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Art. VII—The “Red Rocks” and Associated Beds of Wellington Peninsula. By F. K. Broadgate, M.SC. [Read before the Wellington Philosophical Society, 27th October, 1915] Plates VI, VII. Introduction. The area examined in connection with this paper is the south-west corner of the Wellington Land District, and more particularly is defined by Port Nicholson on the east, and a line drawn west from the head of that inlet to the coast, Cook Strait forms the remaining boundary. The area is conveniently termed the Wellington Peninsula (Fig. 1). Red and green argillites, often with associated tuff-beds, have been noted in various parts of New Zealand. The present paper gives the results of an examination of these rocks as they are represented in the Wellington Peninsula. Such examination must take account of the series of grey-wackes and dark-coloured argillites, as interbedded members of which the red and green argillites occur; some general notes on this series precede the main problem. The conclusion reached is that the red and green argillites were originally green argillites not differing, save in colour, from the ordinary dark-coloured argillites. An attempt is made to explain the changes undergone by the green argillites subsequently to their deposition, and a hypothesis to account for the formation of such argillites is put forward. For convenience, the well-known name “Maitai” is here adopted for the whole of the rock-series under review. No age significance is to be attached to its use in this connection, the only fresh evidence bearing on this question, as related in the text, is of a destructive rather than constructive kind. Topography. The mountainous area of the Wellington Peninsula, together with the imutaka Mountains to the east, form the southern extremity of the main structural axis of the North Island. This axial line is continued in the South Island by the Kaikoura Mountains, of Marlborough. The existing topography is that of a recently uplifted block which had already suffered close folding and distortion, and, according to J M Bell (1, p. 535), had been reduced to a state of peneplanation before uplift. In a report on the Maharahara district, Woodville, J A Thomson states that the second period of general uplift began in late Pliocene times (2, p 165); while A. McKay believes that “the Kaikoura Mountains have been elevated to their present height from a moderately elevated plateau solely by earthquake action, and this since the commencement of Pliocene times” (3, p 11) Elevation commencing in the Pliocene, and, with intervals of standstill, continuing to the present day (4, p. 246), may be fairly assumed to be the case in the Wellington Peninsula, lying midway between the districts mentioned. Compressional forces acting on an area already much disturbed have resulted in tilting and differential movements, with the institution of faults along planes of weakness, and probably a renewal of faulting along old lines.

Fig. 1. Fig. 2.

Outline of the Geology. The Maitai rocks of Wellington Peninsula are a series of argillites and greywackes with a general strike N. 12° E, and having an average dip of 70°, the direction of dip varying from east to west. The rocks to be described under the heading of “Red Rocks” are members of this series. In the Makara Valley, four miles west of Port Nicholson, is a small patch of marine conglomerate which is considered by A McKay (5) to be of Miocene age. From the physiographic evidence it appears that the deposit cannot be younger than Pliocene. The conglomerate is 150ft. above sea-level, and rests on a fault-zone. Its total areal distribution does not exceed 10 acres, and the deposit has no parallel elsewhere in the peninsula. If, as stated by C A Cotton (4, p. 246), the Wellington block was uniformly uplifted to a height of 800–1,000 ft, this conglomerate owes its position, and probably its preservation, to down-faulting since that time. The gravel veneers, relics of former base levels, as described by C A Cotton (4, p. 250), are found at varying heights. Save where complications have arisen through faulting, the highest gravels are the oldest. The Maitai Series. Stratigraphy. These rocks are recognized throughout the length of New Zealand. The complex foldings they have undergone and their general scarcity of fossils, except at a few widely separated localities, have caused much confusion as to their age and correlation. The various classifications proposed by A. McKay for the rocks about Wellington were seemingly based not on evidence from the stratigraphy of the Wellington development of the series so much as from their supposed relations in other places. In the first scheme proposed (6, p 132) the rocks were divided into— Trias and Permian (a) Sandstones and slaty shales, Magazine Point Carboniferous (a) Red and green slates, Sinclair Head " (b) Sandstones and earthy slates Devonian (a) Sandstones and drossy slates, with numerous veinlets of quartz The Devonian rocks are spoken of by Dr Hector as Lower Carboniferous (7, p 30), and this age, he says, is assigned them on account of lithological resemblances to the rocks of the Rimutaka Range. These latter, he considers, resemble rocks underlying the fossiliferous limestone at the base of the Maitai slate near Nelson (7, pp 28, 29). Omitting the red and green slates, the rocks mentioned in this classification do not differ beyond the changes induced by weathering and faulting. In fact, the description of Devonian rocks receives significance when considered as applied to a fault-zone, and a study of the “Devonian” outcrops mentioned—parts of the south coast, Tinakori Valley, and Makara Valley—make it clear that the chief fault-zones of the district were mistaken for an older series of rocks. Thus, in his Progress Report for 1878–79, Dr Hector says, “Before leaving these rocks [the ‘Devonian’ rocks of A McKay] it may be as well to point out that generally when rocks of this age and character occur in the South Island traces of gold are found.” This is easily understood, seeing that the quartz veins of Wellington and Marlborough are silicified fault-zones.

Fig. 1—Grey wacke with argillite inclusions. Makara Valley, polished slab. Fig. 2—Green argillite, partly reddened, polished slab.

Fig. 1.—Greywacke with argillite inclusions, Makara Valley; ordinary light Magnified 34 diameters. Fig 2—Diabase tuft, Red Rock Point; ordinary light Magnified 34 diameters.

In the argillites of the Maitai Series of Wellington Peninsula are found a few obscure animal-remains of small size not yet identified, and some indistinct plant-remains. The only fossil so far determined is the annelid Torlessia mackayi Bather; this fossil has as yet no definite stratigraphic value. Petrography. Microscopic study of the greywacke shows the presence of quartz, feldspar, hornblende, augite, biotite, muscovite, and epidote. The quartz which makes up most of the recognizable material is always angular, with no appearance of secondary growth. Many of the pieces show undulose extinction. Feldspars are both orthoclase and plagioclase. The orthoclase is always considerably altered. The plagioclase feldspars identified range from albite to medium labradorite. Hornblende and augite are in very small amount. The biotite, muscovite, and epidote are probably secondary in some cases. Needles of rutile are sometimes seen in the quartz, and rods of apatite in the hornblende. The greywacke cement is siliceous; much of the groundmass is of indeterminable brown material. The material of the argillites is too fine to reveal much under the microscope. Feldspar and quartz are recognizable under high power. Small veinlets are generally present, these being probably of secondary silica. The common argillite is dark-coloured; prolonged heating leaves a dull red-coloured product. The dark colouring-matter of the rock is most likely carbonaceous material (9, p. 44). Conditions of Deposition. The criteria for recognition of estuarine deposits as given by Hatch and Rastall (10, p. 13) apply well to the rocks of Wellington Peninsula. The rapid alternation of different types of sediments, often in thin layers, is very marked. The greywackes vary in texture from fine conglomerates to fine-grained sandstones, though the change is not gradual in any one band; layers of different degrees of fineness are separated by bands of argillite, the argillite itself being probably only an extreme case of a fine-grained greywacke. The presence of feldspar and the persistent angularity of even the large quartz grains both point to deposition not far from the source of supply. The facies is, indeed, that common to deposition in shallow water of the waste resulting from denudation of an igneous mass—the greywacke being a quartz product from the siliceous content, and the argillite representing the product of decay of the more aluminous constituents. A peculiar type of greywacke is that from Makara Valley (Plate VI, Fig 1, and Plate VII, Fig. 1). Besides the ordinary constituents, this has numerous pieces of argillite up to half an inch in length. These argillite inclusions have an irregular outline, and appear to be invaded by the quartz, as though they were still unhardened at the time of inclusion. This type has been noted in Westland (11, p. 45; 12, p. 85). Such a rock could originate only in shallow water. Faults. The chief fault-zones are indicated on the map. Most likely this represents only a proportion of the total number, but it probably includes the more important lines of dislocation.

Generally the argillite has afforded planes of weakness, so that the faultlines have often a N N.E. direction, following approximately the general strike of the rocks. Only in the case of the Wellington fault is there good physiographic evidence of faulting; in other cases, however, the fault-lines are readily recognized by their zones of crushed and slickensided rock. A secondary effect of the faulting has been the production of silicified fault-zones. In the western part of the area these have been worked for their gold-content. The “Red Rocks”. Tuff-beds, cherts, and red and green slates (with associated quartz veins) have been recorded together at various points, and referred to as the “Red Rocks.” They may conveniently be described under this heading. Tuff-beds. Thin beds of diabase tuff occur at two, and probably three, points, interbedded with the argillite and greywacke. Two of these occurrences are indicated on the map; the third was noted by A McKay as a dyke rock encountered in the gold-mines of Terawhiti, the term “dyke” having been used by that writer for rocks later called “tuff” (8, pp. 66–7). The exposure at Red Rock Point is associated with red and green slates. The rock is chocolate-coloured, but this colour is largely masked by green stainings of epidote and chlorite; it shows also irregular veins and nests of calcite. Under the microscope the rock is seen to be composed largely of colourless needles arranged in sheaf-like bundles, these are embedded in an irresolvable brown paste. The needles polarize in low colours—whitish-grey of the first order—and show negative elongation. Calcite veins and smaller veins of haematite are present. Plate VII, Fig. 2, shows the microscopic appearance of this rock. Dr. J A. Thomson has kindly shown me sections of a rock from Western Australia, which he terms “fine-grained greenstone” (15, p 634). These are very similar to sections of the diabase tuff. The greenstones, according to Dr Thomson, are altered diabase lavas or tuffs (15, p. 670); and the colourless needles, an alteration from the secondary amphibolite, he considers to be hornblende which has in some way had its birefringence lowered. Notwithstanding the evident alteration which the diabase tuff has undergone, its chemical composition still approximates to that of an average diabase rock as given by R. A. Daly (16)—compare analyses 6 and 7 In comparison the tuff shows a deficiency of magnesia, differs in the proportions of ferrous and ferric oxide, and has a higher percentage of loss on ignition. The formation of epidote and chlorite, as noted above, would increase the hydrous content of the rock. The relative proportions of ferrous and ferric iron have probably altered in a way similar to that of the red and green slates. Grey Cherts. The rocks named “grey cherts” by A McKay are abundant in the area. They are well seen on the coast between Lyall Bay and Island Bay, east of Red Rock Point, and at several places between there and Oterongu Bay. They form most of the block west of Oterongu and Ohau Bays (17, p. 3). The rock is quite evidently a greywacke altered by secondary silicification; small veins form a closely anastomosing meshwork in the rock, so it is not possible in parts to select even a small sample free from veining.

Under the microscope the grey chert shows quartz and feldspars as in greywacke, and small amounts of the other minerals noted in that rock. An analysis of a sample of grey chert, as free as possible from quartz veining, is appended; comparison with the analysis of a greywacke from Breaker Bay shows how little the grey chert differs from greywacke. Argillite bands in the grey chert are generally distorted. The grey cherts are readily altered by weathering, the effects of which are well seen on the coast between Lyall Bay and Island Bay. It is these rocks which A. McKay classed as the Otapiri series, and described as “gritty grey sandstones decomposing to a light-brown colour” (8, p. 61). Table: Rock Analyses. — 1 2 3 4 5. 6. 7. S1O2 70.75 70.20 57.89 58.70 61.10 48.62 50.12 T1O2 0.62 0.66

1.00 0.93 0.95 1.66 1.41 Al2O3 12.30 13.53 19.03 18.29 17.60 13.98 15.68 Fe2O3 2.72 1.68 4.48 1.99 3.84 7.68 4.55 FeO 2.74 3.24 2.88 6.03 3.85 2.16 6.73 MnO 0 06 n.d. 0.04 n.d. n.d. n.d. 0.23 MgO 1.22 1.48 1.47 2.96 2.07 1.36 5.85 CaO 1.90 1.80 0.16 1.30 1.07 10.27 8.80 Na2O 3.18 2.04 2.02 2.63 2.78 3.56 1.38 K2O 2.48 3.18 4.21 3.30 3.45 1.69 2.95 CO2 Nil n.d. Nil n.d. n.d. n.d. n.d. P2O5 0.16 n.d. 0 26 n.d. n.d. n.d. 0.37 SO3 0.18 n.d. 0.11 n.d. n.d. n.d. n.d. Moisture at 100° C 0.16 2.03 1.15 4.11 3.42 8.22 1.93 Organic matter and combined water 1.79 5.65 100 26 99 84 100.35 100 24 100.13 99.20 100.00 (1) Greywacke, Breaker Bay, Cook Strait. (2) Grey chert (= altered greywacke), Red Rock Point, Cook Strait. (3.) Argillite, Point Arthur, Wellington Harbour. (4.) Green argillite, Red Rock Point, Cook Strait. (5) Red argillite, Red Rock Point, Cook Strait. (6.) Diabase tuff, Red Rock Point, Cook Strait. (7.) Diabase, average analysis (from R. A. Daly, "Igneous Rocks and their Origin"). (Analyses 1–6 by Dominion Laboratory, Wellington.) Red and Green Argillites. In the reports of the old Geological Survey the term "slates" has been used for these rocks as also for those now called "argillites." The red and green slates do not differ, except in colour, from the common argillites; they show parting parallel to the bedding-planes, and, save where weathering has been active, slaty cleavage is no more developed than in the argillites (9, p 44; 18, p. 43). Their chemical similarity to a typical argillite is seen by comparing analyses Nos. 3, 4, and 5. The name "argillite" is here used for these rocks. The exposures of red argillites in the Wellington Peninsula are indicated on the map (Fig. 1). The outcrop at Red Rock Point, illustrated by the section (Fig. 2), is the clearest. Only in the case of this outcrop is the development of green argillite in connection with red argillite plain. Outcrops on hillsides are conspicuous by reason

of their red colour, but the green rock is hardly to be distinguished from the common darker green or black argillite. The material of the green argillites shows, under the microscope, quartz, magnetite and pyrite, and sericite. The green colouring-matter is indeterminable; in the case of green argillites examined elsewhere this colouring has been considered to be epidote (9, p 47) or amphibole (12, p. 99) Haematite is the chief recognizable mineral of the red argillites. The so-called red and green slates are green argillites partly reddened Sometimes a gradual change of tint from deep red through light red to green is observable. In other cases the colour changes abruptly from red to green. Sometimes the red argillite shows veins of deeper red (Plate VI, Fig 2). The appearance under the microscope with reflected light is of a roughly equidimensional mass of grains, each coated with red, while in places red colouring is gathered in veins which show a deeper tone. The description of the red clays and shales of Nova Scotia as given by J. W. Dawson (19, p 26) applies equally to the microscopic appearance of these argillites. "[the colouring-matter] having indeed the aspect of a chemical precipitate rather than of a substance triturated mechanically. In addition to oxide of iron distributed through the beds, there is, in fissures traversing them, a considerable quantity of the same substance in the state of brown haematite and red ochre, as if the colouring-matter had been subperabundant and had been in part removed and accumulated in these veins." Where the red argillites have been subjected to weathering, cleavage is more pronounced; and often the red colour has been leached out, leaving a light-grey to white product. A similar result of weathering of argillite has been noted by C Fraser (18, p 47) Writing in "The Geological History of New Zealand" (20, p 164), F. W Hutton says, when speaking of the Maitai system, "In several localities in both Islands red-jasperoid slates occur, sometimes associated with manganese oxide, and this, together with the paucity of fossils and the general absence of plant-remains, points perhaps to a deep-sea origin" The manganese oxide which occurs in the rocks of the Wellington Peninsula is found in small nests or stringers in the softer strata. In most cases it forms no more than an incrustation sufficient for blowpipe testing a sample from Duck Creek, Porirua, yielded 5.4 per cent of MnO2. It is never found as concentric shells around a nucleus, nor exhibiting mammillated structure, nor yet impregnating a mass of palagonite or forming layers alternate with any such substance—these being the more general modes of occurrence of manganese oxide in deep-sea deposits (21 22) Here its occurrence seems to have no more significance than that of iron oxides, and in habit it appears to parallel closely the latter oxides. Further, the Maitai rocks of Wellington Peninsula, as mentioned before, yield plant-remains, these having been collected on both sides of the argillites at Sinclair Head and elsewhere, while the black colouring-matter of the argillites is presumably carbonaceous. Paucity of fossils is no criterion of deep-sea deposits. The absence of radiolarian cherts and glauconitic sands anywhere in the rocks of the Maitai series, as well as the nearness in the series of conglomerate bands both above and below the red and green slates, are evidence that the Maitai rocks are not of deep-sea origin. Analyses Nos 4 and 5 of the accompanying list are of green and red argillite respectively. Save for the proportions of ferrous and ferric

iron, the two analyses are almost identical. The total content of iron does not differ by more than 0–4 per cent., but, while in the green argillite the proportions of ferrous and ferric oxide are 3 : 1, in the red argillite the proportions are equal. This shows that the difference in colour is due to the presence of more ferric iron in the red argillite, and indicates that the change of colour has been brought about by the production of ferric iron from the ferrous iron present in the green argillite. In discussing the formation of red sediments it seems a common premise that the iron-content in the sediment was in the higher state of oxidation at the time of its deposition, either as a hydrated sesquioxide, as supposed by Joseph Barrell (23, p 286), or already in the form of anhydrous red haematite, in which state I. C. Russell concludes all red sediments were deposited (24, p. 56). J. D. Dana has attributed the red colour of certain shales to the oxidation of their iron-content by the action of heat resulting from orogenic movements (25). How the oxidation has been brought about is not stated. Some such hypothesis as Dana's seems best suited to the case of the red argillites of Wellington Peninsula. The connection between the red argillites and the strike-faults of the Maitai rocks is indicated by the map. That the areas of red argillites have suffered from faulting-effects is shown by the fact that a quartz lode is developed in connection with each band. As stated above, these lodes are silicified fault or shear zones (26, p. 135). Genetically, however, they are segregated veins, as distinct from true fissure-veins, and as such have been described by J Park (27, p 64). Siliceous solutions, circulating mostly in a downward or lateral direction, may be considered efficient agents in supplying the oxygen necessary to convert the ferrous iron to the ferric state. In the field the appearance of the green argillites is consistent with the idea of leaching; the argillites are of a dull greyish-green colour, and, although quite compact as distinct from weather-rotted, they are without the sheen commonly noticed in light-coloured argillites (11, p. 47; 29, p. 50). The effects of vein solutions on country rock composed of "clay slates, greywacke slate, and similar rocks" have been investigated by A. von Groddeck (28). He finds that the result of such action on "variegated slates" will be a leaching-out of iron and magnesia, a loss in sericite, and a gain in quartz. The final product, however, is a slate composed of "quartz and sericite with a little rutile and considerable specular iron." On comparing the analysis of a typical dark-coloured argillite with that of the red argillite it will be seen that the small differences in the analyses vary in accordance with von Groddeck's results; while the percentage of silica shows a slight increase in the red argillite, the amounts of alumina and potash are slightly less. The total loss on ignition is high in the case of the dark-coloured argillite, due presumably to the carbonaceous matter present. In the case of the red argillite, water-content is probably responsible for the ignition-loss of 3–42 per cent. The leached-out products of iron and magnesia are not necessarily lost to the rock; in the case of the slates investigated by A. von Groddeck the resulting product has "considerable specular iron." Probably the leached iron, as in the case of the Wellington argillites, has been oxidized and redeposited in the rock. Discussing the origin of red formations, Joseph Barrell (23, p. 290) concludes that the chief factors operating in the production of red shales from

those of lighter colour are—(1n) Dehydration of iron oxides under great pressure and moderate temperature; (2) diffusion operating under conditions of warmth and moisture. Oxidation of the ferrous iron might be accompanied by hydration: if so, the conditions postulated by Barrell for its dehydration would obtain in the neighbourhood of a fault-zone. That some diffusion of the dehydrated iron oxide has taken place is evident from the appearance of the reddened argillite, and is also shown by the fact that in most cases the silica of the associated quartz veins is also slightly reddened. The necessary conditions for this diffusion would also be found as an accompaniment of the faulting. The changes mentioned above have no doubt been induced as the result of more than one movement of faulting. The folded quartz vein at Sinclair Head points to movement after its formation. In this connection it is interesting to recall the position of the Tertiary conglomerate at 150 ft. above sea-level. That there has been revival of faulting along old fault-lines has been pointed out by C. A Cotton (13, p 295). Origin of the Green Argillites. It seems clear that the land from the waste of which the Maitai series was derived supported a considerable vegetation, as evidenced by the plant-remains and the general dark colouring of the argillites. The absence of organic matter from some argillites, and its general absence from or less proportion in the greywackes, are points to be explained. The theory of Joseph Barrell (31, p. 428) to account for the sharp demarcation of shales and sands seems the best so far put forward. He assumes that the waste from a land area is laid down in shallow water, the coarser material in general nearer the shore. A violent storm will be effective in churning up the material and carrying the sand-product to a greater depth, where it is deposited. The silt of this depth is also stirred by the storm, and is in part worked farther seaward, in part settles back in place. This latter portion, being lighter, is held longer in suspension, and is deposited after the coarser sands. Repetition of this process results in the development of such finely demarcated series of sands and clays as are common the world over. With the lighter material held in suspension will be the vegetable matter contained in the rock-waste. Lack of organic matter in quantity sufficient to impart a dark colour to the argillites may have been due to an actual scarcity of vegetation on the parent land-mass of the time. To assign causes for such scarcity is rather speculative. It is suggestive, however, to note that in three cases the red argillites of Wellington Peninsula are accompanied by bands of diabase tuffs which in the two cases examined appear to underlie the green argillites; and similar association of tuffs and green argillites has been noted elsewhere (14; 17, p 2, 35, 36). The tuff-beds are proof of energetic volcanic action on the land surface of that time, a condition which would be inimical to plant-growth during and immediately succeeding the time the tuff-beds were laid down. The presence of carbonaceous matter explains why the argillites, where other conditions are favourable, are not more generally red-coloured. That no oxidation of ferrous iron can take place in the presence of organic matter has been pointed out by J S Newberry (32, pp 7 and 8) and H. Newton (33). These writers refer to oxidation of ferrous iron at the time of deposition of the sediments; the reasoning may equally be applied to the case of later oxidation.

"Red Rocks" Elsewhere. The term "jasperoid rock" has frequently been used in describing these developments (14; 17, p. 2; 35; 36). On examining samples from Marlborough and Hawke's Bay I conclude that these rocks did not differ originally from those described above. In the jasperoid rocks silicification has taken place on a microscopic scale throughout the rock, while in the case of the red argillites of Wellington Peninsula the introduction of silica has resulted in the formation of quartz veins. In all cases it seems likely that the various metalliferous ores reported in connection with the red rocks have been introduced as an accompaniment of the silicification. References. (1.) J. M Bell. "The Physiography of Wellington Harbour." Trans. N Z. Inst., vol. 42 (1910), pp 534–40. (2.) J. A. Thomson. "Mineral Prospects of the Maharahara District, Hawke's Bay." Mines Statement for 1913, N.Z. Parl. Paper C.-2 (1914), pp. 162–70. (3.) A. McKay. "Report on the Recent Seismic Disturbances within Cheviot County in Northern Canterbury and the Amuri District of Nelson" Wellington, 1902 (4.) C. A Cotton. "Notes on Wellington Physiography." Trans. N.Z. Inst., vol. 44 (1912), pp. 245–65. (5.) A. McKay. "Report on the Tertiary Rocks at Makara." N.Z. Geol Surv, Rep Geol Explor. during 1874–76 (1877), p. 54. (6.) A. McKay. "The Geology of the Neighbourhood of Wellington." N Z. Geol. Surv., Rep. Geol. Explor. during 1878–79 (1879), pp 131–35. (7.) J. Hector. Progress Report. N.Z Geol. Surv., Rep. Geol. Explor. during 1878–79 (1879), pp. 1–41 (8.) A McKay "On the Tauherenikau and Waiohine Valleys, Tararua Range" N.Z Geol. Surv., Rep Geol. Explor. during 1887–88 (1888), pp 58–67 (9.) J M Bell "The Geology of the Parapara Subdivision, Karamea, Nelson" N Z Geol. Surv. Bull. 3 (n.s.), 1907. (10.) Hatch and Rastall "Text-book of Petrology: The Sedimentary Rocks." London, 1913 (11.) J M Bell. "The Geology of the Hokitika Sheet, North Westland Quadrangle" N Z Geol. Surv Bull 1 (n.s.), 1906. (12.) P. G. Morgan. "The Geology of the Mikonui Subdivision, North Westland" N.Z Geol Surv. Bull. 6 (n.s.), 1908. (13.) C A Cotton. "Supplementary Notes on Wellington Physiography." Trans. N.Z. Inst, vol. 46 (1914), pp. 294–98. (14.) A. McKay. "On the Copper-ore at Maharahara, near Woodville." N Z. Geol Surv., Rep. Geol Explor. during 1892–93 (1894), p. 3. (15.) J. A. Thomson. "The Petrology of the Kalgoorlie Goldfield." Quart. Journ. Geol. Soc., vol. 69 (1913), pp. 621–77. (16.) R. A. Daly. "Igneous Rocks and their Origin," New York, 1914, p 27. (17.) A McKay. "On Mineral Deposits in the Tararua and Ruahine Mountains." N.Z. Geol. Surv., Rep. Geol. Explor. during 1887–88, (1888). (18.) C. Fraser. "The Geology of the Coromandel Subdivision, Hauraki, Auckland." N.Z. Geol. Surv. Bull. 4 (n.s.), 1907.

(19.) J. W Dawson. "On the Colouring of Red Sandstones and of Greyish and White Beds associated with them" Quart. Journ. Geol Soc, vol 5 (1849), pp 25–30 (20.) F. W. Hutton. "The Geological History of New Zealand." Trans. N.Z Inst, vol 32 (1900), pp. 159–83 (21.) Murray and Lee "The Depths and Marine Deposits of the Pacific." Memoirs of the Museum of Comparative Zoology at Harvard College, vol. 38, No. 1, Cambridge, U.S A., 1909, pp 28–35, and 143–48. (22.) Murray and Renard. "Deep-sea Deposits," Report of the Exploring Voyage of H.M.S "Challenger," 1875–76, 1891, pp 341–78. (23.) J Barrell. "Studies for Students—Relations between Climate and Terrestrial Deposits." Journ Geol., vol. 16 (1908), pp. 255–95. (24.) I C Russell. "Subaerial Decay of Rocks, and Origin of the Red Colour of certain Formations" U S.G S. Bull. 52. Washington, 1889. (25.) J. D Dana in Amer Journ Sci, 3rd series, vol 5 (1873), p. 431. Quoted from reference 24, p 49 (26.) A. McKay. "On the Gold-mines at Terawhiti" N Z Geol Surv, Rep. Geol. Explor during 1883–84 (1884), pp 135–40. (27.) J. Park "On the Proposed Low-level Drive, Perseverance Mine, Terawhiti Goldfield." N Z Geol Surv, Rep Geol Explor. during 1888–89 (1890), pp. 63 and 64. (28.) R. Beck. "The Nature of Ore-deposits" Trans and revised by W. H Weed New York, 1909, p. 397. (29.) P. G. Morgan "The Geology of the Greymouth Subdivision, North Westland N Z Geol Surv Bull 13 (n s.), 1911. (30.) A McKay. "On the Geology of Marlborough and South-east Nelson" N Z Geol Surv, Rep Geol Explor during 1890–91 (1892), pp 1–28 (31.) J. Barrell "Criteria for the Recognition of Ancient Delta Deposits" Bull. Geol Soc. of America, vol 23 (1912), pp 377–446 (32.) J. S. Newberry "Fossil Fishes and Fossil Plants of the Triassic Rocks of New Jersey and the Connecticut Valley" Monograph U S G S, vol 14. Washington, 1888 (33.) H Newton "Report on the Geology and Mineral Resources of the Black Hills of Dakota" Washington, 1888, pp 138–39 Quoted from reference 24, p 52 (34.) W. H Hobbs "Earth Features and their Meaning" New York, 1912 (35.) A McKay. "On the Geology of Marlborough and the Amuri District of Nelson" N Z Geol Surv, Rep Geol. Explor during 1888–89 (1890), p 118 (36.) S H. Cox "On Mount Somers and Malvern Hills District" N Z Geol. Surv, Rep. Geol Explor during 1883–84 (1884), pp. 27–28

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- Contact us