No. IV.—An explosion-breccia — appinite complex at Gleann Chàrnan, Argyll

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Abstract

Appinitic and syenitic intrusive masses occupy an explosion-breccia pipe which formed as the result of explosions of gases rising ahead of a volatile-rich basic magma. Transfusion of quartzite, as described by Reynolds (1936) from Colonsay, may be the origin of the syenitic masses and syenitic veins.

1. Introduction

In the corrie at the head of Gleann Chàrnan (Nat. Grid: NN 122517), between Glen Coe and Glen Etive, a small composite mass of appinite and syenite pierces a breccia shown as Lower Old Red Sandstone age on the One-Inch map of H.M. Geological Survey (Sheet 53). Maufe (*in* Kynaston and Hill, 1908, p. 80) interpreted the breccia as a superficial deposit still *in situ*. Bailey (*in* Bailey and Maufe, 1960, p. 151), on the other hand, suggested that the breccia filled an "explosion vent up which appinite subsequently rose".

The association of explosion-breccias and appinite intrusions in the Caledonian orogenic belt has been referred to by Bowes and Wright (1961, pp. 307-308) who described the Back Settlement Complex, near Kentallen, some 10 miles W.N.W. of the Gleann Chàrnan Complex. The mechanism of formation of this complex was "interpreted as the result of gas streaming ahead of a rising volatile-rich igneous magma, with the formation of an explosion-breccia approximately *in situ* followed by the intrusion of the magma which crystallized in a volatile-rich environment" (Bowes and Wright, 1961, p. 293).

The Gleann Chàrnan Complex has been mapped at a scale of 1 inch = 150 feet. Exposures are excellent in and adjacent to the Allt Chàrnan. Elsewhere glacial drift is extensive and large patches of scree are present on the corrie walls. The extent of outcrop is shown by the distribution of the ornament on Fig. 1. The topographic relief is considerable, the northern end of the complex being above 2,100 feet O.D. and the southern end about 1,700 feet O.D., a drop of more than 400 feet in a distance of approximately 1,200 feet.

2. Geological Setting

The Dalradian metasediments cropping out immediately south-west of the Glen Coe Fault Intrusion (Fig. 1 — inset) are mainly Leven Schists. They dip at low to moderate angles to the W.N.W. and are part of an inverted limb, being structurally underlain by the Ballachulish Limestone (Bailey and Maufe, 1960, Fig. 7). Below a slide, underneath this limestone, the succession returns to the right way up with a small thickness of Leven Schists underlain by Glen Coe Quartzite. In the vicinity of the Gleann Chàrnan Complex, more than 1,500 feet of Leven Schists remain and the top of the Glen Coe Quartzite is approximately 2,000 feet below the present level of erosion. The thickness of the Glen Coe Quartzite is not known but it must be at least 750 feet (Fig. 2). Very probably it is much thicker than this, a thickness of 7,000 feet being recorded at the Pap of Glen Coe, 5 miles to the north, although this great thickness may be the result of duplication by sliding (Bailey and Maufe, 1960, p. 100).

The Leven Schists around the complex are coarse-grained garnetiferous quartz mica schists (cf. Bailey and Maufe, 1960, Pl. XII A), in which actinolite is sometimes developed. The schistosity, which is crenulated, results from the parallel orientation of muscovite flakes, groups of quartz grains, and biotite flakes, although much of the biotite is of porphyroblastic habit, a feature common in the Leven Schists (cf. Bailey and Maufe, 1960, p. 84). In the more quartzose bands the biotite porphyroblats show little or no orientation, although some flakes are aligned along the axial plane of the minor folds which cause the crenulation of the schistosity. Garnet porphyroblasts up to 2-3 mm. across are common. They often contain aligned quartz inclusions showing evidence of rotation. As with the biotite, some of the garnet shows retrogression to chlorite, in places as pseudomorphs. Magnetite is an abundant accessory.

An intrusive mass of kentallenite crops out about a mile N.N.W. of the Gleann Chàrnan Complex (Fig. 1 — inset) and a group of appinite and diorite masses are found to the W.S.W. in Glen Creran. A later swarm of N.E.-S.W. trending porphyrite dykes cuts Dalradian metasediments, appinitic intrusions and Glen Coe Fault Intrusion alike.

3. THE COMPLEX

(a) *Form.*

The complex is made up of three main units (Fig. 1) of varying rock type (cf. Plate I). A central plug of syenite is oval shaped and about 325 yards long by 175 yards across. At each end there is a mass of coarse, hornblende-rich appinite. Masses of very coarse breccia, having the characteristics of explosion-breccia (cf. Wright and Bowes, 1963, p. 84) abut against the igneous masses in three places. Their spatial relations indicate formation before the emplacement of both the appinite and the syenite, and transgressive relations of coarse hornblende-rich appinite with breccia are shown in the Allt Chàrnan.

The form of the two larger breccia masses suggests that they are parts of one mass with an irregular oval outline. Both the observed breccia—country rock contact in the Allt Chàrnan and the lack of relation between boundaries of the breccia masses and the very steep topography show the contacts to be nearly vertical. Hence these breccia masses have the form of a pipe (Fig. 2). The other, smaller breccia mass, which also has nearly vertical margins, may be part of the same pipe, or a small separate pipe which joins the larger one at depth.

The form of the igneous masses is that of a central syenite plug, with steep or vertical sides intruded into an earlier, vertically disposed plug of coarse, hornblende-rich appinite. Remnants of the earlier mass are present at both ends of the syenite plug.

The occurrence of a cylindrical plug of syenite in the centre of an elongate cylindrical plug of appinite and the correspondence in form of both of these masses with a pipe-like mass of breccia suggest a genetic relationship between the three main units similar to that described for the breccia-appinite complex at Back Settlement (Bowes and Wright, 1961).

(b) *Explosion-breccias.*

The breccias are largely made up of angular blocks of coarse-

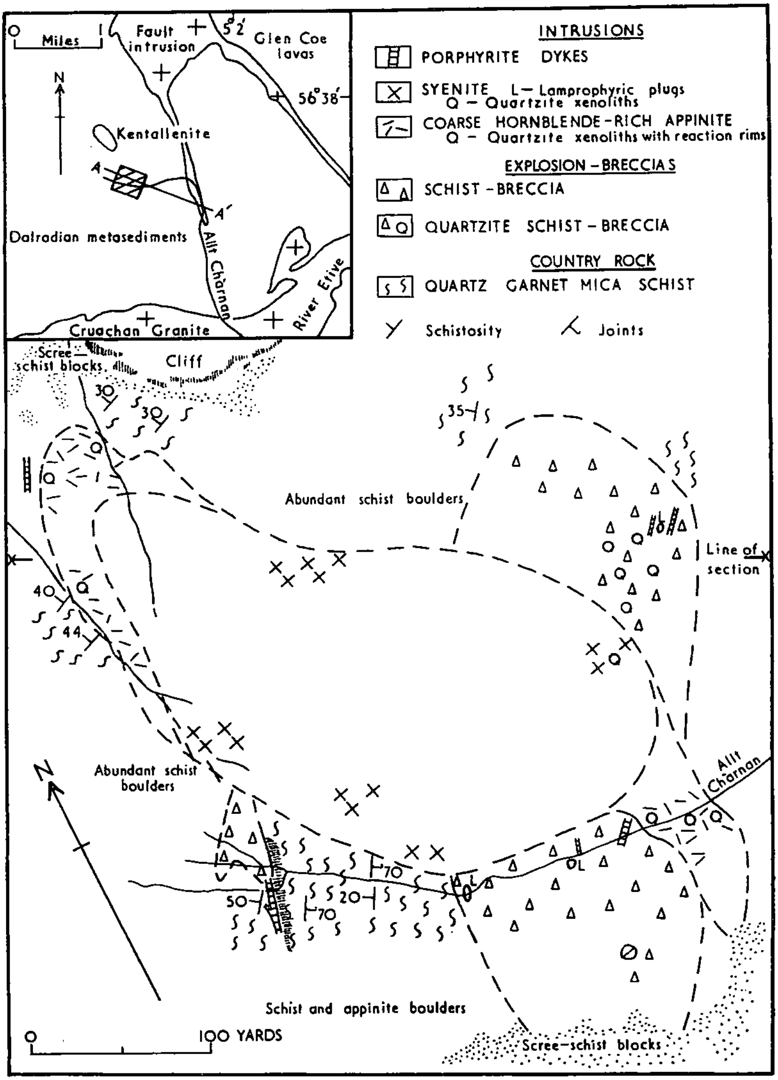

Fig. 1.—Geological map of the Gleann Chàrnan Complex and its situation (inset).

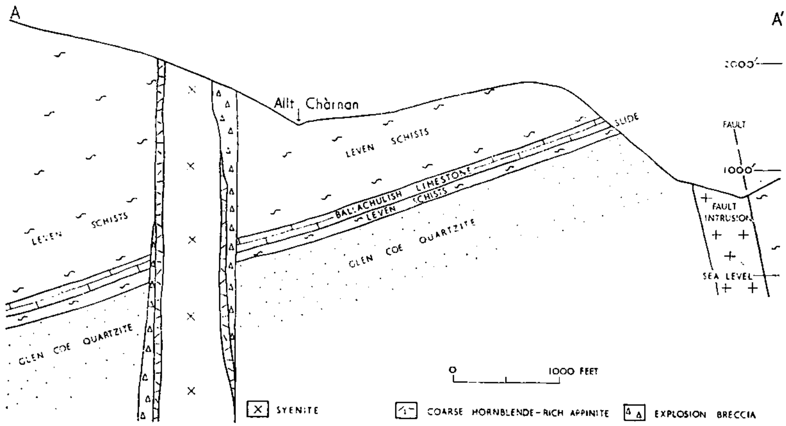

Fig. 2.—Geological cross-section of the Gleann Chàrnan Complex and the surrounding district; line of section (A—A') given on Fig. 1 (inset).

grained, garnetiferous quartz mica schist (Fig. 3a and b). Blocks four feet across are common (Fig. 3b) and some are up to eight feet across. The shape of the blocks varies from place to place. Angular blocks of schist, with little or no evidence of rounding, are tightly fitted together, without a matrix, in the southernmost breccia mass (Fig. 3a). Near the head of the Allt Chàrnan, many of the blocks are very large, and most are sub-angular (Fig. 3b). It is only where quartzite blocks are present in the mass east of the appinite plug, that there is any marked rounding of the boulders or abundance of matrix (Fig. 3c and Plate I A). Here the schist boulders are almost always less rounded and larger than the associated quartzite blocks, which are rarely greater than six inches across.

Where present, the matrix between the larger blocks is made up of numerous quartzite pebbles, of sizes down to individual grains, with abundant quartz and some muscovite, biotite and iron ore representing comminuted quartzite and schist. A few micaceous patches, of angular outline, similar to micaceous patches in the phyllite-breccia of the Back Settlement Complex (Bowes and Wright, 1961, p. 301) are also present.

The quartzite of the blocks is generally fine grained and pure,

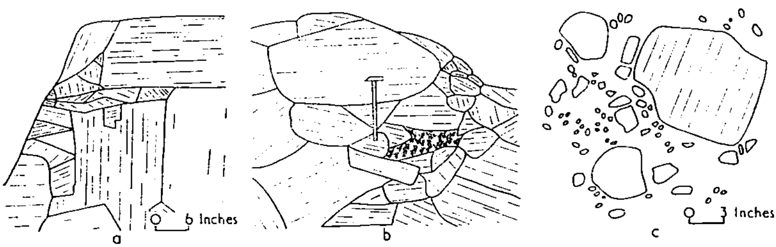

Fig. 3.—Nature of explosion-breccias

a. Schist-breccia with angular blocks; breccia mass at the south-eastern part of the complex.

b. Schist-breccia with angular and sub-angular blocks; small breccia mass near the head of the Allt Chàrnan.

c. Quartzite schist-breccia with sub-angular and rounded quartzite blocks and sub-angular schist block in a matrix (cf. Plate I A); breccia mass at the north-eastern part of the complex.

similar to much of the Glen Coe Quartzite of the district (Bailey and Maufe, 1960, pp. 65 and 95-96). A little sericite, biotite, epidote, black iron ore, and zircon grains showing detrital form are found in a crystalloblastic aggregate of quartz grains which are generally much cracked and fractured. Strain shadows and undulose extinction are invariably present in the quartz crystals of both the quartzite and the schist blocks. The latter are petrographically similar to the country rock of the complex, the garnetiferous quartz mica schists of the Leven Schists (p. 20). No limestone blocks have been seen in the breccia.

(c) *Igneous rocks.*

The *coarse, hornblende-rich appinites,* which contain many quartzite blocks surrounded by felspathic reaction rims, are very variable, both in grain size and in amount of hornblende. Stumpy, green, pleochroic crystals, from a quarter- to a half-inch across, are generally dominant (Fig. 4b), but the hornblende has a bladed habit in parts, particularly near felspathic rims around quartzite blocks (Fig. 4a and Plate I B) and discontinuous felspathic bands. Exceptionally some of the bladed hornblende crystals are up to four inches in length. Crystals of either habit sometimes have light-coloured cores, generally composed of altered alkali felspar and a little quartz, but in a few cases penninite flakes are surrounded by radial fractures such as seen around serpentinized olivine. Rims of alternating dark green and light green amphibole are present as overgrowths on some of the hornblende crystals (cf. Bowes, Kinloch and Wright, in press).

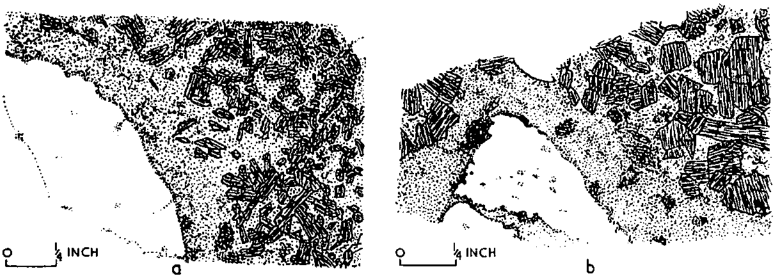

Fig. 4.—Quartzite blocks, with syenitic reaction rims, in appinite (cf. Plate I B); Allt Chàrnan.

Near the boundary with the breccia, in the Allt Chàrnan, the appinite is very rich in hornblende and approaches hornblendite in composition (cf. Bailey and Maufe, 1960, p. 215). Biotite crystals, some with bent or broken laminae and showing alteration to penninite, are common in some of the rocks. The matrix between the ferromagnesium minerals is mainly an aggregate of much-altered alkali felspar, with some quartz, similar to that found in the reaction rims around quartzite blocks (Figs. 4a and b) and may merge into these rims. Both orthoclase and albite are present, the former generally being dominant, and microperthitic and micropegmatitic intergrowths are common. Apatite crystals, often of considerable size are abundant, as an accessory, together with pyrite.

The abundant quartzite blocks in the appinite are generally between one and six inches across and surrounded by a reaction rim which, in many cases, is about a quarter of an inch wide (Figs. 4 and 5, Plate I B). However, the thickness of the rim varies considerably, even for one block (Fig. 5c). It may be thicker at the end of an elongate block than at the side (Fig. 5b) and sometimes fingers into the blocks along pre-existing fracture directions (Figs. 4b and 5a). The original angular form of many of the quartzite blocks can be deduced (Fig. 5c), and the presence

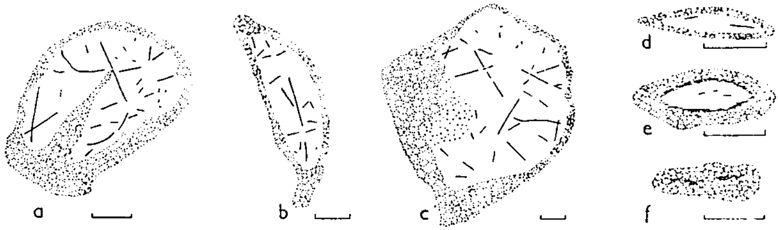

Fig. 5.—Quartzite blocks with syenitic reaction rims (a—e), an appinitic inner rim (e) and complete alteration to syenite with patches of appinite (f); in coarse, hornblende-rich appinite exposed in the bed of the Allt Chàrnan.

of felspathic patches, similar in form to some of the blocks (Fig. 5f), indicates completely transformed quartzite. Felspathic trails lead from the reaction rims around some of the more elongate blocks, and, in parts, narrow short felspathic veins, not attached to any quartzite blocks, are seen. The composition of the reaction rims is very variable (Plate I B), being mainly syenitic, but in parts granitic or appinitic. Alkali felspar is the most abundant mineral, both orthoclase and albite being present, with the former the more abundant. Micropegmatite intergrowths, similar to those described by Reynolds (1936, Pl. XII, figs. 4 and 5) from Colonsay, are very common (Plate I B), and the development of the worm-like felspar replacement can be seen at the margins of the quartzite mosaic. Perthite is common but twinned albite crystals without intergrowths (Plate I B) are also present. The distribution of quartz is patchy and groups of crystals with the crystalloblastic texture of the quartzite are found. Chlorite is the common mafic mineral, particularly in the more leucocratic rocks, but mafic concentrations in a zone between the quartzite and the reaction rim (Fig. 5e), and in patches near the centre of completely altered blocks (Fig. 5f), are generally predominantly of hornblende, together with pyrite and apatite.

The *syenite* of the central plug is grey in colour and in hand specimen resembles diorite. Alkali felspar, together with chlorite, make up most of the rock, with felspar (albite, orthoclase and microperthite) dominant (Plate I C). A few much altered amphibole phenocrysts are present together with patches of chlorite and iron ore which probably represent other amphibole or pyroxene phenocrysts. Most of the chlorite is scattered as flakes throughout the felspathic matrix, together with some quartz veins. Small quartzite blocks are included. These show no reaction rims and are surrounded by a chlorite-rich marginal facies of the syenite. In addition, there is a rudimentary alignment of felspar crystals parallel to boundaries of quartzite blocks.

Small plugs of lamprophyric aspect pierce the breccias (Fig. 1) and in parts intrude between the blocks of the breccias. They consist of much altered pyroxene and amphibole phenocrysts set in a fine grained felspathic matrix, parts of which show well developed flow texture around the phenocrysts. The relationship of these rocks to either the syenite or coarse hornblende-rich appinite cannot be determined in the field. The plugs may be later than either of the two main intrusions but are tentatively grouped as a lamprophyric variant of the syenitic intrusion.

4. Comparisons and Conclusions

The similarity between the Gleann Chàrnan Complex and complexes in Colonsay described by Craig and others (1911) and Reynolds (1936) is remarkable. There is an association of breccia, hornblendite (or appinite), and syenite, while each of the masses has a circular or oval outline with steep walls, the breccia filling a vent. The breccias are composed of angular schist blocks of the adjacent country rock together, in parts, with rounded blocks of quartzite not present in the immediately surrounding district (cf. Fig. 1; Craig and others, 1911, Pl. V). The hornblendite and appinite masses have almost identical petrographic characters (cf. p. 24; Craig and others, 1911, p. 29), even to the presence of the same accessory minerals, apatite and pyrite, the bent and broken nature of some of the biotite crystals, and the overgrowths of amphibole over the large hornblende crystals (cf. p. 25; Reynolds, 1936, p. 377). Abundant quartzite blocks, surrounded by felspathic reaction veins (cf. Fig. 5; Craig and others, 1911, Pl. IV), are texturally and mineralogically similar in the two complexes (cf. p. 26, Fig. 4, Plate I B; Reynolds, 1936, pp. 380-388, Fig. 2, and Pl. XII, Figs. 4 and 5) and similar to discontinuous felspathic veins in the appinites. The central syenite intrusion in Gleann Chàrnan (p. 26) is similar to the syenite north of Port Easdail, Colonsay (Craig and others, 1911, p. 30), both resembling diorite in hand specimen, and the lamprophyric plugs, tentatively connected with the syenite intrusion (p. 27), could correspond with the lamprophyric marginal phase of the syenite north of Port Easdail (Craig and others, 1911, p. 30).

Such a correspondence of characters must indicate the action of similar processes in similar geological environments. Accordingly, the process of the transfusion of quartzite described in detail by Reynolds (1936) from Kiloran Bay, Colonsay, is considered to have been operative in the Gleann Chàrnan Complex (Figs. 4 and 5, Plate I B). This involved the addition of Al_2O_3, K_2O, Na_2O, P_2O_5, S, NiO, BaO and SrO to the rims of the quartzite blocks (Reynolds, 1936, p. 403) and the removal of SiO_2, and led to the development of micropegmatitic and syenitic material capable of movement and intrusion. Because of the similarity in composition of some of the reaction rims, the small discontinuous felspathic veins and the syenitic plug, it appears likely that limited amounts of syenitic magma were formed, at depth, as the result of the transfusion of quartzite.

The breccia and appinite masses of the Gleann Chàrnan Complex and the Back Settlement Complex approximately 10 miles to the W.N.W. (Bowes and Wright, 1961) are also very similar. Both breccia masses are in pipe-like form (cf. Fig. 2 and Bowes and Wright, 1961, Fig. 7) and are associated with appinitic masses, very rich in volatiles, which were intruded into the breccia pipe. In each case variations in the shapes of the blocks making up the breccias appear to be indicative of the amount of transport. Some of the blocks have moved considerable distances: a limestone block in the small pipe at Back Settlement (Bowes and Wright, 1961, p. 304) must have travelled at least 1,200 feet, while the quartzite blocks in the Gleann Chàrnan breccia are petrographically similar to the Glen Coe Quartzite which occurs at a depth of approximately 2,000 feet below the surface outcrop of the breccia (Fig. 2). The appinites of the two complexes are similar in texture and mineralogy (cf. Plate I B and Bowes and Wright, 1961, Pl. XIX A) and display similar variations in composition. Hornblende crystals of the Back Settlement appinites have amphibole overgrowths which vary from light to dark green (Bowes and Wright, 1961, p. 302) similar to those seen in both the Colonsay and Gleann Chàrnan rocks.

Because of these similarities, the mechanism proposed by

Bowes and Wright (1961, pp. 307-310) to explain the formation of explosion-breccia complexes is considered to have been operative in the formation of the Gleann Chàrnan mass. The evidence suggests that the rise of a volatile-rich basic magma was obstructed by a thick mass of Glen Coe Quartzite Fig. 2). With the onset of crystallization, particularly the rapid growth of the large phenocrysts now seen in the appinite, there was a rapid and large increase in gas pressure (Morey, 1922, p. 230) causing an explosion of the gas trapped above the magma. The explosion fractured the quartzite of the structural trap which was subsequently breached as the result of a series of such explosions. During the brecciation, the quartzite was also much fractured with the production of strain shadows in the quartz crystals.

The rounding of the quartzite blocks, and their juxtaposition with angular schist blocks from a higher structural horizon, could only have been developed in a pipe with active gas streams, such as would be operative immediately following the final explosion which broke through the structural trap. Associated with the streaming of gas up the previously brecciated pipe, crystallizing appinitic magma was rapidly injected as a pipe-like plug. Quartzite blocks carried up in the advancing magma were marginally or completely transformed as the result of the action of the hot gas-rich magma.

The central plug of syenite was emplaced subsequent to the intrusion of the appinite mass. The presence of small quartzite xenoliths, without reaction rims, against which there is a thin marginal facies of the syenite (Plate I C) and around which there is developed rudimentary flow texture, indicates crystallization of a viscous magma poor in volatiles. Such a magma could have resulted from the extensive transfusion of quartzite at depth and its injection as very small plugs or dykes would lead to the formation of the lamprophyric types found associated with the complex.

Acknowledgements

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5. References

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Explanation of Plate I

A. Quartzite schist-breccia with quartzite and schist fragments in a matrix of comminuted quartzite and schist; ordinary light, x 2.7 (p. 23).

B. Quartzite block (middle right) surrounded by a syenitic reaction rim (upper right, centre, lower right) with micropegmatitic intergrowths, in coarse, hornblende-rich appinite (left); ordinary light, x 4.5 (p. 25).

C. Quartzite block in syenite which shows a chloritic marginal facies; ordinary light, x 11 (p. 27).

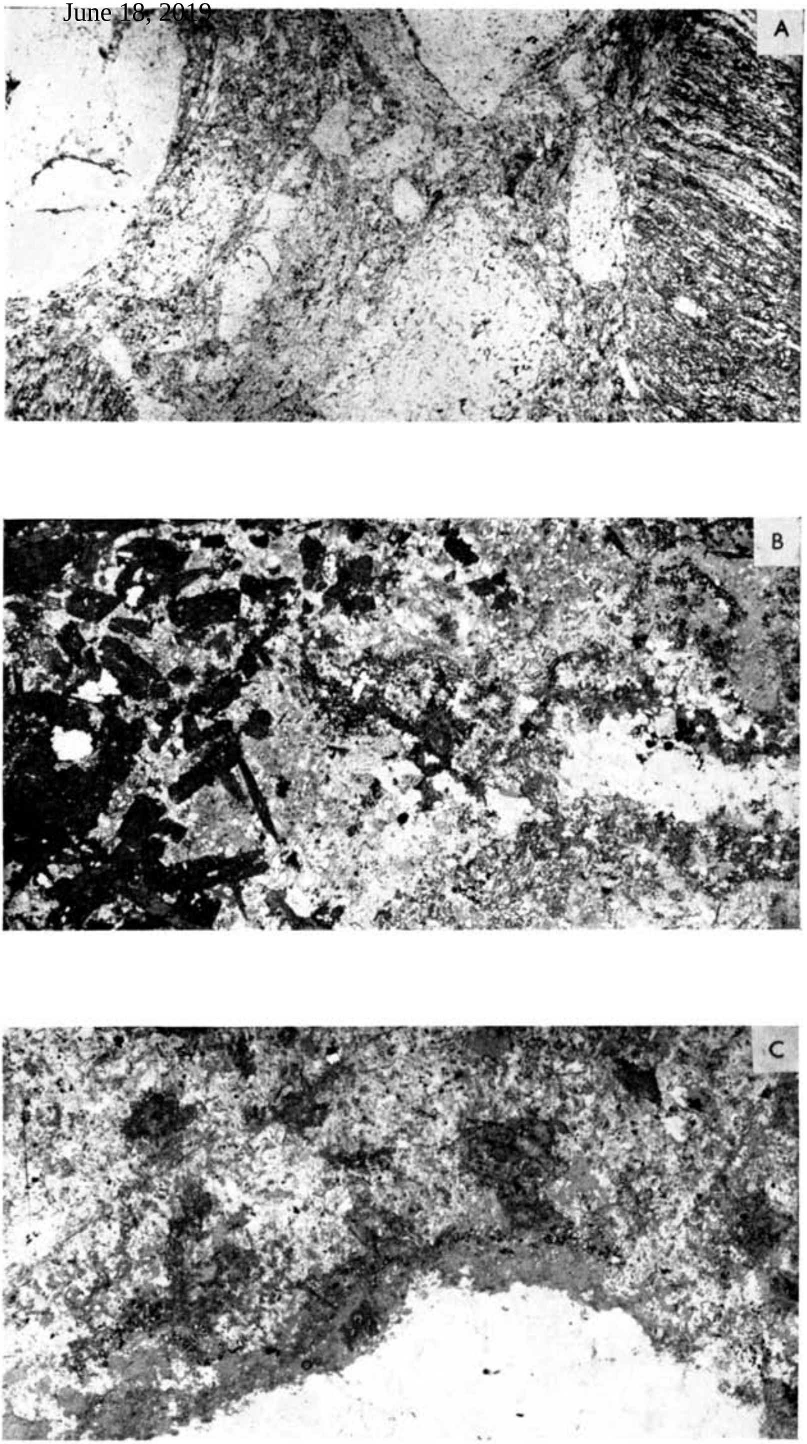

Plate I

facing p. 30.