resemblance to the schists with garnet and staurolite, and that the authigenous minerals in them are neither garnet nor staurolite, but some impure hydrons silicates. Dr. Heim's letter merely asserts the contrary to my contentions, without adducing any fresh evidence.

T. G. Bonney.

THE CULM-MEASURES AT BUDE, NORTH CORNWALL.

Sir,—I have read with much interest the paper by Major-General McMahon on the rocks at Bude. During one of two summer visits to Tintagel I made a short stay at Bude, and saw the extremely contorted strata so well described in the paper referred to. Like the author of that paper, I was desirous of seeing what amount of metamorphism had resulted from so much pressure and dislocation, but expecting to pay a longer visit I took away only two specimens. These were taken from two layers, a few inches apart, of a very sharp fold exposed in a cove a little way south of Bude Haven,—I think it was "Efford Ditch." One of the layers was darker in colour, much softer, and more laminated than the other.

If any conclusions may be drawn from so limited a stock of material (and macroscopically, at least, my specimens appeared fairly representative of many of the rocks in this and other cliffs of the district), the rocks of Bude are entitled to complain that they have been made to appear as being less appreciative of, and as making less return for, the large amount of force expended on them than is really the case.

The microscope shows the general structure and composition of my specimens to be exactly as described by Major-General McMahon; but a close study of very thin portions of slides, under high powers, shows a good deal more, especially in the harder of the two layers.

In among the unaltered original clastic material may be seen a considerable amount of rutile, perfectly distinct from any bits of that mineral which may have come from older rocks. There are large numbers of acicular crystals of it, vividly polarizing, as well as countless minute dark rods, so well shown in many slates, etc. It is also present in grains and granular aggregates, and in plates, some of them of relatively large size. The total amount of it varies much, even in slides from the same small piece, but it is always considerable, and in one slide from the harder layer of rock it is particularly abundant. This slide also shows a good many long crystals of tourmaline (quite distinct from the clastic grains of that mineral) and a good deal of secondary sericitic mica, some of it rich in rutile crystals. Indeed, parts of this slide at once remind one of some of the sericite-phyllites of the Tintagel rocks, in which the rutile occurs in just the same manner; and comparisons of the two leave little doubt that some at least of the Bude strata have made a good start towards the metamorphism which is so intense at Tintagel.

Of course it may be that my two specimens are exceptional, and that Major-General McMahon did not chance on these or similar layers.

But in any case, even though these specimens show that *all* the Bude rocks are not without distinct evidence of metamorphic action, it is still true that the effect produced is not in anything like the proportion we might expect, from the stresses endured by these beds.

I am not able to follow some of the reflections which Major-General McMahon bases on the supposed total absence of alteration at Bude.

Hallock's experiments (as quoted), and still more Hallock's conclusion from them, seem to be beside the mark. It is not generally supposed that pressure is able to liquefy rocks,—quite the reverse in fact,—and there does not seem to be any justification for saying that "consequently" no chemical or mineralogical changes are to be expected.

Again, Spring's experiments are admitted to have proved that pressure can produce chemical combinations and re-arrangements; and nothing that was done by "Professor Spring's pestle and mortar" would be lacking in the intermixture of minute particles of minerals in the fine silt of which these Bude rocks and similar strata are largely composed. There is no call here for rocks to be "crushed and ground to pieces by irresistible geological disturbances." All the crushing and grinding has been done in the gentlest and quietest way, and the resulting material has but to lie and await the pressure.

Whether pressure, with or without movement, is in itself sufficient to intensely metamorphose sedimentary rocks, is another question.

And, if it *is* sufficient, there is still much room for inquiry and speculation as to why it acts so comparatively feebly at one place and so very intensely a few miles away, when, so far as can be judged from the rocks, the feebler metamorphism has by no means corresponded to feebler stresses.

NEWCASTLE-ON-TYNE,
March 10th, 1890.

W. MAYNARD HUTCHINGS.

CONTORTION AND METAMORPHISM.

SIR,—General McMahon's "Notes on the Culm-measures at Bude" in the March Number of this MAGAZINE (p. 106) form a welcome contribution to the petrology of the district, and have a particular interest as indicating the probable derivation of the strata in question from the destruction of granitic rocks. The fact that the Culm-measures are much contorted without having experienced any appreciable mineralogical changes seems, however, to have only a limited bearing on the general question of metamorphism by pressure.

Adopting the familiar treatment employed by Thomson and Tait, we may usefully resolve any system of strains into (i) a uniform voluminal compression and (ii) certain shears. The term shear is here used in its strict sense, viz. deformation apart from change of volume, and it is evident that the varying amounts of shearing from point to point within the mass express themselves completely in the contortion of the rocks affected, faulting being regarded for this