay and associated calcareous nodules of the London and Hampshire Basins." Since no detailed analysis or comparison of the fossil faunas were offered, this conclusion was only tentative. A further opinion was advanced by Selwyn in 1856, when, in his "Report on the Geological Structure of the Colony of Victoria, the Basin of the Yarra, and part of the Northern, North-eastern, and Eastern Drainage of Western Port Bay,"* he relegated the Victorian Tertiaries to Eocene, Miocene, Pliocene, and Pleistocene.

William Blandowski, in 1857 (in a Report written in 1854)† referred to several genera of mollusca and polyzoa as occurring in the Mount Martha beds (= Balcombian), and expressed the opinion that they are co-eval with the uppermost strata of the London, Paris, and various Italian clay basins.

The Mount Gambier Cainozoics (polyzoal limestone) were regarded by the Rev. J. E. Tenison Woods, in 1859,‡ as Eocene; but, later, of the age of the Pliocene Coralline Crag in England.§ The same author finally arrived at a mean in concluding|| that they were older than that series, and younger than the Muddy Creek beds; conclusions which are upheld in the present paper, as far as relate to the lower bed of that series.

Sir F. McCoy, in 1861,¶ regarded the Balcombian beds of Mt. Eliza and Mt. Martha (Balcombe's Bay) as of Upper Eocene age; but this was subsequently altered** to Oligocene, in accordance with the change of nomenclature and subdivision of similar beds in Europe, to which McCoy referred in the following terms:—"These have the general facies, and even specific identity of so many species, so clearly marked that there cannot be the slightest doubt of the great thickness of those beds being Lower Miocene of the date and general character of the Faluns of Touraine, the Bordeaux and the Malta beds; while the base of the series blends imperceptibly with a series of beds having a slightly older facies, and rendering the adoption of the Oligocene formation of Beyrich as convenient for Victoria as for European geologists." In this Essay McCoy draws the inference of a community of strata of Oligocene and Miocene ages exhibited in the Victorian, European, and North American deposits, by noting the occurrence of the teeth of Squalodon†† and typical Middle Tertiary sharks. With his extensive knowledge of European fossil faunas, and a keen eye for resemblances in the facies of widely separated areas, McCoy gave his conclusions, which were at

* Votes and Proceedings, Legislative Council, 1855–56., vol. ii.

† "On an Excursion to Frankston, Balcombe's Creek, Mount Martha, Port Phillip Heads, and Cape Schanck." Phil. Trans. Roy. Soc. Vict., vol. i., p. 24, *et seq.*

‡ Quart. Journ. Geol. Soc., vol. xvi., p. 253 *et seq.*

§ Geol. Obs. in S. Australia, 1862, pp. 85, 86.

|| Q.J.G.S., 1865, vol. xxi., p. 393.

¶ Exhibition Essays, 1861, p. 159.

** Ditto (1866), 1867, p. 322, or sep. paper, p. 16.

†† The Victorian species is now referred to a related genus, *Parasqualodon.* See T. S. Hall. Proc. Roy. Soc. Vict., vol. xxiii. (N.S.), pt. II., 1911, p. 262.

the time almost prophetic, but in reality were based on a knowledge of the guide fossils of both areas. It had yet to be proved whether the Lyellian method of molluscan percentages as a test of the exact age (or as in the case of antipodeal strata, of their homotaxial relationships) could be applied to the Cainozoic beds of this southern continent.

A suggestive contribution bearing on the present subject is found in the Rev. J. E. Tenison Woods' "Palæontological Evidence of Australian Tertiary Formations."* In this paper the author showed that a close relationship exists between the majority of our Tertiary fossils and those of the Miocene of other areas; and although many of the fossil determinations given in that paper require some revision, the conclusions are based on good reasoning. He there says,† "Speaking of the Corals generally, we have more affinities with Miocene forms than any other formation; but a few genera are common to both Eocene and Miocene formations. We have no truly Eocene forms, such as *Turbinolia*, which are found in the Eocene beds both of Europe and America; neither have we among the many Foraminifera such characteristic fossils as Nummulites; but we have certain American genera which have seldom been found, as far as I am aware, above the Eocene." With regard to his remark about the absence of Nummulites in Australia, Tenison Woods was the first to record our commonest nummulinoid form as *Amphistegina*, a determination made for him by Prof. T. Rupert Jones.‡ Subsequently the genus *Nummulites* was recorded from our Cainozoics in error for *Amphistegina*, as will be shown in a separate section, and this has been a factor in the acceptance of the *Eocene* age of the Lower Muddy Creek and other related beds by certain authors.

The corals and echinoids of Victoria were first systematically dealt with by Prof. M. Duncan,§ and yielded that author no very decided evidence as to the age of our Cainozoic fossil series, when compared with the European faunas; although Duncan remarked‖ that the southern Australian fossil deposits with madreporaria, polyzoa, echinodermata, and mollusca have "a facies characteristic of all the European marine tertiary deposits above the Nummulitic." Later on he stated¶ that the aspect of certain genera of the echinoids "gives a Nummulitic-of-Europe-and-India facies to the fauna, whilst the cretaceous aspect is presented by *Catopygus* . . ." also noting other genera the names of which, as well as of the supposed *Catopygus* of Southern Australia (now *Studeria*), have since been changed, redeterminations showing that the forms have a Tertiary

* Journ. Roy. Soc. N.S. Wales, vol. xi. (1877), 1878, pp. 113–128.

† *Loc. cit.*, p. 119.

‡ J. E. T. Woods.—"On Some Tertiary Deposits in the Colony of Victoria, Australia." Quart. Journ. Geol. Soc. Lond., vol. xxi., 1865, p. 391.

§ Quart. Journ. Geol. Soc. Lond., vol. xxvi., 1870, pp. 284–318; and vol. xxxiii., 1877, pp. 42–73.

‖ Q.J.G.S., vol. xxvi., 1870, p. 317.

¶ Q.J.G.S., vol. xxxiii., 1877, p. 69.

relationship. At the same time he admitted that many of the species were almost identical with those of the Miocene of Malta. Duncan was inclined to group the Australian tertiaries in one series as Cainozoic, referring the deposits below the Mt. Gambier beds to the Lower Cainozoic, and all above it to the Upper Cainozoic.*

By the researches of Prof. Ralph Tate, Sir F. McCoy, and others, who have so ably followed in descriptive work, a large number of Tertiary species, particularly in the group of the mollusca, have been carefully diagnosed and figured; although in some cases perhaps scarcely enough attention has been paid to the work of authors who have dealt with fossils from related strata in areas not very far removed, as those of New Zealand. A critical examination of our Victorian lists will in all probability show that in more than one instance the same fossil is credited with two names. On the other hand, this comparative work has been often retarded by insufficient descriptions and inadequate illustrations.

A modification of McCoy's earlier opinion of the age of the Victorian strata was published in the First Progress Report of the Geological Survey of Victoria in 1874 (pp. 35, 36), in which there occurs a list of fossils by that author, correctly placing the Mornington beds at the base of the series, and referring to them as Oligocene. In this list, however, there is an admixture of fossils which are now referred to two different horizons in Victoria.†

In the correlation of the southern Australian Tertiaries by Prof. Ralph Tate and Mr. J. Dennant, in 1893,‡ the clays and polyzoal limestones of the Balcombian and Janjukian Series (giving them the local terms applied by Drs. Hall and Pritchard, *vide seq.*) are there referred to the Eocene. The Cainozoic strata of the Gippsland Lakes and the upper bed at Muddy Creek (= Kalimnan) are there called Miocene. The older and newer mammaliferous drifts are regarded as Pliocene to Pleistocene.

In 1895 Dr. P. H. MacGillivray, fresh from the study of our Cainozoic polyzoa, makes the following statement:—"The age of the deposits has been the subject of a good deal of discussion among geologists. They are now generally referred to the Oligocene or early Miocene, but some are considered by different authorities to belong to the Eocene. It is difficult, however, to believe that any of them can be so old as the Eocene, at least considering it to be comparable to that of Europe. So far as an opinion can be formed from an examination of the Polyzoa, they are not of very different ages."§

Drs. T. S. Hall and G. B. Pritchard, who have worked very assiduously in the study of our Cainozoic faunas and stratigraphy,

* Q.J.G.S., vol. xxvi., 1870, p. 315.

† *Balanophyllia campanulata, Trigonia acuticostata, Spondylus gaederopoides, Volutilithes anticingulatus, Voluta macroptera* and *Cypraea platyrhyncha* are found in beds of later age.

‡ Trans. R. Soc. S. Australia, vol. xvii., pt. I., 1893, p. 216.

§ Trans. R. Soc. Vict., vol. iv., 1895, p. 2.

follow Messrs. Tate and Dennant in the same general reference of the older Cainozoics to the Eocene, but consider the Janjukian beds (*vide postea*), in contradistinction to the last-named authors, to underlie the Balcombian clays. This difference of opinion as to sequence is mainly due to the occurrence of fossiliferous clays resting on the polyzoal rock at Belmont* and Curlewis containing a fauna which was compared by Hall and Pritchard with the Balcombian clays of the Mornington and Muddy Creek type. The difficulty is easily explained by the fact that the species in these upper clays are unrestricted; that is, they pass from the underlying Balcombian into the Janjukian, but are, to a great extent, absent from the intermediate polyzoal facies, purely on account of difference of hydrographical conditions.

Until Drs. Hall and Pritchard instituted local names for those beds showing distinct faunal characters,† references to the various strata were very confusing, since no two authorities were actually agreed as to the use of the terms Eocene, Oligocene, Miocene and Pliocene when applied to the southern Australian Cainozoic.‡ The local names referred to are Balcombian, Janjucian (afterwards phonetically spelt Janjukian), Kalimnan, and Werrikooian. To these terms were afterwards added the comprehensive term "Barwonian," which includes both the Balcombian and Janjukian, as having some faunal characters in common, and distinguished from the Kalimnan, between which and the Balcombian there seemed, to the above authors, to be a greater palæontological break. It is here postulated that the Janjukian is the younger series, and therefore nearer in faunal characters to the Kalimnan; and, moreover, the palæontological difference referred to is not so marked as those authors believed. This is borne out by an exhaustive study of the fossils of the Mallee borings, in which there occurs a gradual passage downwards from Kalimnan into Janjukian, without intercalation of beds containing restricted Balcombian fossils.

In Drs. Hall and Pritchard's important paper on "A Suggested Nomenclature for the Marine Tertiary Deposits of Southern Australia,"§ those authors give a convenient summary of the various opinions as to the sequence and age of our Cainozoic strata, together with their local terms for these beds, which has already proved to be of the greatest use in providing a definite terminology for the various outcrops. The use of local terms consequently prevents that confusion which previously occurred when each author ascribed

* Mr. Mulder informs the writer that the shaft at Belmont, after passing through fossiliferous clays, finally reached polyzoal limestone.

† Proc. R. Soc. Vict., vol. xiv., N.S., pt. II., 1902, pp. 75–81.

‡ For an excellent summary of authors' opinions, see G. B. Pritchard's paper, "On the Present State of our Knowledge of the Older Tertiaries of Southern Australia." Rep. Austr. Assoc. Adv. Sci. Brisbane, 1895.

§ Proc. Roy. Soc. Vict., vol. xiv., N.S., pt. 2, 1902, p. 81.

the same stratum to formations of different ages. The summary referred to is given below :—

	McCoy.	*Tate and Dennant.*	*Hall and Pritchard*
WERRIKOOIAN	—	PLEISTOCENE (TATE) PLIOCENE (DENNANT)	PLIOCENE
KALIMNAN	OLDER PLIOCENE	MIOCENE	MIOCENE
BALCOMBIAN	OLIGOCENE	EOCENE	EOCENE
JANJUCIAN (NOW JANJUKIAN)	MIOCENE TO OLIGOCENE	OLIGOCENE (?) (TATE) EOCENE	EOCENE
ALDINGAN	—	EOCENE (IN PART)	EOCENE (IN PART)

In Drs. Hall and Pritchard's paper above referred to, the sequence given for the Australian Tertiary strata places the Janjukian at the base of the series. There is very strong evidence, however, in favour of the Balcombian being the oldest formation with marine fossils, and of an approximately equivalent age to the Upper Oligocene and Lower Miocene of Europe, North America, the West Indies, and Patagonia. In connexion with the last-named area, Ortmann* lately published an elaborate account of the fossils, and gave his conclusions as to the age of those beds. He also compared them with the Australian Tertiaries, agreeing almost entirely with the early views of McCoy. Dr. Ortmann based his conclusions upon a comparison of the fossil invertebrates with related forms from other localities and horizons in the Tertiaries ; and after giving the percentages of related fossils, goes on to say, "We see a constant increase of the percentages from the Cretaceous to the Miocene, and then again quite a sudden decrease from Miocene to Recent."

As Dall and Ortmann have shown, some of the West Indian faunas used for purposes of comparison have been referred to the Oligocene, and this points to the Patagonian beds having a stronger affinity towards the Older Cainozoic than would otherwise appear from Ortmann's previous calculations ; and accordingly the latter regards them more decidedly as Lower Miocene.†

THE RELATIVE VALUES OF THE PERCENTAGE METHOD ; AND THE COMPARISON OF TYPICAL FAUNAS, IN DETERMINING THE AGES OF THE AUSTRALIAN CAINOZOIC STRATA.

When Sir Chas. Lyell formulated the method of judging the age of the various Tertiary beds of the London, Hampshire and Paris Basins by the percentage of the recent species of mollusca contained therein, he was dealing with a set of strata deposited under fairly constant conditions, and dominated by an entirely different geographical distribution of land and water from that which must have prevailed more or less throughout Tertiary times in southern Australia. Since Lyell's time this once generally

* Reports of the Princeton University Expeditions to Patagonia, 1896–1899, vol. iv., pt. 2, 1902. Tertiary Invertebrates, pp. 48–332, pls. xi–xxxix.

† *Op. supra cit.*, p. 297.

accepted rule has been questioned. Kayser remarks*, "Although the principle underlying this classification has in progress of time proved in the main accurate, the percentages of living species originally adopted by Lyell for the various groups have not remained firm. Thus for the Pliocene we must take 40–90 instead of 35–50, and for the Miocene 10–40 instead of 17."

That the percentage method of correlating strata in widely separated areas is attended with serious difficulties has been early recognised, as, for example, by so able an observer of faunal distribution in the past and present as the late Capt. Hutton, of Christchurch, whose words on the subject we cannot do better than quote. After discussing the relative ages of two beds in the Wanganui System of New Zealand, which, on account of the close percentage of living to extinct species, Hutton was inclined to think, overlapped, and advocating the use of this same means of discrimination in determining the relative ages of beds in the same general area, he speaks thus :—†

"But it does not follow that this method can be trusted for correlating with accuracy sets of beds in widely distant areas. On the contrary, different districts have undergone different physical changes, and we have therefore every reason to suppose that alterations in floras and faunas would proceed with unequal rapidity in different parts of the world. At the same time, as the replacement of a whole marine fauna can rarely be sudden, it follows that the percentage system has some value even here. But it must always be used in conjunction with a comparison of the specific forms of the two areas. And here, again, it is only the wide-ranging oceanic, or deep-sea species—such as sharks, cephalopods, and a few bivalves—which should be depended upon for evidence, but these wide-ranging forms are of the very greatest value in correlating strata all over the world."

Another difficulty which confronts us with regard to the computation of the actual percentage of living species is the variable estimation by different authors of the value of minor characters; as, for example, of shell sculpture in the group of the mollusca, where slight differences are seen only after careful study, or it may be, a trivial variation in form, which, if sufficiently constant would be regarded by some as specific. Hence, critical work on any fauna will always tend to *lower the percentage of living species* in any given fossiliferous series, and consequently to *increase its approximate age*. It seems, therefore, that we, in the southern hemisphere, to use the percentage method, must gradually erect a standard of percentages which will generally accord with the evidence afforded by a study of the strata in this part of the world; never forgetting, however, to exercise a cautious spirit in regard to species-making in working from this stand-point.

* Text Book of Comparative Geology. English translation by P. Lake, 1895, p. 330.

† Trans. and Proc. New Zealand Inst., vol. xviii., 1886 (for 1885), p. 345.

Although Capt. Hutton mentioned certain groups of animals which, by reason of their comparatively deep sea habitat, furnish species of world-wide distribution, it appears highly probable that even these particular forms would be prone to considerable variation should they survive in an environment differing from that of the open ocean; and this will account for the difficulty of discovering universally distributed species for comparative purposes. To aid in this matter of the comparison of facies of widely separated faunas other than recent, it may be suggested that generic types, no matter of what group of organisms, but which are limited to distinct horizons in the northern hemisphere, should also be regarded as of special value in the correlation of the Tertiary strata in the southern hemisphere. A comparison of selected faunal types, more or less indicative of distinct horizons elsewhere, will be made in drawing up a suggested stratigraphical correlation, and discussed in the notes following in the next section.

In connexion with this subject, it is also necessary to draw attention to the recent work of Dr. A. E. Ortmann* as having an important bearing on the present question. From a study of the mollusca he has brought forward strong evidence in favour of correlating the Patagonian Tertiary beds with at least one of our southern Australian series, as well as with the Pareora formation of New Zealand, all of which he regards as Lower Miocene.

With particular reference to the percentage method, Ortmann remarks† :—"In very many cases the age of the Tertiary deposits is determined by the percentage of living species found in them. In my opinion this line of evidence is entirely inadmissible in our case, and I hardly need to say anything to support this view; this method may be safely used in Europe, but in the southern hemisphere it is out of the question."

Dr. Ortmann further points out that, owing to the changes in the systematic views of the various authors of species, the number of the identifiable living forms fluctuates, and one or two doubtful ones obviously lower the percentage considerably. This difficulty, as I have already mentioned, has frequently arisen in respect to the work of our Australian geologists, causing the same stratum to be referred to under three different age-names by as many authors. As a case in point, the work on the faunas of the Lower Muddy Creek section and the Spring Creek beds by Drs. Hall and Pritchard‡ showed a percentage of living species as low as 2.5 per cent. for the former locality, and only about 1 per cent. for the latter. Since only 3 out of 293 species were identifiable with living forms in the Spring Creek fauna, it is clear that by addition of a few more recent species these beds might be reversed in apparent sequence, by the opinion of the investigator of doubtfully valid living species.

* *Tom. supra cit.*
† *Tom. cit.*, p. 288.
‡ Proc. Roy. Soc. Vict., vol. viii., 1895, p. 190.

It is worthy of note that, in connexion with the subject of the value of the percentage method in its general sense, later research has already proved the survival of many other fossils of the Cainozoics in the seas of the present day. For instance, *Lissarca rubricata*, now living in Western Port Bay and elsewhere, occurs in the Janjukian of the Mallee bores; and the Balcombian to Kalimnan *Trivia avellanoides* is found living off the New South Wales Coast.

Some Cosmopolitan and Widely-distributed Fossil Types and their Significance.

Cetaceans.—In the Nodule or Phosphate Bed which is found at the base of the Kalimnan Series in Victoria, remains of cetacea are very abundant. They include ribs, vertebrae, an occasional scapula, digitals, tympanic bones, &c., evidently belonging to several distinct forms, and representing the Toothed Whales, including the Beaked Whales and the Dolphins. Similar remains are found scattered through the Janjukian Beds of Waurn Ponds and other localities where the strata are of considerable thickness, and marly or purely calcareous; and this, with other data of fossil occurrences, show convincingly that the nodular phosphatic bed of the Grange Burn and that at the base of the cliffs at Beaumaris, which there underlie the Kalimnan, represent a remanié bed of the Janjukian series.

One of the toothed whales (*Odontoceti*) occurring in Victoria is now referred to *Parasqualodon*, and another from South Australia is the type of the genus *Metasqualodon*.* These are closely related to Squalodon, a typically Miocene form extending into the Pliocene. The teeth of the squalodonts form a more numerous and closer series† than those in the Eocene *Zeuglodon*; the former being smaller animals, with a shorter rostrum. The southern hemisphere squalodonts have the roots of the molar teeth united, whilst in the northern forms they are separate and incurved. McCoy described a molar tooth of "*Squalodon*" (= *Parasqualodon*) *wilkinsoni* from the "Miocene Tertiary sands of Castle Cove, Cape Otway Coast,"‡ in beds of Janjukian age; and he subsequently figured another example, a canine tooth from Waurn Pounds, near Geelong. Several specimens both of the molar and canine teeth have since been found in the Waurn Ponds quarries in strata of similar age. In describing the *Parasqualodon* teeth, McCoy compared them with *Squalodon grateloupi*, H. von Meyer, from the Miocene of Bordeaux, from which they differ in the conjunction of the roots. Mr. E. B. Sanger, in 1881, described and figured a molar tooth of a cetacean under the name of *Zeuglodon harwoodi*,§ which has been made the

* T. S. Hall. "On the Systematic Position of the Species of Squalodon and Zeuglodon, described from Australia and New Zealand." Proc. R. Soc. Vict., vol. xxiii., N.S., pt. 2, 1911, pp. 257–265, pl. xxxvi.

† Both *Zeuglodon* and *Prosqualodon* have five molars, whilst there are seven in *Squalodon*

‡ Prod. Pal. Vict., Dec. 2, 1875, p. 7, pl. xi., fig. 1; Dec. 6, 1879, p. 20, pl. lv., fig. 3.

§ Proc. Linn. Soc. N.S. Wales, vol. v., 1881, p. 298, woodcuts A.B.

genotype of *Metasqualodon*, T. S. Hall. The specimens were found in yellow, calcareous clay on the Murray River near Wellington, South Australia. The molariform teeth have shorter roots than in *Parasqualodon*, this constituting the chief difference. In a remarkably well-preserved tooth of *Metasqualodon wilkinsoni*, from Mt. Gambier, in the National Museum collection, the enamel of the crown is of a rich brown colour, and the surface covered with minute prickly tubercles. This example is embedded in the white polyzoal limestone of the locality ; the rock being in all probability equivalent to the yellow polyzoal limestone of Waurn Ponds and Jan Juc (Spring Creek). Although new genera have been instituted for these southern types of toothed whales, the conclusion as to their Miocene age is not affected thereby, as they are all members of the Squalodontidæ, belonging to a higher zone than the Eocene Zeuglodonts.

Fishes.—In two papers on the Tertiary fish remains of Australia, published by Dr. G. B. Pritchard and myself,* the general distribution and range in time of each genus and species was fully dealt with ; but no inference was then drawn as to the ages of the beds yielding these remains. It is there stated (op. cit. vol. XVII., p. 292) that " These data do not furnish any very clear evidence of our Tertiary succession and relative age of the beds, since the fauna has a general Tertiary aspect, but the occurrence of the few Mesozoic forms gives an aspect of antiquity to the older portion of our Tertiary strata."

The genera discussed in those papers range from Jurassic to Recent, and none have a restricted occurrence in Tertiary times. This at first sight is disappointing to the palæontological inquirer for exact data of chronological value. However, looking more closely into the relative abundance of the genera of sharks and other characteristic fishes of the Tertiary, we find that all the abundant generic forms are especially typical of Miocene strata in the northern hemisphere. Amongst these may be mentioned *Galeocerdo, Odontaspis, Lamna, Oxyrhina, Carcharodon, Labrodon,* and *Diodon.* Evidence of greater antiquity than Miocene is afforded by the occasional occurrence of *Asteracanthus, Edaphodon,* and *Ischyodus,* which appear to be the survivors in Australian seas of types that are elsewhere found in earlier formations. This is a parallel case with the occurrence of *Trigonia* and other forms of archaic life found in the same area at the present day.

With regard to the group of the sharks, the species common to southern Australia and the northern hemisphere are *Carcharias acutus*†, *Sphyrna prisca, Odontaspis contortidens, O. cuspidata, Lamna crassidens, L. compressa, L. bronni, Oxyrhina hastalis, O.*

* Proc. R. Soc. Vict., vol. xvii., N.S., pt. 1, 1904, pp. 267–297, pls. xi., xii. *Ibid,* vol. xx., N.S., pt. 1, 1907, pp. 59–75, pls. v.–viii.

† This determination was formed on the apical portion of a serrated tooth which nwo appears to belong to a recently recorded genus common to the Patagonian and Victorian series, viz., *Carcharoides.*—See Victorian Naturalist, vol. xxx., 1913, pp. 142, 143.

desori, *O. retroflexa*, *O. eocaena*, *O. minuta*, *Carcharodon auriculatus*, and *C. megalodon*. Of these, 2 are northern Cretaceous forms, 11 are Eocene, 1 Oligocene,* 11 Miocene, and 6 Pliocene. A closer scrutiny of these species reveals the fact that, whereas the genus may be recorded from both Eocene and Miocene, yet in regard to abundance and ubiquity the evidence of the species, as before stated, is decidedly in favour of a Miocene age for the majority of the fish remains in the older portion of our Tertiaries.

With reference to the other fish remains in the Australasian Tertiary, it is interesting to note that the Chimaeroids have a more ancient history elsewhere, whilst around Australia they lived in large numbers in the Balcombian and Janjukian seas. Our Tertiary *Labrodon* is comparable with the typical Miocene species of South Carolina, the Vienna Basin, Italy, Sicily, and Brittany. The Australian gymnodont, *Diodon formosus*, is most nearly allied to *D. vetus* from the Miocene phosphate beds of South Carolina. The fossils of this genus are commonest as Miocene forms.

Mollusca.—Of the tetrabranchiate cephalopods, the *Aturia australis* of McCoy is a typical fossil in the Australasian Tertiaries. It had an extraordinarily long existence, being found in the Balcombian, the Janjukian, and the Kalimnan series; although it seems to be more common in the blue clays of the Mornington and Muddy Creek beds (Balcombian), where it often attains a large size. An exceptionally fine specimen from Muddy Creek in the National Museum collection measures 17.5 cm. (nearly 7 inches) in diameter, and about 6 cm. across in the umbilical region. This species is distinct from the Lower Eocene form, *A. ziczac*, to which it was formerly referred, in having more compressed sides. In this respect it is similar to *A. aturi*, Basterot, originally described from the Miocene of Dax, France, and also occurring at Turin and Malta in beds of the same age.

The true Nautili are also well represented in our faunas, but up to the present only one form has been described, viz., *N. geelongensis*, Foord,† which that author compares with *N. regalis*, J. Sow. The London clay species differs, as Foord remarks, in that "it is a more inflated shell, and its sutures much less flexuous." Examples of what appear to be the same form, in the National Museum collection, are from the Moorabool Valley, Victoria, and the cliffs of the Lower Murray River in South Australia (Janjukian).

The dibranchiate cephalopod, *Spirulirostra*, is one of the most remarkable genera of the Australian fauna. The only southern species, *S. curta*, made its appearance suddenly, but after a very short existence as quickly died out. It is strictly confined to

* The low number of records from the Oligocene is probably accounted for by the fact that certain beds of this system were previously regarded as Eocene. A revision of these records would possibly raise the number for the Oligocene.

† Cat. Foss. Cephal. Brit. Mus., pt. 2, 1891, pp. 332, 333, figs. 69*a*–*c*.

Miocene strata, and in Australia to a very limited horizon of a few feet in thickness in the Janjukian of Spring Creek, near Geelong. Until the Australian species, *S. curta*, Tate,* was described, this genus was represented by two species only, viz., *S. bellardii*, d'Orbigny, from the Miocene of Turin,† and *S. hoernesi*, von Koenen, from the Miocene of Dingden, Berssenbrück.‡

The remaining groups of the mollusc are not especially represented in the Australian Tertiary by genera restricted to any particular horizons elsewhere; but the Australian beds are rich in species of gasteropods, bivalves, and other invertebrates, related to these in the Tertiary faunas of the northern hemisphere, and to which reference will be made.

Echinoidea.—The Australian Tertiary fauna is rich in echinoids; and these furnish some interesting data in regard to closely related forms found in the northern hemisphere. When first authoritatively examined, our fossil sea-urchins were pronounced by Profs. P. M. Duncan and J. W. Gregory and others to have a decided Cretaceous aspect. This opinion has since been abandoned in consequence of the characters of the Australian species having been more clearly defined, showing them to be distinct from apparently related but older forms, as for example, *Holaster* (Cretaceous), and *Duncaniaster* (Miocene). Certain genera, as *Cassidulus*, *Plesiolampas*, and *Prenaster*, are Eocene elsewhere. *Echinoneus* is a genus ranging from Miocene to Recent in other areas. It is represented in our faunas by *E. dennanti*, T. S. Hall, and is found in the Batesford limestone associated with a Miocene foraminifer, *Lepidocyclina*. *Clypeaster*, although unrestricted, attains its maximum development in the Miocene faunas, as at Malta and the south of France. *Linthia* has a range from the Cretaceous to Recent, but is typically a Miocene form. It is represented by several species in our Janjukian series; *L. antiaustralis*, Tate, occurs at Curlewis in beds of that age, whilst *L. mooraboolensis*, Pritchard, is found in the Batesford limestone associated with Miocene foraminifera, as *Lepidocyclina marginata* and *L. tournoueri*. Another unrestricted genus but typically Miocene, is *Schizaster*, and one of its species, *S. sphenoides*, T. S. Hall, from the Barwonian of the Sherbrooke River, is almost identical with *S. scillae*, Desmoulins, a typical Miocene form in Europe.

Foraminifera.—The general facies of the foraminifera from Balcombian strata is that of the Lower Miocene fauna, with a tendency to the Oligocene: but no nummulites are present, as in typical Oligocene strata elsewhere. The Janjukian series, by its included species of *Lepidocyclina*, *Cycloclypeus* and *Amphistegina*,

* Proc. Roy. Soc. N.S. Wales, vol. xxvii., 1894, p. 170, pl. x., figs. 1, 1*a*, *b*.

† Ann. Sci. Nat. 1842, vol. xvii., p. 262, pl. xi. See also Michelotti, Foss. Terr. Miocènes, Ital., 1847, p. 346, pl. xv., fig. 12.

‡ Zeitschr. d. deutsch. geol. Gesellsch., vol. xvii., 1865, p. 428. Palæontographica, vol. xvi., pt. 3, 1867, p. 145, pl. xiv., figs. 6*a*–*h*.

is proved to be of Miocene age, as contrasted with the Eocene. This group of organisms, however, will be discussed in detail in a subsequent section.

Comparative Types.—The following comparative types of European Tertiary fossils have been selected as comprising some of the more striking forms which are isomorphous with the Australian species. It is by no means an exhaustive list, but will serve to illustrate the trend of evidence now brought forward, which proves that the greater part of the southern Australian series is of Miocene age; whilst below are beds of Oligocene to Lower Miocene, and above, of Pliocene, ages :—

B. = BALCOMBIAN ; BW. = BARWONIAN* ; J. = JANJUKIAN ;
K. = KALIMNAN.

SOUTHERN AUSTRALIA.	EUROPE.
Bw. — *Ceratotrochus typus*, Seg. sp.	*C. typus*, Seg. sp. (Up. Miocene).
J. — *Deltocyathus aldingensis*, T. W.	*D. italicus*, Ed. and Haime (Upper Miocene).
B.J. — *Balanophyllia australiensis*, Dunc.	*B. praelonga*, Michelotti (Oligocene and Miocene).
J. — *Balanophyllia cylindrica*, Michelin	*B. cylindrica*, Mich. (Upper Miocene).
Bw. — *Balanophyllia selwyni*, Duncan	*B. italica*, Ed. and Haime (Miocene).
J. — *Psammechinus woodsi*, Laube sp.	*P. monolis*, Desmoulins sp. (Miocene).
B.J.K.—*Clypeaster gippslandicus*, McCoy	*C. grandiflorus*, Bronn (Miocene). NOTE.—McCoy refers to *C. subdepressus*, Gray, a W. Indian and W. African living species, as a near ally.
Bw. — *Linthia gigas*, McCoy sp. ..	*L. crucia*, Desor (Miocene).
B.J.K.—*Lovenia forbesi*, Woods and Duncan	*Lovenia hoffmanni*, Goldfuss sp. (Upper Oligocene). This species is usually referred, apparently erroneously, to the genus *Hemipatagus*, for, judging from specimens in the National Museum collection, it has the sub-anal fasciole well developed, and should therefore be transferred to the Prymnodesmia.

* Probably almost all the Barwonian localities will eventually be found to represent an argillaceous phase of the Janjukian.

COMPARATIVE TYPES—*continued.*

SOUTHERN AUSTRALIA.	EUROPE.
A small depressed variety of *L. forbesi*, more frequent in the Janjukian and Kalimnan	*L. ocellata*, Defr. sp. (Miocene).
B.J.K.—*Cucullæa corioensis*, McCoy	*C. crassatina*, Lam. (Eocene-Miocene).
B. — *Limopsis morningtonensis*, Pritch.	*L. aurita*, Brocchi sp. (Oligocene-Recent). *L. scalaris*, Sow. sp. (Upper Eocene).
J. — *Arca* (*Barbatia*) *limatella*, Tate sp.	*Arca* (*B.*) *appendicula*, Sow. (Upper Eocene and Oligocene).
B.J.K.—*Arca* (*Barbatia*) *consutilis*, Tate sp.	*Arca* (*B.*) *biangula*, Lam. (Middle and Upper Eocene).
B.J.K.—*Glycimeris cainozoicus*, T.W. sp.	*G. pulvinatus*, Lam. The variety described by Brongniart from the Miocene.
B. — *Pteria crassicardia*, Tate sp.	*P. phalaenacea*, Lam. sp. (Miocene).
B.J. — *Pecten peroni*, Tate ..	*Pecten spinulosus*, Münster (Miocene).
B.J. — *Pecten hochstetteri*, Zittel ..	*Pecten burdigalensis*, Lam. (Miocene).
B.J. — *Pecten sturtianus*, Tate ..	*Pecten fistulosus*, Eichw. (= *malvinae*, Dubois) (Miocene).
B.J.K.—*Pecten yahliensis*, T.W. ..	*Pecten hoffmanni*, Goldfuss (Upper Oligocene).
B.J. — *Hinnites corioensis*, McCoy	*H. cortesii*, Defr. (Miocene).
J. — *Spondylus gaederopoides*, McCoy	*S. gaederopus*, Linné (Miocene).
B.J. — *Lima bassi*, T. Woods ..	*L. inflata*, Lam. (Miocene).
K. — *Cardita calva*, Tate ..	*C. orbicularis*, Bronn (= *chamaeformis*, Goldfuss) (Pliocene).
B(?).J.—*Carditamera compta*, Tate sp.	*C. crassicosta*, Lam. sp. (Miocene).
B.J. — *Chama lamellifera*, T. Woods	*C. squamosa*, Sol. (Upper Eocene).
B.J.K.—*Dentalium mantelli*, Zittel	*D. kickxi*, Münster (Oligocene).
B.J.K.—*Crepidula unguiformis*, Lam.	*C. unguiformis*, Lam. (Miocene-Recent).

COMPARATIVE TYPES—*continued.*

SOUTHERN AUSTRALIA.		EUROPE.
B.J.	— *Natica hamiltonensis*, Tate	*N. helicina*, Brocchi sp. (Miocene).
B.J.	— *Natica wintlei*, T. Woods	
B.J.	— *Natica subnoae*, Tate ..	*N. noae*, d'Orb. (Eocene).
B.J.K.	—*Turritella tristira*, Tate ..	*T. vindobonensis*, Partsch (Miocene). *T. triplicata*, Brocchi.
(?)B.J.	—*Cypraea archeri*, T.W. ..	*C. sphaericulata*, Lam. (Miocene).
B.J.	— *Trivia avellanoides*, McCoy	*T. affinis*, Wood (Miocene and Pliocene).
B.J.	— *Lotorium tortirostre*, Tate	*L. argutum*, Nyst sp. (Middle Eocene-Miocene).
J.	— *Murex tenuicornis*, Tate ..	*M. spinicosta*, Bronn (Miocene).
J.	— *Murex legrandi*, T. Woods	*M. cristatus*, Brocchi (Miocene).
J.	— *Typhis tripterus*, Tate ..	*T. fistulosus*, Sow. (Upper Eocene).
B.J.	— *Typhis maccoyi*, T. Woods	*T. pungens*, Sol. sp. (Upper Eocene).
J.	— *Fasciolaria johnstoni*, T.W. sp.	*F. bilineata*, Partsch sp. (Miocene).
B.J.	— *Fasciolaria decipiens*, Tate	*F. tarbelliana*, Grat. (Miocene).
J.	— *Volutilithes anticingulatus*, McCoy sp.	*V. cingulatus*, Nyst sp. (Oligocene).
B.J.K.	—*Volutilithes antiscalaris*, McCoy sp.	*V. scalaris*, Sow. sp. (Upper Eocene).
B.J.K.	—*Voluta strophodon*, McCoy	*V. spinosa*, Lam. (Eocene).
B.	— *Olivella angustata*, Tate sp.	*O. clavula*, Lam. sp. (Miocene).
B.	— *Ancilla subampliata*, Tate sp.	*A. dubia*, Deshayes sp. (Middle Eocene).
B.J.	— *Ancilla hebera*, Hutton sp.	*A. glandiformis*, Lam. sp. (Miocene).
B.	— *Ancilla lanceolata*, Tate sp.	*A. obsoleta*, Holl (Miocene).
B.	— *Cancellaria exaltata*, Tate	*C. varicosa*, Defr. (Miocene).
K.	— *Terebra angulosa*, Tate ..	*T. pertusa*, Bast. (Miocene).
B.	— *Terebra platyspira*, Tate	*T. acuminata*, Bors. (Miocene). *T. melaniana*, Grat. (Miocene).
B.	— *Pleurotoma murndaliana*, T.W.	*P. planum*, Giebel (Oligocene).
J.	— *Apiotoma bassi*, Pritchard	*Pleurotoma ramosum*, Bast. (Miocene).
B.J.K.	—*Bathytoma rhomboidalis*, T. Woods sp.	*B. cataphracta*, Brocchi sp. (Miocene).
B.	— *Bathytoma decomposita*, Tate	*B. turbida*, Bronn sp. (Oligocene).
B.J.	— *Conus heterospira*, Tate	*C. dujardini*, Desh. (Miocene).
B.	— *Conus hamiltonensis*, Tate	

COMPARATIVE TYPES—*continued.*

SOUTHERN AUSTRALIA.	EUROPE.
B.J.K.—*Conus cuspidatus*, Tate ..	*C. raristriatus*, Bell. and Mich. (Miocene).
B.J.K.—*Conus extenuatus*, Tate ..	*C. procerus*, Beyrich (Oligocene).
B. — *Vaginella eligmostoma*, Tate	*V. strangulata*, Grat. sp. (Miocene).
B.J.K.—*Aturia australis*, McCoy	*A. aturi*, Bast. (Miocene).
J. — *Spirulirostra curta*, Tate	*S. bellardi*, d'Orb. (Miocene). *S. hoernesi*, von Koenen (Miocene).
K. — *Scaldicetus macgeei*, Chapm.	*Scaldicetus carreti*, Du Bus (Lower Pliocene).

ON THE ABSENCE OF NUMMULITES IN THE TERTIARY OF SOUTHERN AUSTRALIA.

One of the chief factors which gave support to the conclusion that the Australian Tertiary beds belong in part to the Eocene or Nummulitic formation, was the erroneous record of the genus *Nummulites* from the lower beds at Muddy Creek, near Hamilton, Victoria. The nummulinoid foraminifer occurring so commonly throughout the main portion of our Tertiaries was, however, correctly assigned to the genus *Amphistegina* as early as 1865 by Tenison Woods*, for whom, as before stated, it was named by Prof. Rupert Jones. In describing the foraminifera from Muddy Creek, Woods writes as follows :—" The foraminifera are large and numerous ; indeed one species, *Amphistegina vulgaris*, d'Orb., is so common that the clay is principally composed of it. Its large lenticular form can be traced in almost every pinch of the *débris*, and what makes the individuals more conspicuous is that they have all received the ferruginous glaze which makes them look like little coins. From their numbers the strata may in truth be called an *Amphistegina*-bed, similar to that in Vienna, and possibly of the same age. Other Foraminifera occur, such as *Discorbina turbo, Pulvinulina pulchella, Planorbulina Haidingeri, Operculina complanata, Polymorphina lactea, Textularia sagittula, Miliolina semiluna*, and *M. trigonula.* Next in frequency to the *Amphistegina vulgaris* is the *Operculina complanata*, Bast., and though equal in size to the species found at Mount Gambier, it is much more common in the latter locality."

The earliest reference to the supposed occurrence of Nummulites in Australia appears to be that given by T. R. Jones in 1882,† when a descriptive note on specimen P.253 in the British Museum

* Quart. Journ. Geol. Soc., vol. xxi., 1865, p. 391.
† Cat. Foss. Foram. Brit. Mus., p. 67.

was published, reading as follows :—" Small Nummulites (near *N. variolaria*) and *Amphistegina?* In the Muddy Creek Tertiaries (Hamilton beds). South Australia.* T. Rupert Jones Coll."

The previous determination made by Prof. Jones in 1865 was the correct one; and here he was evidently misled by the large size of the *Amphisteginae*, which on casual inspection might be readily assigned to the genus *Nummulites*. In his earlier determination, Rupert Jones had, without doubt, carefully examined these forms and satisfied himself as to their amphistegine nature.

Mr. Walter Howchin, in his valuable and comprehensive account of " The Foraminifera of the Older Tertiary of Australia (No. 1, Muddy Creek, Victoria)."† recorded *Amphistegina lessoni*, d'Orb., and *Nummulites variolaria*, Sow., from the upper and lower beds (Kalimnan and Balcombian), and mentioned in the description of *N. variolaria* the probability of the specimens from the upper bed being derived from the lower bed.

In the course of work on the Tertiary fossils of southern Australia since 1902, I have had occasion to microscopically examine samples of foraminiferal rocks from nearly all Victorian and many South Australian and other localities, and in every case have failed to find a true Nummulite, although many specimens were put aside as doubtful until sections were made from them. Latterly I wrote to my friend, Mr. Howchin, asking him for samples of the supposed Nummulites which he possessed. These he very kindly forwarded, and on my returning to him sliced examples of the shells, Mr. Howchin concurred with me as to their relationship with *Amphistegina*. At the same time he very generously favoured me with a note for publication which will explain how the confusion had arisen in the determination of these difficult forms.

Mr. Howchin writes :—" When working up the foraminifera of the Muddy Creek beds, I was writing to Brady on sundry matters, and enclosed a few of the large nummuline-like forms that are a prominent feature in the Muddy Creek material. Under date, 25th October, 1886, Brady replied as follows :—' Firstly with regard to your specimens. 1. Nummulites in quill. So far as can be made out, this does not materially differ from Num. variolaria—assuming these are fully-grown species and not the young of some larger species. I do not altogether trust my knowledge of the distinctions marking the allied varieties of this group—the subject has become a special one. However, von Hantken, of Pest, to whom I was writing, and enclosed one or two of the specimens, replies to the same effect.' I am afraid that I accepted too readily, and without due examination, the testimony of those two experienced authorities. It is only fair

* For South Australia read Victoria; a frequent error, made even by some Australian naturalists.

† Trans. R. Soc. S. Austr., vol. xii. (1888), 1889, pp. 1–20, pl. i.

to say that neither Brady nor von Hantken made sections of the specimens, and the very large size of the Amphistegina was no doubt a misleading factor in the determination."

This common little nummulinoid species of the Australian Tertiaries is without doubt referable to *A. lessonii*, d'Orbigny; and the fresh or unworn examples resemble the variety found in the Vienna Basin, known as *A. hauerina*, d'Orb. Some of the larger specimens occurring in the Balcombian marls of Muddy Creek, T. Woods remarked upon as being "glazed with a ferruginous deposit." It appears, however, that abrasion and polishing has occurred in these examples, presumably by aeolian agency, and that they have been subsequently stained by the action of ferruginous water. The large sized tests of the *Amphisteginae* found in the Muddy Creek shell-marl can be matched by those from moderately shallow water of tropical or subtropical areas. At Funafuti the examples of this genus are similarly of large size, and frequently wind-worn or even polished; the latter character appearing on specimens of the tests from various depths in the deep boring. *Amphistegina lessonii* occurs at Funafuti at all depths down to 200 fathoms, and it was at its largest at about 36 fathoms.*

For the convenience of workers in other fossil groups who may not be conversant with the characters separating the genera *Amphistegina* and *Nummulites*, the following table is given.

Common and differential characters of—

	Amphistegina.	Nummulites.
Arrangement of chambers	Spiral, equitant	Spiral, equitant
Peripheral aspect ..	Asymmetrical. Chambers more spacious on the lower side	Symmetrical; therefore chambers equal on both sides
Umbilical axis ..	With unequal-sized cones of finely tubulate shell substance; apices of cones directed inward	Without umbilical cones
Septa	Curved backward, angulately; and either with simple septal wall, or with ill-developed interseptal canals	Roundly arched, not thrown so far backward. Intermediate skeleton and interseptal canal-system highly developed, resulting in double shell-walls.
Alar prolongations, or lateral development of chambers	Forming supplementary lobes on each side; those of the lower surface nearly severed, excepting for a narrow neck, and forming the astral lobes	Alar prolongations completely covering the earlier convolutions, and enclosing either a simple laminar space, or one subdivided into loculi
Aperture ..	A rotaline or crescentic slit on the lower face	A simple V-shaped slit at the junction of the penultimate whorl

* Linn. Soc. Journ. Zool., vol. xxviii., 1902, p. 414.

The Evidence of the Complex-structured Foraminifera in the Australian Tertiary System.

The shells of foraminifera exhibit great diversity of form, as well as a wide range of complexity in shell-structure. It is too often assumed that, because these ubiquitous marine organisms belong to the lowest phylum of the animal kingdom, they cannot therefore be of value in helping to decide the age of the beds in which they occur. This, however, is far from the truth, for, *primâ facie*, no one with a special knowledge of palæontology would dispute the proofs of the restriction of the Nummulites to a limited series of strata (Eocene and Oligocene), or ignore the zonal value of certain species of the genera *Lepidocyclina* and *Miogypsina*.

With regard to the genera of foraminifera which possess simply constructed tests, we may for the present dismiss these from consideration; for, although they have a certain distributional value in affording evidence of geographical facies dominated by local conditions of life, or controlled by sedimentation and hydrographical factors, there is a much more important section to be dealt with in the specialized forms constituting the Family Orbitoididae, and some other more or less related forms with highly specialized shell-structure.

Gypsina howchini, Chapman.—I have already shown* how closely the above species agrees with the Miocene ancestor of *Gypsina*, viz., *Miogypsina*. The chief difference lies in the absence of the vertical pillars as seen in cross-sections of *Miogypsina*; the only differentiation of the chamberlets in the median plane in the test of *G. howchini* being in their more spacious character.†

Amphistegina lessonii, d'Orbigny.—The inequilateral *Amphistegina* took the place of the equilateral *Nummulites* towards the close of the Oligocene, and was the predominant form in many foraminiferal deposits of Miocene age.‡

Cycloclypeus pustulosus, Chapman.—This species is, so far as known elsewhere, confined to the Miocene (Burdigalian), being found in the Island of Santo, New Hebrides, where it is associated with *Miogypsina burdigalensis*, Gümbel sp.; *M. complanata*, Schlumberger; *M. irregularis*, Michelotti sp.; *Amphistegina lessonii*, d'Orbigny; *Heterostegina depressa*, d'Orb.; *H. margaritata*, Schl.; *Lepidocyclina martini*, Schl.; *L. andrewsiana*, Jones and Chapman; and *L. insulae-natalis*, J. and C.

With regard to the Orbitoididae, this group has a range from the Cretaceous to the Miocene. In southern Australia these foraminifera, represented by the Oligocene-Miocene genus *Lepidocyclina*, play the very important part of forming a large proportion of certain limestones such as those of Batesford and Keilor; whilst they are also

* Proc. Roy. Soc. Vict., vol. xxii. (N.S.), pt. 2, 1910, p. 291.

† Proc. Roy. Soc. Vict., *tom. supra cit.*, pl. liii., fig. 5.

‡ See also *loc. supra cit.*, p. 308.

found, often in abundance, in the shallow-water deposits of some of the beds in the Tertiary series, such as those of Clifton Bank, Muddy Creek, and Waurn Ponds, near Geelong.

The earliest reference to the " Orbitoides " group in the southern Australian Tertiaries was made by the Rev. W. Howchin, F.G.S., who, in 1889, recorded *Orbitoides dispansus*, Sowerby, *O. mantelli*, Morton, and *O. stellata*, d'Archiac, from the lower beds at Clifton Bank, Muddy Creek, near Hamilton, Victoria.* An examination of the median layer of the Muddy Creek forms shows them to belong to the genus *Lepidocyclina*, a group that was imperfectly worked out when Mr. Howchin made his determinations. The lepidocycline relationship was suggested by Lemoine and Douvillé in their paper, " Sur le Genre Lepidocyclina, Gumbel,"† where they say, " à Muddy-Creek (Victoria), dans des couches que l'on considère comme d'âge éocène, M. Howchin a signalé *O. mantelli* et *O. stellata* d'Archiac ; cette dernière forme, d'après la description de M. Howchin, possède des loges hexagonal es et doit, par suite, être rangée dans le genre *Lepidocyclina*." This latter form I had already determined to my own satisfaction as belonging to that genus, and have since been able to refer it to *L. martini*, Schlumberger.

In 1891 Messrs. Hall and Pritchard recorded *Orbitoides mantelli* from the Filter Quarries and Upper Quarry at Batesford ; and also at Griffin's and near Madden's in the Moorabool Valley to the south-east of Batesford.‡ These specimens were identified by Mr. Howchin.

Genus *Lepidocyclina*, Gümbel.—Examples of the genus *Lepidocyclina* have been collected by me from four of the known localities in Victoria, and this collection has been further increased by specimens kindly given me by Dr. T. S. Hall. The localities furnishing this interesting group of foraminifera are, in the Balcombian series—Clifton Bank, Muddy Creek ; in the Janjukian series—Waurn Ponds, Batesford, Griffin's, near Madden's, along the Moorabool Valley, all near Geelong; and at Green Gully, Keilor. Quite recently I found a rich horizon for *Lepidocyclina* in Western Victoria, in the Janjukian limestone of the Grange Burn opposite Mr. Henty's farmstead.

It has already been pointed out in another place§ that, whilst the Burdigalian species, *Lepidocyclina tournoueri*, Lemoine and R. Douvillé, occurs in great abundance at Batesford, the Keilor ferruginous limestone contains, besides this form, another species, *L. verbeeki*, Newton and Holland, a species also met with at Clifton Bank (Balcombian). This fact seems to point to the Keilor horizon representing, although Janjukian, a bed slightly older than the Batesford limestone. To illustrate this more clearly we may note

* Trans. Roy. Soc. S. Austr., vol. xii., 1889, p. 17.
† Mem. Soc. Geol. France, vol. xii., fasc. ii., 1904, p. 32.
‡ Proc. Roy. Soc. Vict., vol. iv., pt. 1, 1891, pp. 10, 18, 19.
§ Chapman. " A Study of the Batesford Limestone." Proc. Roy. Soc. Vict., vol. xxii. (N.S.), pt. 2, 1910, p. 311.

that Douvillé has pointed out* that the *Lepidocyclinae* fall into two groups :—1st. The *L. dilatata* group, in which the vertical pillars are small and uniformly distributed over the shell, the test being typically large, as *L. chaperi*, *L. insulae-natalis*, *L. verbeeki*, and *L. elephantina*. 2nd. The *L. marginata* group, in which the pillars are more or less developed, but always more crowded towards the centre of the test, as *L. raulini*, *L. morgani*, *L. tournoueri*, *L. submarginata*, and *L. sumatrensis*.

The beds in Borneo, Italy and Panama (San Juan), characterized by the first group, that of *L. dilatata*, belong to the Aquitanian stage. The beds in Borneo, the south of France and Panama containing those of the second, *L. marginata* group, belong to the Burdigalian stage.†

The distribution of the Victorian forms of *Lepidocyclina* may best be shown by the following schedule :—

Victorian Localities.	Species.	Beds elsewhere.
Batesford	*L. tournoueri*, *L. marginata*, *L. martini*	Burdigalian of southern Europe
Keilor	*L. tournoueri*, *L. verbeeki* ..	Gaj Beds of India ; Upper Aquitanian, S. of Europe ; *L. insulae-natalis* Beds of Christmas Id.
Clifton Bank, Muddy Creek	*L. verbeeki*	Lower Aquitanian

F. Sacco has studied the faunas containing *Lepidocyclina* and *Miogypsina* with especial regard to the Tertiary basin of Piedmont, Italy ; and, although he differs from Douvillé and Prever with reference to the precise horizon of *L. marginata* in that area, yet that question does not affect our present conclusions. M. Sacco fixes the *L. marginata* beds as Aquitanian (but Miocene), whilst Douvillé and Prever place them in the Burdigalian (still Miocene). The succession remains the same, and the periods follow suit. It is thus merely a local adjustment of terms.‡

Prof. A. Silvestri, in his " Distribuzione Geografica e Geologica due Lepidocicline communi nel Terziario Italiano,"§ cites the occurrence of both *L. dilatata* and *L. tournoueri* in the Priabonian (Oligocene) in Italy and Greece, and their recurrence in Italy in the Miocene. In the former instance those species are associated with more archaic forms, as the striated nummulites and *Chapmania*, which, however, are absent from the Australian Tertiaries.

* Bull. Soc. Géol. France, sér. 4, vol. vii., 1907, p. 57.
† H. Douvillé. Bull. Soc. Géol. France, sér. 4, vol. v., 1905, p. 454 (Table), and p. 455.
‡ " Sur la Valeur Stratigraphique des Lepidocyclina et des Miogypsina." Bull. Soc. Géol. France, sér. 4, vol. v., 1906, p. 882.
§ Mem. Pont. Accad. Rom. dei Nuovi Lincei, vol. xxix., 1911, pp. 54, 55.

STRATIGRAPHICAL NOTES BEARING ON THE SEQUENCE OF THE STRATA.

A.—The Port Phillip Area.

A boring at Sorrento close to the Port Phillip Heads has been lately put down by the Mines Department of Victoria to a depth of 1,693 feet.* The results obtained from this, perhaps the most valuable boring from a scientific stand-point which has yet been made in the Cainozoic strata in this State, sets at rest any doubt as to the succession of these beds. In the marls from 1,310–1,426 feet there are bands of *Vaginella eligmostoma*, a pteropod occurring in the fossil beds at and above sea-level at Mornington and Grice's Creek, about 18 and 22 miles to the north-east. This difference in level of the same strata between the two places within so short a distance is explained by the fact that the great Dandenong to Cape Schanck fault cuts between the two areas; Sorrento, being on the down-throw side, and Mornington and Grice's Creek on the upthrow side. These lowest beds of the bore are proved by their fossil contents to be of Balcombian age. In the same boring Janjukian marls are distinguished, at 990 and 758 feet, by containing typical Spring Creek fossils, as *Eutrochus fontinalis* and many others. From 741 to 585 feet *Limopsis beaumariensis* and other typical Kalimnan fossils denote this portion to belong to the upper series. Above this again, the Werrikooian or Upper Pliocene is represented probably between 585 and 489 feet; whilst above this comes a Pleistocene and Holocene succession of estuarine muds and sand-dune rock.

The Cainozoics at Sorrento were not bottomed at 1,693 feet. Judging from the exposure of Mesozoic shales with *Thinnfeldia* on the foreshore south of Grice's Creek, it is highly probable that the Cainozoics at Sorrento may rest on these same Mesozoic rocks.

Following the Port Phillip coast-line in a north-easterly direction beyond Dromana, we find, at the north end of Balcombe's Bay, typical Balcombian blue clays with septaria containing *Vaginella eligmostoma*.

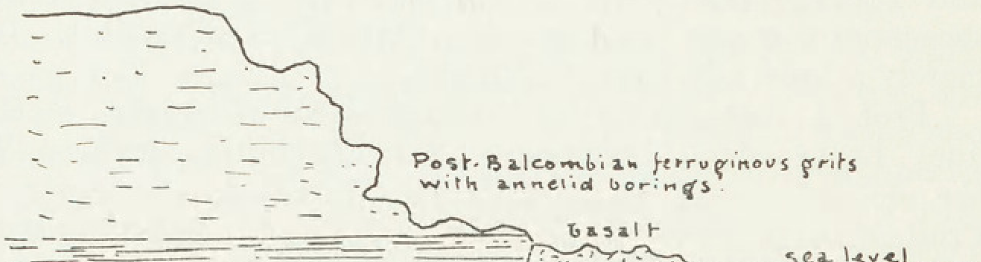


Fig. 1. SECTION AT POINT S. OF CEMENT WORKS, BALCOMBE'S BAY

This bed passes upwards into a grey marl with gypsum crystals. Going southward from the Cement Works past the low point with tumbled ferruginous grits (Fig. 1), a shallow indent in the coast

*See Ann. Report, Dept. Mines, Vict., for 1910 (1911), p. 152.

reveals a thick series, about 80 feet in extent, of a grey clay with gypsum similar to that north of the Cement Works, and which is evidently part of the same Balcombian series. The upper beds are seamed with fracture-lines due to local faulting, and through these minor rifts percolation has taken place through the surrounding strata containing pyritous matter, resulting in the replacement of the fossil shells by gypsum (Fig. 2). The occurrence of the marl-bed

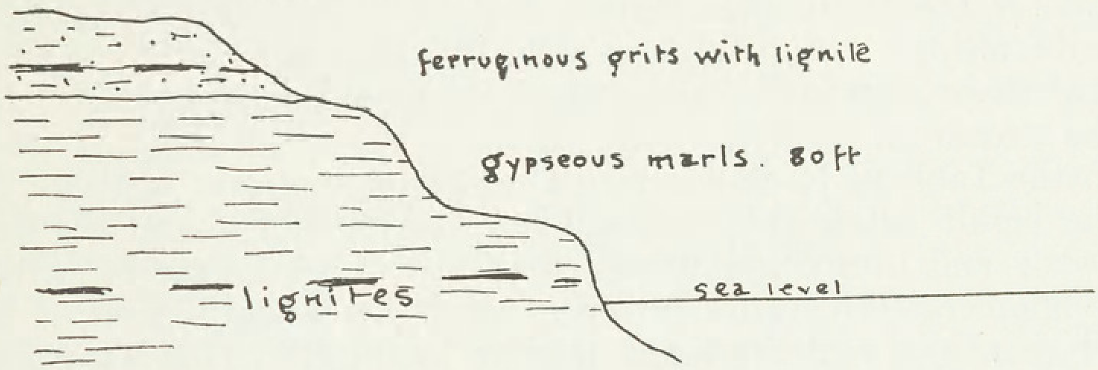


Fig 2. SECTION OF CLIFF NEAR MIDDLE OF BALCOMBE'S BAY.

at this place is compatible with the general character of an Oligocene fluvio-marine series, as typified on the other side of the Bay at Newport and Altona. The relationship between the older basalt and the Balcombian clays is obscure at this part, owing to the masking by landslips and extensive faulting; but near Landslip Point* the basalt is seen to overlie the granite and conglomerate, the latter being referred by Messrs. Hall and Pritchard† to the Balcombian or older, and to underlie the fossiliferous ironstone conglomerate with a typical Janjukian fauna. In a recent visit to Frankston, Mr. R. A. Keble and the writer obtained several restricted Janjukian fossils from the fossiliferous ironstone; thus linking this bed with similar ironstones at Flemington, Keilor, and South Yarra (see postea, p. 29).

Older basalt is met with at various points along the coast, as between Chechingurk Creek and Mornington, between Mornington and Grice's Creek, and between Wallace Bay and Frankston.‡ Leaf-beds also occur, associated " with quartz pebbly drift " . . . " in the base of a high cliff in Balcombe Bay,"§ and Mr. Kitson thinks the leaves resemble those of the Janjukian at Sentinel Rock, Cape Otway. Mr. J. S. Green has lately obtained some leaves from these beds, which show a marked resemblance to the genera described by H. Deane from Berwick, as *Apocynophyllum*, cf. *Tristanites; Lomatia*, and cf. *Fagus*. No leaf-beds were met with

* See Section C–D of A. E. Kitson's Report on the Coast Line between Frankston, Mornington, and Dromana. Geol. Surv. Vict., Monthly Prog. Rep. No. 12, 1900.

† Proc. Roy. Soc. Vict., vol. xiv. (N.S.), pt. 1, 1901, p. 43.

‡ See Kitson. Monthly Prog. Rep. Geol. Surv. Vict., No. 12, 1900, p. 8. Also Hall and Pritchard, Proc. Roy. Soc. Vict., vol. xiv., pt. 1, 1901, p. 35, *et seq.*

§ Kitson, *loc. supra cit.*, p. 11.

in the Sorrento Bore, so we may conclude that that area was outside the influence of fluviatile conditions of the continental seaboard of that time. As regards Kitson's reference to these leaf beds as resembling those of the Otway Coast, it is interesting to note that one specimen collected by Mr. J. S. Green is practically identical with branchlets of a *Casuarina* from Sentinel Rock.*

The exact relationship of the basalt to the Balcombian blue clays in the Mornington district appears to be obscured by slipping and faulting; but at Grice's Creek, Drs. Hall and Pritchard mention that these clays are "succeeded by basalt, which occupies the bed of the stream for nearly a chain, and over which the ascent is steep."† In the Table of Rock-Succession, however, the same authors‡ place the basalt below the blue and grey clays, and above the lignitic beds; and in another place§ mention the occurrence of grits and conglomerates (lignitic) as "passing under a small mass of basalt which shows well-developed tabular jointing." This basalt is not seen intercalated between the clays and lignites in the cliff section at Balcombe Bay. Hall and Pritchard offer two possible explanations of this problem. Either a narrow stream of lava flowed down an eroded valley, cutting through the upper sandy beds till the

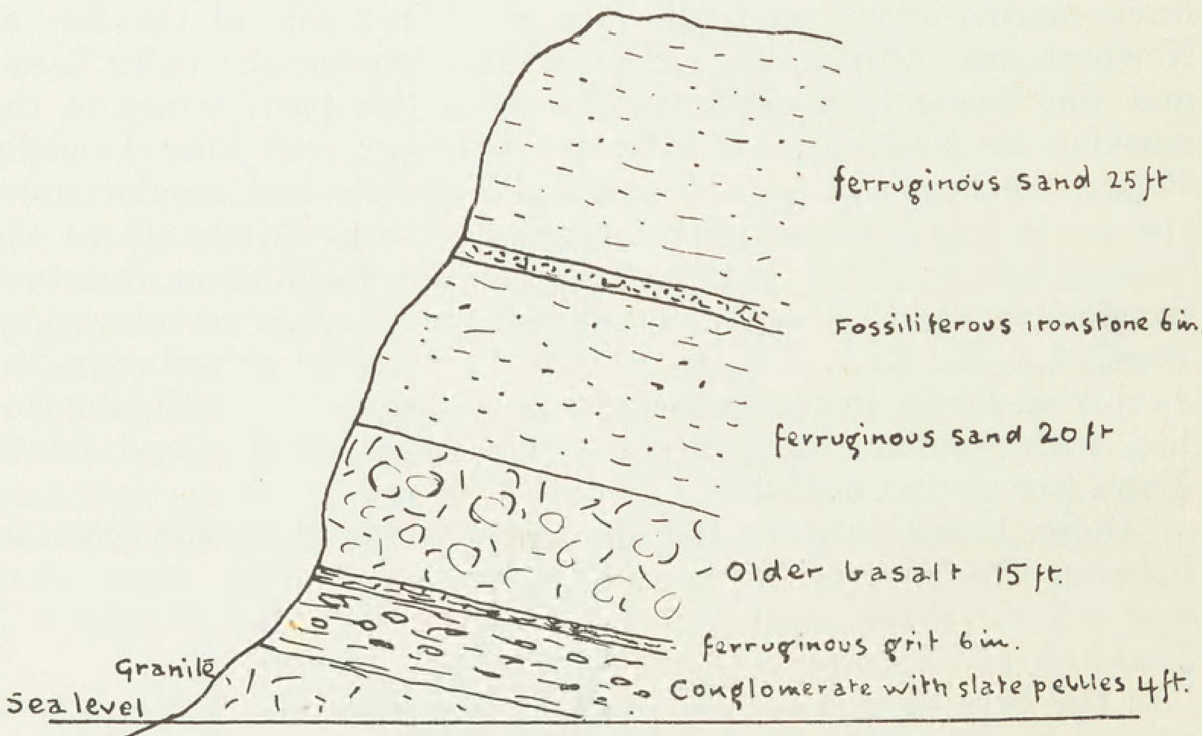


Fig. 3. SECTION AT LANDSLIP POINT, FRANKSTON (S SIDE).

lignitic series was reached, or a sheet of basalt was laid down upon the lignitic series, and subsequently partially removed by denudation before the deposition of the overlying sandy beds.

* Cf. Ettingshausen. *Callitris prisca,* from Vegetable Creek, N.S. Wales, in Mem. Geol. Surv. N.S. Wales, Pal. No. 2, 1888, p. 95, pl. viii., figs. 3, 4.

† Proc. Roy. Soc. Vict., vol. xiv., pt. 1, 1901, p. 37.

‡ *Loc. cit.*, p. 41.

§ *Loc. cit.*, p. 40.

The most clearly defined section of this much disturbed and masked coast-line is that given by Mr. Kitson,* from Landslip Point to Narringalling Creek (Kackeroboite Creek of Kitson). At Landslip Point (Fig. 3, a generalized section) the succession is shown to be :—

6. Ferruginous sands.
5. Ferruginous grits with fossils.
4. Basalt.
3. Hard ferruginous grit.
2. Conglomerate (with slate pebbles).
1. Granite.

The discovery of fossils in the ferruginous bed No. 5 mentioned above was made some years ago by Mr. Kitson, F.G.S., who, in his paper, "Report on the Coast-line and adjacent Country between Frankston, Mornington, and Dromana,"† stated that "The [fossil] casts obtained have been examined by Mr. Dennant, who unhesitatingly pronounces them to be of Eocene age."

A fairly extensive series of fossils from this ferruginous band was obtained and recorded by Hall and Pritchard in 1901.‡ Although their list comprises 36 species, none of them seems to be restricted to Balcombian strata. In point of fact, an examination of that list shows that the affinities of the species enumerated lie as closely with a Janjukian as a Balcombian facies, with which latter series Hall and Pritchard state they "show a close agreement."

During the last year I have visited this locality in company with Mr. R. A. Keble, and we have made a fairly comprehensive collection of the ironstone fossils. The impressions, as a rule, are very clean, and in some cases even the shell is preserved. Several of the forms found are noteworthy as being restricted Janjukian species, and as such give strong evidence as to the precise age of this band of ironstone. The fossils amongst the collection made by us which are new to the already published list referred to are :—

Corals—
Placotrochus sp.
Sphenotrochus emarciatus, Duncan.

Vermes—
Ditrupa cornea, L. sp. var. *wormbetiensis*, McCoy.

Brachiopoda—
Terebratula (?) *aldingae*, Tate.
Magellania garibaldiana, Dav. sp.

* Monthly Prog. Rep., Geol. Surv. Vict., No. 12, 1900; section facing p. 4, C–D.

† *Loc. supra. cit.*, p. 10.

‡ Proc. Roy. Soc. Vict., vol. xiv. (N.S.), pt. 1, 1901, pp. 44 and 46–53.

Pelecypoda—
Pecten foulcheri, T. Woods.
Pecten cf. *flindersi*, Tate.
Pecten praecursor, Chapman.
Limatula sp.
Cuspidaria sp.

Scaphopoda—
Dentalium mantelli, Zittel.

Gasteropoda—
Latirus (?)*actinostephes*, Tate sp.
Oliva sp.
Columbarium acanthostephes, Tate sp.

Of the above forms the following are worthy of especial note :—*Sphenotrochus emarciatus* has a remarkably extensive range, being found alike in Balcombian, Janjukian, and Kalimnan strata. *Ditrupa cornea*, var. *wormbetiensis* is especially typical of Janjukian beds ; it is a characteristic and abundant fossil in the polyzoal rock of the Mallee Bores and of the upper limestones of the Spring Creek series, and so far as I am aware, only a single specimen has occurred in the Balcombian, at the top of the series, at Muddy Creek. The brachiopod provisionally referred to *Terebratula* (?) *aldingae* is a cast, which, by its compressed shape and outline, is nearest that species, only occurring in Janjukian strata ; the squarish anterior is matched very closely by specimens in the Dennant collection ; and the only other species with which it could be compared is *T. vitreoides*, T. Woods, also a Janjukian form. *Pecten praecursor* is a specially characteristic Janjukian form. *P. flindersi* is also of similar age, being found at Aldinga.

From Mornington towards Frankston, and over the hinterland, thick deposits of fine and coarse sands, often ferruginous, are largely

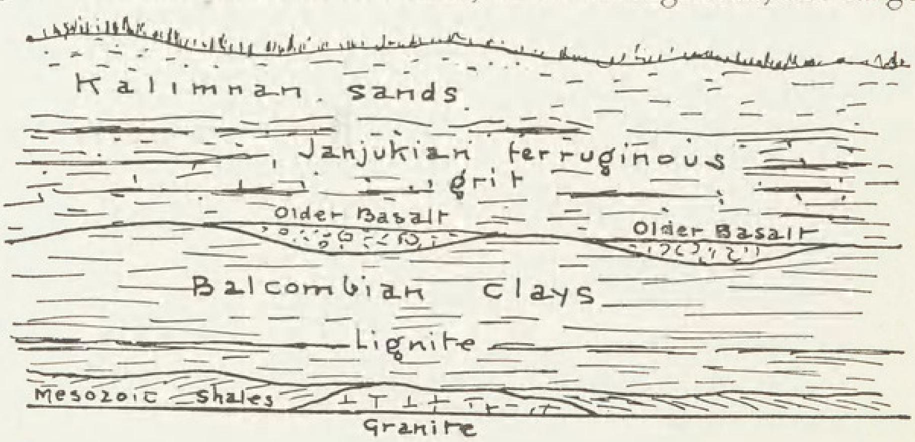


Fig. 4. GENERALIZED SECTION OF STRATA BETWEEN FRANKSTON AND MORNINGTON.

overspread. The age of this series is doubtful, being unfossiliferous, but the lower portion is undoubtedly of Janjukian age, as shown above, and comparable with those beds known elsewhere, as in Western Victoria, as the "older gold-drifts." The general sequence of the strata in Port Phillip between Frankston and Mornington appears to be easily explained by the accompanying diagram (Fig. 4).

Still on the downthrow side of the great fault of Port Phillip and on the opposite (west) side of that great inlet, are situated Altona Bay and Newport, at which places deep shafts have been put down, extending into Balcombian strata, and affording a continuous series from surface level. These bores reveal several seams of lignite or brown coal, one of which is 74 feet in thickness. Unfortunately, no detailed and scientific account of the strata passed through in these bores is available, but the data given by the engineers show that the beds are very variable in character, and a general idea may be gained as to their nature. The bed-rock, probably an Ordovician slate (Fig. 5), was struck in Bore No. 1 at Altona Bay (Sect. VII., parish of Truganina) at 656 ft. 3 in., and penetrated a thickness of 238 ft. 4 in.* Above this bed-rock there is a variable series of gravelly sands and lignitiferous clays, with occasional seams containing broken shells, which amounts to a thickness of 235 ft. 6 in. Above this, again, occurs a brown coal bed 70 ft. 5 in. thick. The succeeding calcareous clays and limestones, as well as those just mentioned, are of Balcombian age, and have yielded an extensive fauna, chiefly of mollusca, which have been listed by Messrs. Thiele and Grant,† and more recently by Messrs. Dennant and Kitson.‡ The latter list

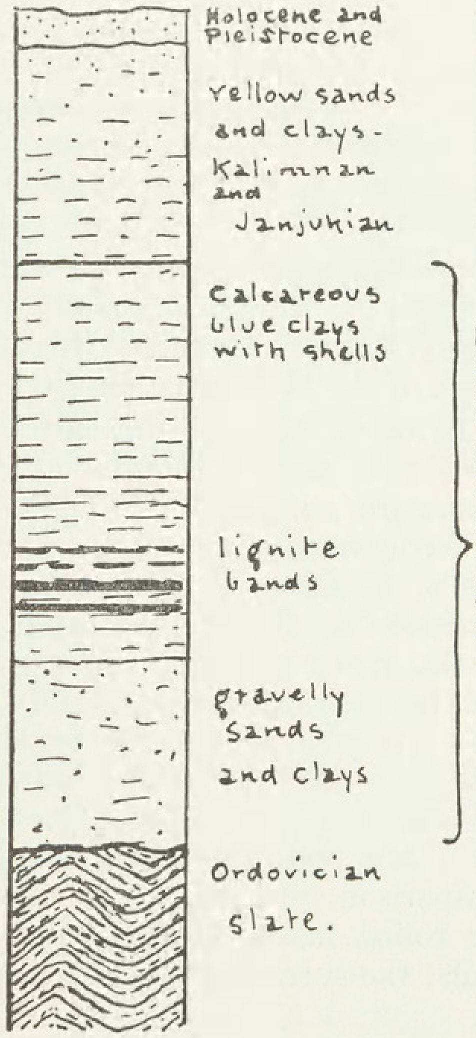


Fig. 5.
DIAGRAM SECTION OF BORES NEAR ALTONA BAY. PORT PHILLIP.

* Ann. Rep. Dept. Mines, Vict., for 1902 (1903), p. 69.
† Proc. Roy. Soc. Vict., vol. xiv., pt. 1, 1901, p. 145.
‡ Rec. Geol. Surv. Vict., vol. 1, pt. 2, 1903.

also include the occurrences from the Newport Bores. Above the calcareous clays there are alternating bands of ferruginous clays and sands, which afford strong evidence of belonging to the Janjukian series of the Corio Bay marly facies; since from these beds Messrs. J. S. Green and W. J. Parr have obtained many fine examples of the large Magellanias characteristic of the beds at Corio Bay, which crop out to the south-west at the locality named. As collecting on the spoil-heaps from these borings has been done somewhat indiscriminately, it is possible that the published lists of fossils from these localities may include some forms which are not actually from the Balcombian series.

In the report of Messrs. Thiele and Grant it is stated that this "cream-coloured sandy clay, with nodules of yellow limestone . . . . is very full of foraminifera (largely of the genus *Operculina*), and contains a fair number of brachiopods, but few gastropods or lamellibranchs." The brachiopods were not included in their list.* They also noted the uppermost bed as consisting of "a coarse ferruginous grit," in which they "failed to find any traces of fossils." In all probability this bed is the equivalent of the marine Kalimnan series of Brighton and Beaumaris and the subaerial sands of the Melbourne district.

Crossing again to the eastern side of Port Phillip, and on the Melbourne side of Frankston, the cliffs in the neighbourhood of Beaumaris are mainly composed of the Kalimnan beds, consisting of ferruginous clays and sands, which contain typical Kalimnan fossils, as *Limopsis beaumariensis* and *Trigonia margaritacea*, var. *acuticostata*. On the foreshore may be commonly found teeth of sharks, many of which are common also to the nodule bed seen at the Grange Burn and on Muddy Creek; and which by their position there are seen to form the basal bed at Macdonald's and Forsyth's. Although the beds on the foreshore at Beaumaris are covered by a thick deposit of shingle, it has been proved that, by sinking a shaft for a few feet, the basal nodule bed is exposed *in situ*. By a comparison with the beds of the Hamilton district it is evident that the rolled fossils of the nodule bed constitute a remanié fauna, whilst the surrounding clay contains indigenous Kalimnan fossils.

B.—Flinders.

An interesting little patch of polyzoal limestone is found on the coast at Flinders, resting on the older basalt. The limestone has evidently been deposited in an eroded hollow on the surface of the lava,† and it has a maximum thickness of about 20 feet. The fossils contained in this friable limestone show unmistakeable affinities with the Cainozoics of the Moorabool Valley and Curlewis,

* Proc. Roy. Soc. Vict., vol. xiv., pt. 1, 1901, p. 145.

† See also Kitson. Rec. Geol. Surv. Vict., vol. i., pt. 1, 1902, p. 49.

both of which must be referred to the Janjukian. For instance, the numerous *Amphisteginae** present in the Flinders rock make it comparable to the Filter Quarry stone at Batesford; whilst the occurrence of an abundance of calsisponges shows its time-relationship with Curlewis and the Moorabool section at "Griffin's." At Curlewis I have lately obtained numerous examples of *Tretocalia pezica*, which were only recorded previously from Flinders. Other Janjukian (restricted or post-Balcombian) fossils found at Flinders are—*Arachnoides* (*Monostychia*) *australis*, *Cidaris* (*Leiocidaris*) *australiae*, *Pecten gambierensis*, and *P. subbifrons*.

Besides affording positive evidence for a Janjukian age, it is interesting to note that this limestone rests on the older basalt (Fig. 6), as does the fossiliferous ironstone of the Flemington railway cutting and many other Miocene (Janjukian) occurrences. Whilst far from assuming that the older basalt so-called represents an effusion of one definite period, it is always so closely associated with those beds, which are proving themselves to be merely different lithological phases of the great Janjukian and Mount Gambier series, that we are forced to the conclusion that during this period of maximum sedimentary deposition on the southern Australian coast, an intermittent series of flows were poured out of a generally dense, magmatic basalt, which in some measure represents the relieving outbursts consequent upon the extraordinary strain that was exerted at that period on the continental shelf.

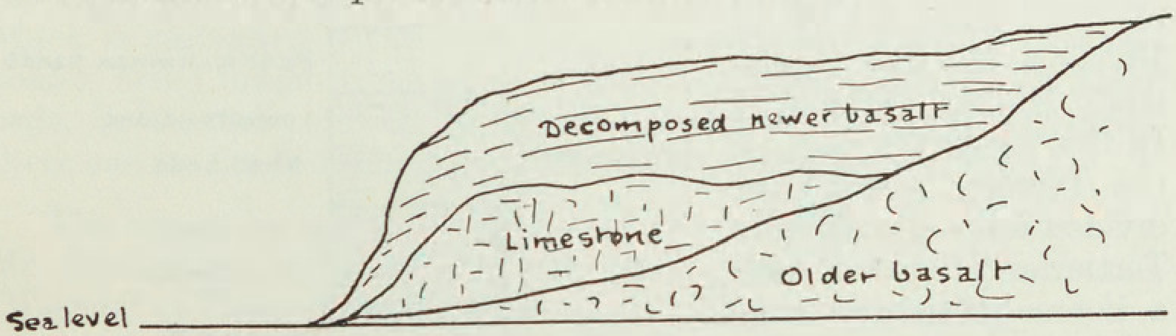


Fig. 6. DIAGRAM SECTION OF JANJUKIAN LIMESTONE AND ASSOCIATED STRATA AT FLINDERS.

The Flinders limestone, by the abundance of its foraminifera, polyzoa, and calcisponges, indicates a fairly deep water and tranquil condition, with little or no solution of the ferruginous constituents of the volcanic sea-bed. At Flemington we have the opposite conditions, of a shore-line with littoral shells, as *Haliotis* and *Patella*, and much alteration of the original shell-conglomerate, resulting, by its absorption of iron probably both from above and below, in a highly ferruginous rock.

An extremely interesting discovery was lately made by Mr. R. A. Keble, of the Mines Department, of a small patch of polyzoal rock resting on older basalt at the back of Cape Schanck. The position of this rock is about 1 mile north-west of the junction of the

* Referred in error to *Nummulites variolaria* by Mr. Kitson.

Lighthouse and Sorrento roads. Besides generally resembling the Flinders limestone, to which horizon it clearly belongs, it proves on examination to contain tests of *Lepidocyclina*, the first recorded east of Port Phillip, the previously known localities being Batesford, Keilor, and Muddy Creek, Hamilton. This occurrence strengthens the view that the beds in the Mornington district also, that overlie the older basalt, belong to the Janjukian and not to the Balcombian, as Hall and Pritchard supposed,* judging from their examination of the fossils at Landslip Point, Frankston. This assemblage, by the way, does not contain any restricted Balcombian species, for even *Vaginella* is found very sparingly as high in the geological series as the younger beds of Muddy Creek (Kalimnan), according to the list of Dennant and Kitson.† Moreover, the Frankston locality contains some restricted Janjukian species, as shown earlier in this paper. The reason one might advance for the absence of *Lepidocyclina* from the Flinders limestone is its deep-water aspect, the foraminifera belonging to that genus appearing to favour shallow to moderately deep-water conditions, but this evidence is not conclusive, since the Filter Quarry deposit is both polyzoal and Lepidocycline in constitution.

C.—The Bairnsdale District.

The Cainozoic rocks of this area were first noticed in detail by Dr. A. W. Howitt, in his paper "Notes on the Geology of Part of the Mitchell River Division of the Gippsland Mining District."‡ In this paper the beds of the Tertiary system are divided into—1st. Middle Tertiaries (Miocene), with a coarse limestone containing marine fossils; marly beds with similar remains. 2nd. Upper Tertiary (Pliocene) ferruginous pebble conglomerate; clayey and sandy beds, stained with iron oxide, and containing marine fossils in concretionary layers of arenaceous ironstone; imperfectly flaggy sandstones.

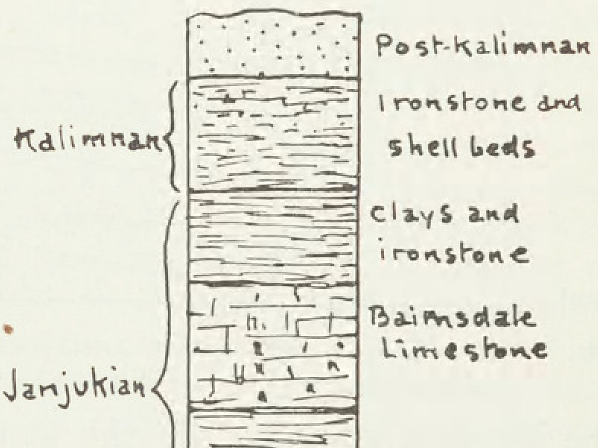


Fig. 7. DIAGRAM SECTION IN THE MITCHELL RIVER DISTRICT.

* Proc. Roy. Soc. Vict., vol. xiv. (N.S.), pt. 1, 1901, p. 36.
† Rec. Geol. Surv. Vict., vol. i., pt. 1, 1902, p. 137.
‡ Prog. Rep. Geol. Surv. Vict., No. 2, 1874, p. 59. Also *ibid.*, No. 4, 1877, p. 122.

The fossil determinations and age of the rocks were reported upon by McCoy*; and their joint conclusions are very nearly the same as advanced in the present work. A similar sequence is given by Mr. Dennant,† who, however, relegates the two beds to the Eocene and Miocene respectively (Fig. 7).

As shown in the previous part of the present paper, the subdivisions of the Cainozoics are regarded by the latter author as of greater age than is justified by the fossil evidence. The Bairnsdale and Mitchell River limestones and calcareous fossil beds contain a facies resembling the polyzoal series of Mount Gambier and the Corio Bay marl beds. The difference in the two series, of the Bairnsdale and Mount Gambier deposits, lies in the fact that in the former the marine conditions during the Miocene were of a shallow-water nature, more akin to that of the Corio Bay series, as shown by the community of fossils, such as *Hinnites corioensis*. At Sale, in similar beds (Dutson's Quarry) the rock is a true *Amphistegina* limestone, like that of the middle series at Grange Burn, and the Flinders limestone. At Bairnsdale a large echinoid, the *Clypeaster gippslandicum*, is fairly common; it is a form which also occurs in the lower (Balcombian) stage at Muddy Creek, but of smaller dimensions, and in the higher (Kalimnan) stage at Beaumaris, where it is also of less size than at Bairnsdale. This is one of many good examples in Victoria of the law of maximum development in the Miocene. Another fossil we may note from Bairnsdale, but which is restricted to beds of Janjukian age, is *Spondylus gaederopoides*, being found in common at Maude, Torquay, the Aire coastal beds, in Victoria, and Table Cape, Tasmania. Of these localities, there can be no doubt regarding their stratigraphic position.

The upper series in the Mitchell River district, as shown by Mr. Dennant,‡ is referable to the beds now classed as Kalimnan (Miocene of Dennant and others, Lower Pliocene of McCoy and the present writer). Many of the fossils found therein are also common to the upper beds at Muddy Creek. A part of the fauna, however, (that of Jemmy's Point), indicates deep-water conditions as compared with that of the last-named locality; and the fauna, as a whole, is perhaps more comparable with the deposits which were laid down in the Kalimnan sea of the Murray Gulf, now found underlying the Mallee district of Victoria and South Australia, and also of Beaumaris. As a case in point, *Turritella pagodula* may be mentioned, which is a common fossil in the Mallee bores, and also found in the Beaumaris cliffs. Evidence as to deep-water conditions in the Kalimnan beds at Jemmy's Point is seen in the aspect of the foraminifera, several

* Proc. Roy. Soc. Vict., vol. iii. (N.S.), 1891, pp. 53-69.

† Op. supra cit. See also Dennant and Clarke, Proc. Roy. Soc. Vict., vol. xvi., pt. 1, 1903, p. 46.

‡ Proc. Roy. Soc. Vict., vol. xvi., pt. 1, 1903, p. 21.

species of which indicate deeper bathymetrical surroundings than the upper beds at Muddy Creek, and clearer water than prevailed in the Beaumaris area.

The view that the Bairnsdale limestone indicates a somewhat low horizon in the extensive and extremely variable Janjukian series is supported by the fact that the two Tertiary groups as revealed in geological sections along the course of the Mitchell River in the Bairnsdale district are unconformable.* Here, as indicated by Dr. Howitt, the Upper Cainozoics rest on an eroded surface of the Bairnsdale limestone. This is also clearly set forth by Messrs. Dennant and Clarke,† who state that at Rose Hill, "Immediately underlying the Miocene [Lower Pliocene] marls there is the typical Eocene [Miocene] limestone of the area, which was here evidently an eroded surface when the later beds were deposited upon it." The same authors also record the Kalimnan series at Belle Vue, represented by a fossiliferous ironstone bed.

D.—The Geelong Area.—Corio Bay.

The strata exposed in the low sea-cliff of Corio Bay consist of yellow and occasionally greyish shelly and earthy marls, in which the large Magellanias, large Pectens, and solitary corals are conspicuous. The beds are evidently an argillaceous phase of the Janjukian stage. An extensive comparison of the fauna with that of some Balcombian marls would at first sight lead one to suppose the ages of the two beds to be identical, so many species of mollusca and other fossils being common to both beds. If, however, we test the faunas from these beds and select the restricted species, we find the following list of nine species of fossils present in the Corio Bay series,‡ which are elsewhere entirely confined to Janjukian localities. They are :—

Bullinella paucilineata, Tate and Cossman.
Ancilla ligata, Tate sp.
Scala echinophora, Tate sp.
Turbonilla liraecostata, T. Woods.
Limopsis insolita, Sow. sp.
Pecten praecursor, Chapman.
P. peroni, Tate.
Nucula semistriata, Tate.
Linthia (?) *gigas*, McCoy sp. (probably referable to *L. moorabolensis*, Pritchard).

Besides these Janjukian restricted forms, another species, *Mysella sericea*, Tate, is recorded which elsewhere only occurs in the overlying Kalimnan series at Beaumaris, the upper beds of Muddy Creek, and in

* Prog. Rep., vol. ii., 1874, p. 62, section No. 4.

† Proc. Roy. Soc. Vict., vol. xvi., pt. 1, 1903, p. 21. The terms in square brackets are inserted by the present writer.

‡ See list of Cainozoic Fossils, by Dennant and Kitson. Rec. Geol. Surv. Vict., vol. i., pt. 2, 1903.

the upper beds of the Murray Cliffs. On the other hand, only one species in the Corio Bay series, *Capulus danieli*, Crosse, is restricted to Balcombian elsewhere.

This particular phase of the earthy limestone of Corio Bay is also found to the east of Geelong, in the outer harbor at Curlewis, and its faunistic and lithological similarity was pointed out by Drs. Hall and Pritchard.*

Curlewis.—The interpretation of the succession of the strata exposed in the cliffs from Clifton Springs to Curlewis is rendered somewhat difficult by the numerous faults which have occurred, and further made more obscure by landslips. By carefully piecing the evidence together the succession appears to be as follows. The lowest bed is a stratum of volcanic ash, almost black,† followed by a 2-ft. bed of blue clay with fossils which passes into a greenish sandy clay with similar forms. The argillaceous fossil beds of this locality have yielded several restricted Janjukian fossils‡ including *Bela woodsi*, Tate, *Cypraea ovulatella*, Tate, and *Pecten praecursor*, Chapman. Above this bed comes a hard polyzoal limestone, altogether about 6 feet thick. This limestone band crops out again a little way beyond the shore at low water, near the point of intersection of the parish boundary with the coast-line, as a curved or slightly undulating reef (Fig. 8).

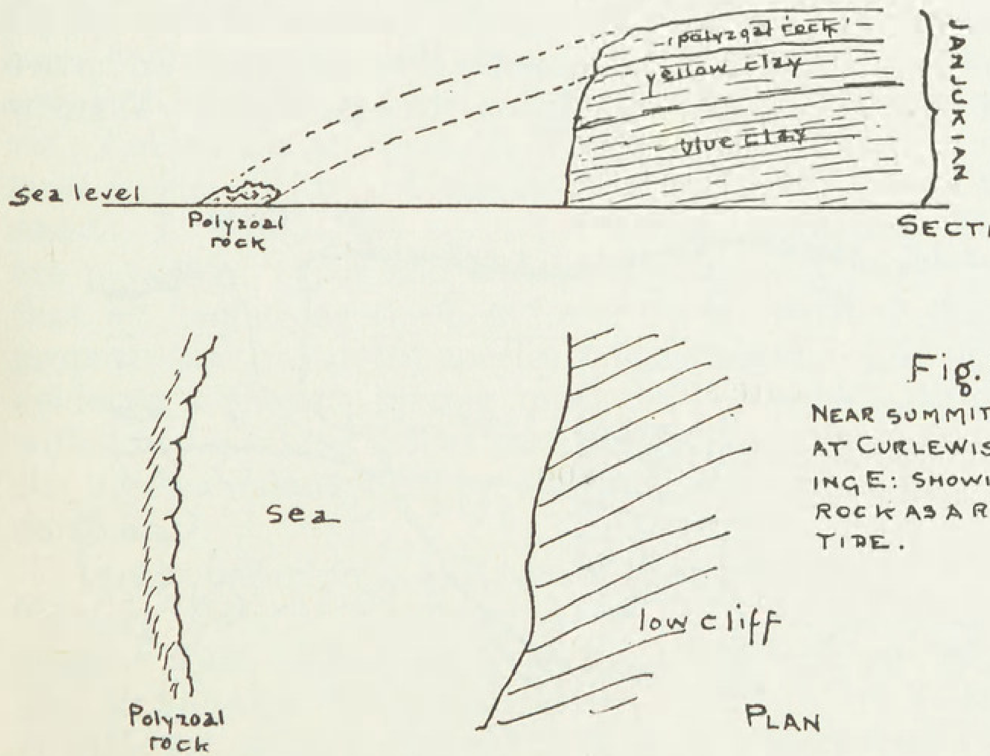


Fig. 8.

NEAR SUMMIT OF ANTICLINE AT CURLEWIS (Ad 12), LOOKING E: SHOWING POLYZOAL ROCK AS A REEF AT LOW TIDE.

This limestone, as pointed out by Messrs. Hall and Pritchard,§ is similar to that of the Moorabool Valley. To the westward, at the Geological Survey locality (Ad 12), I found in this

* Proc. Roy. Soc. Vict., vol. vi. (N.S.), 1894, p. 6.

† *Idem, ibid.*, p. 4.

‡ For some of these fossils the Museum is indebted to Mr. J. Hay Young.

§ Loc. cit., p. 3.

polyzoal rock some calcisponges typical of the Janjukian, as well as a fine specimen of *Thamnastraea sera*, a Table Cape coral. At the locality, Ad 14, the reef of limestone before mentioned is seen to have been once continuous with the limestone band in the middle of the cliff, and thus forms part of an anticline with a steep pitch of 28° to the N. 21° W. These beds dip to the west at about 15°, and are succeeded by yellow and brown clays, in the former of which

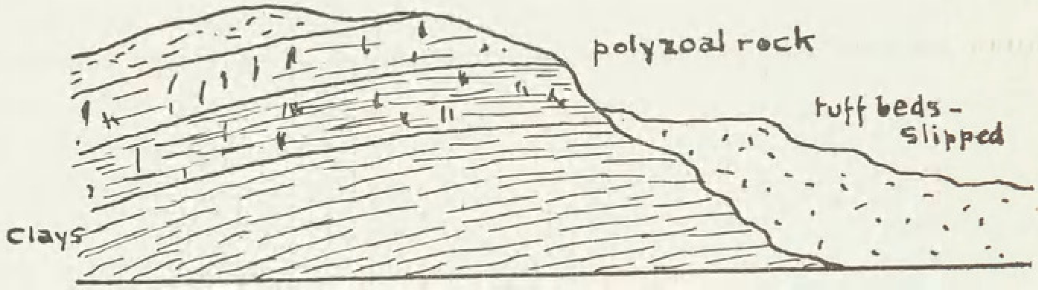
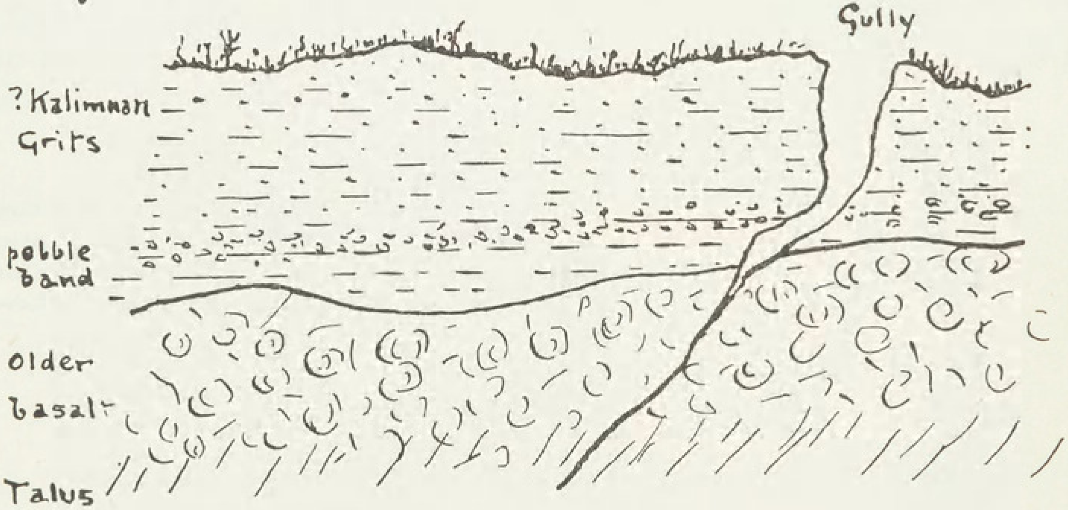


Fig. 9. CLIFF-SECTION 150 YARDS W. OF Ad 12, CURLEWIS: SHOWING OVERLYING TUFF BED BROUGHT DOWN BY LAND-SLIP.

there is a band of earthy limestone nodules. The Janjukian beds are followed by extensive ash and tuff beds of a brown and yellow colour, which are here seen to have slipped *en bloc* from above down to shore level (Fig. 9). To see the relation of the volcanic tuffs and the basalt to the beds immediately succeeding, we have to go eastward to within 1 mile of Clifton Springs Hotel. There we

Fig. 10.



(?) KALIMNAN GRITS RESTING ON ERODED SURFACE OF BASALT.- 300 YARDS W. OF CLIFFE HOUSE, CLIFTON SPRINGS.

have the bedded tuffs, agglomerate and basalt underlying the grit beds (Fig. 10). At the base of the grit beds there is a coarse pebbly deposit of quartz and metamorphosed rocks, but the bulk of the deposit is a coarse white and iron-stained sand, identical in appearance with the Kalimnan sands of the Melbourne district, and like them, in all probability of Kalimnan age. The view here maintained, that the main volcanic series occurs above the yellow limestone and under the Kalimnan grits, is the same as brought forward by Mr. Daintree as early as 1861. A reproduction of Daintree's sketch-section of the cliff at Curlewis (Ad 12) is given in my paper on some Tertiary fossils.* On a recent visit to this place (shown on Quarter-sheet 23 sw) the section of the cliff showed a bed of tenacious blue clay resting on an ash bed, and above this a polyzoal limestone about 5 feet thick. This is surmounted by about 13 feet of basalt, and on this a thin layer of hill wash.

The present occurrence of older basalt as high as the top of the Janjukian is unique in the experience of the writer, for it generally occurs interbedded with or underlying the sedimentaries of that epoch. It further strengthens the view that the Janjukian episode was not only intermittently subject to volcanic disturbance, as already found in the Anglesey district by the occurrence of tuffs interbedded with the sedimentaries,† but that the effusions did not cease until about Kalimnan times.

Fyansford.—The Orphanage Hill section consists of grey clays passing into yellow clays. These beds probably represent an argillaceous phase of the Janjukian. The molluscan fauna has not been completely worked over, but by comparing the list of Hall and Pritchard, it will be seen that five species recorded by them,‡ viz., *Terebratula vitreoides*, T. Woods, *Natica gibbosa*, Hutton, *Pleurotoma haastii*, Hutton, *Limopsis insolita*, Sow. sp., and *Cardita gracilicostata*, T. Woods, are restricted Janjukian fossils. The remainder are persistent types and widely distributed forms. It is probable that by diagnosing the new forms to be found in this locality the proportion of restricted species will be raised. The palæontological evidence, although leaving much to be desired, points to affinity with the Janjukian rather than to the Balcombian, since not one of the species enumerated by Hall and Pritchard is confined to Balcombian.

In my paper on " A Revision of the Species of *Limopsis* in the Tertiary Beds of Southern Australia,"§ in following the general usage I there placed the Orphanage Hill beds as well as the Corio Bay Beds in the Balcombian series. The above evidence, however, is sufficient proof to my mind of their affinities with the younger, Janjukian, series.

Moorabool Valley and Batesford.—There is no doubt as to the position of these beds in the Victorian Cainozoic series, for their

* Proc. Roy. Soc. Vict., vol. xx. (N.S.), pt. 2, 1908, p. 215.
† Hall, T. S., Proc. Roy. Soc. Vict., vol. xxxii. (N.S.), pt. 1, 1911, p. 49.
‡ *Ibid.*, vol. iv. (N.S.), pt. 1, 1892, pp. 19 and 24. Table II.
§ *Ibid.*, vol. xxiii. (N.S.), pt. 2, 1911, p. 419.

faunal relationships are decidedly Janjukian. From Batesford, extending up the Moorabool Valley, the polyzoal rock is greatly in evidence. This deposit at the base is largely composed of *Lepidocyclina* shells, with abundant granite detritus from the adjoining coast. The overlying white polyzoal limestone with *Amphistegina* replacing to a large extent the *Lepidocyclina* indicates fairly deep water conditions, and a general freedom from terrigenous material. During this phase, therefore, the Janjukian sea probably represented a fjord-like aspect in which an arm of the sea extended up a drowned valley. In the neighbourhood of Steiglitz there are certain fault-lines which run in a parallel direction with the general trend of the axis of outcrop of the polyzoal rock, and these may have been developed as a small rift-valley cutting into the Ordovician ranges of the country beyond Maude and Steiglitz. That the conditions were not stable for a long

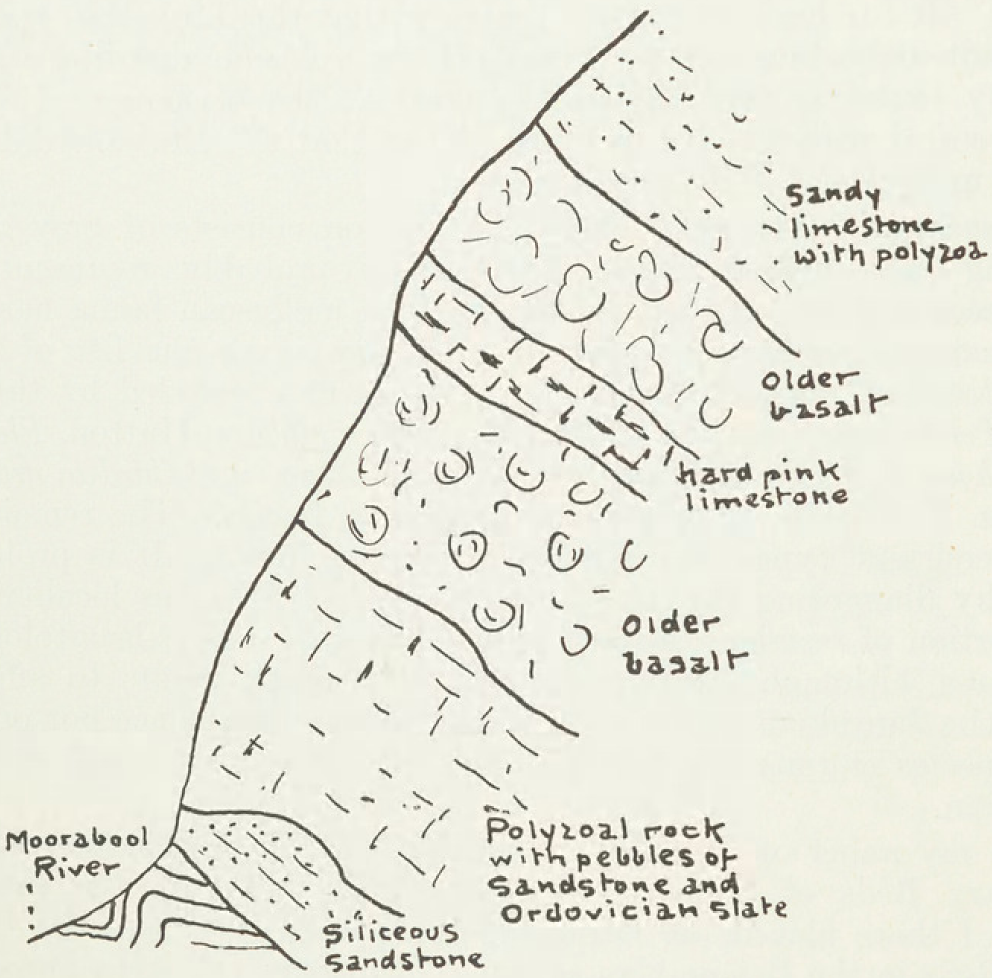


Fig. 11. SECTION IN THE MOORABOOL VALLEY NEAR MAUDE.

period is seen in the presence of argillaceous beds between the polyzoal rock as at Torquay, and above the same at Waurn Ponds and Batesford.

The relationship of the Curlewis polyzoal rock to that of the Moorabool Valley has already been pointed out. The latter locality has yielded a species of Cerithium (*C. pritchardi*, Harris), which is a typical Table Cape fossil. This species also occurs at Mitchell River, Bairnsdale, being additional evidence for the correlation of the latter series with the Janjukian. Further proof of the relationship of the Maude beds to other Janjukian occurrences is furnished by the discovery in this Museum collection of *Lucina planatella*, Tate, and *Modiola pueblensis*, Pritchard, in samples of the hard limestone beds collected by the Geological Survey of Victoria (WTM2). The former shell is a Table Cape fossil and the latter occurs at Torquay.

From an examination of the sections along the river-valley at Maude below Mr. MacDonald's house, I was able to gain a clear idea of the succession of these beds (Fig. 11), which is as follows:—

At the base is a bed of Ordovician slate, covered by a siliceous or quartzose grit, containing impressions of plant stems. This is followed by polyzoal rock containing, in places, pebbles of Ordovician slate and siliceous sandstone derived from the two underlying beds.

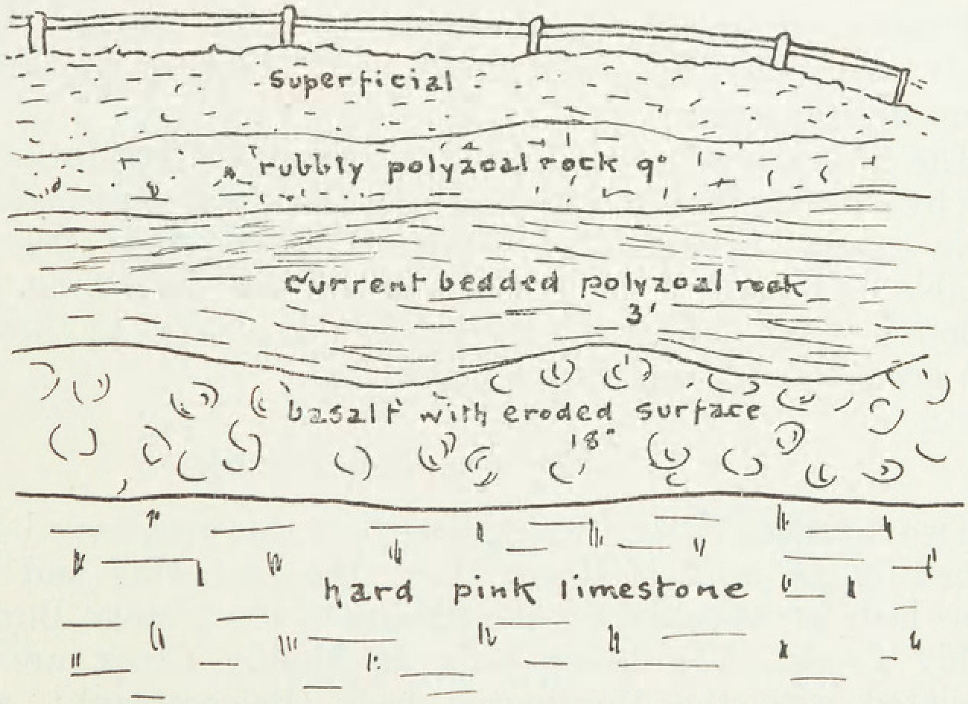


Fig. 12. SECTION AT 100 FEET BELOW MAUDE TOWNSHIP, ON ROAD TO KNIGHT'S BRIDGE.

This polyzoal rock corresponds to the specimens marked TM3 of Wilkinson's survey of this locality, and occurs about 80 feet above the bed of the Moorabool at the spot where I examined it. Lying upon the polyzoal rock is a bed of older basalt, and above this again a bed of pink limestone, thoroughly indurated and containing shells of littoral species, such as the *Cerithium* before-named and *Haliotis*. Upon this lies another bed of basalt, covered by a rubbly polyzoal rock.

At 100 feet below Maude township, on the road to the bridge (Knight's-bridge), the following section was seen (Fig. 12) :—

	Thickness in feet by aneroid.
Surface deposits passing downwards into limestone ..	100
Basalt, near top of which is an intercalated band of hard limestone, followed by (?) polyzoal rock, probably masked by talus	200
Siliceous grit	40
Ordovician slate	40

Close to the basalt an excavation at the side of this same road showed :—

	ft.	in.
Rubbly polyzoal limestone	0	9
Current bedded polyzoal limestone resting on an eroded surface of basalt	3	0

This basalt is only about 18 inches in thickness. Under this basalt occurs the hard pink limestone (WTM4) of the littoral type before mentioned.

The above section supports the survey interpretation of these beds by showing that in some localities there was a second somewhat feeble effusion of the older basalt. It also proves the extremely variable thickness of the basalt and polyzoal limestone. In other sections not far distant the second flow is absent, as shown by the data given by Hall and Pritchard.

E.—The Hamilton District.

Two divisions of the Cainozoic beds in this area have been clearly defined by the work of Messrs. Tate, Dennant, Hall and Pritchard. These beds are revealed by the erosion of the Grange Burn and the Muddy Creek. The lower beds at Muddy Creek are correctly correlated with the Mornington beds (Balcombian) ; whilst the upper series, seen at Grange Burn and MacDonald's, belong to the same geological horizon as the Beaumaris and Jemmy's Point beds (Kalimnan).

There is, however, a third and intermediate series, which has to be intercalated between these beds, but which up to the present has been entirely overlooked, in relation to its stratigraphical importance and position. In all probability this was a neglected factor on account of its great variability, even in the same district. I have already postulated the middle position of the Janjukian or Spring Creek series in the Cainozoics; a view indeed held by Messrs. Tate and Dennant, the former using the term Post-Eocene for these beds. If such be the case, this series should be either represented between the upper and lower beds in the Hamilton district, or should be negatively represented by an unconformity. That this middle series is present the following data will show:—

During a visit paid to this district six years ago I was struck with the important development of the pink limestone with echinoids (*Eupatagus rotundus* and *Linthia mooraboolensis*), polyzoa, and foraminifera. This rock can be followed from the bed of the Grange

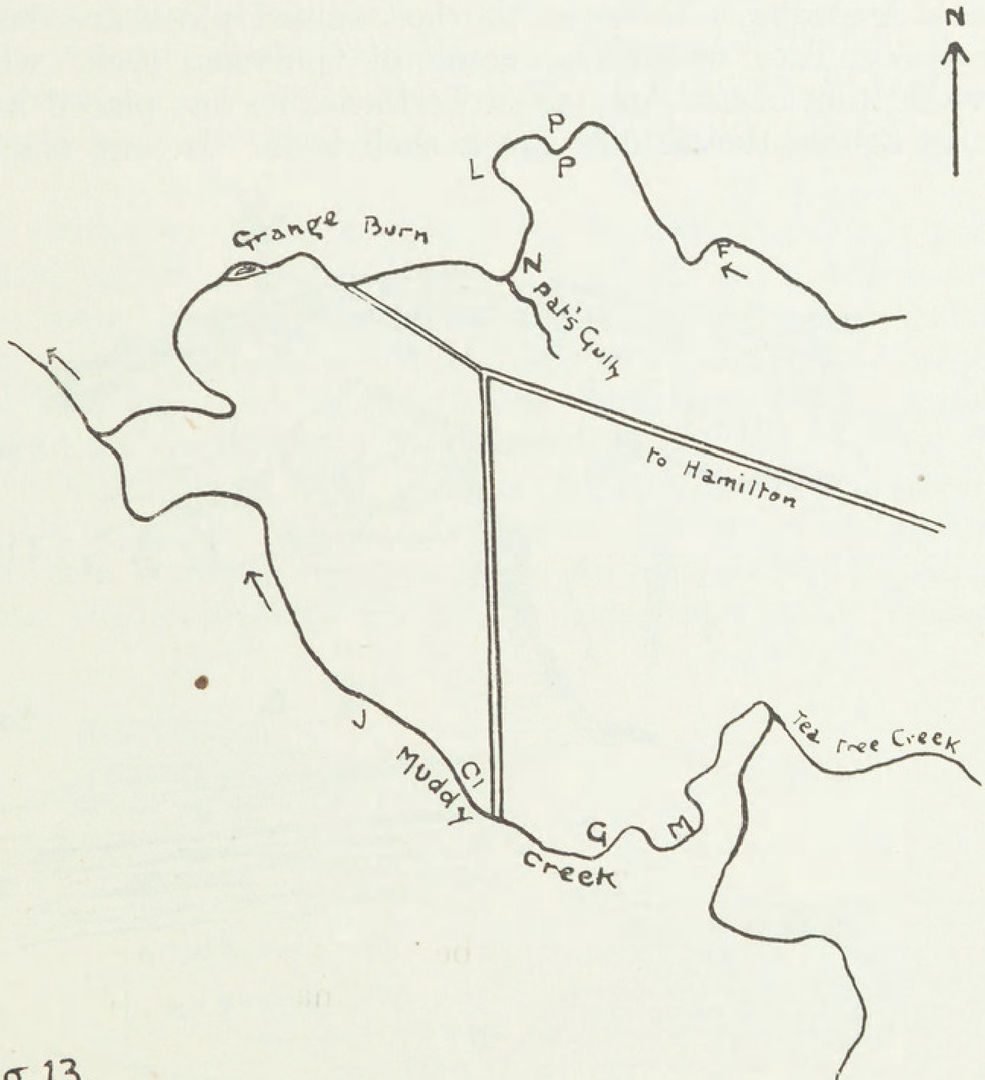


Fig. 13.

SKETCH MAP OF THE GRANGE BURN AND MUDDY CREEK AREA.
2 inches to 1 mile. Cl. = Clifton Bank (Balcombian). G. = Nodule bed (Kalimnan) on Janjukian clays. J. = Junction of Balcombian and Janjukian. L. = Lepidocyclina limestone (Janjukian). M. = MacDonald's (Kalimnan). N. = Nodule bed (base of Kalimnan) P. = Quartz Porphyry, overlain in places by Cainozoic beds.

Burn at Forsyth's, past Henty's, where it is developed on the west in a limestone cliff 60–80 feet high, with caves, and can be traced down the Grange Burn for $1\frac{1}{2}$ miles to its junction with Muddy Creek (Fig. 13). Anent this polyzoal limestone Mr. Dennant remarks* as follows :—" So far as the Muddy Creek itself is concerned, all the beds consist of the clayey and calcareous layers already noticed, but in the Grange Burn, fossiliferous strata of a different character appear, which have not, I think, been referred to by any previous geological writer. They form a rather friable rock, composed mainly of bryozoan remains, with spines of echini, and occasional shells, chiefly pectens, scattered through it. In outward appearance, it resembles almost exactly the strata on the Crawford River, about halfway between Muddy Creek and the south coast of Victoria. Somewhat similar strata are also found at Apsley, on the western boundary of Victoria, and also at Narracoorte, in South Australia. Those at the last-named place are described by Professor Tate under the name of 'polyzoal rock,' which in his classification of the Australian Tertiaries he has placed as antecedent in age to the Muddy Creek shell beds. In one place only

Fig. 14. POLYZOAL ROCK RESTING ON BALCOMBIAN. S. BANK OF MUDDY CREEK, 20 CHAINS N.W. OF CLIFTON BANK. A = BALCOMBIAN BLUE CLAY ; B = BALCOMBIAN BROWN SHELL MARL ; C = POLYZOAL LIMESTONE (JANJUKIAN), IN SITU.

have I seen the strata in close proximity, and there the polyzoal rock appeared to underlie the shell beds. As, however, I was unable to trace actual contact, I am not prepared to speak definitely on the point. As I said before, this rock is nowhere visible in

* Trans. Roy. Soc. S. Australia, vol xi., 1889, p. 34.

the Muddy Creek, but it abounds in the Grange Burn, not only above but also for a long way below its junction with Muddy Creek."

In a recent visit to the Hamilton district I was able to trace the Cainozoic beds in succession along both creeks, and at one spot, about three-quarters of a mile up the Muddy Creek, from the junction of the Grange Burn, was fortunate enough to find a small landslip revealing the polyzoal rock resting on the Clifton Bank beds (Balcombian), and not underlying them as Mr. Dennant supposed (Fig. 14). This occurrence of the limestone in Muddy Creek is only 20 chains from the well-known Clifton Bank exposure. The section there gives 3 feet of rubble; foraminiferal and polyzoal limestone, 3 feet; brown sand (fossiliferous), 20 feet; and blue clay, 2 feet down to the water line of Muddy Creek. The two last-mentioned beds are comprised in the Balcombian or Clifton Bank series.

The Cainozoic strata in the Hamilton district are not perfectly horizontal, as Mr. Dennant believed (see loc. cit., p. 33), and consequently their irregularity does not "only arise from denudation." In fact, were the strata perfectly horizontal, the great thickness of the polyzoal limestone in the Grange Burn area would present an insurmountable difficulty. The latest data I have collected goes to prove that Clifton Bank itself is on the axis of an anticline, in which the beds dip from 2 to 5 degrees. On the west bank of the Grange Burn, opposite Henty's, there are high cliffs of *Lepidocyclina* limestone surmounted by Kalimnan beds, that is, an oyster bed

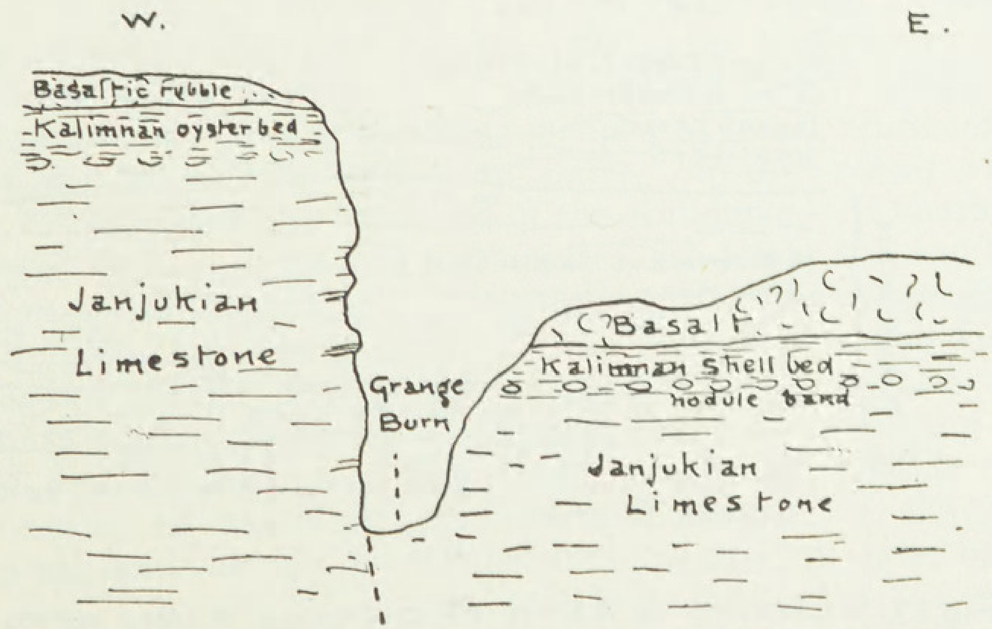


Fig. 15. LIMESTONE SCARP ON GRANGE BURN AT HENTY'S. AREA OF MAXIMUM FAULTING.

with *Natica cunninghamensis*. This elevated position of the middle series shows that the cliff at this spot represents a fault scarp; and further, that the western bank of Grange Burn at Henty's has been uplifted for at least 40 feet (Fig. 15). Moreover, the Grange Burn from this point to the junction bears the aspect of a rejuvenated stream, flowing in a deep, entrenched valley (*see* Fig. 16). The line of fault referred to passes almost due north and south

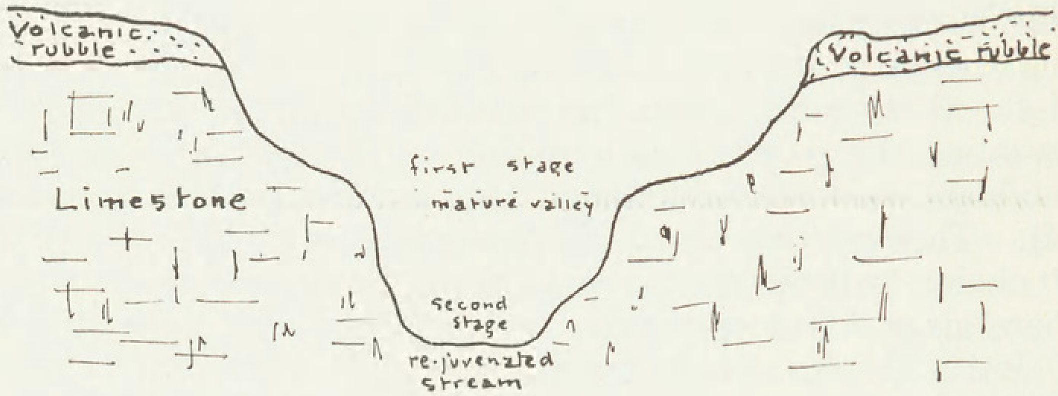


Fig. 16. VALLEY OF THE GRANGE BURN BETWEEN HENTY'S AND THE JUNCTION WITH MUDDY CREEK

cutting the Muddy Creek at MacDonald's, 1 mile south of Forsyth's (*see* sketch map Fig. 13). The effect of this fault is seen on the course of the Grange Burn below Forsyth's, where the mature stream, after coming from Hamilton and flowing over Kalimnan strata (Fig. 17), taking a more northerly turn, cuts through high banks of polyzoal limestone resting on quartz porphyry, thence flows to the west for 20 chains, and then southward for another

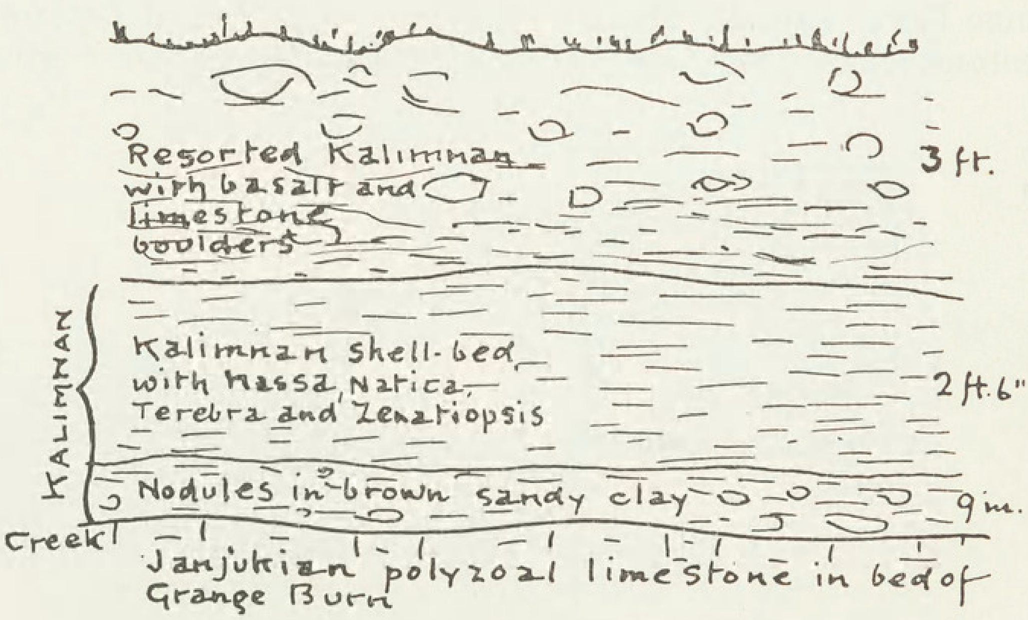


Fig. 17. SECTION IN BANK OF GRANGE BURN OPPOSITE FORSYTH'S.

20 chains, after which it follows its normal westerly course towards the Wannon. On the same area of uplift at Muddy Creek, starting from Clifton Bank, the Balcombian beds gently dip, with some slight undulations, towards MacDonald's, but are still seen at a

slight elevation, about 10 feet, at 40 chains east of Clifton, when the Muddy Creek suddenly turns north-east for 25 chains and as suddenly turns back to the south-east, indicating a small downthrow at this point, which brings the Kalimnan beds almost to creek level.

From the above observations it is clear that the polyzoal rock of the Grange Burn directly succeeds the typical Balcombian of the "Lower beds, Muddy Creek." It is further proved by the occurrence of *Linthia mooraboolensis* and *Lepidocyclina tournoueri* in that limestone, that this polyzoal rock is the precise equivalent of the Batesford limestone. On a previous visit to this locality I had failed to find the tests of *Lepidocyclina*, although that genus, represented by *L. martini* occurs in the older Balcombian beds at Clifton; but on the last occasion was delighted to find that a large portion of the bluff (60 feet) opposite Henty's was composed of a *Lepidocyclina* rock containing species identical with those occurring at Batesford. At the top of the bluff west of Henty's the beds are somewhat inaccessible, but at one spot, where I was accompanied by Mr. C. J. Gabriel, we found the rock passing into a concretionary bed with Kalimnan oysters and other shells (*O. manubriata* and *Natica cunninghamensis*). This upper bed was 15 feet thick, so that the total height of the cliff from the bed of the Grange Burn is 75 feet; whilst exactly opposite, the top of the Kalimnan from the creek is only about 45 feet. At about 30 chains up stream the same Kalimnan beds are only a foot or so above the bed of the creek. As to the succession of the beds above the polyzoal rock, the data are very clear along the Grange Burn, for at Pat's Gully* the top of the polyzoal rock is concreted by the leaching out of the phosphoric acid from the bones and coprolites of the nodules immediately overlying it. The nodule bed, I was at one time inclined to think, represented a remanié deposit of the Janjukian series, but my recent visit convinces me that it is the basal bed of the Kalimnan. It consists, as before stated, of cetacean and turtle bones, fish teeth, &c., and lies embedded in a stiff brown clay. The rolled portion of the deposit is probably derived from the underlying Janjukian, since I discovered in a similar bed on the Muddy Creek a scutum of *Lepas pritchardi*, a fossil only found, hitherto, at Waurn Ponds and Torquay in undoubted Janjukian strata. The brown clay of the nodule bed usually contains typical Kalimnan fossils, thus proving the age of the deposit, and making it without doubt a conglomeratic basal bed.

The most complete evidence of the succession of all our Cainozoic series in one locality is therefore to be gathered from the Grange Burn exposures. Let us, however, examine the data afforded on the other side of the Clifton Bank anticline. At about 35 chains

* Named after Mr. Pat. String, a local resident.

up the Muddy Creek past Clifton, at a point marked " G " on the sketch map (Fig. 13) the Balcombian fossiliferous sandy clays appear a few inches above the bed of the creek, and show a dip to the east of 8 degrees. This is surmounted by 4 feet of polyzoal rock with rolled fragments, containing many fossils common alike to either Balcombian, Janjukian, or Kalimnan strata, as *Arca* (*Barbatia*) *consutilis*, *Cucullaea corioensis*, *Chama lamellifera*, *Pecten sturtianus*, *Cardita delicatula*, and *Venus* (*Chione*) *propinqua* (specimens small and approaching the Spring Creek form *V.* (*Ch.*) *halli*, as well as a tooth of *Galeocerdo*, a form which has not occurred lower than the Janjukian. There is no doubt that whilst the Grange Burn area was rapidly subsiding, and given over to clear water conditions, on this, the east side of Clifton, the Janjukian sea was shallow, and subjected to currents, whilst very little deposition took place. Above this 4-ft. bed of polyzoal rock follows the typical Kalimnan strata resting on a nodule bed, the latter containing typical fossils of that stage, as *Glycimeris halli*, and fully developed specimens of *Venus* (*Chione*) *propinqua*.

F.—The Mallee (*Victoria*) *and the Mount Gambier District, the Adelaide Plains, and the Eucla Basin* (*South Australia*).

The first two of the above localities, so far as their underground geology is concerned, are comprised within one area of deposition. In Janjukian times that which is now the Southern Ocean extended for some hundreds of miles inland, forming a great gulf—the Murray Gulf. This gulf was bounded on the west by the great palæozoic axis of which the Mount Lofty Ranges forms a part. Its deposits form the rocks of the Mount Gambier district, and an extension of the area underlies the Adelaide Plains. The fossil fauna of the latter area, as exemplified in the polyzoal limestones of South Australia, is practically identical with the white limestone and marls of the lower portion of the borings in the Mallee of Victoria. The sediments laid down to the north of Gregory's " Primitive Mountain Chain "* formed the foundation of the vast area occupied at the present day by the basins of the Wimmera, Murray, Darling, Murrumbidgee, and Lachlan Rivers; and which form the great subartesian basin of the Murray Gulf. In New South Wales alone this subartesian area comprises, according to C. S. Wilkinson, no less than 22,000 square miles.

These older deposits revealed by boring in the Mallee, Victoria, in South Australia and New South Wales, show, by their fossil contents, that they are Janjukian or Miocene in age. The only Cainozoic fossils found in the New South Wales bores occurred at Arumpo,† and one of them is strongly confirmatory of this conclusion

* Gregory, J. W. Geography of Victoria, 2nd ed., 1912, p. 75.
† Rec. Geol. Surv. N.S. Wales, vol. iii., pt. 4, 1893, p. 115.

as to age; for it has been identified by Mr. Robt. Etheridge as *Trigonia semi-undulata*, of the type-form which is only found in the Janjukian series in Victoria, in being ornamented with fimbriated rugæ instead of almost plain sulcations as in the Balcombian variety.* In the last boring in the Mallee which I have examined (No. 11), there are 333 feet of white polyzoal limestone with occasional black cherty bands, and the bottom of the series was not reached. The fauna altogether showed a strong Aldingan and Batesfordian aspect; both Aldinga (lower beds) and the Batesford Limestone being of Janjukian age. To the westward these bores showed a thinning-out of the deep water polyzoal facies, the strata being replaced by terrigenous greensands with a rich fish fauna. The Janjukian polyzoal limestone and greensands pass upwards by gradual sequence into Kalimnan (Lower Pliocene) shell marls and sands of a decided littoral aspect. The maximum thickness of this Kalimnan series is 92 feet. These are followed by estuarine foraminiferal sands, which I regard as Werrikooian (Upper Pliocene), similar in age to the upper beds of the Glenelg River. The maximum of these deposits is 163 feet. Pleistocene beds are indicated by barren quartz sands and grits. The later Pleistocene and Holocene stages are represented by ferruginous sands, and pinkish concretionary limestone, with occasional land-shells; this series attaining a maximum thickness of 148 feet. A full report on the bores of the Mallee district, Victoria, is being prepared at the National Museum, and will be published shortly.

Another but smaller sub-artesian basin, or gulf of the Janjukian sea—really the remanet of a once very extensive area—is seen in the Eucla Basin, north of the Great Bight, and underlying the Nullarbor (= treeless) Plains. The absence of running water in this locality is due to the porous character of the white polyzoal limestone; any moisture falling upon its surface being absorbed as by a sponge, to be carried away by means of underground streams. The average height of the Bunda Plateau, as this country round the Great Bight is called, is from 800 to 1,000 feet.

The limestone country of the southern part of Western Australia is of great thickness, since, according to Mr. H. Deane (in a lecture before the Royal Society of Victoria in 1911), a Government bore passed through 1,370 feet of limestone before reaching bed-rock. From the description it appears to be a similar limestone to that of the Eucla Basin. It is to be hoped that some data will be gleaned in the near future from borings and well-sinkings in this area during the construction of the Transcontinental Railway.

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* *Trigonia semiundulata*, var. *lutosa*, Pritchard, Proc. R. Soc. Vict., vol. xv. (N.S.), pt. 1, 1902, p. 92, pl. xv., figs. 6, 7.

Table of Cainozoic Strata in Australia.

Epochs in Europe.		Equivalent Strata in Australia.
Holocene		Dunes, beaches, shell-beds, and delta deposits now forming.
Pleistocene		Raised beaches; river terraces (younger); swamp deposits with *Diprotodon*; cave breccias with extinct marsupials in Victoria, New South Wales, Queensland, South Australia, and Western Australia *Helix* sandstone of Barren and Flinders Islands; older sand-dunes of Warrnambool and Sorrento.
Pliocene	Upper	Estuarine beds of the Murray Basin; (?) hard sandstone with microzoa at 520 feet in Sorrento Bore; shell-beds of Limestone Creek, Glenelg River, Victoria; upper beds of Moorabool Viaduct. (= Werrikooian, Hall and Pritchard).
	Lower	*Terrestrial Series.*—Red Sands of Nillumbik Peneplain, near Melbourne; newer deep leads of Victoria. *Marine Series.*—Shell-beds of Jimmy's Point, Gippsland; sandy shell marl of Beaumaris; *Limopsis beaumariensis* bed of Sorrento Bore; upper beds, Muddy Creek, Hamilton. (= Kalimnan, H. and P.); Upper Aldingan of South Australia.
Miocene		*Terrestrial Series.*—Older deep leads, Victoria; leaf-beds of Maddingley, Bacchus Marsh, Victoria, and Dalton and Gunning, New South Wales. *Marine Series.*—Fossiliferous beds of Cape Otway and Spring Creek, Victoria, and Table Cape, Tasmania. Batesford and Grange Burn limestone (*Lepidocyclina tournoueri* and *L. marginata* beds, = Burdigalian). Polyzoal rock, Flinders, Victoria, and Mount Gambier and Nullarbor Plains, South Australia; Older Cainozoic of bores in Murray Basin; Lower Aldingan of South Australia; middle series of Sorrento Bore with *Eutrochus fontinalis.* (= Janjukian, H. and P.). Fossiliferous marls, of Fyansford, Camperdown, Corio Bay and Bairnsdale.
Oligocene		Shelly clays and leaf-beds of Mornington; lower part of Altona Bay and Newport Bores with sandy shell-marl and brown coal; lower beds of Sorrento bore; lower beds of Muddy Creek. (= Balcombian, H. and P.).

Summary of Conclusions.

1. The oldest fossiliferous beds of the Cainozoics of southern Australia are represented by the Balcombian series (of Hall and Pritchard), as exemplified by the blue clays of Mornington and Altona Bay Coal-shaft, in Port Phillip, and the Clifton Bank series at Muddy Creek, Hamilton.

2. The homotaxial equivalents of the Balcombian in European stratigraphy is the Oligocene (approximately Priabonian to Rupelian), including the fluvio-marine beds of the south of England and the

Isle of Wight, the Septaria Clay of Hermsdorf and Latdorf, in North Germany, and the Tongrian of Belgium. In Patagonia the Magellanian beds probably belong to this series, as well as the Waimangaroa series of New Zealand.

3. The stage above the Balcombian is the Janjukian (of Hall and Pritchard), including the Lower Aldingan (of Tate), in South Australia. During this period enormous subsidence of the coastal plains and adjoining sea-beds took place, which resulted in the accumulation of a great vertical thickness of deposits; consisting of polyzoal limestones, foraminiferal limestones (with *Lepidocyclina* and *Amphistegina*), foraminiferal soapstone, echinoid limestones, shell marls, and deeper water blue muds with gasteropods.

4. The Janjukian marine beds are, in all probability, synchronous with the terrestrial ironstone, sandy, or pipe-clay leaf-beds of Maddingley, Pitfield, Narracan, Berwick, Cobungra, Dargo, and Bogong.

5. The older basalt, in exposures where fossiliferous evidence is available, is either contemporaneous with the Janjukian, that is, interbedded; or underlying, and probably post-Balcombian; or overlying the Janjukian, and pre-Kalimnan.

6. The homotaxial equivalent of the Janjukian in Europe is the Miocene (approximately Aquitanian to Tortonian), and its greatest development approximates to the Burdigalian. In the Miocene of the Vienna Basin a somewhat similar fauna and flora existed, as seen in the accumulated banks of foraminiferal tests of *Amphistegina*, of a variety with sharp keel, found at Batesford, and by the prevalence of the calcareous alga *Lithothamnion ramosissimum*.

7. The Janjukian of southern Australia is the homotaxial equivalent of the Patagonian beds of Santa Cruz in Patagonia; and approximately of the Oamaru series of New Zealand.

8. The Miocene age of the Janjukian receives strong support from the rule of maximum development in certain types of fossil forms of that geological epoch. As for example, in the occurrence of gigantic Clypeasters in the Bairnsdale beds, and the enormous tests of *Linthia* in the Murray River and Batesford beds.

9. The occurrence of the complex-structured foraminifera, as *Lepidocyclina*, of species which are elsewhere Aquitanian and Burdigalian, as in southern Europe, India, Java, Sumatra, Borneo, and New Hebrides, further support a Miocene age for the Janjukian; as well as the extremely prolific growth of myriads of *Amphistegina*æ which, although found more sparingly in the lower, Balcombian stage, constitute whole beds of limestone, often of great thickness in the Janjukian series. The absence of Nummulites from the Australian Cainozoics is significant of their being younger than Eocene.

10. Although the precise use of the percentage method for testing the relative ages of the beds is here questioned, its value in a general sense is not overlooked. Later researches into our molluscan fauna

and of recent dredged material are continually revealing living species, which are also found in Janjukian or even Balcombian strata.

11. The Kalimnan of southern Australia is seen, from the occurrence of widely distributed fossil types, as *Scaldicetus*, as well as from its associated stratigraphical relationships, to be of Lower Pliocene age.

12. The complete sequence of the Cainozoic strata occurring in the following order, Balcombian, Janjukian, and Kalimnan, is seen in the Hamilton District, as first shown in the present paper; and also in the sequence of strata revealed in the deep boring at Sorrento. The Mallee bores demonstrate the gradual transition of the Janjukian into Kalimnan.