【国外研修報告】

Basaltic lava flows and basalt plateau at the northernmost area in Northern Ireland

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北アイルランド最北部における玄武岩質溶岩流と玄武岩高原

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Abstract: Basaltic lava flows are widely distributed throughout the northeast area in Northern Ireland. They form the spectacular Giant's Causeway with hexagonal columns of basalt. And also they form clear geomorphological plane of basalt plateau which is from 80m to 100m above sea level. It is able to recognize that there were a few cycles of the basic volcanic activities which were between about 60Ma and about 55Ma.

Keywords: basaltic lava, basalt plateau, cooling joint, hexagonal column

1. Introduction

Many kind of sedimentary rocks (Palaeozoic, Mesozoic and Cenozoic formations), igneous rocks (intrusive and volcanic) and metamorphic rocks (schist, gneiss and other meta-sedimentary rocks) are widely distributed over Ireland. The two main rocks are Carboniferous limestone in the central area of Ireland and basaltic rock in Northern Ireland. Especially the Giant's Causeway region where basalt with polygonal form of the columns is distributed widely is registered into the World Heritage of UNESCO. The seashore of Giant's Causeway is introduced to the cover of the fourth edition of *Holmes' Principles of Physical Geology* which is a very famous and traditional textbook about geology.

According to the observation of rocks and landform in the field, a few kind of geological maps of Ireland and some materials about geology in Northern Ireland, some features of the basaltic rock, basalt plateau and polygonal form of the columns which are cooling joints of basalt at the northernmost area in Ireland are introduced in this report.

2. Geological and geomorphologic background

About sixty million years ago the northern area in Ireland was subject to intense volcanic activity, when highly fluid molten rock was forced up through fissures in the chalk bed to form an extensive lava plateau. Great thicknesses of essentially horizontal flows of plateau basalt were erupted from fissure volcanoes in the established Mesozoic basin.

There were three periods of volcanic activity which resulted in the lava flows, known as the Lower Basalt Formation, Inter-basalt Formation and Upper Basalt Formation. Within the lava group there are very few examples of sedimentary deposits intervening between the basalt lava flows.

The stepped effect is caused by the fact that each successive lava flow has a vesicular top full of gas babble holes and weathers back more easily. They are horizontal or gently inclined and form distinctive flat hills with stepped sides. The dramatic cliff like edge of the plateau forms the Causeway coastline. The larger fissures, through which the lava flowed, can be clearly seen as bands of dark rock which cut down the cliff faces and jut out to sea.

There are many kinds of dykes such as dyke swarms, sill, cone sheets, and ring dykes at the area along the northern shore in Ireland.

3. Stratigraphy

There is about 10Ma time gap between the end of deposition of the Cretaceous white chalk with flints and the first extrusion of basalt lava at Palaeocene in the northern region of Ireland. The unconformity between the lava flow and the basement of the Cretaceous

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formation is exposed at the northern end part of the plateau in Ireland. The earliest sediments above the chalk is the formation of clay and flints which had masked the river valleys and karstic scenery of the gently rolling landscape. Such sedimentary formations are overlain by basaltic lava flows.

The earliest evidence of explosive volcanism at the base of the lava in this area is vent agglomerates, ash-fall deposits (layers of pyroclastic tuff) and small volcanic cones that resulted from localized, explosive activity and were followed by fissure eruptions of olivine tholeiite lavas. Chalky and basaltic tuff which have a thickness of about 60m occur at the base and in lower levels of the Lower Basalt Formation.

Between episodes of eruptions red laterite which is iron rich soils developed on top of the flows and these contain plant remains of Tertiary age.

4. Cooling joints

The six-sided columns are the result of the perfect cooling of a basalt lava. As it cooled and hardened, cracks or joints formed in a perfect mathematical pattern. The rapidly cooling lava contract and variations in the cooling rate result in the famous columnar structure. It is common that there are some pentagonal columns in the aggregation of many hexagonal columns which form colonnade. Only the central part of the flow shows these columns. The tops of the lavas are usually broken and slaggy with gas bubble holes which are vesicles filled with minerals which have amygdaloidal structure. The basalt lavas and sills of various ages show such structures in this area.

5. Feature of basalt and occurrence

Multi-stairs-like landform of basalt at rock seashore and cliff can be seen in the Photograph 1. It shows the basaltic lava-flows at the northernmost tip part of Ireland which is a distant view of Giant's Causeway at the north end of basalt plateau in Northern Ireland which faces the North Sea.

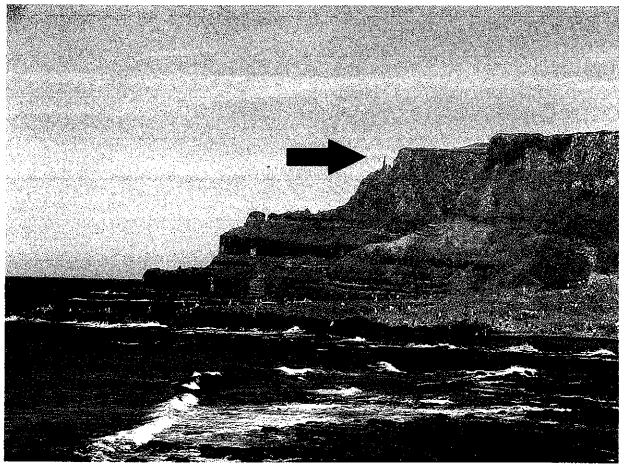
Two flows of tholeiitic basalt lava overlie the reddish brown Inter Basaltic Formation which is able to recognize as the horizontal narrow zone with a little dark gray in Photographs 1 and 2. The lower part of the cliff is formed of five flows of the Lower Basalt Formation in this region. These older lavas below the foot path are not columnar.

The end of the plane of basalt plateau is recognized very clearly, the upper geomorphic surface is about 80m above sea level. The foot path, at the middle level in Photograph 1 or at the lower level in Photograph 2, is corresponding with the highly weathered zone of basalt.

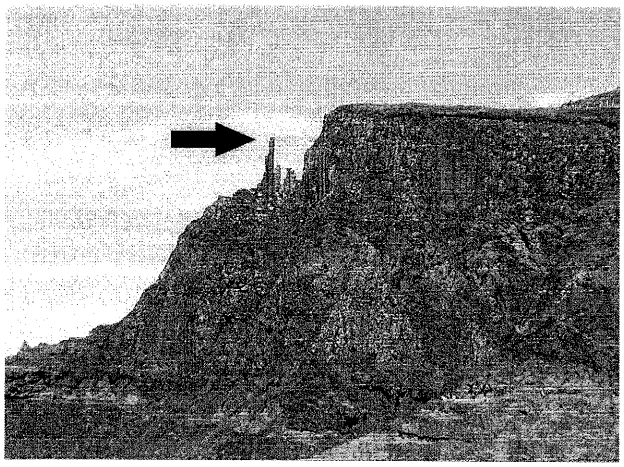
The conspicuous pillar of the rock similar to a chimney is shown by the arrow in Photograph 1 and Photograph 2. The big chimney is next to the end of the plateau which is about 80m above sea level. This situation is also shown in Photographs 3. The height of the highest chimney is from six to seven meters. Such pillars which exist as a result of exquisite balance have been made by physical weathering of basalt and erosion of the plateau for long time after forming the basalt plateau. It is able to recognize that there are many pre-pillars state of basalt on the rock face of the cliff showing Photograph 3.

The Inter-basalt Formation normally consists of orange-red lateritic palaeosol which is from 10 to 15m in thickness, but also in parts may still retain relict igneous and mineral textures in the purplish red or dark red, deeply weathered basalt and is referred to as lithomarge. Alteration has resulted in an iron-rich latelite composed mainly of the secondary clay mineral kaolinite. The main clay mineral is gibbsite and aluminum content as Al_2O_3 is at least 50%. But bauxite or aluminous laterite is more restricted in distribution. Such occurrences in this region are able to be recognized along the foot path which is along the middle level of the cliff in Photograph 1 or the lower level of the cliff in Photograph 2.

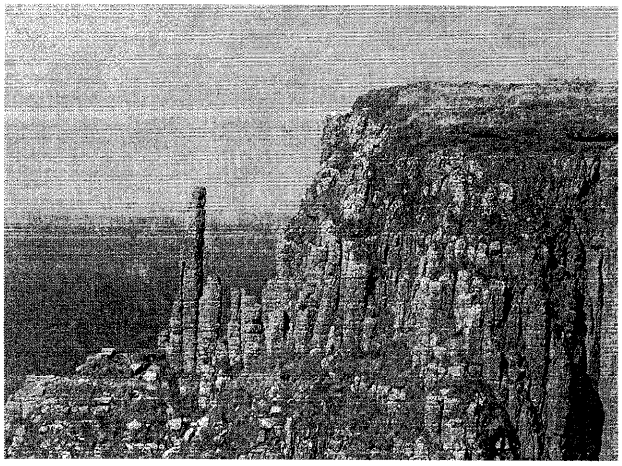
Hexagonal chimneys of basalt have been formed by physical weathering and erosion of basalt plateau. The chimneys will be destroyed in not distant future.



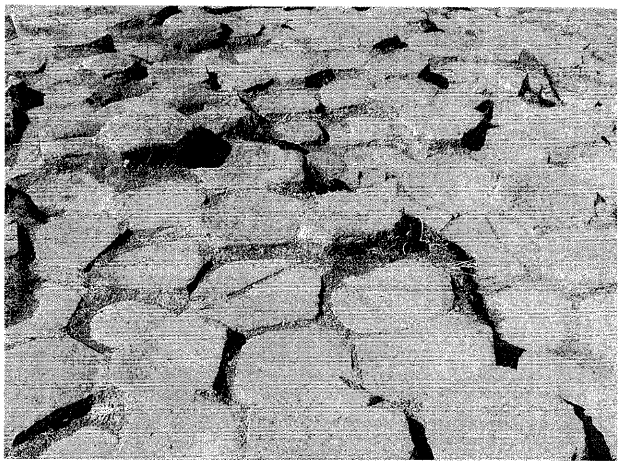
Photograph 1.
The jut of the basalt plateau toward the North Sea.
The arrow points out the chimney of basalt. The cliff of basalt shows a step-like landform.



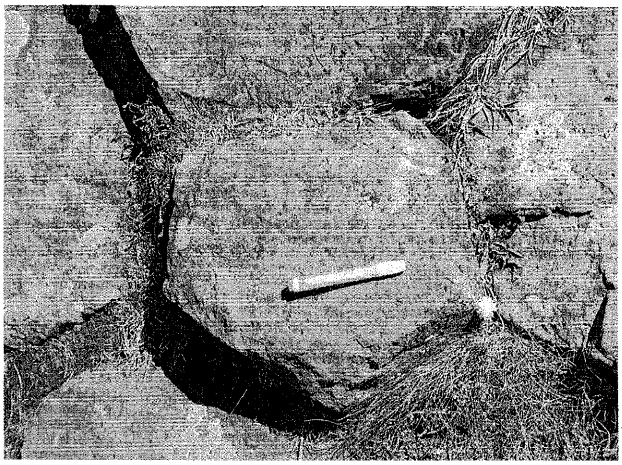
Photograph 2. The upper part of Photograph 1.
The surface of the basalt plateau is about 80m above sea level. The horizontal pale gray belt at the bottom is a foot path belong Inter-basalt Formation. The arrow points out the chimney of basalt. (cf. Photograph 1)



Photograph 3. A close-up of the conspicuous pillars of basalt which are a chimney-like next to the end of the basalt plateau. (cf. the arrow in Photographs 1 and 2).
The highest pillar is about 6～7m in height. The basalt cliff is in a weathering process and erosion.



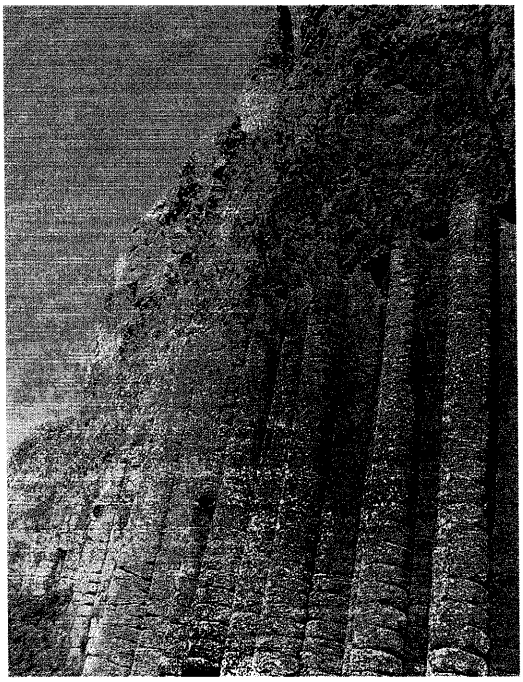
Photograph 4. The surface of rock seashore formed by polygonal basalt columns.
Most of columns are hexagonal. There is variation in shape and size of a column. The diameters of them are range from about 30cm to about 60cm.



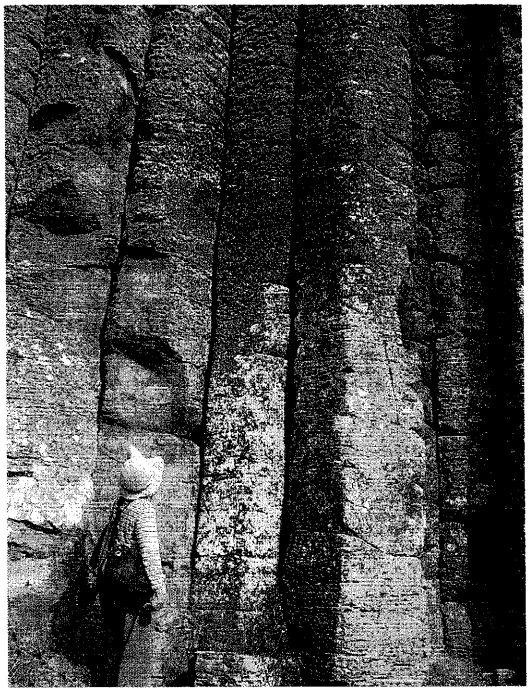
Photograph 5. An example of a pentagonal column of basalt in the aggregation of hexagonal columns.
Many other columns are regularly hexagonal at seashore in Giant's Causeway. The pencil on the rock is about 15cm in length.

Photograph 4 and Photograph 5 show that the columns are mainly hexagonal though there are some with up to eight sides at the seashore in Giant's Causeway region. And they show the polygonal jointing in the *colonnade* portion of a thick basalt lava flow. Cracks nucleate at points on surfaces of uniform temperature which is so-called isothermal surfaces. Three-pronged cracks at about 120 degrees tend to develop, intersecting to form polygonal columns, often approaching regular hexagonal columns.

Photograph 6 is upper sequence of Photograph 7. Photograph 6 shows a part of cliffs at the north end of the basalt plateau. The under half of the cliff is composed of basalt with the perfect six-sided columns which are typical cooling joints in basalt. Such perfect hexagonal columns are the results of cooling under perfectly stable conditions in the central part of lavas. The less regularly jointed upper sequence is where the lavas were filled with escaping gases, giving a vesicular slaggy texture.



Photograph 6. A central part of the basalt cliff shown in Photograph 1.
The upper part is slaggy and the lower part is composed of perfect hexagonal columns.



Photograph 7. The huge hexagonal columns of basalt.
The upper part of the columns follows the lower part of Photograph 6. The diameters of hexagonal columns are longer than those in Photograph 5.

The rapidly cooling lava contract and variations in the cooling rate result in the common columnar structure. There are some pentagonal columns and other polygonal columns in the aggregation of many hexagonal columns which form colonnade. The central part of the basaltic lava flow shows such columns. The most of upper parts of the lavas are usually broken and slaggy with gas bubble holes which are vesicles filled with minerals which have amygdaloidal structure. Such structures can be seen in the basalt lavas and sills of various ages.

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