to belong to *S. Morrisiana* King, a species which is rather common at Thickley.

I shall not in this short note attempt to give a complete list of the rather numerous fossils that occur at Thickley, as I am preparing a synoptical table of the fauna of the chief fossiliferous horizons of the Durham Permian for a future paper. The difficult group of the Permian Strophalosias of England is one on which much might be written, including among them the curious small form called by King *S. parva*, which domiciles itself in the interior of empty valves of *Productus horridus* in the Shell Limestone reef. A sound revision of the Permian fauna is a task which would undoubtedly repay the effort expended on it.

EXPLANATION OF PLATE XII.

Surface of a block of Calcareous Lower Magnesian Limestone from East Thickley Quarry, Durham, about $\frac{2}{3}$ natural size. In middle *Productus horridus* Sow., with long spines. At A, a *Strophalosia goldfussi* Münt. attached to the *Productus* spines; BBB, specimens of *Streptorhynchus pelargonatus* Schloth.; C, specimen of *Spirifer alata* Schloth.

On the Rocks of the Avon Section, Clifton.

By SIDNEY H. REYNOLDS, M.A., Sc.D.

AN account of the lithological succession of the rocks of the Avon Gorge was given at the Bournemouth meeting of the British Association in 1919, and a summary of the rock-characters mainly from the lithological aspect was published in the GEOLOGICAL MAGAZINE (1919, p. 523). Further work has now been done, and a full account of the rocks is published in the current issue of the *Quarterly Journal of the Geological Society*.¹ The following summary prepared for the above paper was considered redundant owing to the fact that the matter it contains is already incorporated in the text of the paper. In view, however, of the importance and accessibility of the Avon Section it is thought that a brief statement such as the following, in which the rock-characters are summarized firstly from a stratigraphical and secondly from a lithological aspect may be useful.

I. DESCRIPTION OF THE ROCKS FROM THE STRATIGRAPHICAL ASPECT.

A. The *Cleistopora* Beds.

The Modiola Shales K_m .—The lower beds, which are ill-exposed, consist of sandy shales, of tencalcareous, and impure limestone. The upper beds consist of thin-bedded, often sandy, and rubbly limestones with reddish shaly partings. Small lamellibranchs, ostracods, and calcareous algæ are the most characteristic organisms. Small gastropods, brachiopods, and crinoids are also

¹ *Quart. Journ. Geol. Soc.*, vol. lxxvii, 1921, p. 213.

frequent and tubicolous annelids occur. The beds are of shallow-water character, and constitute the earliest *Modiola* phase of the Avon Section.

The Bryozoa Bed (horizon *a*) consists of massive ferruginous limestone, mainly composed of crinoids, but with very plentiful bryozoa at certain levels.

*K*₁.—Consists of shale and mudstone alternating with thin-bedded limestone. The principal limestone builders are crinoids and brachiopods. Ostracods and bryozoa are sometimes plentiful. In the "Palate Bed" at the base Elasmobranch teeth are abundant.

*K*₂.—Only the upper part of this horizon is well exposed, the rocks consisting of thin-bedded highly fossiliferous limestone alternating with shale. Crinoids and brachiopods are the principal limestone builders. Ostracods and bryozoa are plentiful at some levels. A little dolomitization has taken place in some of the highest beds.

B. The *Zaphrentis* Beds.

Horizon β.—On the right bank this horizon consists of rather massive limestone with crinoids and brachiopods. On the left bank the rock is thinner-bedded.

*Z*₁.—The lower beds are crinoidal and brachiopodal limestones overlain by thick-bedded dolomite, capped by a chert band. The upper beds are dark dolomitized crinoidal limestone (petit granite), with many fossils, especially brachiopods.

*Z*₂ and horizon *γ*.—Consists almost throughout of dark crinoidal limestone (petit granite). The matrix is almost everywhere completely dolomitized, but where this has not taken place foraminifera and *Calcisphaera* become for the first time plentiful. The larger fossils, particularly the crinoids, resist dolomitization and are the chief limestone builders. Brachiopods are less and corals more common than in *Z*₁. The "Fish Beds" at the top of *Z*₂ contain numerous Elasmobranch teeth and spines.

C. The *Syringothyris* Beds.

*C*₁. (*a*) *The Laminosa Dolomite*.—Consists of crinoidal limestone almost completely replaced by dolomite. At the top is the sub-oolite bed with abundant *Chonetes* and *Orthotetes*.

*C*₂ (*b*) *The Caninia Oolite*.—This is a fine-grained white oolite, the grains often enclosing foraminifera. Other fossils are scanty.

*C*₂. *The Caninia Dolomite*.—The lower beds are composed of grey and pale dolomite alternating with calcareous shale and mudstone occasionally algal. The dolomite was originally in the main oolitic or foraminiferal limestone. The upper beds are mainly china-stones with ostracods and calcareous algæ. The *Caninia* dolomite commences the second *Modiola* phase of the Avon Section.

D. The *Seminula* Beds.

S_1 continues the second *Modiola* phase of the Avon Section.

S_1 (a).—Mainly calcite mudstones with algal, ostracodal, and *Seminula* layers and a *Lithostrotion* (*Diphyphyllum*) band at the base. Overlying these beds are limestones with *Lithostrotion martini* and thick shaly partings.

S_1 (b).—Mainly dark, massive, much dolomitized limestones, with abundant *Lithostrotion martini*, but including shaly partings and some bands of china-stone type.

S_2 (a) *The Seminula pisolite and associated rocks*.—These consist of shallow-water deposits—calcite mudstones, dolomites, and pisolites associated with massive dolomitized *Lithostrotion* limestones. At the top are dolomites with three chert bands.

These rocks form the upper part of the second *Modiola* phase of the Avon Section.

S_2 (b) *The Seminula Oolite*.—The lower part consists of massive white fossiliferous oolite, the grains being often formed round foraminifera. The upper beds, in addition to oolites, include foraminiferal limestones.

S_2 (c).—The rocks of this level are chiefly massive foraminiferal limestones with *Chonetes* and *Lithostrotion* bands, and are often considerably dolomitized. The upper beds include china-stones and pisolites and commence the third and last *Modiola* phase of the Avon Section.

S_2 (d) *The "Concretionary Beds"*.—These consist largely of china-stones with bands of *Seminula* pisolite and more rarely oolitic layers, but their most marked feature is afforded by the numerous "Concretionary" (algal) bands.

E. The *Dibunophyllum* Beds.

D_1 .—The lower part consists of highly foraminiferal and coral-bearing white limestone associated with layers of coarse red oolite, and numerous bands of pseudobreccia. Thin shaly partings often separate the limestone bands. The upper part consists in the main of bands of coarse red oolite alternating with thick bands of shale and red grit.

D_2 .—Except for the fact that this horizon commences with a band of quartz conglomerate, the lithological types are identical with those in D_1 . The lower beds are chiefly grey foraminiferal limestones and pseudobreccias, in the middle part coarse red oolites prevail, while the upper beds include much red grit and shale.

II. DESCRIPTION OF THE ROCKS FROM THE LITHOLOGICAL ASPECT.

(a) *Calcareous Rocks*.

These may be classified according to the nature of their chief organic constituent :—

(1) *Algal Limestones* are abundant in all the rocks which accumulated under *Modiola* phase conditions, viz.: (a) in K_m ; (b) at the top of the *Caninia* dolomite, C_2 ; (c) in the lower part of S_1 ; (d) in the *Seminula* pisolite bands of the lower part of S_2 ; (e) in the Concretionary Beds of the upper part of S_2 . Calcareous algæ have also been met with in the lower part of C_2 and the middle part of S_2 .

Mitcheldeania is the most persistent form ranging from the extreme base of the section to the top of S_2 . *Ortonella* is characteristic of the K beds. *Solenopora* is found occasionally in the K beds. *Spongiostroma* associated with subordinate *Mitcheldeania* is prevalent in the calcite mudstones which are so abundant throughout C_2 and S. *Girvanella* tubules are seen forming the centre round which some of the oolitic grains in the lower part of D_1 have formed. *Aphralysia* was found in C_2 and S_2 (d).

The algal material commonly tends to form nodules, but in K_m it also occurs as narrow layers interbedded with gritty bands, and in S_1 the *Spongiostroma* masses tend to form undulating sheets. In S_2 , especially in the lowest beds, the *Seminula* pisolite type prevails, characterized by the *Spongiostroma* and sometimes *Mitcheldeania* layers being arranged concentrically, often round *Seminulæ*. Lastly the Concretionary Beds of the top of S_2 form the most important of the algal developments, *Mitcheldeania* being the prevalent form.

(2) *Foraminiferal Limestone*.—Foraminifera first begin to be fairly common in Z_2 . They are abundant in the *Caninia* oolite and are seen frequently in non-dolomitized bands (whether belonging to the calcite-mudstone series or to the oolites) in C_2 and the whole of S. They occur in great abundance in the white limestones of the upper part of S_2 , and the lower part of D_1 . They abound in the pseudobreccias. *Calcisphaera* first becomes plentiful in Z_2 .

(3) *Coral Limestone*.—Zaphrentid corals play an appreciable part as limestone builders throughout the *Zaphrentis* zone, and there is a well-marked *Caninia* band in S_1 . Bands full of *Lithostrotion martini* are most characteristic of the S beds, and there is a well-known band of basaltiform *Lithostrotion* in S_1 . The abundance of corals in the D beds is so familiar that it need not be emphasized.

(4) *Crinoidal Limestone*.—Crinoids occur in considerable abundance throughout practically the whole Lower Avonian, except in the *Modiola* shales and *Caninia* oolite, but are specially plentiful in (a) the Bryozoa Bed, (b) K_1 and K_2 , (c) the petit granite of the whole *Zaphrentis* zone. In the Upper Avonian crinoids are not specially characteristic, but occur in some abundance, and often reach a very large size in the white limestones of the D beds. Sections of echinid spines presumably to be attributed to *Palechinus*,

have been met with at various levels throughout practically the whole section from the lower part of K_1 to D_2 .

(5) *Brachiopod Limestone*. — Brachiopods associated with crinoids are very characteristic of K_1 and K_2 . They are abundant in horizon β and Z_1 , often forming well-marked bands in which *Spirifer clathratus* and *Chonetes hardrensis* are the most conspicuous forms. *Seminula*-bands are one of the most characteristic features of the S beds. *Productus* and *Chonetes papilionacea* bands are frequent throughout S and much of D. The suboolite bed (top of C_1) is also a strongly marked band of *Chonetes papilionacea*.

(6) *Bryozoa* occur abundantly in the Bryozoa Bed at the base of K_1 and in the upper part of K_2 , and are met with at various levels throughout the whole section.

(7) The presence of worms is often indicated where *Modiola* phase rocks are met with, thus small spirorbid annelids are common in K_m and C_2 . Tubular bodies probably due to worm borings are characteristic of the very white calcite-mudstones of S_1 and S_2 (a). Some of the shales of S_1 are full of "worm tubes".

(8) *Ostracods* are very plentiful wherever the rocks are shaly or of the calcite-mudstone type, viz. throughout K, at the top of C_2 , in the lower part of S_1 , and at certain levels in upper S_2 .

(9) *Molluscs* do not play an important part, though small lamellibranchs and small gastropods are plentiful in certain bands in K_m , and *Euomphalus* occurs sparingly in S_1 . Small gastropods seem characteristic of *Modiola* phase conditions, occurring in the calcite mudstones of S_1 as well as in K_m .

(10) Elasmobranch teeth and spines are very characteristic of the "Palate Bed" just above the Bryozoa Bed in K_1 , and of the "Fish beds" at the top of Z_2 .

Oolites occur at the following levels :—

- (1) In the upper part of C_1 , the *Caninia* oolite.
- (2) At the middle of S_2 , the *Seminula* oolite. Both these are very white rocks and of great thickness.
- (3) Thin bands of oolite occur at various levels in the Concretionary Beds of S_2 and in C_2 .
- (4) Thick bands of coarse red oolite occur at intervals throughout the D beds.

(b) Siliceous rocks.

Grits are met with only in the D beds (D_2 and upper part of D_1), where bands may reach a thickness of 20 feet. Sandy limestones are frequent in K_m and K_1 . Quartz grains occur frequently throughout the limestones of the C, S, and D beds, and at many levels secondary growth has converted them into doubly terminated crystals. In other cases the crystals seem to have been formed independently of pre-existing grains. Bands of chert due to the replacement of the limestone occur (a) near the middle of Z_1 , (b) just below the *Seminula* oolite, and (c) between the *Seminula* oolite and the Concretionary Beds. Partial silicification (beekite)

affects the fossils of upper K_2 , β , and Z_1 , and the Lithostrotiont corals, and occasionally the *Seminulæ* at many levels in the *Seminula* beds.

(c) *Argillaceous rocks.*

Thick shales are met with at three levels :—

- (1) Throughout the *Cleistopora* beds.
- (2) In the upper part of C_2 (*Caninia* dolomite) and in the lower part of S_1 .
- (3) In the upper part of D_1 and of D_2 .

Thin shaly partings occur in upper S_1 , in S_2 (c), and throughout the more calcareous parts of the D beds, where they are often associated with pseudobreccias.