the Portlandian of the Boulonnais, has convinced the present writer that the last-mentioned name must also share the same fate.

Rhinobatus Bugesiacus thus occurs in the Lower Kimmeridgian of Bavaria and S.E. France and in the Lower Portlandian of N.E. France: in the first and last localities it attains its maximum dimensions, while in the second it is comparatively dwarfed. The same species may also perhaps be met with in the English Kimmeridgian, but as only detached vertebræ have hitherto been discovered,¹ it is at present impossible to arrive at a specific determination.

WOODWARDIAN MUSEUM NOTES.

V.—ON "EYES" OF PYRITES AND OTHER MINERALS IN SLATE.

By ALFRED HARKER, M.A., F.G.S.

AMONG instances of the bodily deformation of rocks by lateral pressure, the case of the *phyllade aimantifère* of Monthermé is well known. By its strong cleavage this rock gives evidence of considerable lateral compression. Professor Renard² has shown that prior to this compression the magnetite crystals already existed in the rock, and were surrounded by a coating of chlorite. The crystals yielded to the pressure much less readily than their matrix, and the latter, having already a firm consistence, became separated from the crystals, carrying the chlorite with it, and was displaced along the planes which are now cleavage-planes, that is, in a direction at right angles to that of the pressure.

My object is to show that similar phenomena are not uncommon among cleaved rocks in our own country. Some years ago I obtained from the Penrhyn quarry a specimen of slate with cubes of pyrites, in which the displacement of the matrix around the imbedded crystals is well exhibited. As in the French *phyllade*, the vacant spaces left have been subsequently filled by infiltrated quartz, which grew roughly perpendicular to the faces of the crystals. The arrangement is represented in figure 1 (p. 397). As the "eyes" are from half an inch to an inch in length, the pyrites, quartz, and chloritic mineral can be easily distinguished with the naked eye, while a thin section makes a pretty object under the microscope (No. 501). In the *phyllade aimantifère* the magnetite crystals are only 0.2 to 0.8 mm. in length (No. 502). M. Reusch³ has noticed a precisely similar disposition of quartz and chlorite around dodecahedra of pyrites in a schistose diabase dyke: here too the crystals appear to be only about one-hundredth of an inch in diameter.

The phenomenon is probably one of wide occurrence. It is seen in sericitic slates at Blaenau Ffestiniog and at other places in North and South Wales; also in the very pyritiferous slates of Ballachulish near Oban. The "eyes" are always flattened parallel to

¹ Catal. Foss. Fishes, Brit. Mus. pt. 1, p. 83.

² Bull. Mus. Roy. Hist. Nat. Belg. vol. ii. p. 134, and plate vi. 1883. See also Gosselet's "L'Ardenne," p. 61 and fig. 17, 1888.

³ Bömmelöen og Karmöen, pp. 69, 70, 1888.

the cleavage-planes and drawn out along the line of cleavage-dip (*longrain* of the French). It indicates that in those cases the pyrites is of very early origin, and that it became coated at an early stage with a chloritic envelope; further, that the rock became thoroughly compacted before it was subjected to the lateral thrust, so that in yielding it was able to leave vacant spaces, which were filled at a later date by crystalline quartz. This last point is proved by the manner in which the quartz has been formed with its crystals perpendicular to the faces of the pyrites. There are, however, other cases in which the quartz has a fibrous structure, the fibres being set parallel to the *longrain*, that is, to the direction of movement, as diagrammatically shown in fig. 2. This is presun-

Sections at right-angles to the cleavage-planes. P = pyrites; Q = quartz;
C = chloritic mineral.

ably due to the quartz having been deposited concurrently with the process of deformation, so that no vacant space was actually formed. The examples cited by Loretz¹ from the Thuringerwald must be referred to this kind of action. In these the pyrites has been subsequently converted into limonite.

Another variety of "eye" is found in the Llandeilo slates of Whitesand Bay near St. David's. Here the whole external surface of the "eyes," which are about an inch and a half to two inches long, has a strongly fibrous, slickensided aspect. On making a section, it is seen that the pyrites cubes have their angles and quoins rounded off, and little fragments of pyrites are detached and enveloped in the quartz which occupies the corners of the "eyes."

It should be noted that these lenticular or eye-shaped masses are essentially characteristic of *discontinuous* sliding movement, in which actual disruption has taken place between substances capable of different degrees of yielding, such as the hard pyrites and the less hard rock surrounding it. The same rocks often exhibit the ellipsoidal green spots (distorted spheres) first noticed by Dr. Sorby, which indicate *continuous* deformation without abrupt slipping.

¹ Jahrb. d. königl. preuss. geolog. Landes. for 1881, pp. 283-289.