A. Liversidge.

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ERRATA.—Sixth line from bottom of page xx of "Proceedings," for "two," read *five* saddle horses.

addition to our knowledge, will sympathize with their sufferings, and will admire their wise arrangements and their perseverance, or, will learn from their experience how to guard in future against the difficulties which beset their path, or how success may be secured by those who boldly volunteer to resume their labours.

Much has been done, but much remains to be achieved! And if the greatest genius which ever mankind possessed, after his most brilliant achievements, left us, with the modesty which always characterises a son of science, an immortal and self-denying word, we may regard the labours of our own great explorers only as leading stars for future discoveries, and we may apply to them Newton's philosophic words, "I have played like a child with the pebbles on the shore while the great ocean of truth lies unexplored before me."

ART. XX.—*Observations on some Metamorphic Rocks in South Australia.* By the REV. JULIAN EDMUND WOODS, Catholic Missionary, Penola.

[Read before the Institute, 25th November, 1857.]

There is no part of the science of Geology which is in a more unsatisfactory state than that portion which has to do with metamorphic rocks. While one section of scientific men propound various theories as to the manner in which metamorphism is effected, others are questioning the very facts upon which they generalise, and not a few are found who give a very reluctant consent to the results which long investigations on the subject have produced. This state of things is, no doubt, owing to the want of a systematic series of observations in those countries in which metamorphism is most strongly manifested, and until this is accomplished we may be certain that the present difference of opinion will prevail. With a view therefore to call attention to a country where observation is most wanted, I am induced to lay before the Institute the result of some investigations among metamorphic rocks in the northern settled districts of South Australia, and while I state that I believe I have been labouring in a place which offers a wide field for an experienced

geologist, I must premise that what I have to offer is but a little thing in itself, and compared to what could be effected, scarcely anything more than a few facts imperfectly generalised.

The whole of South Australia is, however, with few exceptions, a vast array of metamorphic rocks. Whether at Cape Jervis, in the South, where the slate rocks form huge and majestic cliffs ; whether at Mount Lofty, near Adelaide, where immense ridges are formed of schist slates and eurite ; or whether at Mount Remarkable, far north, the same phenomenon of metamorphism is constantly represented, and the intervening country everywhere gives the same appearance, with all the various gradations of form, colour, or mineral structure. To attempt to sum up all the evidence here offered, would require the patient investigation of ages : we can only make remarks on peculiarities here and there, and bring them before the notice of those better able to form theories from facts. Some twelve months ago, I was for some time residing not very far from the celebrated Burra Mines, and for some time occupied myself in recording the wonders of the rocks to be seen there. I saw enough to convince me that all the mineral deposits, whether iron, or copper, or lead, of that rich mining country, were all found amongst rocks that had been once stratified, but had since been altered by heat. One phenomenon however, I saw, gave me ample room for speculation, and occupied my attention for a considerable time, and being something more curious and singular than anything I have observed in this country, I wish to make it the subject of a paper to the Institute. I repeat, however, that it is but a small thing in itself, perhaps hardly worth more than a passing notice.

About four miles south of the little township of Clare, in the hills which render Minaro, Shiligolee Creek and the vicinity so beautifully picturesque, one notices a most singular appearance along those hills which extend their ridges in a northerly direction. On every hill and in the gaps where the chain is for a moment broken, ascending and descending, there is a band of broken stone about two yards, or sometimes less in width, which is traceable without the smallest interruption, as long as the chain continues. These bands present the appearance of a roadway metalled with large fragments of stone, and though they are found on every chain of hills which runs in the same direction, they *never* run along the summit, but always a little to the right or left. As seen from the top of a hill they form so prominent a feature in the landscape that they cannot escape attention, and their regularity, their uniform width and compact appearance

make it difficult at first to realise that they had not been laid down by human hands.

Had South Australia been longer inhabited, these bands would have been invested with some traditionary history. Some legend would probably give us a satisfactory reason for these royal roads, perchance calling in the assistance of the giants who balanced the rocking stones on the coast of Cornwall, or who fought with boulders at Stonehenge. The country where the phenomenon is most apparent, may be included in a square bounded on the north by Clare, on the south by Watervale, on the west by the Wakefield scrub, and on the east by Mintaro and Farrel's Flat. This tract encloses some of the most beautiful scenery in the colony. The hills, sometimes abrupt and sometimes gently undulating, are covered with a rich vegetation, bearing large trees, which, raising their branches in the air, throw their shadows on some huge rock, which seems like a gem embedded in the shrubs and ferns below. Grassy slopes break out here and there, and these combined with a multitude of flowing brooks, bring back to one's recollection that union of peace and sublimity which is so common at home.

To return to the bands of stone. In trying to account for them I was led into a series of observations, which would carry me much beyond the limits of an ordinary paper to attempt to describe. I must endeavour then to give only what bears upon the subject, and all imperfect as my solution is, I am encouraged by knowing the matter must fall into abler hands than mine: for it is too remarkable to be left alone for any length of time, being in my opinion, quite as singular and as unparalleled as the far-famed parallel roads in the Highlands of Scotland. I have said the bands run a little on one side of the top of the chains of hills. They are also found in the valleys or troughs between the ridges, only with this difference, that the band, which in its passage goes along the hills, is composed of small fragments of stone, while those which run in the valley are composed of boulders. The higher the chain too, the smaller are the fragments and *vice versa*. Both bands and hills run parallel, and the direction is north 12° west, and though the bands are continued over the hills, and in the valleys, wherever a gap or break in the chain occurs, they never are on the highest part of the ridges or anticlinal axis, but always at an equal distance away from it, perhaps about ten yards. At first sight, it would be said these are volcanic dykes. Had they been so, there would have been nothing remarkable in

their appearance in such a form, and I should have been spared any investigation. The stone, however, of which they are composed is not of volcanic origin, but is a quartzose granular stone, probably eurite, and though crystalline, bearing distinctly lines of former stratification. Taking this fact into consideration, a great many difficulties arise in the way of an explanation of the origin of these bands. There is something so different in these appearances from any geological observations made elsewhere, something altogether so original, that the experience of others becomes useless as a method for finding a clue, and one must set to work entirely unaided. Fortunately the rocks in the immediate neighbourhood help us a little. On either side of the chains of hills (and it must be remembered that there are at least a dozen running parallel), except in the aforesaid bands, on the plains for a long distance, the only rock that is visible is clay slate, inclined at nearly right angles to the horizon, dipping to the west on the western side, and to the east on the eastern side. This slate is extremely fissile, and the stroke is N. 7° W. or five degrees more northerly than the hills. This latter fact is of much importance, as it tends to show that whatever force upheaved the hills, it was different from the one which upheaved the slate to its present highly inclined position.

On the east side the latter rock is more fissile, often possessed of veins of segregation, composed of either quartz, laterite, carbonate of lime or specular iron, and containing throughout small cubical crystals of the above named iron ore, or hœmatite in such numbers, that where the slate has decomposed and given rise to surface soil, the ground after a shower of rain is literally covered with these crystals, most beautifully exact in form.

On the west side the slate is entirely schistose, so highly laminated as to crumble into scales when rubbed, and so micaceous, that it looks like delicate silk. The strata have become finely waved and exceedingly brittle. Sometimes on both sides the slate passes into an aluminous shale slate, soft and unctuous to the touch, and containing innumerable veins of dolomite and steatite. The latter is found in such quantities in one spot, as to form an article of food for the natives, when pressed by extreme hunger.

I think there can be little doubt that heat has produced here a chemical change, to cause these appearances both on the east and west sides of the hills. For in a deep crevice or gully on the western side, which descends precipitously to the base of the hill, one sees (at the base), the extraordinary alteration the strata have undergone. The schist has become contorted, so as

to make immense curves, doubling back upon itself and making large folds, taking most wonderful forms. In fact, I can compare it to nothing else than the contortions of strata in the largest of the Cyclopian Islands as described by Sir Charles Lyell. The schist always contains the little crystals before alluded to, is very brittle, of a dull green colour, and always preserving that beautiful silky appearance. Now, as such contortions are known to have been caused by heat and volcanic action in the Cyclopian Islands, we may reasonably argue from analogy, that the same cause has operated here, though not apparent. In no part of the slate, wherever it is met with, is it entirely free from alteration, for in the valleys it is sometimes met with, where the strata become crystalline (eurite), which pass into slate and again into eurite alternately, for some distance. The crystalline portions bear the marks of stratification, with segregated veins of quartz, and the slaty parts are intersected with veins of carbonate of lime, running at right angles to the plane of stratification. Here then, we have something which throws light upon the subject of inquiry. We have evidence first of a force which upheaved the slate into its present position. A force distinct from that which raised the hills, because it has been exerted in a more northerly direction. Secondly, we have evidence of heat which altered the strata so raised. We are sure that the heat was subsequent to the upheaval, because it caused the veins of segregation partly, if not entirely, which run through several strata in an almost unbroken line, and if upheaval occurred afterwards, such line must necessarily have been disturbed, which is not the case. There can be but little doubt, that the heat which altered the slate, also crystallised the bands of stone, but whether this was before the upheaval of the hills, on which the most of them run, or afterwards, we have yet to inquire.

The theory which I am inclined to adopt for the origin of the "bands," would be in favour of the heat having preceded, and the best explanation of the reasons on which this is founded, will be to give the theory. Supposing, after the upheaval of the slate, and before it had commenced to decompose, certain portions of it running in parallel lines were exposed to the influence of caloric coming from the depths of the earth, either by longitudinal and parallel cracks in the crust overlaying some subterranean igneous mass, or by the flow of currents of trap in underground channels. The rock so exposed would be crystallised, and the surrounding strata more or less affected, provided we can suppose a narrow opening happening

in the under crust without reaching the upper surface. The crystalline portion would not be liable to decomposition while the latter would. Let ages do their work then on the uncrystallised portion, and the strata will become decomposed into surface soil, and so disappear ; but the really altered rock would be unaffected, except, perhaps, rounded and weather-worn, and would stand out in ridges of boulders. Upheaval now begins, at a centre a little removed from them, and they become broken from the under-pressing force, much more, of course, in proportion as the upheaval is greater, and then we have the bands precisely in the state in which we find them now. Be it observed, that everything bears out this view. For in the first place, the soil has formerly been composed of slate. Fortunately the plough has never yet broken the turf, and we have but to dig a foot or two to find the truth of this. The soil on being uncovered, shows the former marks of stratification as plain as possible. Again, the bands are broken smaller in proportion as they go over a higher ridge.

But as to the cause of the crystallisation, I know great exception may be taken. It may be said that on the supposition of parallel cracks, I am calling to my assistance phenomena that have never been observed elsewhere. This is true. But are not these appearances in question such as have not been observed elsewhere ; and are we not as yet in ignorance of the greater portion of geological phenomena in the world? And to answer all objection, let me say that here are appearances (the bands), which are clearly not dykes, nor due to anything that in our present state of geological knowledge we can account for ; and I only take upon myself to say they might be caused by such or such an agent, at the same time showing, as far as evidence goes, my theory is borne out. If, notwithstanding everything, I am not correct in my views, at least it will be admitted that a cause has been in operation which we are not cognisant of, and it is some slight advantage to geology to know that there are more things in the earth's crust than its present philosophy can account for. If it can be shown, however, that the upheaval was prior to the crystallisation, then my theory falls to the ground. But nothing seen supports such a view. It is true that some of the hills which are the very highest (where their height, if they existed previously, would keep them more out of the reach of subterranean agents) the bands are less crystalline and sometimes unaltered, but this is occasionally observed in the bands of the valleys, and again in some very high hills they are the most completely crystallised of

all, though still preserving former lines of stratification, so that this difference must be entirely attributed to mere local causes. Now as to the probability of parallel cracks. If these were made at all, they would probably give rise to dykes of trap. But if owing to some unknown cause, the cracks only extended through some strata, and not through others (more moderately tilted, for instance), the trap would stop some distance from the surface, and crystallise the stone above. I know this appears far-fetched, but we must remember that far less probable theories have been verified by investigation.

There is, however, another cause to which the bands may be attributed. They may have arisen from under-ground flows of lava, prior to the raising of the hills. This view has only two circumstances to support it. There is an extinct volcano about thirty-seven miles to the N.N.W., above the river Broughton, and we know from experience, that lava occasionally flows underground. The volcano I allude to, which I never had an opportunity of examining closely, appears to have greatly disturbed the features of the country around; and may probably be not yet quite extinct, as shocks of earthquakes are frequently felt at Mr. Fisher's home station at Bundalier (some of which have shaken the walls of the house); and what is of more importance just now, this volcano has given rise to immense quantities of lava. It is not difficult to suppose lava to have flowed under ground for such a distance, and if it did it would have given rise to such appearances as the bands. I may mention a case by way of illustration. In a paper I have published about the geology of Mount Gambier, I have shown that the lava has there flowed under ground. At Mount Schank it has come to the surface, and though it appears in the form of trap rock, it runs in a band similar to the one we are here speaking of. But the resemblance is more striking even than this. At Mount Schank, where a second flow of lava has occurred the uppermost flow has been forced into upright boulders, and appears in form exactly like one of the bands which occur in a valley. Now, as from a second flow of under trap, we should expect an appearance like the bands, from the way the cool trap would be tilted up: the trap in this case occupying exactly the place of the metamorphic rock. The similarity is, to say the least, very remarkable.

But supposing neither theory to be the true one, we are not entirely at a loss to suggest a cause. There is evidence of upheaval nearly in the same direction at distinct periods, showing a uniform disturbance in the same place at different times.

Such a disturbance must have had some particular cause to make it exert itself in so uniform a manner. Thus, there is upheaval of the slate, crystallisation of the same, and upheaval of the hills in nearly the same direction. We are not at present aware of the mode in which hills are upraised, but the general supposition is, that fire causes the disturbance : and if fire was so long an active and yet so partial an agent, as to cause the same disturbance, at the same places, at different times, it can easily be imagined to have been equally partial in affecting the slate, though the manner in which it did so is not patent. Or to make it plainer, if it upheaved parallel and narrow chains of hills, leaving sometimes wide valleys between, it can be easily understood to have altered some part of the slate and spared others. If these facts should hereafter be looked into, the idea that mountains are upheaved through igneous agency, will become something more than a mere supposition.

I have one more question to settle, that is the age of these rocks. They are very (geologically) ancient, but enclose no fossils. Had they done so formerly such remains would, of course, have been obliterated by the metamorphic action. They are probably of either the Cambrian or Silurian formation, but this is mere guesswork, supported by little more than resemblances in mineral character, &c. That they have existed for ages in their present position cannot be doubted, for it takes no small time to decompose hard slaty rock into a surface soil, sometimes many feet deep. Veins of segregation too, as I have observed, are common. Some of them are of quartz, and have doubtless been formed in many cases by silica filtering into crevices already made in the metamorphic rock. This is a fact where observation is much wanted, as it is not at the present moment in any way clear, to what we are to attribute the quartz veins which occur so commonly in rocks. In the instances I am mentioning it is difficult to attribute them to heat, and yet though filtration is the only resource to explain them, the peculiar manner in which it is exercised in these cases is but very imperfectly understood. The Dolomites I have mentioned have doubtless been formed in the wet way, by the re-action upon each other of carbonates of lime and magnesia. The same may be said of the steatite. The altered rock where the crystallization has been perfect is a light granular stone, with white flour-like feldspar disseminated through it. It is sometimes of a pure white colour, sometimes a pinkish yellow, and again a deep red and highly ferruginous. The specific gravity ranges from 2.4 to 2.86.

There is one rock which is so rich in magnesia as to give rise to great beds of steatite, and another is so aluminous as to affect the taste of water in the neighbourhood, which water gives large quantities of alumina on analysis. In both the rocks the stratification is perfect, and their composition gives one an idea of the singular state of the ocean from which they were deposited. Sulphur is also present. I exposed a large quantity of the powdered rock, to heat in a retort, and the quantity of sulphur that sublimed was quite surprising. I could detect no sulphates. At a place, east of the hills, so often alluded to, there is a vein of iron ore, and the strata on each side are variegated with most singular colours. I have one specimen where the rock is changed to a most beautiful blue, of the finest hue that could be imagined, so distinct was the colour that I actually analysed a portion to detect copper or cobalt before I became aware that this was owing merely to the influence of heat.

In conclusion, it may be said to those who are fond of regarding South Australia as a country, the whole of which has been recently raised from the sea, that these rocks at least, and a great portion of the country immediately around, were certainly dry land at a time when the sea rolled over the spot where Adelaide now stands; and if, as I believe it may be proved, the south coast of South Australia was under water at a recent period, tracts of country such as Clare, and the Mount Lofty ranges formed an Island Archipelago. The sea beat overland where the busy hands of men have now raised a city,, using for that purpose the very spoils which the ocean left behind, but while it did so, it spared a spot where fire had exerted its underground ravages ages before, leaving rocks and stones to tell to man, the magnitude and power of the earth's Great Framer.