W. Annis.

# CUMBERLAND GEOLOGICAL SOCIETY



DIORAMA—LAKELAND SCENERY

Lake Derwentwater, from Castle Head, near Keswick. The hills left (east) of the lake are formed of lavas and tuffs of the Borrowdale Volcanic Series : these rest on Skiddaw Slates, occupying the low ground and the nearer hills to the right. Castle Head in the foreground is a mass of igneous rock (dolerite), smoothed and striated in the Ice Age.

# PROCEEDINGS

No. 1 1962

Two Shillings and Sixpence

# CUMBERLAND GEOLOGICAL SOCIETY

Session 1962

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[redacted]

R.E.O.Pearson,
Secretary,
1st. June. 1962.

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Proceedings of the Society Winter and Spring 1962.

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# GRANITE AND GRANITISATION

Granite is a crystalline rock, familiar alike to both geologist and layman. All over Britain the highly-polished, usually light-coloured granites have been used for facing and decorating our more important buildings, and probably one of the most familiar to us all is the lovely granite from Shap. The layman may not know its origin, he may never have seen the great quarry from which it comes or the works where it receives its polish, but the grey base and large pink crystals are well-known throughout the length and breadth of the land.

There are many other granites used for this purpose and they come from as far apart as Aberdeen and Cornwall. They vary in appearance from greys to almost white on the one hand, to pinks and near reds. One thing, however, they all have in common; they are all made up of crystals which fit together like a mozaic, and this is at once evident either to the naked eye or under a lens.

In the early days of geology the granites were regarded as comparitively simple rocks presenting no special problem. We can, I suppose, forget Werner's grandiose theory that granite was the first precipitate from an all-enveloping primordial ocean, but can we, I wonder, be so sure that we have as yet found an entirely satisfactory explanation for this great class of rocks ?

Possibly because so much early geology was done in our own little island, where granite masses themselves are comparitively small, granite and its mode of origin tended to be over-simplified. Granites were igneous rocks which had been intruded or emplaced in other rocks. They were just one variety of the many rocks which bore within themselves the evidence of a fiery origin.

All this in the early days of geology before Sorby had laid, with his patiently-produced thin sections, the foundations of Petrology, and before the chemists had taken a hand to provide what seemed at first a magnificently simple way to 'classify' the enormously-varied 'Igneous rocks'. To both of these groups of workers we must come back. But let us make a start, as all 'Knights of the Hammer' ought to make a start, with what can be seen in the field.



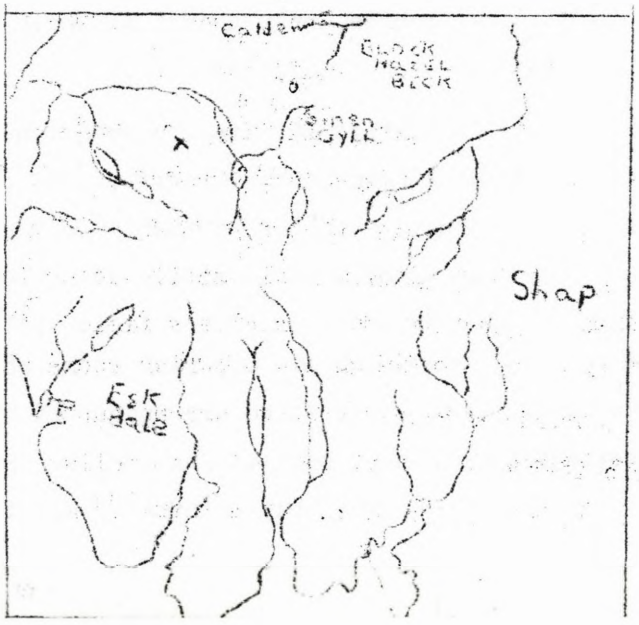
Our first illustration shews the exposure of the Skiddaw granite at Sinen Ghyll. Notice carefully the 'blocky' jointing of the rock and its general appearance. Once familiar with this type of exposure there should be little difficulty in recognising rocks of the granite class in the field. Now it is quite true that by merely looking at such an out-crop you could not be certain that it was in fact a granite. There are other members of the clan that weather in the same blocky way. Being a geologist, however, it is expected that you will have a hammer and with this you can soon provide a hand specimen. This you can examine with a lens, something which all good geologists should carry.
What would you see ?

In this case you would see a mass of white, mostly rectangular crystals bespattered with tiny fragments that vary in colour from almost white, through brown, to black. In the interstices between the crystals you would find fragments of a glass-like substance. Here you have the three essential constituents of a granite. The white crystals are felspar. That may be all you can make out with your hand lens. It will depend on your knowledge and experience. It is sufficient for our purpose, so apart from pointing out that in many granites that the felspars are pink, not white, we will leave them for the moment. If you look carefully at the darker fragments you will notice that they are very thin and that here and there are odd bits that shew a more or less completely hexagonal form. These are crystals of mica. Whether they shew this idiomorphic form or not, these darker fragments are mica, and notice too - for this is important - that these mica fragments are found growing from, or enclosed within the felspars.

Now the glassy bits.

These you will notice are completely formless and seem merely to fill in the interstices between the other crystals. This substance is quartz, and you will find that this too tends to have mica occluded in it. From what we have observed here we can be sure that from the field geologist's point of view we are dealing with a granite. It shews in the exposure the normal blocky weathering. Our hand specimen shews the three essential constituents; felspar, quartz and mica.

Now let us look at this sketch map of the Lake District.



The exposure we have just seen lies in Sinen Ghyll. In Blackhazel Beck there is a second exposure about the same size as the first, whilst in the bed of the Caldew there is a third and much bigger patch. The total amount of granite exposed at the three places is not great, no more than an odd acre or so, and this after many millions of years of active erosion.

Now those of you who are familiar with the Skiddaw Granite will be well aware that there is a contact metamorphic area which covers some thirty square miles. This suggests some rather important conclusions. In the first place, the extent of this alteration of the country rock over so wide an area implies that the actual mass of the granite is very considerable. Secondly, the fact that the exposures are so small, even after millions of years, suggests that granite is a rock of the depths, a rock which is found only after much denudation. Two more points are worthy of note before we leave the Skiddaw Granite. Firstly, it has been found in recent years that there is another metamorphic area, away from the Skiddaw group altogether, in the Western Fells, at the place marked by X on the map. Secondly, and this for our mineralogy friends, it is interesting to note that in this western area the country rock is again Skiddaw Slate, and the mineral veins shew galena, zinc blende and barytes at Force Crag at the head of the Coledale valley. In the Scar Crag area about Causey Pike is a touch of arsenic and cobalt, whilst the famous copper and lead veins of Goldscope are not far away. Whether this further metamorphic area is also underlain by Skiddaw Granite, only a deep borehole would shew, but were I asked to guess, I should say, probably.

Leaving the Skiddaw Granite, but still sticking to granites, we have here in the east of the district the famous Shap Granite. The best-known and certainly one of the most attractive of our British granites, it is regarded as of Devonian age. Even without radio-active determinations we can feel pretty certain of this from the granite's field relations. Surrounded for the most part by Ordovician and Silurian rocks which shew marked contact metamorphism, close by there are undoubted bits of the granite in the Carboniferous basement beds at Shap Wells. Some of you will have seen all this for yourselves, but I think it might well be

worth revisiting during the summer. We will leave Shap for the moment, but we shall have to come back to it later.

In the southwest of our area we have the Eskdale Granite, and this is a very variable rock, in some places almost white, sometimes grey, but often pink or red. My old Prof. who knew it intimately, used to say there were at least a score of different varieties. Petrologically it varies from a perthite to a granodiorite, but we need not worry too much about that, for in the field we can regard it as a granite and it covers some thirty six square miles. It carries within it many rich veins of haematite and at Boot this was once worked successfully, a point which may be worth remembering when considering the vexed question of the origin of haematite. The country rock is mostly Borrowdale Volcanics, but in places is Skiddaw Slate, and on Muncaster Fell part of what looks like the original roof of this rock can still be seen.

Ignoring the Granophyre which, whilst of the granite class, is not a true granite, it can be said that within our Lake District we have quite a large amount of granite to explore. Doubtless we think we know something about it, but in spite of the fact that it has been worked over by many famous men from Harker and Dwerryhouse to Marr and recent workers, I feel there is still a great deal we do not know. But let us return to the wider aspects of granite itself.

I have remarked that in the early days there was a tendency to over-simplify greatly. Granite was a rock intruded from below - it was an igneous rock - and that was that ! As time went on, however, and geological enquiry spread to wider and ever wider fields, many new and interesting facts emerged. This could be said from purely field exploration alone, but parallel with field investigations other approaches were being made. The cutting of thin sections of rock, after the pioneer efforts of Sorby, became commonplace, and with better microscopes a sub-science was added to Geology - Petrology. But there was also another line being followed - the chemical investigation of rocks. Now whilst you can, if you have the knowledge, hazard some observations about Petrology in the field by using your lens and accumulated experience, there is nothing you can do about the chemistry. The chemical analysis of rocks is a complicated

and highly-skilled business calling for much equipment, time and patience, and it can only be done in a laboratory.

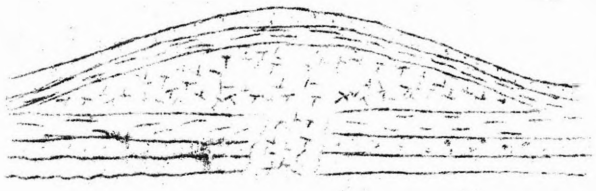
If I might be allowed to digress for a moment, let me say that in the last few decades our science has been overwhelmed with help (with a capital H !) from all sorts of people. We have had the chemists and the geochemists the physicists and the geophysicists, and whilst we can be grateful for the many thought-provoking theories and suggestions made, at the same time there is a difficulty. If you spend your time in a laboratory surrounded with rock cutters and microscopes, or with the paraphernalia of chemistry, you are, not unnaturally, apt to overlook that the many rock samples you deal with have all been provided by someone with a hammer. "So what ?" I have heard it asked. "Any idiot with a bit of beef and a hammer can knock off a piece of rock." So he can, and so he does. What our laboratory friends can hardly be expected to appreciate is that the mode of occurrence and the field relations of a rock may well be just as important - more important in fact - than a nice neat analysis or rock section.

Let it not be thought for one moment that I wish to denigrate all this patient work. Far from it. It is all very necessary and useful. What I wish to say, and say with all the emphasis I might, is this. In the end, it is a geological problem that is really being considered, and the last word must be with the geologist who can relate the lab. findings with the field relations. Latterly there has been a tendency to forget this. Even at geological conferences we are inundated with observations from all and sundry. Sometimes very valuable observations, but I have noticed myself that often enough the really useful things come from people who have spent most time in the field. I have been somewhat distressed of late by the diffidence shewn by our own experts when faced by the latest emanations from chemists, geochemists and geophysicists, and I believe the time has come quietly to remind some of these experts that in the end Geology is a science which can only properly be understood by those who, from long and patient work, know exactly what happens in the field. Forgive the diversion but I am unimpressed by the expert who can tell you all about the genesis of minerals, but cannot recognise a mineral vein when he sees it !

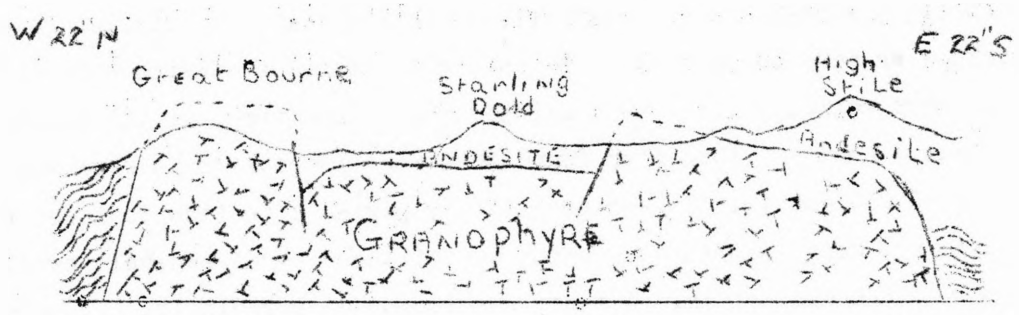
Those of you who, like myself, have collected rocks for any time must

be well aware of the bewildering variety of those rocks which we blithely refer to as 'Igneous'. Should you have any doubts about this, a visit to a good museum will soon convince you. Simpler still, perhaps, ask my wife. She sometimes wonders rather wistfully whether it would be simpler to shift my rocks - or move out ourselves ! But this state of affairs - in the igneous rock world, I mean - had existed for a long time, so the chemists would take a hand and they soon found that most igneous rocks were made up of a very few elements. It was possible by paying attention to these few elements, the most important of which was silicon, to pigeon-hole neatly any rock of igneous origin. A table was produced accordingly, and when I was young, great emphasis was laid upon it. If, even then, some of us scratched our heads a little, we were not encouraged to be over-critical. And yet to what absurdities it can lead. If you throw your hammer away and stick to test tubes, you may easily reach the conclusion that basalt and dolerite are exactly the same rock. On analysis, even our gabbro is not so very different, whilst granites, granophyres and granodiorites can be dumped together. But is this good enough ? Whilst we can acknowledge and indeed be grateful for any help received, I feel that we must remember that the science is Geology - and we are the geologists. Time is too short to go into the details of our indebtedness to all on the subject of igneous rocks in general and the granites in particular so I am going to proceed with the immediate subject of our discussion.

A granite, according to the old theory, is a rock generated in the depths and then injected into the existing country rocks. Long observation of granite masses in the field in many parts of the world has cast doubts upon this in recent years. There was a time when most granite masses were thought to be laccolithic in form, like this:-



but far from this being the case we now know that the greater number of such masses are found in this form:-




This is in fact a section of the Buttermere and Ennerdale Granophyre as worked out by the Survey and to this form we give the name 'Batholith' - 'Bathos', the depths, and 'Lithos', a stone. This is so because usually we cannot find any bottom to them, either from field observations or from deep boreholes.

Now from a study of granite masses in the field it is found that Batholiths generally follow the 'grain' of the country and more often than not they are to be found at the roots of some deeply-eroded anticline, as in fact our Skiddaw Granite is. What is most striking is the enormous size of some of these batholiths. In the heart of the Sierra Nevadas in North America, one such mass is 400 miles long by 80 miles wide. Another in the Coast Range is 1,100 miles long by over 100 miles wide. In other parts of the world there are similar masses of like, or even bigger proportions. The question arises: if these enormous masses of granite were intruded, as older theory holds, what became of the rocks that were there in the first place ? The simple answer is that there is little or no trace of them; they have simply vanished ! But there is a further point. When traces of the original rock do remain, they rarely shew any evidence of having been pushed aside. On the contrary, the granite quite often merges almost imperceptibly with the rock it is supposed to have displaced.

Quite definitely, as H.H. Read says, there is a 'room problem'. Two things cannot occupy the same place at the same time, and we must either accept the fact that there is a 'room problem', or do, as some geologists still do, and ignore the problem altogether. Even if we are prepared to do this we do not escape problems. Let us look again at the batholith in

the heart of the Sierra Nevadas. Near its Californian margin the rock is a granite with biotite mica. It is quite light-coloured and evidently consolidated from a magma, but between this and the country rock of schists and sedimentary rocks a dark-grey granite intervenes. This is very variable in appearance but contains many porphyritic crystals. Now in America geologists have the advantage that intense denudation has taken place over a long period of time and in a deeply-cut gorge or canyon in the nearby Inyo Range the rock has been deeply dissected. What can be seen is both very interesting and a little puzzling. In one exposure over a mile in length schists can be seen containing many large crystals of orthoclase felspar. How do we account for these ? Orthoclase felspar in schists is no new thing. Many augen schistose or gneissose rocks contain it, but mostly in knotts or stringers. This you can see for yourself if you examine some of the specimens on the bench tonight, specimens that have come from many parts of the world.

In the case we are discussing, however, we have to deal with idiomorphic crystals of felspar which grew in situ. It would seem that some activating fluid or emanation penetrated the schist, and slowly caused the crystals to grow. But how ? However carefully you may look, there is no sign that the existing material has been pushed aside to make way for the crystals, the felspar simply replaces what was there before.

Now you may say, with some justification, that this is all very well but what we are discussing is six thousand miles away; it is not something we can see for ourselves. True; you have to accept my word for it as I have to accept the word of our American friends. On the other hand, there are specimens on the bench which shew exactly the same phenomena, except that in this case the specimens came from no further away than Shap, and in this case the country rock is an andesite.

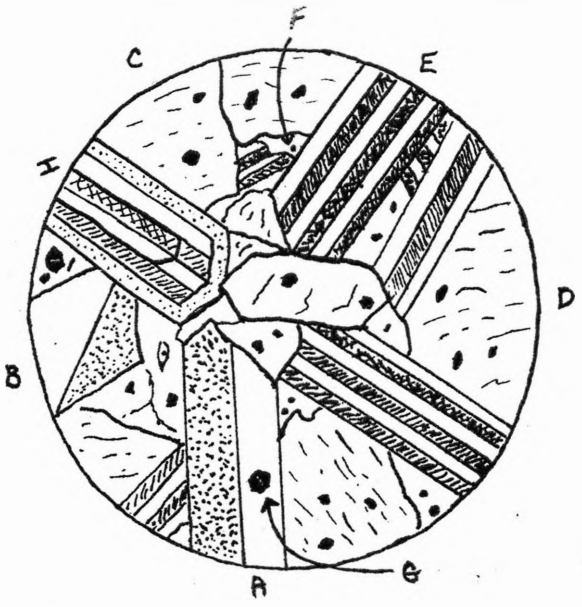
Thus it would seem that emanations, and I use the word in preference to fluids since we have, and can have no certain knowledge here, but in some way the rock has been penetrated to provide the material from which these potash felspars grew, and this not by displacement but by a rearrangement of existing crystal lattices with the addition possibly of potash. But to go back to the section we were discussing. Further along the gorge both quartz and felspar appear as wavy stringers between the folia of the schists. Further along still only wisps of schist and porphyritic felspars can be seen

enclosed in granite until finally all trace of schist disappears and the rock merges into a perfectly normal granite. This most interesting series of exposures in the Inyo Gorge may have been the first place where this phenomenon was seen, but it is certain that it is no isolated case; many such exposures are now known in many parts of the world, including our own Highlands of Scotland. The peninsular of Ardnamurchan shews a very similar sequence where it is indeed hard to say where the country rock ends and true granite begins. To this kind of rock which seems to be betwixt and between, the name 'Migmatite' has been given, and the process we call 'Migmatisation'. In passing, I might say that I have seen by the roadside similar rock amongst undoubted Eskdale Granite, and it would be interesting to know where it came from.

This process of migmatisation visualises the wholesale transformation of sedimentary or metamorphic rocks into granite. Perhaps it might be regarded as the last step in deepseated metamorphism. This kind of metamorphism, regional metamorphism, is something which always takes place in the depths and often on a grand scale. It involves both intense heat and pressure. If this theory of granitisation be held valid, it might be as well to remove granites from the category of igneous rocks and put them along with the metamorphics, classing them both as 'Plutonic' - rocks of the depths.

Now we have talked a good deal about granites and granitisation, but we have not yet taken a close look at a granite. Here is an attempt to portray a granite as seen in thin section under the microscope. I want to be quite frank about this drawing, it is very much an idealised section. To find all the things depicted you would have to hunt through a good many actual slides using various techniques and powers of magnification. Also, alas, if you were not to get bogged down in difficulties of interpretation you would need to be a better Petrologist than I am nowadays!

First you will notice that the section is made up mostly of crystals grown together. Also it is plain that some of these crystals enclose others. For this to be so, the enclosed crystal or fragment must have been in existence for another to grow round and enclose it. At 'A' we have a piece that shews some crystal form. Half of it is light and half of it is dark. Here I have tried to depict a twinned crystal of felspar of the orthoclase variety, under polarised light. At 'B' is a similar crystal shewn end-on.




Both of these can be seen occasionally but it is rather improbable that you would find both forms on one slide ! To get orthoclase shewing twinning at all is only possible if your section cuts the crystal in the right plane. Mostly this is not the case and what one sees then is a rather cloudy patch with fine cracks as at 'C' and 'D'. Often there are two kinds of felspar present, Orthoclase, a potassium felspar, and Plagioclase, a sodium calcium felspar. The plagioclase group shew a banded arrangement under polarised light as at 'E', a form of twinning known as 'lamellar'. This is much easier to find than the twinning of orthoclase, but in each case, as the section is turned, the twin planes go alternately light and dark. In this maze of crystals there are patches which are transparent and usually formless. These are patches of quartz, as at 'F'.

Any good granite section would shew you some of these features. No slide that I have ever seen would shew you them all, but by patiently studying many, some important conclusions can be reached. Dotted about the section are many black patches, some of which are roughly hexagonal; these are micas. For simplicity, I have shewn only dark, biotite mica, but it must be remembered that many granites shew a light mica also, muscovite, either alone or along with biotite. These bits of mica are scattered quite indiscriminately. They are to be seen in the felspars and in the quartz,

so evidently the micas were formed before either. If we look closely at odd pieces of mica, like the one at 'G', a transparent needle can be seen. Since the needle is enclosed in the mica, it must be our starting point. The needle is in fact a tiny Zircon, the only substance in the mineral world that rivals the diamond in splendence.

Ignoring for the moment any question of origin, let us try to imagine a magma, a silicate melt. Such a melt analysed into its chemical constituents would give a table like this:-

| | | | | | |
|---|---|---|---|---|---|
| $SiO_2$ | 70.18% | CaO | 1.99 | $H_2O$ | 0.84 |
| $Al_2O_3$ | 14.47 | FeO | 1.78 | $TiO_2$ | 0.39 |
| $K_2O$ | 4.1 | $Fe_2O_3$ | 1.57 | $P_2O_5$ | 0.19 |
| $Na_2O$ | 3.48 | MgO | 0.88 | MnO | 0.12 |

All these elements are present, either in the elemental state as atoms, or more probably as molecules, oxides of the elements. Since we have a melt, all these units are free to move about according to their atomic or molecular velocities. Sooner or later, however, our melt will begin to cool, and a temperature reached at which crystal lattices can be formed. One of the first unions to take place relates to the comparitively few Zirconium atoms. These attach to themselves atoms of silicon and oxygen to form minute crystals of Zircon. With the temperature still falling, more complex unions follow. Silicon, aluminium, potassium, oxygen and hydrogen with, sometimes, magnesium and iron, form crystals of mica. Now any existing crystals in a melt will act as focal points, and thus zircons come to be enclosed in mica. Later, scattered nuclei of felspar appear, grow, and enclose any bits of mica that happen to be in their path.

Felspars are divided into two main groups differing in their chemical composition and in their crystal lattices. The Orthoclase felspars are potassium aluminium silicates. The Plagioclases contain sodium and calcium instead of potassium. They form a graded series differing in the relative proportions of soda and lime. At one end is Albite, which is predominantly a soda felspar. At the other is Anorthite in which calcium, or lime, is dominant, and varying mixtures of these two account for the series. Sometimes this can be seen as a zoned structure in a plagioclase felspar crystal. The core of such a crystal might be anorthite, the lime felspar,

and grade outwards to Albite, pure soda felspar. This I have tried to illustrate at 'H'.

So much then for our micas and felspars. But what of our quartz ? Quartz is the last to solidify and so has to take up any vacant place in the crystal mesh it can find, but even so, it is not without interest. Sometimes, under a high-powered lens quartz shews what are known as 'liquid cavities'. The fact that such a cavity does contain a liquid is not difficult to demonstrate for it usually contains a bubble that moves about as the slide is rotated. Often this liquid is carbon dioxide, and sometimes it contains minute crystals of common salt. This may remind us that our silicate melt contains within itself the constituents of the gases which are constant features of volcanic eruptions.

The bubbles themselves are of great interest, and are not an original feature. They appeared because of the contraction of the liquid as the temperature fell. Careful research has shewn that these bubbles could have been formed when the temperature was no higher than 700$^{o}$C. - a little lower than that of liquid lava.

Much work has been done on silicate melts in the laboratory, and whilst the requisite temperature presents little difficulty nowadays, there are yet other factors. One is pressure. A natural silicate melt exists at pressures which man may try to simulate, but it is doubtful if he can altogether succeed. The other factor is time. Many granites must have cooled under cover of thousands of feet of sedimentary or other rocks and taken millions of years to do so. Against this background of time, what is man's brief span ? Such experiments can be helpful, but because of the factors mentioned we must not unthinkingly build too much upon them.

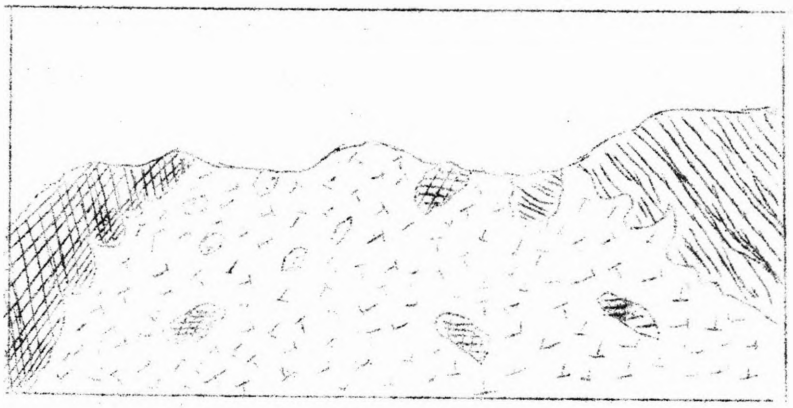
We now have, I hope, a fairly clear picture of granite as a rock. What happens to it when at long last, millions of years after it was formed, it appears at the surface, I think we all know. The weather begins to attack it, and it soon shews its characteristic form. If we look a little more closely into this business of weathering, we find that it is the felspars that are the weak link. Rainwater bearing carbon dioxide in solution, and thus acting as a weak acid, attacks the felspar, and breaks it down in this way:-

| | | | | |
|---|---|---|---|---|
| $2KAlSi_3O_8$ | + $CO_2$ | + $6H_2O$ | ----- | $Al_2Si_2O_5(OH)_4$ Clay |
| Orthoclase | Carbon dioxide | Water | | $4SiO_2.4H_2O$ Silicic acid |
| | | | | $K_2CO_3$ Potash |

From the equation we see that the aluminium silicates become hydrated to form clays. These will be carried away to end up as muds in lake or sea, ultimately to give mudstone or shale. The potassium and sodium salts pass into solution. Much of the sodium reaches the sea, but most of the potassium will enter the life cycle via plant life.

Of the other constituents of granite, mica and quartz; the latter we can readily dispose of. Apart from very small amounts which go into solution, the rest becomes grains of sand, and ultimately sandstones. Of the micas, the muscovite or potash mica is well nigh indestructible and usually turns up as the glistening particles which glimmer on the bedding planes of many sandstones. Biotite is more vulnerable. By way of sericitisation it breaks down and ends up as a clay, added material for mudstone or shale. Now it so happens that not many yards away from our Skiddaw Granite exposure in Sinen Ghyll there is an exposure which shews this process magnificently. In this bank, a mass of decomposing granite, one can pick out felspar crystals so demoralised that they can be squeezed between the fingers. I only found this exposure a few years ago, but I think it might be a suitable place for investigation on one of our summer excursions.

Now let us return to the subject of granite and granitisation. It is one of those vast and exciting topics which fire the imagination, one of those topics which will I hope give a salutory shock to those of you who imagine that our great subject is played out, a subject with all the answers neatly tabulated. This subject is still wide open. Some geologists think there is no 'room problem', or if there is it can be taken care of by what is called 'magmatic stoping'. What this means is shewn by the section; a magma rises into the country rock, and by a mixture of fracturing and melting eats its way upwards. The broken pieces, of whatever material, will be heavier than an equal bulk of liquid magma and will founder in the manner shewn. This is an actual quarry section taken from Daly's "Igneous Rocks and the Depths of the Earth" and is, of course, American. But we do not need to go to America for our examples, Shap Quarry will do, and there you will find specimens of what the quarrymen call 'heathens' - undoubtedly stoped-off



Monzonite Stock.
Tintic District of Utah. After Daly.

fragments, partly absorbed and granitised. It is very interesting to note that one of the first men to suggest 'magmatic stoping' was our own J.G. Goodchild, about 1900.

We can conclude then that stoping does take place, and I myself feel fairly certain that some small granite masses have been emplaced in this way. It is when we come to the enormous granite batholiths of other countries that one is compelled to wonder if magmatic stoping can be an adequate answer. Can we look, with Read, to times of Orogenesis, the times when our earth was involved in its great Mountain Building periods ?

We know that such mountain building periods always start with long periods of deposition - with geosynclines. From these vast accumulations of sediment, 20,000 to 40,000 feet thick, mountains are built. In the great folding movements that always accompany mountain building, much sediment must find its way down to great depths - and high temperatures and pressures. We have seen that much of this sediment is itself the residuum of igneous rocks, possibly at one or two removes, so most of the necessary constituents are already there: silica and alumina ad lib., calcium too from limestones, magnesium from dolomites, and iron most certainly. Sodium may be present as evaporite deposits, but what of potassium ? Potassium today does not find its way into the sea and hence into deposits in any quantity because most of it goes into the life cycle via plant life. What we have to remember, however, is that plant life itself, at least on land, is not very old when measured against aeons of geological time.

It would seem then that the essential elements in any activating medium

to effect granitisation would be potassium, and possibly to a lesser degree, sodium. Where do we look for these ? If we look at present day earth theory we find we have postulated continental sialic rafts on a substratum of sima - the sima being mostly basalt. In any earth storm such as the Hercynian or Alpine mountain building movement, considerable amounts of molten sima must be brought into contact with downwarped sediments which are the mountain roots. Nor must it be forgotten that the enormous compression and shearing involved gives rise to considerable heat. It is suggested by H.H. Read (and Arthur Holmes) that it is here we must look for Pluto's Laboratory, where sediment becomes Migma, and Migma becomes Magma. This was once summed up in the Proceedings of the Geologists' Association by a rather hilarious cartoon, but one wonders now if it is really so funny and far-fetched as it seemed.

We do know that these huge granite masses tend to follow the 'grain' of the country, that grain itself being but the result of earth storms and mountain building movements. We also know that true abyssal granites, batholiths, came to light only after long-continued erosion had worn away the original mountains. From isostatic theory, mountains rise because of their comparitively light roots, and this compensating movement takes place over long ages. And yet there are old mountain chains that have unaccountably failed to rise. Why ? Might it be that the roots themselves have melted off in the inferno of Pluto's Laboratory.

The origin of granite, to my mind, must take its place with such questions as that of Continental Drift in exercising the minds of geologists for a long time to come. Probably there is no one, simple, grandiose solution; different granites had different origins, and the key to each separate problem must be sought primarily in that particular granite's field relations. Let us, then, gladly accept all the help we can get from chemist, geochemist, physicist and geophysicist. Let us be ready to listen to them, but at the same time, let us never forget that the problem of granite must always be a geological one.

In conclusion may I point out how well-placed our Society is, if we have any enthusiasts amongst us, to take up here in our lovely Lakeland what I hope I have been able to shew is an absorbing study. In any such work I would suggest again that attention to field relations and particularly to marginal facies would be necessary. Such studies as have been made on our granites latterly seem to have been confined to the development of joints and faults - interesting work, but joints and faults do not develop until granite has become granite, and it tells us but little about origins.

E.H. Shackleton, F.G.S.

EXCURSION TO HAILE MOOR MINE, EGREMONT. 22nd. January, 1962.

A party of nine members met at the Haile Moor Mine and were made welcome by Mr. Walker the underground manager, and one of the Company's Geologists, Dr. Pott.

After an interesting discussion in the mine's office of the underground plan of the mine, the run of the prevalent faults and the ore bodies, the party went underground. The main object was to see a section of the mine which was once visited by the International Congress on Geology. This area shews the basement bed of the Carboniferous lying in very close proximity to the Brockram, the basal bed of the Permian.

On our way to this unique exposure the party saw a good deal of the lie of the Lower Seventh Limestone, and in one place a shale which divides the Upper from the Lower Seventh. This bed of shale, although comparitively thin, is quite persistent through the mining area and can be used as a "marker band". At one place a reef of Lithostrotion martini was seen, and specimens obtained. This again is a useful marker and occurs some 40 to 45 feet above the base.

Penetrating further into the workings the party reached the exposure they had come to see. There was a fault, on the downthrow side of which could be seen the basement bed. Here this basal bed is a coarse grit rather than a conglomerate, and it seemed to be several feet in thickness, some six feet being visible. In this grit we were fortunate enough to find Cyrtina carbonaria, a small but distinctive brachiopod which usually occurs in the bottom bed of the Seventh Limestone, and a specimen was obtained. Cyrtina has been found in the bottom beds of the nearby Beckermet Mines, and also at Wilton at Mouseghyll Quarry by Mr. Shackleton.

Above our heads the roof of this exposure was in undoubted Brockram, and the often large pieces of angular stone were well displayed. This was not the exposure which our leader, Mr. Shackleton, had seen before, but it was probably quite close to it. Neither Mr. Shackleton nor the Company's Geologist was able to put forward a clear explanation of what was to be seen. Generally speaking it would appear that to bring these two basement beds into juxtaposition would require a fault of about one thousand feet, but

both were very doubtful about this being the case. What seems more likely is that the fault is of no great dimension but is a post-Carboniferous one, and that erosion had been carried a great way before faulting took place.

In a bed of shale close by a most interesting phenomenon was seen. A large block of limestone seemed to have slipped from a nearby bank into the soft shale, and the shale was all disturbed and rucked-up around the block. This seemed to have been contemporaneous, something that had happened whilst the shale was still in a partly unconsolidated state.




After leaving this part of the mine, opportunity was made to visit a part of the mine not now worked where many interesting specimens occurred, and the party collected many beautiful pieces of Specular Ore, as well as Quartz crystals. On returning to the surface, the party expressed their thanks to the people who had so kindly shewn them around the workings. All were very well satisfied with a most interesting visit.

## EXCURSION TO ULLCOATS MINE, EGREMONT.

A party of ten arrived at Ullcoats Mine on the night of February 23rd., and were met by the Underground Manager, Mr. Casson. After being fitted out with safety hats and lamps, the party descended the shaft, which is about 950 feet deep. The whole party walked for some way along the main road, cut for the most part in the Sixth Limestone, and noted the regularity of the bedding and the excellent roof given by the bedding planes. Then the party divided into two sections.

One section proceeded to where a fine bed of Kidney Ore was being worked. The working was several yards across in each direction and about ten feet high, one wall of which was entirely of Kidney Ore. It was explained that most of this was not sold as ore, but was put aside for examination by people who came from abroad to buy it for the making of Haematite Jewellery. Some specimens of Dolomite, or Pearl Spar as the miners call it, were obtained along with specimens of Specular Ore and some fine Quartz crystals. The Quartz crystals were of interest in that they were six-sided pyramids, sometimes double-ended and with a very small prism. This type is usually regarded as a high-temperature form of Quartz.

Going further into the workings, the "Thin Beds" at the top of the Sixth were seen. These are thin beds of limestone with very thin shales between, and are typical of the top of the Sixth. Going deeper, the party passed through the Seventh Limestone and were shewn what appeared to be a dyke in the Skiddaw Slates. It was about fifteen feet thick, and a specimen was obtained by Mr. Shackleton who was able to confirm later that it was Dolerite. Continuing further, the party was shewn the basement bed of the Carboniferous lying on Skiddaw Slates.

The basement beds consisted of stained shales which shewed much slickensiding, and this was also seen in the basal limestones overlying the shales. Search was made for Cyrtina Carbonaria, but without any success. On the way back to the shaft various workings were visited, and in one a band of unaltered shale was seen running through iron ore. Mr. Shackleton pointed out that this was a clear indication that Haematite was in fact a replacement, in situ, of the original limestone.

The party returned to the surface and expressed their thanks to Mr. Casson and others of the Mine's Staff who had so kindly assisted in giving the party such an interesting time.

# OUTING TO ST BEES AND FLESWICK. 17th. March, 1962.

The purpose of the meeting was twofold:

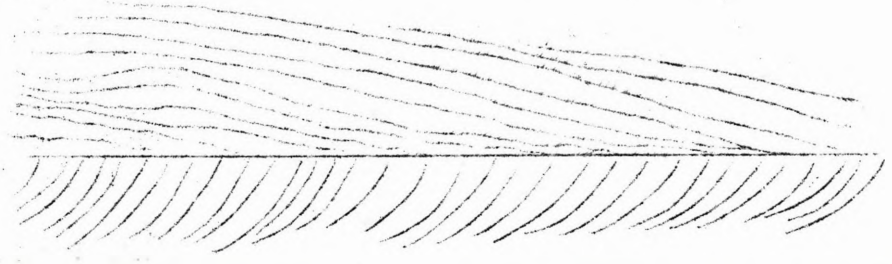
i. to survey the new groynes at the North end of St. Bees beach, and to plot the distribution of shingle and sand in the area, and,

ii. to study the rocks between St. Bees and Fleswick, and to look for agate, jasper and other semiprecious stones in the shingle of Fleswick Beach.

The main party under the leadership of Mr. Tripp, leaving the surveyors (Messrs. Dodd, Gate and Walmsley) to their work on the beach, looked first at the boulder clay cliff to the north of Rottington Beck. At this stage the leader gave a short geological outline of the area.

The St. Bees Sandstone is a fine-grained unfossiliferous rock of Triassic age, dipping in this area at about $10^{\circ}$ to the south west. It was laid down in shallow water under desert conditions. This accounts for the predominantly red colour and the considerable false-bedding to be seen. It is underlain by shales containing beds of gypsum and anhydrite, mined inland under Sandwith. This in turn is underlain by Magnesian Limestone and Brockram (Permian) to be seen at Barrowmouth, and then the Whitehaven Sandstone (Upper Carboniferous).

The party, in scrambling along the foot of the cliffs, noted the considerable jointing of the sandstone, the unevenness of the bedding planes, and the false-bedding beautifully displayed. Several instances of contemporaneous erosion were seen, where the false-bedding had been planed off flat, and further fine layers laid down, as shown in the following diagram.



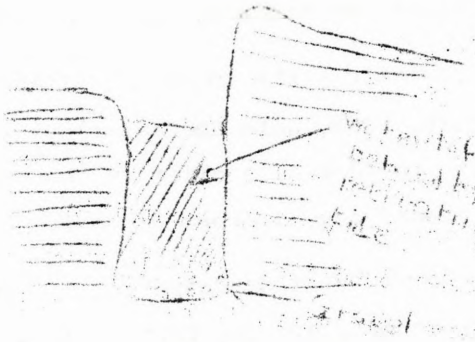
A particularly fine fault was seen in the cliff face at about three quarters of the distance along towards Fleswick. The main fault could be seen clearly as well as a certain amount of criss-cross shattering of adjoining rocks.

Several interesting erosion features were seen, including:

1. Cliff falls. The sea, pounding in along the bedding-planes and joint-planes, had prized off blocks of rock from the base of the cliff by

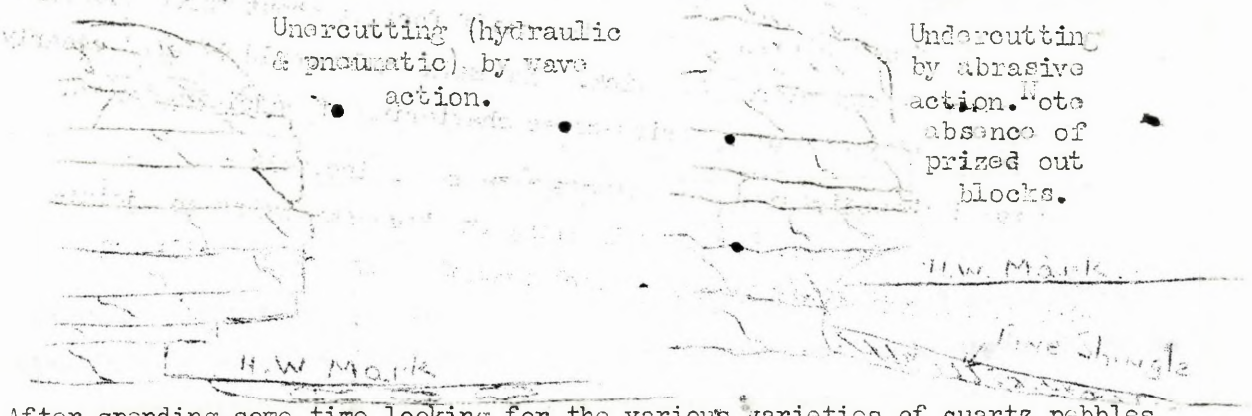
hydraulic and pneumatic action, causing an overhang. This becomes more and more unstable and finally crashes down.

2. Potholing. Several perfect potholes were seen, one being three feet across and several feet deep. These features are caused by pebbles trapped in a crack in the rock being swirled round by water. These pebbles abrade the bedrock and work their way downward forming an almost circular hole which usually widens as it goes down, and which may be surprisingly deep. Potholes formed in a similay manner to these seaside examples are to be found in the beds of many Lakeland becks. For instance, good ones are to be found in the waterfalls just below Watendlath Tarn.



3. Surface abrasion. The surface of the wave-cut platform was seen in several places to be ridged and pitted to a depth of ½" to 1". It was thought that this was caused by differential abrasion of the rock surface caused by wave-borne sand.

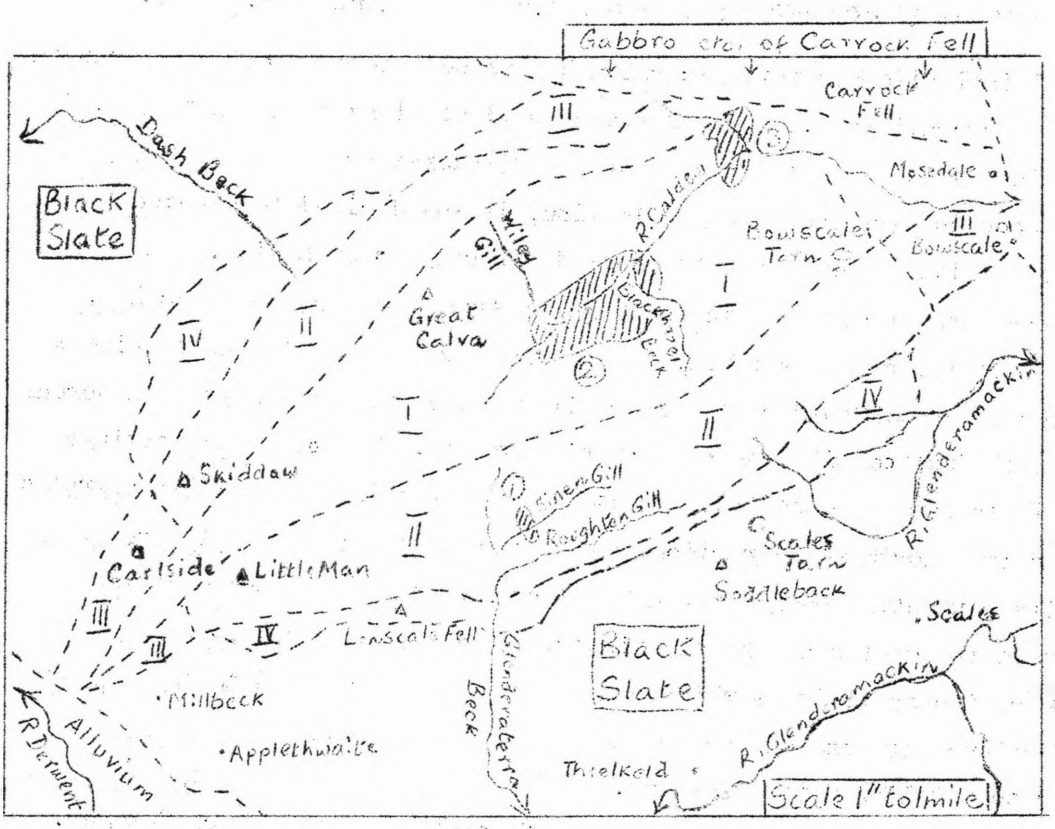
4. Undercutting. On Fleswick beach itself, the party observed the undercutting of the cliffs caused, not so much by purely hydraulic action, as mentioned in paragraph 1, but by the abrasive action of wave-flung gravel. The differences between the two types of undercutting are shown below:




After spending some time looking for the various varieties of quartz pebbles on the beach, especially for agate which seemed disappointingly rare, the party made its way back to St. Bees along the cliff top.

T. Shipp, B.Sc.

# THE SKIDDAW GRANITE




Sketch-map based on one in "The Geology of the Lake District" by J. E. Marr (Cambridge University Press, 1916) page 103.

The Skiddaw Granite occurs (1) In Sinen Gill, (2) In the Caldew valley at Blackhazel Beck, (3) Around the confluence of the Caldew and its tributary the Grainsgill. The nature of the exposures indicates a mass of laccolithic character, for there is evidence that the junction between the granite and the overlying rock approaches the horizontal. The normal rock is "essentially a biotite-granite consisting of orthoclase, oligoclase, quartz and brown mica.". . There are often scattered flakes of muscovite. The rock is medium-grained and of a light grey colour. The age of the Skiddaw Granite is uncertain, but is probably Devonian.

The intrusion has metamorphosed considerable areas of the Skiddaw Slates, the alteration in the character of the rocks being greatest near the exposures of granite. The "Black Slates" show no metamorphism, but passing inward toward the granite the first sign of alteration is the occurrence of spots, perhaps embryo crystals of chiastolite (IV). Passing inwards, chiastolite crystals become abundant in the well-known "chiastolite-slate". Similarly the "Grey Flags" (III) on the outer edge of the aureole show changes as the centre is approached. Spots appear first, and then chiastolite, while the dominant minerals are cordierite and biotite (II). Close to the granite of Sinen Gill the Grey Flags are converted into the so-called mica-schists with garnet and staurolite in contact with the granite. Area I represents metamorphosed "Grey Grit", often resembling impure quartzites.

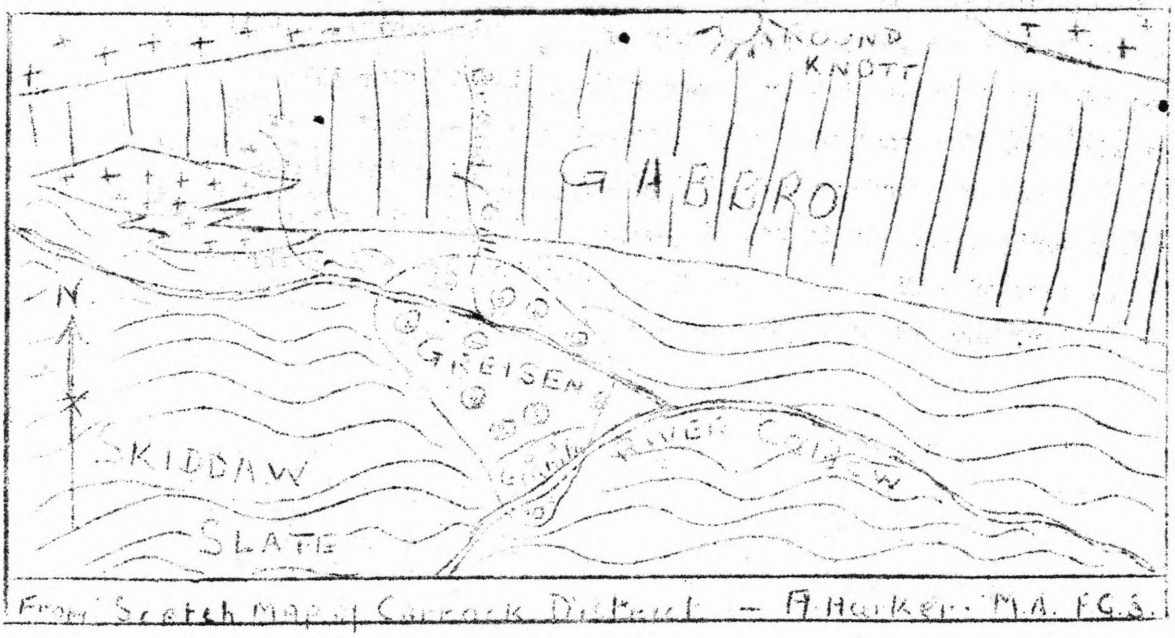
# THE SKIDDAW GRANITE.

## REPORT OF AN EXCURSION LED BY DR. F.H. DAY. April 1st., 1962.

The original plan for this excursion had to be somewhat modified because of the weather conditions. The party assembled at Blencathra Sanatorium, it being originally intended to proceed up the Glenderaterra Valley. With the threat of snow showers and a very cold wind, it was decided to abandon the walk through Skiddaw Forest and to proceed directly to Swineside. The party then went by cars along the main road around Saddleback as far as Scales, where the fellside road was taken. A stop was made to examine some Skiddaw Slate exposures near Southerfell, where it was seen that the slate was normal and evidently just outside the metamorphic aureole. The old lead workings near Threlkeld had been noticed, and it was remarked that they had penetrated the slates in a northerly direction, and were said to have actually reached the granite contact. Passing through Mungrisdale the party saw a small quarry where the slates are highly distorted, partly as a result of the intrusion of two small dykes which may be genetically related to the granite. A stop for lunch at Mosedale bridge provided a view of the Caldew valley which was then followed to Swineside. Here the Skiddaw Slate rocks are well within the metamorphic zone, and consist of hornfels showing much folding. The general course of the Mosedale Fault which separates the slates from the igneous rocks of Carrock Fell was pointed out.

The party then worked up the main Caldew Valley where the hornfels is well seen in the river, and slightly above the confluence with Grainsgill the granite was encountered. It is here a fairly 'normal' granite, exposed in the river bed and having a deep skin of weathered material, but the fresh surfaces of the rock were seen to carry the usual granite minerals.

This, the most easterly of the three exposures of the granite, was followed up the river until the junction with metamorphosed Skiddaw Slate was reached. Examples of spotted schist and cordierite schist were obtained. The party then traversed the granite back over the side of Comb Height and a gradual change in the character of the granite was observed. Descending into Grainsgill it was seen that quartz veins became more numerous, and close to these the rock had been modified into greisen. The extent of true greisen is however much less than formerly supposed and at the north eastern




From Scotch Map of Carrock District - H. Harker, M.A. F.G.S.

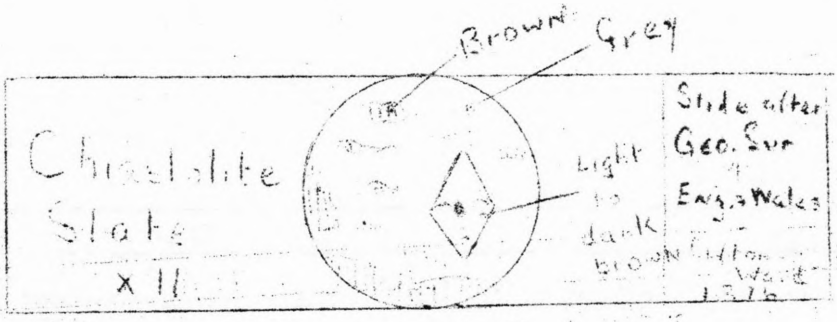
boundary of the mass a return to the more normal type of the rock is evident.

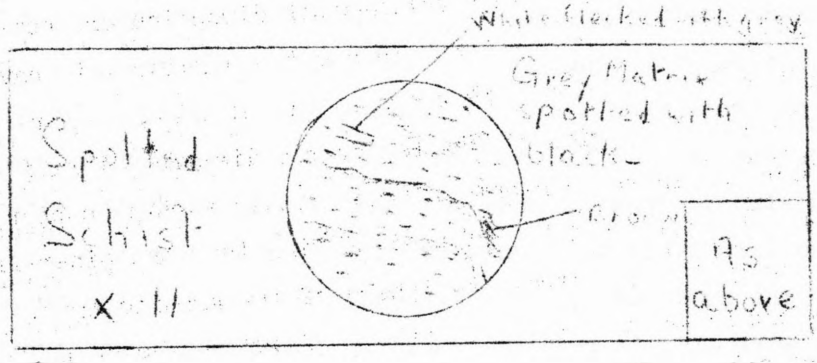
The special feature fof the Grainsgill mass is the interesting mineralisation.

Quartz veins, running mainly in a north-south direction are numerous, and the large Emmerson vein, the Smith vein and the Harding vein have all been worked, mainly for tungsten. It was pointed out that, as a result of analyses of the rock in a series of samples over a distance of half a mile, a progressive increase in the content of trace metals such as copper and arsenic, and also phosphate had been found, showing that the mineralisation was localised largely in the extreme periphery of the granite mass. Specimens of the numerous minerals can still be found on the dumps, and some members were able to collect examples of wolfram, arsenopyrite, molybdenite and galena (the latter from a small cross-vein) and various other species for which the locality is famous. The northward penetration of the veins into the Carrock Fell rocks was observed in Brandygill, where it was also seen that a deposit of scorodite had been formed, presumably by oxidation of arsenopyrite.

The general relations of the granite to the surrounding rocks were described, and its probable later age than the Carrock Fell gabbro-grano-

phyre complex was noted. It was also remarked that there are some affinities in the residual minerals with some of those found also at Shap. The time and weather did not permit a complete study of the metamorphism, but it was pointed out that it is of a widespread and rather mild thermal type, consistent with the view that the granite mass was emplaced at no great depth below the present surface, and that its contact with the slates is approximately horizontal. It is practically certain that the three granite exposures are part of a single mass which is therefore upwards of three miles in diameter, and only recently exposed by erosion.



# EXCURSION TO THE NEWLANDS VALLEY. May 20th., 1962.

The valley of Newlands runs from Braithwaite in the North, along the Western side of Catbells to Dale Head in the South, a distance of just over 5 miles.

In 1561 a Company was incorporated for the purpose of working the Newlands mines. This was probably the first Mining Company to be formed in the North of England. In 1566, the largest copper smelting works was erected at Keswick, and by 1567 six furnaces were in operation, supplied chiefly with ore from the mines of Newlands. It is generally supposed that the ore from Newlands was conveyed to the Western shore of Derwentwater, and thence by boat to Keswick.

The work was carried out principally by a colony of Germans under their chief steward, Hechstetter, specially recruited from Augsburg by the Mines Royal. This venture was under the direct control of the Queen herself, who doubtless hoped that the rich mineral deposits which were known to exist would yield gold to rival the rich flood pouring into Spain from that country's recent conquests in the Americas. The only gold found, however, was in such small quantities that it was not worth exploiting. Operations continued until 1650-51 when the mills, works, and most of the mines were destroyed during Cromwell's campaign.

The valley is traversed by at least six main lodes, and also at the North end by the Brandlehow Lode. All these run in a roughly N-S direction and split into numerous secondary lodes. All these are lead lodes. The only other lode of any importance in the valley is the Goldscope Copper Lode which runs in an E-W direction, and is displaced by at least two of the N-S veins. It will be noted that the main part of the N-S veins run in the form of the ribs of a fan with its apex about the Thornthwaite Mines, and its wide end covering the Newlands Valley area. The lodes are:-

1. The Newlands Lode.
2. The Scope End Lode.
3. The Castle Nook Lode.
4. The Yewthwaite Lode.
5. The Barrow Lode.
6. The Stonycroft Lode.
7. The Brandlehow Lode.

There are at least six main mines in the Valley:-

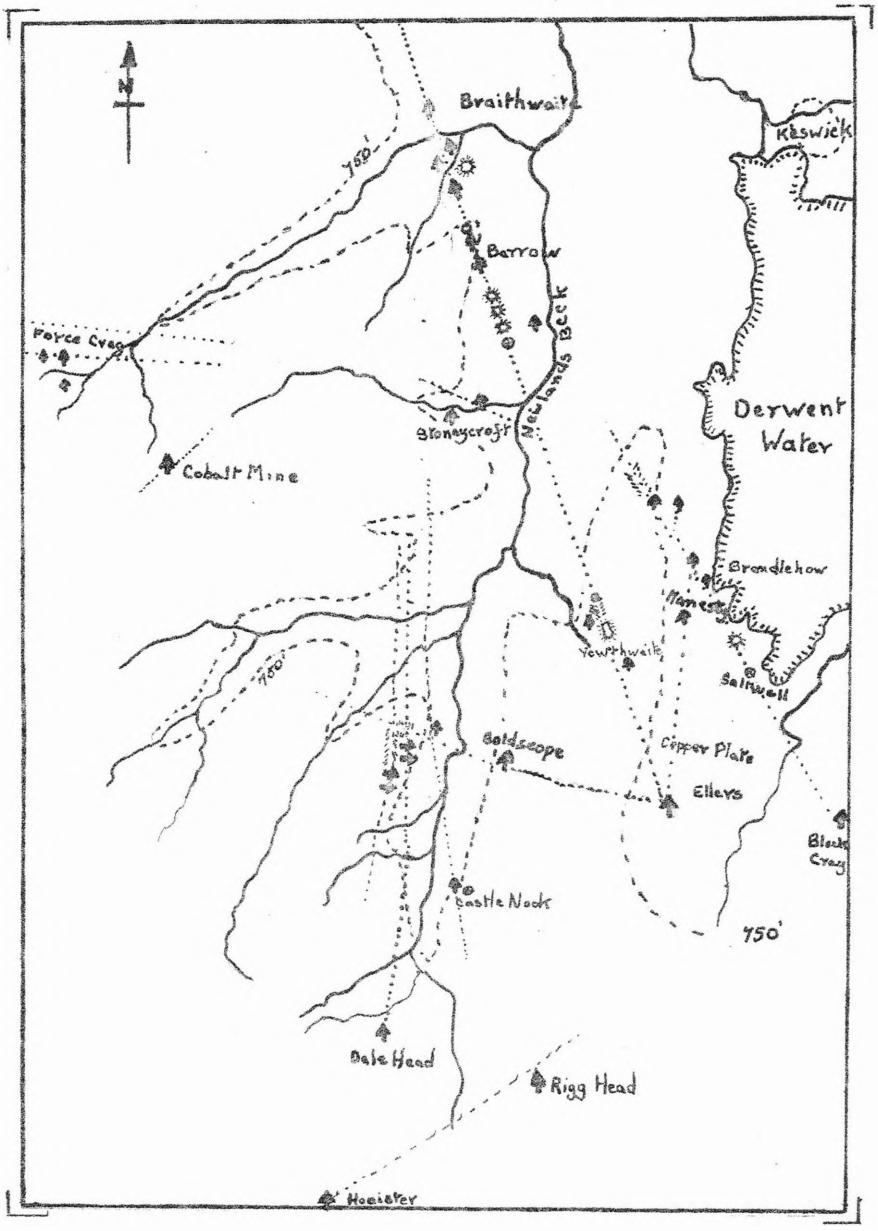
Barrow, Yewthwaite, Stonycroft, Castle Nook, Dale Head, Goldscope, with numerous small trails and open workings scattered throughout the fell-sides. There are numerous examples of very old workings in the valley,

i.e., open vein workings which were worked by the 'old men' and then later workings in the form of 'Bell Pits'. The best examples are to be found at Barrow Mine, Uzzicar, and also at Braithwaite and Yewthwaite.

The most important mine of the valley is the Goldscope, which was first recorded in August 1566, but the vein was probably worked open long before that by the 'old men'.

The objects of the excursion to the valley were:-

1. A general overall look at the valley with its evidence of mining, the tips or waste heaps, and the open vein fissures.
2. To visit the Goldscope Mine, its present adit, and the open old vein workings over the ridge of Scope End. Also to visit the back adits through which water to work the machinery in the main shaft inside the mine was taken. Finally to see the Pan Holes which are probably where the Sealby Lode was stoped out to the surface.
3. To see where the Newlands Lode crosses the stream between Castle Nook Mine and Goldscope.




THE NEWLANDS MINING AREA.

J. Moon F.G.S.

Key

- Vein bearings
- Adits.
- Bell Pits
- Shafts
- Vein fissures

About 25 members assembled at Braithwaite and, led by Mr. John Moon, FGS., proceeded by car to the tip loft by the Barrow Mine workings. The veins, outcropping high on the fellside, were worked by adits (horizontal tunnels into the hillside) for lead ore, galena. Good specimens of galena, often covered with a crumbly white outer envelope of anglesite (lead sulphate) caused by prolonged weathering, were picked up on the tip. Small fibrous crystals of another lead mineral, cerussite (lead carbonate) were also found- this again is a secondary mineral, formed by the weathering of galena.

Further on, the leader showed the site of the Uzzicar Mine.* He also pointed out some circular depressions in the fields, the sites of old 'Bell Pits'. Following the track that leads round the shoulder of the fell at Stonycroft, the party next examined the site of the Stonycroft Smelting Mill. This mill, which dated from the time of Elizabeth I, was fed from the mine, flooded now, whose entrance may be found in the narrow cleft above the road bridge. One can conjecture from the size of the slag heap what dreadful vapour poisoned the air from the exhaust chimney which 'lay' up the side of the fell, and whose position can still be traced. On the slag heaps, now occupied by a small reservoir, lumps of black, red and green slag looking remarkably fresh and unweathered were picked up, also a remarkable globule of 'Copper Matte', inadvertently tipped out with the waste slag.

Unfortunately, an unfriendly landowner prevented the party's direct access to the Goldscope area, so the party proceeded by car round Catbells to what is left of the Brandlehow Mine on the Western shore of Derwentwater. The outcrop of the Brandlehow Lode can easily be traced down the fellside. Below the road, the party explored two open adits, one of which, inside the wall of the neighbouring wood, went in for a short distance and ended in an abrupt shaft. Working down to the lake shore, the party covered the old tips in searching for specimens of galena and blende (and also quartz boulders for a member's rockery !). It is interesting, and a little puzzling, to note that no cerussite could be found here.

* Which was worked for galena. Zinc blende, relatively useless in those days, was dumped - which explains its relative abundance on the tip.

Fourth Limestone

Bench with Girvanella.
(Base of Rough Beds)

White Limestone
x Lons: duplicata duplicata

Sandstone & Shales

Large Quarry in
5th. Limestone
(Flooded)

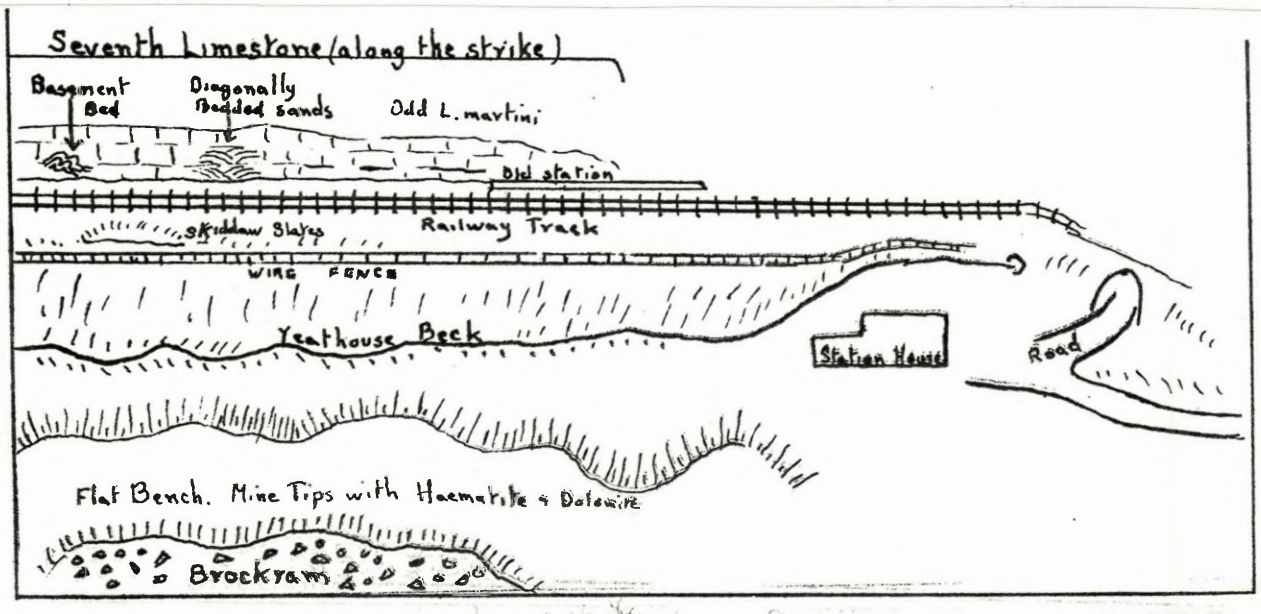
5th Limestone with
Palaeosmilia &
carcinophyllum

Chonetes hardrensis, Ch. polita
Productids and Productid spines

Chonetets Shales,
very fossiliferous.

DIP

6th Limestone.
Shale at base with
algal nodules.




Rough sketch map of Yeathouse Quarries.

E.H.S.

## FIELD EXCURSION TO YEATHOUSE, FRIZINGTON.

A good number of our members met at Yeathouse Road, Frizington on Saturday afternoon, April 14th. Both our President and Vice-president were present.

Permission had already been obtained from the farmer, Mr. Long, to visit the quarry. The cars were parked by the Yeathouse Station, and here Mr. Edmonds briefly described the area. Parallel to the railway runs the Yeathouse Fault, and this weakness has been exploited by the elements to give the little valley. On the north side of the valley St. Bees Sandstone occurs, and beneath it the Breccia. Whilst the Breccia (or Brockram) at the base of the Permian at Barrowmouth Bay is only a few feet thick, here it is some 350 feet thick. This, said Mr. Edmonds, is to be explained by closer proximity to the Fells, the source of the fragments composing the Brockram. At this point the only Permian beds visible in the north bank are Breccia, but a little further west, the overlying St. Bees Sandstone can be seen.

The tips visible are old iron ore mine workings, for haematite which was found on the downthrow side of the fault. The great throw of the fault can be estimated from the fact that whilst the northern bank of the valley shows the basement beds of the Permian, the southern bank shows the basal beds of the Carboniferous.

Mr. Shackleton then led the party along the old railway track to where the basement bed of the Carboniferous is exposed. The bed is composed of sharp angular fragments of quartz cemented by iron pyrites. It was pointed out that iron pyrites is a common feature of basement beds and this is due, according to Tuenhofel, to stagnant bottom conditions as the waters slowly invade the sinking land surface. We have here, of course, an unconformity, the Seventh Limestone lying, with its basement bed, upon upturned Skiddaw Slates. The Slates are not visible immediately beneath the basement bed but are well exposed on the opposite side of the line. No fossils have so far been found in the Slates at this point. The basement bed was noted and compared to similar beds seen recently in the Florence Mine at Egremont.

Working along the strike of the Seventh Limestone, the haematised joints were noticed, together with an old adit, a working for haematite. Mr. Shackleton next drew the attention of the party to the diagonally bedded sands, a feature of the Lower Seventh in the area, and one that is fairly widespread. It points to shallow water conditions with fairly strong currents sweeping in bands of current-bedded sands.

Whilst the younger members of the party looked for fossils in the Seventh, others brought up the surveying equipment kindly supplied by Mr. Heron of the Mines Department of Workington Technical College.

Mr. Edmonds and Mr. Shackleton led the party to the entrance cutting to the quarries. The first limestone seen here is the Sixth and at the base in a dark shale algal nodules were found. The Sixth is overlain by shales, the Chonetes Shales. In these, many fossils were found, amongst them a small Chonetes polita and Productus undatus, with lovely golden spines.

From the cutting, the party entered the first quarry which is in the Fifth Limestone. Most of this quarry is deeply flooded and inaccessible, but Mr. Shackleton pointed out an exposure where the typical Palaeosmilia (cyataphyllum) murchisoni can be found.

The Fifth is followed by a shallow water phase which here is sandy. The sandstones are exposed in a cutting beyond which the big quarry opens out. The first limestone exposed here is the White Limestone, and the leader was able to point out a fine corallum of Lonsdaleia duplicata. The specimen had evidently been washed into position as it was lying upside down.

At this point Mr. Heron set up his plane table and demonstrated surveying methods to an interested and enthusiastic group of members. Unfortunately the whole quarry floor was flooded making access and direct measurement an impossibility.

Whilst this was being done, Mr. Shackleton and some members of the party made a search for 'marker' fossils. After much search the fossil algae, Girvanella, was found and this marks the base of the Rough Beds. Much search in the White Beds failed to discover Cyrtina septosa, but the Gigantella Muirwoodi which usually occurs with Cyrtina was found along with sections of Davisiella.

Because of flooding, the quarry proved unsuitable for the survey project the Society had in mind, but all agreed the meeting had been interesting and instructive.