

In this region of East Anglia we have evidence of pebbly gravels in the Crag Series, in the Middle Glacial (Westleton Beds), and in the Plateau Drift.

Where one gravel is largely derived from another and is welded on to it, there must often be difficulty in fixing a plane of demarcation, as there would be (in the absence of fossils) in separating other strata of identical lithological character.

Similar occurrences, observed in Egypt by Mr. H. J. L. Beadnell, where Cretaceous and Eocene clays appear to merge together, though not in uninterrupted sequence, have been aptly referred to by him as "*unconformable passage-beds*."¹ The term is at any rate a useful one to bear in mind in connection with gravels, ancient and modern.

V.—THE PETROGRAPHICAL CHARACTERS OF THE DARJILING GNEISS.

By JOHN PARKINSON, F.G.S.

WELL known as Darjiling is to nearly every stray traveller in India, the solid geology of the district has been left almost (I believe quite) untouched since the publication of Mallet's paper² in 1874. There the Darjiling gneiss was described as the metamorphosed representative of the sedimentary Gondwana rocks of the south, and has so remained, albeit under protest, for a disclaiming paragraph³ appears in the Manual of the Geology of India. In the report of the Committee⁴ on the recent landslip at Darjiling it is stated that the rock of the country consists of "a well foliated and banded biotite gneiss with occasional lenses and deformed veins of granitic rock"; moreover, that "the foliation planes are often highly contorted"; and Mallet defines it as true gneiss "passing into mica schist or an intermediate variety." These descriptions are meagre, and it is hoped that the following notes on specimens collected by the author may not be superfluous.

Description.

The gneiss outcropping near the Jelapahar Road, on the eastern side of the ridge on which Darjiling stands, is a streaky or roughly banded, rather massive rock, the planes of greatest fissility glittering with black mica and containing a few pink garnets the size of a small pea. In a thin section (Fig. 1) the mica is the most conspicuous mineral. It is a dark green to reddish brown for vibrations parallel to the basal plane, and of a deep straw colour for those at right angles. The irregularly shaped garnets are very pale pink in colour, cracked, and rather dirty. The colourless constituents slightly predominate, and consist largely of quartz with orthoclase and plagioclase; some crystals of the former felspar exhibit a micropertthitic intergrowth; the latter is rare and apparently

¹ Report iii, Geol. Survey of Egypt, Cairo, 1901.

² Mem. Geol. Surv. Ind., 1874, vol. xi, pt. 1.

³ Geology of India, 2nd ed., p. 76.

⁴ Report of the Committee on the Landslip at Darjeeling, September, 1899; published October, 1899.

lbite or oligoclase. The quartz also occurs sparingly as 'quartz ermiculé.'¹ In addition, the rock contains a few grains of zircon and some crystals of an iron oxide, probably hematite. This completes the list of constituents with the exception of a fibrous mineral seemingly derived from the mica. Loss of the characteristic colour and pleochroism precede the assumption of the fibrous appearance. It then consists of a felted mass of crystals which are of a brown colour in the aggregate by an ordinary light and exhibit a rather vivid polarization. Finally, the brown colour is entirely lost and the constituent crystals fray out in a brush-like way. The mineral is no doubt sillimanite, and the thin section as a whole forcibly recalls some of the fibrolite and cordierite gneisses of Germany. The Darjiling rock is therefore a garnetiferous sillimanite gneiss, in which the presence of cordierite is to be suspected. This mineral no doubt does occur, but the rock has suffered slightly from pressure and the feldspars are usually fresh and unaltered; facts not conducive to the ready determination of such a mineral as cordierite, which appears to be free from its characteristic decomposition products. The inclusion of one mineral by another is a characteristic feature; e.g., rounded 'spots' of mica are often present in the quartz, or of quartz in the feldspar. The larger quartz grains are much cracked and the lines of fracture marked by infiltrated substances. A cementing of the parts has, however, always taken place.

A specimen from a roadside outcrop below Tigar Hill is a massive rock with a distinct foliation;² distinguished by a large quantity of silvery-brown mica, many of the flakes measuring 15 inch across. In a thin section two micas are conspicuous—a reddish brown, recalling that of some Kinzigites, and a white. They occur closely associated, so that thin laminae of the brown mineral are found inserted parallel or, occasionally, transversely to the basal cleavage of the white. Sillimanite is locally mixed up with films of the latter, and possibly the rock contains cordierite. Feldspar is rare, and the slide contains much quartz, exhibiting very irregular outlines. Some large apatite grains (1 inch across), considerably cracked, are also characteristic, as well as numerous small zircons. A pale yellow stain, together with the absence of a basal cleavage, in some of the white micas suggest this mineral is not always normal. A third specimen, collected near the last, shows a well-marked wrinkled structure. It contains a few irregular, but not torn, garnets, and a good deal of sillimanite associated with white filmy mica, as in the preceding slide.

The rock figured is the common type of the Darjiling gneiss, and in this bands of finer texture occur, one of which from the Rungeet Road has been sliced. Macroscopically, the constituent minerals

¹ By this term is meant the thread-like intergrowth of quartz in feldspar. The branching threads are grouped often in a kind of bunch, not uncommonly radiating from a point. In the examples I have met with I believe it to be an original structure.

² This rock differs in appearance from the others that I collected. The specimen is browner in colour, the flakes of mica more conspicuous, and the foliation less marked.

are only just discernible to the naked eye, and the presence of mica gives it a uniform grey tint. Part of the specimen is a much coarser compound of quartz and rather decomposed felspar, with but a few flakes of mica, and containing a band, .1 to .15 inch thick, consisting almost entirely of the last-named mineral. The thin section shows the part of finer grain to consist of the following constituents, the whole rather crushed: brown mica which is plentiful, some white mica in part secondary, zircon fairly common, garnet rare, quartz the most abundant mineral, orthoclase and plagioclase. The felspars are commoner in some parts of the slide than in others. The plagioclase, which appears to be albite or oligoclase, is often rather unusually translucent. The quartz forms large irregular grains, and occasionally occurs as quartz vermiculé. The orthoclase frequently contains a micropertthite intergrowth. Sillimanite is found in another specimen from the same locality.



FIG. 1.—Usual type of the Darjiling gneiss, $\times 20$. An irregular crystal of garnet appears on the left side towards the top of the stage. Near it are crystals of white mica (*m.w.*). The centre of the field is occupied by brown mica (*m.b.*); basal sections are cross-hatched. Sillimanite (*sl.*) is seen on the left side. The rest of the section is composed of orthoclase (*of.*), quartz (*q.*), and a single grain of sphene (*s.*).

Amongst a pile of trimmed blocks by the roadside, I found one with a hard nodule-like 'eye' some six inches across, surrounded by the ordinary gneiss. The whole of the periphery was not seen, but the mica folia of the gneiss appeared to bend round it. Fracture, texture, and composition distinguish this inclusion from the ordinary rock. It is hard and compact with no conspicuous foliation, and breaks with almost equal ease in any direction. It has a rather dirty grey appearance from the presence of black specks of mica, .007 inch and under in length, and it is faintly mottled by pinkish patches consisting of clusters of garnet grains, each group being roughly .1 inch across. Under the microscope two principal constituents appear in addition to the garnet, viz. quartz and felspar. The latter forms an allotriomorphic network, indented and embayed

by large quartz crystals and honeycombed by a pegmatitic inter-growth of the same mineral. A large grain adjacent to a felspar does not as a rule send offshoots into it. Only small groups of the quartz granules polarize together, though we find exceptions. Nearly one-half of the felspar shows no twinning, and the remainder, judging by the extinction measured parallel to the trace of the plane of twinning, is much more basic than might be supposed, symmetrical angles ranging from 35° to 40° . The larger quartz grains exhibit rows of inclusions parallel the one to the other. The garnets are a pale claret-red, subangular in outline, and occasionally making an attempt at idiomorphism, and rather cleaner than those of the gneiss. Grains of zircon and sphene are not uncommon. Flakes of brown mica are scattered sparingly and rather irregularly across the slide.

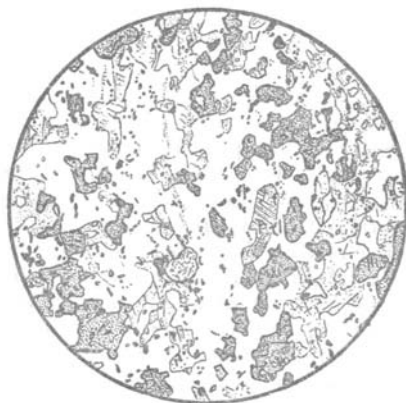


FIG. 2.—Nodule-like inclusion, $\times 20$. Near the centre of the stage, or slightly below it, the following letters are placed to indicate the various constituents: *gt.* garnet, *p.* plagioclase (faintly dotted), *gr.* graphite, *q.* quartz (colourless), *i.* idocrase, *s.* sphene. The small colourless microlites mentioned in the text are also indicated.

Passing away from the centre of this 'eye' towards the surrounding gneiss, we find that this hard and compact rock graduates into one of slightly granular texture, rather whiter and containing larger flakes of brown mica and less clear garnet spots. A thin section cut near the junction shows the latter mineral associated with some good-sized crystals of sphene.¹

On the western side of the ridge the same general characters are repeated. Thus, on the road from Darjiling to Ghoom, a common type of the gneiss contains numerous streaks or elongated lenticles of quartz and felspar, arranged usually in an undulating manner and occasionally retort-shaped in section. The rock weathers to a grey tint and contains characteristically a rather large quantity of mica. A hard lenticle or eye, resembling that noticed as occurring in the gneiss of the Rungeet Road, was found in this rock. The length was

¹ Occasionally $\cdot 02$ inch long. The slide contains a little augite.

about 9 inches, the thickness 2·5 inches. The specimen was rather darker in colour than that above described, with a siliceous aspect, and faintly mottled with red garnets (Fig. 2). The quartz grains are subangular in outline, occasionally exhibiting crush shadows. They contain very many small crystals of a colourless mineral in the form of prisms having lath-shaped sections, which I am unable to name. The groups of garnet grains show a distinct attempt at a general linear arrangement, and a similar elongation occurs in all the minerals. The slide contains sphene and at least two other minerals which are noteworthy. I am indebted to Canon T. G. Bonney for suggestions concerning these. First, a considerable quantity of an opaque mineral characterized by its elongated shape (commonly about $0\cdot0038 \times 0\cdot00055$ inches). The outlines are rather jagged and uneven, the colour by incident light is grey, and the lustre metallic. It is associated with a little specular iron, which is also met with elsewhere in the slide. In order to test the streak I powdered a small quantity of the rock, and by means of a lens isolated a few of the black flakes and pressed them with a knife blade upon a sheet of notepaper. They yielded readily to the pressure and left a dull grey mark. I concluded, accordingly, that the mineral is graphite. It occurs, though less plentifully, in slides of other nodular eyes. The second mineral usually forms small and more or less rounded grains. An idiomorphic outline is sometimes indicated by the occurrence of stumpy rectangles, (extinction takes place parallel to the sides) with unequally truncated corners. The refractive index is higher than that of apatite, to which we see a resemblance in double refraction, slightly bluish colour, roughened aspect, and absence of cleavage. A grain occasionally appears isotropic. I incline to refer the mineral, but with hesitation, to idocrase.

Another specimen from the same locality, as seen in a thin section, consists of a network of large quartz grains and very irregular plagioclase, exhibiting as before much micropegmatitic quartz. Garnets, some dozen grains of sphene, and a number of mica flakes make up the rest of the slide.

On the western side of the Darjiling ridge, near St. Joseph's College, scattered sections of the gneiss are found sufficient to enable its characters to be studied. The rock is frequently gnarled with irregular bands; once I saw such a one, rich in quartz and felspar, diminish in thickness in 3 feet from 9 inches to 2·5 inches. Close by, a broad band at least a foot across was streaked and veined irregularly by darker, i.e. by more micaceous, material. Parallel to this were others shaped like very elongated lenticles. Again, the gneiss on Birch Hill Road was occasionally beautifully puckered in successive V's; and some infiltration veins had been formed subsequently to the folding. The gneiss *in situ* about three-quarters of a mile from Darjiling is a finely foliated, slabby rock of medium grain, containing a considerable quantity of mica. A thin section discloses the presence of sillimanite, white and brown micas, and a few irregular pinkish garnets about $0\cdot04$ inch

across. The very irregular grains of quartz are frequently cracked and show crush shadows. Plagioclase is not uncommon, zircon as before, and some quartz vermiculé. Possibly the rock contains cordierite.

Conclusions.

One characteristic feature of the rock, the irregular outline of the grains and the inclusion, or partial inclusion, of one mineral by another, may, in my opinion, be best explained as the result of movement in a somewhat viscous mass. The cracked quartzes and garnets, the lines of fracture in which are now healed, together with a confused grouping often found among the smaller particles of quartz and felspar, indicate that, at one time, the rock has suffered from the effects of crush, from which it subsequently, more or less completely, recovered. The outlines of the quartz and felspar, which, as just remarked, may be accounted for by fluxional movement, at the same time suggest that pressure has been at work forcing them, as it were, into the minimum space.

The presence of sillimanite and probably of cordierite, which render the alumina percentage unusually high,¹ may possibly be due to an incorporation of argillaceous material, although no obvious reason exists why the magma may not have been exceptionally rich in this constituent from the beginning. However this may be, the Darjiling gneiss is certainly not a result of the metamorphosis of Gondwana beds.

Another point requiring elucidation is the presence of the hard siliceous 'eyes.' Conceivably during the movement preceding its solidification, the magma picked up small fragments of a foreign rock, which, being softened and permeated by their liquid surroundings, have resulted in the mineral assemblage seen. The graphite must have formed, if not from igneous fusion, then from a state closely approaching it. The structure as a whole is indicative of crystallization where freedom of molecular movement was restricted.²

To Canon T. G. Bonney I am indebted for many valuable suggestions which are embodied in the preceding notes.

NOTICES OF MEMOIRS.

- I.—ICE-EROSION IN THE CUILLIN HILLS, SKYE. By ALFRED HARKER, M.A., F.G.S. Trans. Royal Soc. Edinburgh, 1901, vol. xl, pt. 2, pp. 221-252.

THOSE who are interested in hill-climbing will know that "Sligachan, in Skye, is the rock-climbing centre *par excellence* of the British Isles"; and as Mr. Charles Pilkington further remarks in the fascinating Badminton volume on Mountaineering, "The Alpine climber will find an additional interest in the district from

¹ See Mr. J. J. H. Teall's Pres. Address to Geol. Assoc., Proc. Geol. Assoc., 1899, vol. xvi, pp. 72, 73.

² See paper by Canon T. G. Bonney, Quart. Journ. Geol. Soc., 1891, vol. xlvii, p. 105.