

XIV. *The Origin of the Andalusite-Schists of Aberdeenshire.*

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PERHAPS the most difficult question in the science of Geology at present, is the explanation of the origin of the metamorphic crystalline rocks which occupy large areas on the surface of the globe. These rocks have been generally regarded as having undergone a vast amount of change in lithological character, to which the term metamorphism has been applied. By local or contact metamorphism is meant the transformation which has been effected in ordinary sedimentary strata by the intrusion of igneous rocks, the extent of which depends on the relative size of the intrusive mass. Where a thin sheet of dolerite has been injected amongst Carboniferous strata, which is of common occurrence in the Scotch coalfields, the coal seam is frequently converted into anthracite. Where a large mass of granite has been intruded among Silurian rocks, as is the case in the south of Scotland, then the local metamorphism occurs on a larger scale. In the belt of strata encircling the granite masses in Galloway it is possible to trace the gradual passage of the greywackes, flagstones and shales, into quartzites, argillites and mica-schists, while the fossiliferous black shales become so altered within two miles of the granite that all traces of the graptolites are destroyed. The origin of this local metamorphism is therefore surrounded with little difficulty. It is different, however, with regional metamorphism. This term, which was first used by Daubrée, is intended to refer to those wide tracts of country which are wholly or mainly occupied by stratified crystalline rocks, such as gneiss, mica-schists, and quartzites. Various theories have been advanced in order to account for the origin of these crystalline rocks. By many geologists they are believed to be the altered representatives of ordinary sedimentary deposits, the nature and extent of the change being determined in a great measure by the chemical composition of the original sediment. This theory has been advocated by Bischof, Rose, Haidinger, Dana, and Sorby. An explanation has also been advanced which ascribes many of the metamorphic rocks to chemical precipitation.

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The advocates of this theory maintain that the chemical ingredients necessary to form the various kinds of schist were held in solution and precipitated as sediments on the sea floor. The minerals now found in these schists crystallised during this sedimentation, and cannot be regarded as of subsequent origin. One of the ablest advocates of this theory is Dr. Sterry Hunt, and it has been supported with certain modifications by Gumbel, Delesse, and Scheerer.

The object of this brief communication is to show that the phenomena presented by the clay-slates and andalusite-schists of Aberdeenshire are quite at variance with the latter hypothesis. The clay-slate series, which is admirably displayed on the coast-line between Macduff and Gamrie, consists of well-bedded flags and shales, with occasional bands of quartzose grit and fine conglomerate. These beds cover a belt of country from eight to ten miles broad, stretching south-westwards from the sea-coast by the Culsalmond, Foudland and Kirkney Hills to the high grounds of Aberdeenshire. Over a large part of this tract the strata are nearly as unaltered as many of the Silurian rocks of the south of Scotland; indeed no one who is familiar with the appearances presented by sedimentary rocks could possibly doubt the sedimentary origin of the clay-slate series. Cleavage is more or less developed in many of the flags and shales, and in certain areas they are true slates.

On both sides of this belt of argillaceous strata there are zones of andalusite-schist, which stretch far into the country from the coast. At various points along the boundary lines between the clay-slates and the andalusite-schists it is possible to trace an intermediate zone of knotted schists, which are analogous to the rocks termed *Knotenschiefer* by the Germans. The detailed microscopic description of these different types of rock will be published at a subsequent date; but from a careful examination of a number of microscopic sections, it is clear that there is a gradual passage from the one to the other. In the rudimentary stage a rude foliation is developed, the quartz and mica being arranged in lines more or less distinct. The ordinary clay-slate merges at this stage into a slaty mica-schist. To this succeeds more perfect foliation, with the development of extremely minute ovoid knots or concretions, which under the microscope present few appreciable differences from the surrounding matrix. From the microscopic evidence it seems clear that they are formed by the segregation of portion of the matrix. Sometimes the knots are surrounded with a well-marked border or periphery, while again in other examples no border is visible. In the more advanced stages of alteration the matrix becomes more coarsely crystalline, the wavy outline of the mica-schist

being very apparent. There are two varieties of mica present, a brown, and a pale greenish coloured variety; the former of which exhibits marked dichroism. These are arranged in close bands with intervening quartz grains. The nodular segregations present certain differences from the surrounding matrix. They consist of an extremely fine-grained substance which has little action on polarised light, with some recognisable grains of quartz and mica. Along with these are abundant minute specks of a black substance resembling magnetite, which is also distributed throughout the rock. In the last stage of alteration the perfect rhombic prism of andalusite is observable in the soft mica-schist. Frequently the perfect prisms are associated with the knots in the same specimen, while in others the schist is studded all over with regular prisms. These *knotenschiefer* occupy extensive areas in the county, and present features of great interest. The gradual passage from the clay slates, which are truly sedimentary deposits, through the *knotenschiefer* into the andalusite-schists, seems to me to be quite at variance with the hypothesis of chemical precipitation advocated by Dr. Sterry Hunt; while it is satisfactorily explained by the theory of regional metamorphism established by Bischof.