Chapter 40 General description

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Under the name of "Eastern Schists" is here included the great series of crystalline schistose rocks which lie upon the uppermost of the major thrust-planes of Sutherland and Ross, and stretch eastwards into the rest of the Highlands. These rocks have been the subject of much discussion. They were once regarded as portions of the oldest or Azoic architecture of the country. Murchison considered them to be a metamorphic series of mainly sedimentary formations, later in date than the Lower Silurian (Cambrian) limestones and quartz-rocks which underlie them, and into which they seemed to pass downward in a conformable succession. The detailed study of them by the Geological Survey has thrown considerable light on their composition and structure, but the problem of their age and origin has not yet been completely solved. In this and the following chapters nothing more will be attempted than a general account of their characters as these have been ascertained along the belt of country examined between the north coast of Sutherland and the Point of Sleat in Skye. When the rest of the Highlands lying to the east of that belt has been surveyed, it may be possible to offer some more definite opinion as to the stratigraphical relations and history of these rocks.

The "Eastern Schists" have had various names applied to them. Most of these appellations have had reference to the petrographical characters of the rocks, such as "gneissose flagstones", "quartzose schists", "flaggy schists". Sometimes the designation selected has expressed their supposed stratigraphical position, such as "younger gneiss" or " upper gneiss". The members of the Geological Survey when they began to map them in the north of Sutherland and found them spreading over the wide tract known as The Moine in that county, distinguished them as the "Moine schists". As no one petrographical term will adequately describe them, and as their stratigraphical relations are somewhat complex and obscure, it has seemed best to class them in the meantime under some geographical name which will involve no theoretical implications. Accordingly they may be conveniently described as the "Eastern Schists" or "Moine Schists".

The detailed descriptions and illustrative sections given in Chapters 32 to 39 of this Memoir have shown that, throughout the long belt of complicated structure in the North-West Highlands, however much that structure may vary in tectonic arrangement from district to district, every section taken across its breadth invariably terminates eastwards in the oncoming of the Eastern schists above the Moine thrust-plane or most easterly of the great displacements. If the actual plane of this thrust could always be seen it might be taken as the western limit of these schists. As already mentioned, it has been clearly exposed in some places, such as the precipitous sea-cliff east of Loch Eireboll, the Stack of Glencoul, near Knockan in Assynt, and between Stromeferry and Loch Alsh. But it is often extremely difficult to determine the precise position of the Torridonian-thrust-plane. Owing to the development of mylonised rocks about its horizon, the actual "sole" or plane of displacement is apt to be lost among the crushed and rolled-out materials which have been driven along in the line of movement.

Near Tarskavaig in Sleat, Skye, a considerable body of schistose rocks, resembling in some respects the Moine schists, has been brought forward in advance by displacements below the horizon of the Moine thrust. These rocks, which have been termed the Tarskavaig Moine scbists (Chapter 42), comprise phyllites, sometimes interleaved with siliceous schists and gritty beds, which, in one locality, present a spotted appearance, due to the presence of minute aggregations of black mica or chlorite evidently of secondary origin. It is suggested that the micaceous spots may have resulted from contact metamorphism near some igneous intrusion, and though probably earlier than the thrusting movements, must have been later than the regional metamorphism. Overlying the phyllites come schistose grits with pebbles of quartz and microcline-felspar, the quartz grains being elongated and in part granulitised.

Again, on the mainland, in the Cnoc Daimh Burn in the Coulin deer forest, Kinlochewe, close to the Moine-schists, though the junction is concealed by alluvium, certain fine-grained platy rocks and siliceous schists are to be'seen presenting petrographical types intermediate between normal sediments and crystalline schists, which may not improbably belong to the basal division of the Torridonian system, though this correlation cannot be demonstrated. (Chapter 37)

The material3 which supervene above the Moine thrust may be grouped in four main divisions: (1) Mylonised rocks; (2) phyllitic schists, siliceous schists. and limestones, especially characteristic of the Burness-Eireboll district (crushed rocks and frilled schists of the one-inch map, Sheet 114); (3) granulitic quartzo-felspathic schists, frequently referred to as Moine-schists, with which are associated thin bands of garnetiferous mica-schist; and (4) inliers of micaceous and hornblendic gneiss recalling, in certain areas, types of Lewisian rocks to the west.

(1) A remarkable feature of the Moine displacement is the belt of mylonised rocks found either above or in association with that plane. In some places this belt measures a mile or more across, elsewhere it may be only a few hundred yards, while sometimes it appears to be absent, the granulitic crystalline schists then lying immediately upon the plane or sole. In the field and under the microscope it can be shown that mylonites of variable tints — grey, green, pink, and striped — have been derived in part from different members of the Lewisian gneiss. All the stages in the process of deformation are to be found, the dark hornblende gneisses have been rolled-out into green platy schists, the pink pegmatites exhibit flow-structure like that of rhyolites, and the acid gneiss with pink quartzo-felspathic veins merge into the Torridonian striped or banded mylonites. But in certain cases also it is apparent that the materials of this crush-zone are of sedimentary origin, for in Eireboll, in the Glencoul district, and in Assynt into platy of basal Cambrian quartzite have been rolled-out nto platy homogeneous quartzites in which the individual grains are hardly discernible with the unaided eye. Southwards in the Kinlochewe district it would appear that the epidotic grits and basal shales (Torridon) have also undergone mylonising processes in association with the Moine displacement.

The effects of crushing on the micro-structure of the rocks can be best studied in the acid gneisses, pegmatites, quartzites, and Torridonian quartzo-felspathic grits. The original grains of quartz and Torridonian felspar have been broken, and detached fragments now lie in Torridonian crypto- or micro-crystalline matrix which represents the ultimate results of the mechanical action. The plagioclase felspars illustrate the cataclastic effects in the greatest perfection on account of their twin lamellation. The first effect is seen in a simple faulting of the twin-lamely, and from this action to the breaking up of a large individual into innumerable fragments and the separation of the fragments in the matrix of fine-grained mylonitic material every stage may be followed. The same phenomena may be seen in quartz, especially in quartzites, but when quartz and felspar in juxtaposition have been simultaneously affected they behave somewhat differently. Quartz appears to yield without fracture to stresses tending to produce fluxion more readily than felspar, and what may be termed quartz-flow round angular grains or crystals of felspar may sometimes be observed. In such cases the appearance under the microscope suggests that an original grain of quartz of approximately equal dimensions in the different directions has been converted into a curved lenticle, and that in the process of deformation the crystalline individuality of the grain has been lost. In place of the original individual an aggregate has been produced, the constituents of which are also more or less lenticular in form.

In this connection it is worthy of note that two different types of schistose rocks have been produced in the north-west of Scotland by the deformation of solid rocks. In. the pre-Torridonian shear-zones granular gneisses have frequently been converted into hornblende-granulites (see page 64) by shearing, without the development of cataclastic structures, or, in other words, by plastic deformation; whereas in the region of the post-Cambrian thrusts similar rocks have been converted into mylonites with marked evidence of the mechanical fracture of the original constituents. These two types no doubt correspond to differences of pressure and temperature at the time of deformation. The mylonitic type may be regarded as characteristic of the zone of fracture, and the granulitic type as characteristic of the zone of flow, but neither the two types nor the two zones are sharply separated from one another, for, as we have just seen, quartz may be in the zone of flow, while felspar is still in the zone of fracture.

(2) The phyllitic schists, siliceous schists, and limestones represent a sedimentary series which has been powerfully affected by the post-Cambrian movements. It is well developed in the Eireboll district, and may be studied also at Sangomore Bay and Fair-aird Head. The phyllitic schists often closely resemble phyllites, but under the microscope they are seen to have been highly crystalline before the final movements took place. The principal constituents are white mica, chlorite, and a microcrystalline quartz-felspar aggregate. The rocks are usually dark-green in colour with wavy foliation planes, and the general appearance of a freshly-prepared hand specimen is not unlike that of a rock made up of broken oyster-shells; hence the term "oyster-shell rock" which has been frequently applied to these phyllitic schists. The movements which gave rise to this peculiar feature were posterior to the development of the plates of white mica which are seen under the microscope to have been bent and broken.

The siliceous schists are intimately associated with the phyllitic schists, sometimes as thin alternating lamina' and sometimes as thick bands which can be readily traced in the field.

They are compact halleflinta-like rocks, with well-marked parallel structure, mainly composed of quartz, but containing also a few thin flakes of white mica. The micro-structure is of so fine a grain that the outlines of the constituents can only be made out in very thin sections and with a high magnifying power. The individuals of quartz are then seen to be irregular in form and greatly flattened in the planes of foliation. In other less typical varieties calcite is present, and this indicates a passage into the limestones with which they are also associated. The limestones are well-banded crystalline rocks, composed of calcite with a few flakes of white mica and grains of quartz and felspar. The banding is well shown on a weathered surface in consequence of the projection of the more siliceous layers.

(3) The granulitic quartz-schists have the largest development in the belt between Eireboll and Sleat, and it was to these characteristic rocks that the name of "gneissose flagstones" was more particularly applied. They are usually flaggy, though sometimes massive, with muscovite and less frequently biotite along their divisional planes. Augen of quartz and felspar, which are of common occurrence, may represent the remnants of original clastic grains. Indeed, at one place, in the Rhidorroch Forest, six miles east of Ullapool, schistose pebbly grits are associated with the siliceous schists, the pebbles of quartz and felspar measuring a quarter of an inch across.

Important evidence regarding the relation of the post-Cambrian movements to the internal structure of the Eastern schists is furnished by the associated intrusive rocks. Thus, in the area south-east of Glendhu and Glencoul intrusions of foliated granite have their foliation-planes parallel to those in the adjoining siliceous schists. Again, at Leckmelm, near Ullapool, bands of foliated porphyrite resembling the type of oligoclase-hornblende-porphyrite in the thrust masses in Assynt (Chapters 29 and 30) are interleaved with platy mica-schists of Moine type. Similar evidence is obtained in the area east of Loch Ailsh and near the Knockan. in Assynt, where sills of sheared porphyrite and syenite porphyry are intercalated among the Eastern schists, with which their foliation-planes coincide in angle and direction of dip. These metamorphosed sheets so closely resemble some of the intrusive sheets among the Cambrian rocks of Assynt, which were injected before the post-Cambrian movements (Chapter 29), as to justify the inference that, whatever may have been the origin of the Moine schists, the dominant structures impressed on them and on the porphyrite sills must have been produced by the same movements. In addition to these acid intrusions, bands of basic material, composed of garnetiferous hornblende-schist and hornblende-biotite-schist, are associated with the granulitic schists of the Moine series, and display a similar parallelism of dip and strike.

Further evidence of the mechanical movement which all the Eastern schists have undergone is supplied by certain fine parallel lines on the divisional planes, alike of the platy mylonites, of the siliceous schists, and of the foliated granitic sills. The same striping or parallel lineation is sometimes seen in the sheared Torridonian strata that overlie the Kinlochewe thrust-plane. In all these positions the trend of the lines is usually W.N.W. and E.S.E., which has been shown to be the general direction of movement of the thrust masses.

Under the microscope the main mass of a typical Moine-schist, taken at some distance from the thrust-zone, is seen to be a micro-granulitic aggregate of quartz and alkali-felspar, in which flakes of mica are embedded. The grains of quartz and felspar are of approximately uniform size and shape. and the mica flakes do not merely lie between the constituents of the aggregate but are included in it, so that a single flake may pierce one or more contiguous grains. A rock of this character shows no traces of clastic or cataclastic structures; it is a holocrystalline schist.

But although these features are common in rocks which cover a very large area to the east of the Moine-thrust, they are not especially characteristic of the rocks immediately overlying the thrust. In these rocks cataclastic structures are not uncommon, and the question has arisen as to whether they represent crystalline schists more or less broken down or sedimentary rocks which are on the way, so to speak, to become Moine-schist. Both views have been held by different members of the Survey, and both views may be right, though not, of course, as applied to one and the same rock. The age and origin of the rocks that have been mapped as Moine-schists is a complicated problem which has not been finally and definitely solved, but abundant evidence has been accumulated to show that under the influence of the post-Cambrian movements rocks of diverse age and origin have acquired a common type of structure, and that true crystalline schists have been simulated if not actually produced.

(4) The inliers of gneiss, probably of Lewisian age, that are intercalated among the granulitic Eastern schists are specially prominent on the western slope of the ridge east of Loch Eireboll, between the Kyle of Tongue and the River Borgie in the north of Sutherland, and between Loch Carron and Loch Alsh in the south of Ross-shire.

The granular hornblende- and biotite-gneisses between Tongue and the River Borgie resemble the corresponding types in the undisturbed Lewisian gneiss of the western area; but certain granulitic gneisses — as, for example, those which occur to the south-west of the village of Tongue in the direction of Lochan Hacoin and Ribigill — are more closely allied to the rocks which occur in the pre-Torridonian shear-zones.

In the course of the survey of the Eireboll and Tongue area, it was inferred that the relations of the Moine-schists to the gneiss inliers were determined by the post-Cambrian movements, and that the original structures and stratigraphical connexions of the rocks had been more or less completely masked by these movements. More recent work, however, between Stromeferry and Loch Alsh has led Dr. Peach to the belief that the Moine-schists in that district rest unconformably on gneisses of Lewisian type. He has found what he regards as a conglomerate locally developed at the base of the Moine-schists and overlain by a definite order of succession among the schists analogous to that in the Diabaig group of the Torridon Sandstone. (Chapter 38)

In connection with this view of the stratigraphical relations of the Eastern Schists, it should be mentioned here that, in the district between Stromeferry and Loch Alsh and also in Sleat, evidence has been obtained of the breaking down of the structures of the siliceous schists close to the Moine thrust-plane. It would thus appear that at least some of these rocks existed as crystalline schists before they had reached their present position. It may be further noted that a band of what is obviously a crush-conglomerate occurs in Balmacara Bay within the belt of Lewisian gneiss east of the great Moine displacement.

A striking characteristic of the Eastern schists is presented by the double system of folding which they possess. One system has a N.N.E. and S.S.W. strike, the inclination of the axial planes being E.S.E., thus harmonising with the strike and direction of dip of the Moine thrust-plane and of the divisional planes of the mylonised rocks in association with that displacement. This plication may be regarded as an obvious accompaniment of the movement of the thrust masses in a W.N.W. direction. The other system strikes generally W.N.W. and E.S.E. as if produced by forces acting at right angles to this trend. On looking at an escarpment of Moine-schists, the observer sees the ends of a series of folds, the axes of which run W.N.W. or north-west, lying along the inclined foliation-planes. Hence arises what might be termed "mullion" structure — that is, the production of a series of rods trending towards W.N.W. or north-west. This structure is admirably illustrated by the quartzite-rods of Beinn Thutaig (1340 feet) in the Moine-schist area east of the mouth of Loch Eireboll. (Chapter 41) It frequently happens that ridging-up has taken place along these axial lines, and that the divisional planes dip towards N.N.E. and S.S.W., the pitch of the folds being towards E.S.E. This second system of folding is to be regarded as one of the structures that have resulted from the post-Cambrian movements.

One final important feature in the stratigraphical relations of the Eastern schists remains to be noted. In the Durness district they are superimposed on the highest surviving sub-division of the Cambrian series; elsewhere they may be found resting on any formation among the displaced masses, including the thrust Lewisian gneiss, while in some places they have been driven completely across the belt of complicated ground, so as to lie on the undisturbed Cambrian strata further west.