of the ground-mass. A little bright green matter is also present, which appears to occupy irregular vesicles, and which is either green earth or some closely allied mineral of secondary origin. The angles of extinction of the feldspars seem to indicate that the triclinic ones are labradorite.

The rock from Tower Falls closely resembles that just described, except that it contains apparently no augite and more hornblende. The crystals of the latter mineral are also surrounded by opaque borders, which are often broad, and consist of an internal zone of magnetite and an external one of hæmatite, which appears sharply defined at its contact with the magnetite. The rock is hornblende andesite. It is of paler colour than that from Mount Washburn, the hand-specimen being grey, with minute reddish brown, black, and white specks*.

APPENDIX.

On the MODE of OCCURRENCE of some of the VOLCANIC ROCKS of Montana, U.S.A. By JAMES ECCLES, Esq., F.G.S.

THE volcanic district of the Yellowstone National Park, from which I obtained the various rock-specimens referred to in the foregoing paper, has been already described in detail by Dr. Hayden, Dr. A. C. Peale, and Prof. Bradley, in the reports of the U.S. Geological Survey of the Territories for the years 1871 and 1872.

In the autumn of 1878 I had the good fortune to accompany Dr. Hayden and other members of his survey in some parts of the district referred to; and although I have no intention of giving a detailed description of the volcanic phenomena which were observed, a short notice of the localities whence the specimens were obtained, and of the general mode of occurrence of the rocks, may be of some interest as a supplement to Mr. Rutley's description of their microscopic characters.

The Yellowstone National Park, within which are the head-waters of two of the great forks of the Missouri (the Yellowstone river and the Madison) and of the Snake river (one of the branches of the Columbia, comprises an area of about 3600 square miles, nearly the whole of which is covered up by volcanic rocks of great thickness. There are very few exposures of underlying sedimentary or other formations; and these are almost entirely limited to the extreme northern edge of the area. Some fifteen miles south of the southern boundary the extension of these volcanic rocks is seen to rest upon the northern spurs of the Teton range of mountains, at which point the underlying formation has been ascertained by Prof. Bradley to be of Carboniferous age. On approaching the Park from the south along the upper valley of the Snake, these volcanic rocks appear to form an irregular plateau densely covered with forest. From the point at which we first struck this plateau, as far as the Upper Geyser basin on the Firehole river (the chief branch of the Madison),

* For the discussion upon this paper see p. 412.

Fig. 3.—Map of part of the Yellowstone Park.
(Scale about 20 miles to 1 inch.)

is a linear distance of about twenty-five miles, but three days of hard travelling. The rocks consist entirely of varieties of obsidian and trachyte, the latter almost invariably being found in great mass under the former.

The obsidian, though frequent, is somewhat irregularly distributed. It is both black and reddish brown, is occasionally columnar, and is nearly always porphyritic. The most common form is a coarse, rapidly weathering variety, containing many crystals of sanidine. The disintegration of this rock produces some curious fine conglomeratic deposits in the old watercourses and river-beds (No. 8).

The trachyte is constant and of very great thickness, and is evidently closely allied to the obsidian. A cliff-section in the Upper Geyser basin suggests a transition from trachyte to obsidian. (Nos. 4 and 6 were obtained from this section.)

East of the Firehole river and across the divide between the Madison and Yellowstone rivers the section presents the same general characters as that between the Snake and the Madison. High up on the divide the trachytes are light in colour, and there is some pumice occurring on the surface. On the east of the divide the obsidian thins away for some distance, but is found again above the Great Cañon of the Yellowstone, where it is capped by fully 300 feet of fine sandstones and shales, probably of Quaternary age, which have doubtless been deposited by the Yellowstone lake in a former period of extension. The rocks in this basin, and especially in the section exposed in the Great Cañon, have been minutely described by Drs. Hayden and Peale; and I have nothing to add to their description. It is sufficient to say that the order and general character of the rocks is almost precisely the same as in the upper part of the Madison basin.

Up to this point the volcanic phenomena had been almost uniform. The trachyte-flows, although dipping slightly here and there (as much as 20° in the Upper Geyser basin), were approximately level; and the country through which I had passed seemed to be quite destitute of any features which I could recognize as vents from which such an enormous mass could have been poured out. Seven miles north of the head of the Cañon a change is observable. Mount Washburn here attains an elevation of from 2500 to 3000 feet above the trachytes of the Cañon, and is a true volcanic cone. The summit is a broken-down crater; and the lava-flows, which are basaltic (No. 9), dip away in all directions, and conform generally to the slopes of the mountain. I found no contact between the basalts and the trachytes on the southern side of the mountain; but it is quite evident that the former overlie, and are more recent than, the great mass of trachytic rocks just described.

Descending on the north side of the mountain, the Yellowstone river was reached again near Tower Falls, a distance of ten miles from the peak; and here the trachytes are again seen in the river-section, with columnar basalts resting on them. I was not sure whether these basalts had flowed from Mount Washburn or from some vent on the east side of the Yellowstone; but, compared with the trachytes, they were comparatively insignificant both in extent and, except on the mountain itself, in thickness. These basalts had been poured out before the formation of the present Cañon; for the river here cuts its way through basalt and trachyte nearly 400 feet deep.

The locality of Gardiner's river, whence the specimen No. 7 was obtained, as well as the intervening space between this river and Tower Falls, was passed over most rapidly by me, owing to bad weather and Indian troubles. The trachyte in this locality resembles strongly that of the Great Cañon in mineral character. Although there is a considerable distance between Tower Falls and Gardiner's river where the trachyte does not exist, owing, probably, to denudation, I am inclined to regard this Gardiner's-river trachyte as belonging to the great mass of trachytes further south.

EXPLANATION OF PLATE XX.

Vitreous rocks of Montana.

- Fig. 1. Black obsidian containing trichites. Yellowstone district. $\times 250$.
2. Red obsidian showing in thin section reddish-yellow bands of glass, and grains of quartz, in a nearly colourless glass. Yellowstone district. $\times 25$.
3. Black spherulitic obsidian with bands of microliths and radiately crystalline spherules. Yellowstone district. $\times 77$. Nicols at 85° .
4. Spherulitic obsidian, consisting of dull dark-greyish and vitreous black bands, flecked with white glassy porphyritic crystals of sanidine. The dull bands are composed of radiately crystalline spherules, while the vitreous bands consist of glass, black in the hand-specimen and colourless in thin section. Yellowstone district. $\times 25$.
5. Black porphyritic obsidian with spherulitic bands. The drawing shows part of a section of one of the porphyritic crystals of sanidine, which is surrounded by an isolated girdle of small spherules. Yellowstone district. $\times 18$.
6. Yellowish grey spherulite rock with small porphyritic crystals of sanidine. Yellowstone. $\times 32$. Crossed Nicols.
7. Rhyolite with peculiar Damascene structure and grains of quartz. Between crossed Nicols it is seen to have a microcrystalline structure throughout. Gardiner's River. $\times 55$.
8. "Obsidian sandstone," a finely granular blackish tuff, composed of angular grains of vitreous rocks of different appearance, the majority being perlitic, others showing merely microlithic streaks, but all probably derived from approximately the same source and representing the disintegration and cementing in place of vitreous rocks. The drawing shows part of one of the perlitic fragments, in which, between crossed Nicols, an interference-cross is seen in the centres of some of the perlitic spheroids, similar to the crosses seen under similar circumstances in artificially strained or compressed glass. In the lower part of the field a crystal of triclinic felspar is shown. Lower Geyser basin, Yellowstone district. $\times 18$. Nicols at 85° .

Note.— Except when otherwise stated, the drawings have been made by ordinary transmitted light.

Frank Rutley del A.S. Ford lith

Mintern Bros. imp.