The composite dike at Brockhill, Worcestershire.[1]

(With Plate XXIII.)

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[Read March 7, 1940; communicated by Dr. J. Phemister.]

(1) *Introduction.*

At Brockhill in Worcestershire, some 11 miles west of Droitwich, in the valley of the river Teme, a small dike of igneous rock is intruded into the red marls and sandstones of the Downtonian Series.

The dike was figured and described by Phillips[2] in 1848. On the Old Series one-inch Sheet 55 N.E. it was indicated as having a very limited outcrop on the eastern side of the river Teme; but a report of an excursion to Brockhill in 1874[3] records the presence of igneous rock on the opposite bank. The intrusion was examined during the resurvey on the six-inch scale of the New Series one-inch map, Sheet 182 (Droitwich), and is of interest both on account of its petrographic character and its remoteness from other igneous rocks. It has recently been traced by magnetic methods for a distance of over three-quarters of a mile.[4]

(2) *Field Relations.*

The principal exposures are indicated on the sketch-map (fig. 1) which shows the trend of the dike to be some 8–10° north of west and south of east. The largest and most important outcrop is a quarry some 250 yards north-west of Brockhill farm, on the east bank of the river. Here a 70-foot vertical section shows the dike cutting Downtonian marls and sandstones and inclined at about 70–75° to the south. Near the base of the pit much of the dike has been quarried away and the centre

[1] Published by permission of the Director, Geological Survey of Great Britain.

[2] J. Phillips, The Malvern Hills, compared with the Palæozoic districts of Abberley, Woolhope, May Hill, Tortworth, and Usk. Mem. Geol. Surv. Great Britain, 1848, vol. 2, part 1, pp. 155–158.

[3] Trans. Worcestershire Nat. Club, 1874, vol. 1, pp. 211–212.

[4] A. F. Hallimond, Magnetic observations on the Brockhill dyke. Bull. Geol. Surv. Great Britain, 1939, no. 2, pp. 85–92.

is completely obscured by rubble. Higher up the face it is well exposed and reaches a maximum of about 25 feet in thickness. In the main it is a moderately coarse, dark-grey to black dolerite which weathers to greyish-brown rock speckled with white felspar and analcime and gives rise to a brownish soil lighter in colour than that derived from the

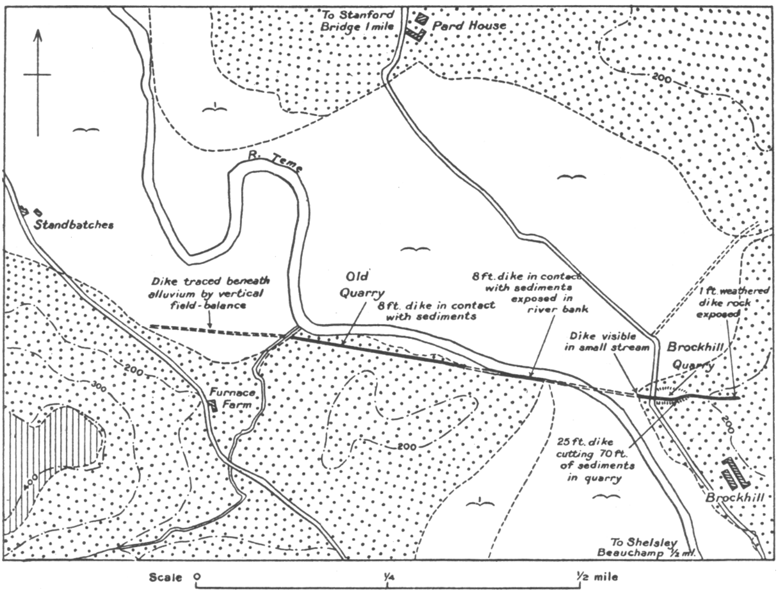

FIG. 1. Sketch-map of the Brockhill dike. Alluvium and low-terrace gravels (blank), Dittonian (ruled); Downtonian (stippled). Course of dike indicated in black.

adjoining sediments. The dike is well jointed parallel to the contacts, less well at right angles to them, and this rectangular arrangement of the jointing may have assisted in the inception of the spheroidal weathering which is common. The rock appears very homogeneous and is finer grained only for an inch or two along each contact: this fine-grained margin (p. 543) is quite distinct in character from the main mass of the dike.

The country-rock, which here has a slight dip to the north of west, consists of red marl and marly micaceous felspathic sandstone and includes, near the top of the quarry, a thin cornstone band containing fish fragments. All these rocks have suffered some degree of alteration to a distance of about 30 feet on both sides of the dike. Near the contact, both marls and marly sandstones have been converted into compact dark rocks, often closely jointed at right angles to the junction with the dike. A common and striking form of alteration of the marls, seen at its best in the upper part of the section on the south (hanging) wall of the dike, has given rise to fine-grained, dark-purplish rocks which show numerous cream-coloured to pale green more coarsely crystalline streaks and blotches. Many of these streaks are elongated vertically and, being roughly circular in cross-section, bear a superficial resemblance to pipe amygdales. Their distribution is apparently governed by differences in the composition of the marls as suggested by the section illustrated in fig. 2. Near the top of the pit the cornstone band, which is less than one foot thick, has been converted into a compact yellowish crystalline lime-silicate rock. It is difficult to match up the sediments on the two sides of the dike, and it is possible that the intrusion has taken place along a small fault.

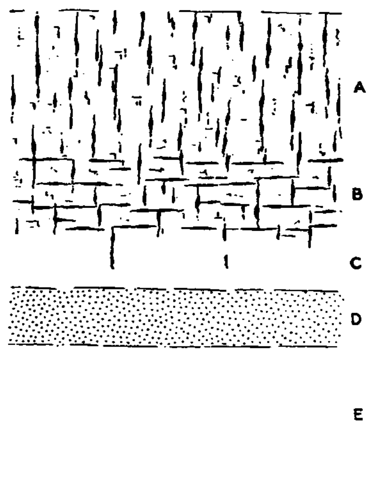

FIG. 2. Section of metamorphosed sediments from half-way up face of Brockhill quarry.

A. Soft marl, much vertical piping by pale greenish material.

B. Soft marl, vertical and horizontal joints infilled with pale greenish material.

C. Hard marl, few pipes.

D. Sandstone.

E. Hard siltstone; no piping.

At several points eastward of the quarry, fragments of weathered dolerite and altered sediment are visible. About 70 yards to the east weathered dike rock is exposed, and unaltered red marl turned out of burrows 2–3 yards farther down the slope shows that the metamorphic effects produced by the dike are here comparatively slight. The last exposure in this direction is some 120 yards east of the quarry where one foot of fine-grained weathered dike rock is exposed.

West of the Brockhill quarry the dike disappears under the alluvium of the river Teme, but in dry seasons is visible as a reef running obliquely across the river. On the opposite bank, some 300 yards west of the quarry, it is again exposed in contact with red and green marls both to the north and south. Here the thickness of the dike has diminished to 8 feet, spheroidal weathering is prominent, and jointing across the dike is much better developed than that parallel with its length. The intrusion has a distinct chilled margin 6 inches or so wide, but the zone of contact-metamorphism in the marl is very narrow, never reaching as much as one foot in width. The alteration is slight and is of the same order as that 25–30 feet from the contact in the main quarry, that is, the marl has been indurated to form a compact red-brown to purple-brown rock.

The most westerly exposure seen is in a small coppice 750 yards west by north of the main quarry. Here 8 feet of dike rock with a 6-inch chilled margin is seen in contact with grey shaly indurated sediment on its south side. A short distance to the west the dike again disappears beneath the alluvium and its further course has been traced by magnetic methods for several hundred yards.

(3) *Petrography.*

(*a*) *The igneous rocks.*—The rock from the central portion of the dike in the main quarry is a teschenite with abundant pyroxene and felspar, subordinate olivine, and interstitial analcime and zeolites (pl. XXIII, fig. 1). The pyroxene is a slightly purplish titanaugite which forms prisms with a strong tendency to idiomorphism and also occurs frequently in groups of subhedral crystals. Olivine is almost completely altered to deep green or olive-green serpentine: in many cases the outlines are irregular, but occasionally the characteristic shape of olivine is preserved (17672).[1] The amount of felspar varies and while usually in the proportion of 30–40 per cent. may fall so low that the rock might be classed as a picrite (17949). It is predominantly plagioclase but includes a considerable proportion of orthoclase. The plagioclase forms diversely arranged prisms up to about one millimetre long, centrally of labradorite composition, but zoned marginally to oligoclase. The prisms are often replaced in the centre by fibrous green chlorite and are penetrated by strings of analcime. Orthoclase builds stout clear prisms and may mantle the plagioclase (17951). Analcime is common in the interstices between the felspars and also occupies large residual spaces. Very rarely, a short rectangular prismatic outline within an area of analcime suggests the possibility of original nepheline though no more definite evidence of the presence of this mineral could be found. Both felspar and analcime are commonly replaced by pale brown, fibrous radiating natrolite: in specimen 17949 granular chabazite is also present

[1] These numbers refer in all cases to the English series of microscope slides at the Geological Survey Office, Exhibition Road, South Kensington, London.

interstitially. Iron-ore, probably a titaniferous magnetite, is abundant, and is sometimes bordered by irregular flakes of brown biotite. Accessory minerals include many long needles of apatite and an occasional prism of zircon.

An analysis of the teschenite has been made and is given below (col. I), together with analyses of a teschenite from Blackburn, Linlithgowshire (A), and of the analcime-dolerite of Clee Hill, Shropshire (B) for comparison.

	I.	A.	B.		I.	A.	B.
SiO_2 ...	...46·28	45·71	48·4	SO_3 ...	... 0·01	—	—
TiO_2 ...	... 2·56	1·64	3·1	Cl ...	... trace	trace ?	—
Al_2O_3 ...	...14·90	15·23	13·4	F ...	... 0·04	—	—
Fe_2O_3 ...	... 3·52	2·84	4·0	S ...	... —	0·08	—
FeO ...	... 7·13	6·93	8·5	FeS_2 ...	... 0·20	—	—
MnO ...	... 0·54	0·54	—	Cr_2O_3	... 0·00	0·02	—
MgO ...	... 6·12	8·11	6·5	V_2O_3 ...	... —	0·03	—
CaO ...	... 6·58	7·34	8·6	(Ni,Co)O	... —	0·02	—
Na_2O ...	... 4·49	3·96	3·1	BaO ...	... 0·05	0·04	—
K_2O ...	... 1·72	1·31	2·1	SrO ...	... —	trace ?	—
$H_2O > 105°$	... 4·36	4·70	2·2	Li_2O ...	... —	trace	—
$H_2O < 105°$	... 1·28	1·54			100·52	100·51	99·9
P_2O_5 ...	... 0·74	0·47	—	Less O for F	0·02		
CO_2 ...	... 0·00	0·00	—		100·50		

I. Teschenite. Dike at quarry 250 yards north-west of Brockhill farm, Worcestershire. Analyst, C. O. Harvey.

A. Teschenite. Probably Carboniferous sill. Leckstone quarry, Blackburn, Linlithgowshire. Analyst, W. Pollard, Summ. Progr. Geol. Surv. United Kingdom, for 1905, 1906, p. 74; Geology of the Neighbourhood of Edinburgh, Mem. Geol. Surv. Scotland, Sheet 32, 1910, p. 299.

B. Analcime-dolerite. Clee Hill, Shropshire. Analyst, J. H. Player, in F. H. Hatch, Text-book of petrology, 2nd edit., London, 1892, p. 179.

The norm, mode, and Niggli values for the Brockhill teschenite are as follows:

Norm.		Mode.		Niggli values.	
or	10·01	orthoclase	5·0	si	117
ab	30·92	plagioclase	29·4	al	22·2
ne	3·98	serpentinized		fm	46·0
an	15·29	olivine	4·2	c	17·9
di	10·32	augite	19·8	alk	13·8
ol	12·48	analcime	16·0	qz	−38
il	4·86	natrolite	2·6	k	0·20
mt	5·10	chlorite	11·5	mg	0·50
ap	1·68	biotite	1·0	c/fm	0·39
	94·64	iron-ore	9·1		
		apatite	1·4		
			100·0		
Sp. gr. 2·71		Camptonose		Symbol III. 5. 3. 4.	

The Brockhill rock is similar in chemical composition to the teschenite of Blackburn, a sill of Permo-Carboniferous age in the Midland Valley of Scotland: compared with the Clee Hill rock it is poorer in silica and lime and richer in alkalis.

The marginal rock proves to be a fine-grained quartz-dolerite or basalt (pl. XXIII, fig. 2). It is composed of stout mutually interfering prisms of plagioclase and numerous idiomorphic or hypidiomorphic prisms of colourless augite, which may be fresh but are usually traversed by cracks, along which serpentine is developing, and speckled with many granules of iron-ore. In some specimens the pyroxene is altered to highly birefringent fibrous bowlingite. The plagioclase is labradorite, zoned towards the margin to oligoclase, and, while of uniform grain in individual specimens, the prisms range from about 0·3 mm. to 1 mm. in length. Augite shows continuous gradation in size from microlitic prisms to large crystals, 2 mm. long, in the same rock-section.

There is considerable divergence in the proportion of the minor constituents which include alkali-felspar, quartz, chlorite, iron-ore, and serpentinous pseudomorphs after olivine. In specimen 17948, which shows many small prisms of green fibrous material after olivine or perhaps orthopyroxene, quartz is present in very small quantity as interstitial grains, alkali-felspar is observed as partial mantles to oligoclase and as small prisms in quartz, and spherulitic chlorite is present but not abundant. Specimens 17944, 17572, and 17953 show decrease in the proportion of ferromagnesian minerals, and an increase in alkali-felspar, including perhaps cryptoperthite; quartz is present interstitially. Further variation is shown by specimens 17951 and 17952, in which alkali-felspar and interstitial spherulitic chlorite are abundant, while the ferromagnesian minerals are almost entirely replaced by chloritic material.

Iron-ore, which is abundant in all sections, probably includes both ilmenite and magnetite, and is leucoxenized in the more alkalic specimens. Accessory constituents include clear red-brown biotite and apatite.

Across the Teme, where the dike is much narrower, the rock is distinctly finer grained. A specimen from the centre of the dike (17675) shows altered ferromagnesian minerals set in a groundmass of small andesine-labradorite laths. A considerable amount of augite is still recognizable, but olivine has been completely replaced by yellow-green serpentine and chlorite. Iron-ore is plentiful and some epidote occurs as an alteration product of ferromagnesian minerals and felspar. There is no trace of either analcime or quartz. At its margin the dike is still more decomposed. Large phenocrysts or rounded masses which now consist of calcite with subordinate chlorite are set in a fine-grained groundmass of felspar microlites, chlorite, and iron-ore. In some cases (17676) the crystal outlines of both augite and olivine are recognizable in the calcite-chlorite pseudomorphs.

(*b*) *The metamorphic rocks.*—The commonest type of hornfels is an altered felspathic sandstone consisting of grains of quartz and subordinate felspar surrounded by finely divided aggregates of quartz, felspar, and abundant ferromagnesian minerals which are not always determinable. The quartz is present as subangular grains some of which are seen to have grown, incorporating at the edges minute specks of the other minerals. Many of the quartz grains are surrounded by fringes having the form of tridymite laths (pl. XXIII, fig. 5). The tridymite has now inverted to quartz which is optically continuous with the parent grain. The larger quartz grains are separated by a fine-grained mosaic of quartz and alkali-felspar. Of the coloured constituents, much is yellowish-green chlorite, increasing in amount towards the contact. Small scales of red-brown biotite, about 0·02 mm. across, are present and ragged prisms of green hornblende are also recognizable, while minute octahedra of iron-ore are very abundant. In 17953 what appear to be yellowish pinitic clots after cordierite are present.

A similar development of tridymite fringes to quartz grains is recorded from siliceous xenoliths in the igneous rocks of Vulcano,[1] Braefoot in Fife,[2] and Mull.[3] Bowen[4] and Larsen[5] have expressed the opinion that the presence of this mineral is not necessarily an indication of high magmatic temperature, and this is borne out in the present instance, where it is associated with what is essentially a low-temperature mineral assemblage, though there is a probability of late chloritization.

Where the country-rock was marl rather than marly sandstone, the percentage of coloured minerals in the hornfels is higher, much of the brown and colourless mica of the original sediment appears unaltered, and there is a great deal of indeterminable brown material. The cream-

[1] A. Lacroix, Les enclaves des roches volcaniques. Macon, 1893, pp. 168–169.

[2] R. Campbell, T. C. Day, and A. G. Stenhouse, The Braefoot outer sill, Fife. Trans. Edinburgh Geol. Soc., 1932, vol. 12, pp. 360–361; 1934, vol. 13, pp. 166–167.

[3] H. H. Thomas in Tertiary and post-Tertiary geology of Mull, Loch Aline and Oban. Mem. Geol. Surv. Scotland, 1924, pp. 198, 274.

[4] N. L. Bowen, Geologic thermometry. Chapter X in The laboratory investigation of ores (edited by E. E. Fairbanks). New York, 1928, pp. 180–184.

[5] E. S. Larsen, The temperature of magmas. Amer. Min., 1929, vol. 14, pp. 86–88.

coloured pipes and blotches which so commonly occur in the altered marls are of special interest (pl. XXIII, fig. 6). The central portion consists of large plates of calcite and analcime, the latter showing complicated twinning effects: commonly the two minerals are intergrown in a manner suggesting replacement (17680, 17781). Scattered through both is much semi-opaque material consisting of greenish-brown chlorite with mean refractive index 1·556, and numerous small colourless garnets, hardly ever larger than 0·02 mm. across. This clear central portion is surrounded by a white opaque zone composed largely of finely divided carbonate and small garnets, and this in turn passes outwards into a zone of reddish spotted mudstone which passes into the normal metamorphic rock described above.

The only other type of hornfels present is that resulting from the alteration of the cornstone band mentioned on p. 540. This has been converted into what is essentially a quartz-calcite-garnet-rock (17681–3). Small crystals of a colourless grossular garnet are scattered through the rock in such numbers as to render parts of it almost opaque and are imbedded both in large irregular plates of calcite and in a fine-grained quartz mosaic. Frequently a thin ring of somewhat more coarsely crystalline quartz separates the calcite plates from the quartz mosaic. Pale green chlorite is not uncommon and often has small granules of magnetite associated with it, while occasional wisps of brown mica and grains of epidote are also present.

(4) *Age of the Intrusion.*

The only field evidence as to the age of the Brockhill dike is that it is post-Downtonian. Other analcime-bearing rocks of the Midland counties include the dolerites and basalts of Clee Hill, Wednesfield, Pouk Hill, Rowley Regis, and Little Wenlock, now commonly regarded as of Carboniferous age,[1] and it seems probable that the Brockhill intrusion may be assigned to the same period. Similar rock types are to be found among the Carboniferous intrusions of the Midland Valley of Scotland, though in that region there appears to have been a considerable time interval between the intrusion of the teschenites and the quartz-dolerites.

In many ways the Brockhill intrusion bears a close resemblance to

[1] R. W. Pocock, The age of the Midland basalts. Quart. Jour. Geol. Soc. London, 1931, vol. 87, pp. 1–12. See also Shrewsbury district. Mem. Geol. Surv. Great Britain, 1938, appendix VI, p. 281.

the basic dike at Bartestree near Hereford.[1] This is also composite, consisting of teschenite, olivine-free dolerite, and basalt, intimately associated with one another and regarded by Reynolds as successive intrusions. Small quantities of quartz in the dolerite near the contact are presumed to have been picked up from the Old Red Sandstone into which the dike is injected. Slides 7604, 7606 of metamorphosed marly sandstone close to the contact with the Bartestree dike show tridymite fringes to the quartz grains similar to those in the contact zone of the Brockhill dike.

(5) *Relations of the teschenite, quartz-dolerite, and country-rock.*

The quartz-dolerite shows variable contact relations to the country-rock. In some cases (17572, 17673) the contact is sharp. The igneous rock shows only a slight diminution of grain-size, the country-rock maintains its hornfelsed sedimentary character. Between the two distinct rocks is a zone 0·5–1 mm. wide, which is sharply defined by difference in grain-size and by marginal concentration of small prisms of augite or its pseudomorphs from the quartz-dolerite, and which shows abrupt difference in texture and composition from the country-rock (pl. XXIII, fig. 3). The origin of this zone is uncertain, but it is suggested that it represents sediment to which magmatic material has been added. It is clear that the quartz-dolerite has been intruded as molten magma along this contact while the country-rock was hot.

In other cases (17945–7, 17952) there is a passage between contact-altered sediment of a muddy siltstone type and felspathic fine-grained rock of quartz-doleritic affinity resembling craignurite, and one section is made up partly of altered sediment, partly of fine-grained holocrystalline igneous rock and partly of rock which shows igneous texture yet includes contact-altered quartz with tridymite fringes (17947). In 17952 the transitional zone shows a lathy plagioclase base containing many prismatic pseudomorphs in yellow chlorite and greatly obscured by dissemination of similar material (pl. XXIII, fig. 4). Abundance of small fresh granules and prisms of pyroxene suggest contamination by incorporation of a pyroxene-hornfels (17945–6). In several cases a coarser grained quartz-dolerite or basic craignurite shows a sharp contact against fine-grained contaminated igneous rock of similar type (17944, 17952), and it seems as if the quartz-dolerite had been intruded against a metasomatized semi-igneous skin of the country-rock. A

[1] S. H. Reynolds, The basic intrusion of Bartestree. Quart. Jour. Geol. Soc. London, 1908, vol. 64, pp. 501–511.

similar state of affairs is shown in 17953, where the transition zone consists of laths of plagioclase and alkali-felspar, abundant chlorite frequently as long prisms disposed roughly at right angles to the contact, and much finely divided iron-ore.

Seven specimens of the contact were collected from different positions and all showed the intrusive rock to be of the quartz-dolerite type. Teschenite has not been seen in contact with the sediments nor was any trace of a chilled junction between teschenite and quartz-dolerite observed. Specimens 17953–5, representing a three-inch depth of the igneous rock at the northern contact near the base of the quarry, form a series showing a gradual passage between the teschenite and quartz-dolerite. Specimen 17953, in contact with the sediment, is a quartz-dolerite with abundant plagioclase laths, fresh augite, iron-ore, interstitial alkali-felspar, some green serpentinous material, and a little quartz: on the side of this section, away from the contact, chlorite becomes abundant in interstitial spherulitic aggregates. Specimen 17954 is a quartz-free dolerite containing a higher proportion of interstitial spherulitic chlorite than 17953, and carrying, towards the interior of the dike, prismatic and rounded pseudomorphs in semi-opaque orange serpentinous material; biotite also increases markedly in this direction. The section 17955, about one inch farther into the dike, shows on the edge close to 17954 a rock similar to the latter, but within a few millimetres a little analcime appears, and this mineral, together with pseudomorphs after olivine, rapidly becomes so abundant that on the other edge of the section the rock is a normal teschenite.

From a consideration of the thin sections two points are evident:

(1) that the quartz-dolerite was intruded as a molten magma which reacted locally with the sediment to form a thin metasomatized zone;

(2) that the teschenite and the quartz-dolerite were intruded almost simultaneously, since there is a gradual passage from one to the other.

The passage relations of the quartz-dolerite to the teschenite, and the very restricted development of the former—confined to a two-inch zone on either side of the dike—do not encourage the hypothesis that the two rock types represent successive intrusions. A possible explanation is that the quartz-dolerite represents a modification of the teschenitic magma by reaction with the country-rock. An example of quartz-dolerite formed in this manner is recorded from the Braefoot outer sill in Fife (Campbell, Day, and Stenhouse, loc. cit.), where acidification of teschenitic magma by abundant xenoliths of sandstone and quartzite has given rise to a rock approximating in composition to quartz-dolerite. That the modification of the teschenitic magma cannot have taken place in situ at Brockhill is obvious from the sharp nature of the contact between country-rock and quartz-dolerite. It is possible, however, that reaction between teschenite and country-rock was operative during the passage of the magma through the sediments.

The richness of the teschenitic magma in volatile constituents is shown both by abundance of zeolites in the igneous rock and by analcimization of the contiguous marls, and this may have provided a medium for exchange of materials between magma and sediment, silica being added to the magma. It is suggested that this acidified magma mounted in advance of the main uncontaminated teschenitic magma and coated the walls of the fissure, in places chilling against the country-rock, in others reacting further with it. Local contact of quartz-doleritic rock with chilled facies of the same type suggests a pulse-type of advance through the fissure. The main influx of magma which followed immediately would be protected from the country-rock and would come into place as teschenite forming the central portion of the dike.

In conclusion, the author wishes to record his indebtedness to Dr. J. Phemister for taking the photomicrographs and for much kind assistance and criticism.

Explanation of Plate XXIII.

Photomicrographs of Brockhill rocks.

(E numbers refer to microscope slides and M numbers to photographs in the Geological Survey collection.)

Fig. 1. Teschenite (E 17672, M 2120). Shows serpentinized olivine, titanaugite, iron-ore, prismatic felspar, and interstitial analcime. Ordinary light. $\times 20$.

Fig. 2. Quartz-dolerite (E 17673 duplicate slide, M 2121). Shows prisms of zoned plagioclase, prismatic augite, chlorite, iron-ore, and patches of fine-grained quartzo-felspathic mesostasis. Ordinary light. $\times 20$.

Fig. 3. Junction of quartz-dolerite and marly sandstone (E 17572, M 2124). Quartz-dolerite (on left) contains lathy plagioclase, augite, chlorite, iron-ore, and little quartz. The sediment contains quartz grains separated by quartz-felspar mosaic and chloritic material. Along the junction is a 0·5 mm. zone in which augite is concentrated. Ordinary light. $\times 20$.

Fig. 4. Passage rock between quartz-dolerite and muddy siltstone (E 17952, M 2123). Quartz dolerite (on left) consists of lathy plagioclase, some augite, much chlorite, and iron-ore. This type ends by concentration of small prisms of chloritized augite against a more granular rock of same type which in turn passes into a fine-grained turbid lathy plagioclase-rock with much chlorite both interstitially and as prismatic pseudomorphs. A short distance outside the field of the photograph this rock type passes into hornfelsed muddy sediment. Ordinary light. $\times 9$.

Fig. 5. Hornfelsed sandstone (E 17947, M 2125). Shows quartz grains, many with acicular offshoots of tridymite, fine-grained quartz-felspar mosaic, and much chloritic material. Crossed nicols. $\times 30$.

Fig. 6. Light coloured patch from contact altered marls (E 17680, M 2122). Showing large plates of cleaved calcite and in the lower part of the photograph clear analcime. Through these is scattered greenish-brown chlorite surrounding numerous small garnets. Ordinary light. $\times 28$.

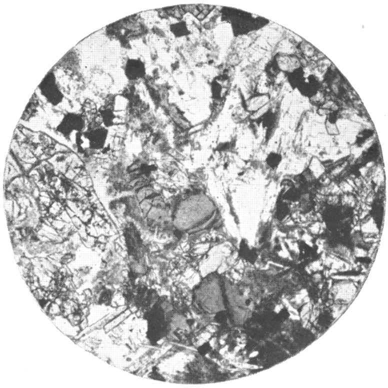

Fig. 1.

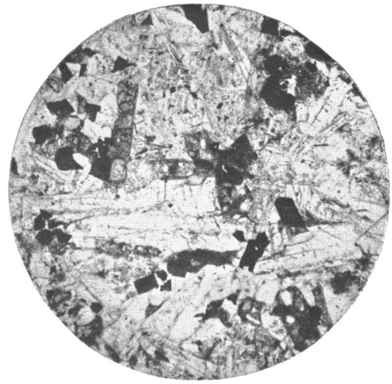

Fig. 2.

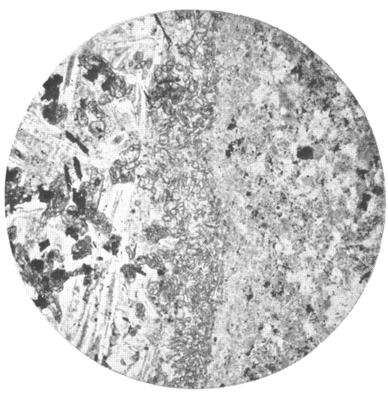

Fig. 3.

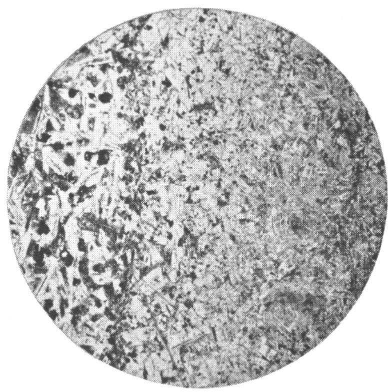

Fig. 4.

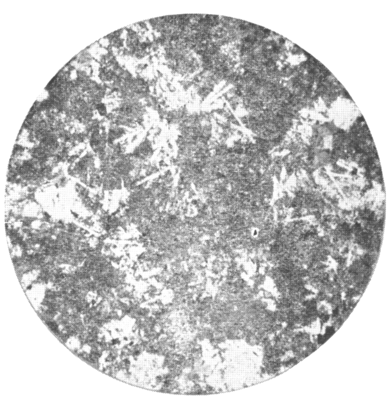

Fig. 5.

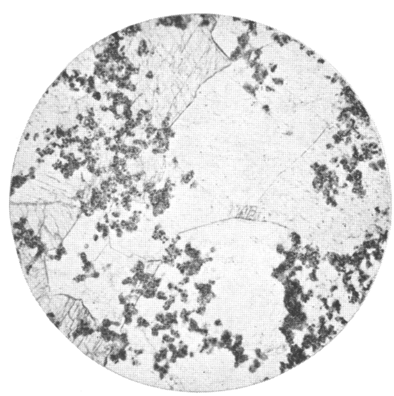

Fig. 6.

J. H. TAYLOR: BROCKHILL ROCKS.