Terminology and History of Investigations

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Terminology

The OSLO REGION is a geographic term referring to an area of about 100,000 km^2 in which the rocks are younger than the surrounding Precambrian terrain, and where the city of Oslo has a central situation. Synonyms are OSLOFELTET (Norwegian) and das OSLOGEBIET (German). In a north-south direction its length is 200 km, reaching from the outer southern part of the Oslofjord to the Lake Mjøsa district in the north. Its width varies between 35 km and 65 km.

The Oslo Region contains a sedimentary sequence of Cambrian, Ordovician and Silurian rocks as well as sediments and plutonic and volcanic rocks of Permian age (possible also late Carboniferous and Triassic age?). It is surrounded by Precambrian rocks, except in the north where the region adjoins the complex Caledonian nappe region and the late Precambrian (Eocambrian or Vendian) to early Cambrian 'sparagmite' sediments (the Hedmark Group). The northern limit of the Oslo Region is not well defined. Our palaeontologists include the Cambro–Silurian rocks on both sides of Lake Mjøsa. The petrologists consider the isolated small area of Permian (Triassic?) rhomb porphyry lava and sandstone at Brumunddal near Lake Mjøsa as a part of the Oslo Region, even though the nearest Permian plutonic rocks are found 30 km further south; Precambrian and Cambro–Silurian rocks are exposed in between. Structurally the Brumunddal area is clearly a part of the block fault system of the Oslo Region.

The OSLO DISTRICT or OSLO AREA should be considered as non-genetic, purely geographic terms referring to the urban area of Oslo and its immediate vicinity.

The above-mentioned terms, and several others indicated below, have been used by geologists during more than a century both as non-genetic and as genetic terms. As the name of the capital until 1924 was Christiania (Kristiania), the terms *das Kristianiagebiet* (German), *Kristianiafeltet* (Norwegian), *Christiania-territoriet* (Norwegian) and das *Christiania Übergangs-territorium* (German) (transition territory) were in common use until then. The term '*das Christiania Silurbecken*' (basin) was used in the middle of the last century to mean the area in which Cambrian, Ordovician and Silurian sediments were deposited.

The OSLO PROVINCE or more completely the 'Oslo petrographic province' refers to the various igneous rocks in the Oslo region, derived from one or several, common, hypothetical parent magmas. "Die Eruptivgesteine des Oslo-

gebietes" and the "*Igneous Rock Complex of the Oslo Region*" are the titles of two monograph series. The first mentioned series, in seven volumes, was written in German by W. C. Brøgger from 1894 to 1933; the second started in 1943 as a continuation of the first one, with the title translated into English. This new series now comprises 25 numbers written by several authors, in English.

The term OSLO GRABEN is clearly genetic. Structurally we have here a good example of a graben, even though master faults are found only in the SE and NW, and the whole area is intersected by smaller faults in a rather complicated pattern. The present topographic surface represents a deep section through the graben. As areas of exposed Precambrian rocks are included in the graben, a difference is established between the designations 'Oslo Region' and 'Oslo Graben'. Geomorphologically only minor parts of the Oslo Region show typical graben features.

The OSLO RIFT (zone) refers to the more extensive fracture zone active in Permian time, of which the Oslo Graben is only a part. Its extension to the north is uncertain since the age of the major faults is not defined more accurately than 'post-Caledonian'. It may be noted that many of the Permian faults wer already established as fractures in Precambrian time and may still be active. The Oslo rift zone extends southwestward beneath the Skagerrak at least as far as Kristiansand.

Igneous rocks of the Oslo Province type are also found in dykes, explosion breccias, etc., far outside the Oslo Region.

The subdivision of the Cambro–Silurian sedimentary sequence in the Oslo Region is dealt with in the next chapter, by G. Henningsmoen, and the special Oslo Province terminology for the igneous rocks is described in the contribution, "Petrology of the plutonic rocks" (Neumann, this vol.).

The history of investigation

The study of the Oslo Region bears a close connection to the geological departments of Oslo University (founded in 1811). Their precursor — the first mining school in the world, the Bergseminar at Kongsberg (1757–1814) (famous for its native silver mines) — did not focus investigations on the Oslo Region except from a general mining point of view. Its last lecturer was *J. Esmark* (1763–1839) who became the first Oslo University professor in geology (1814). Esmark, after extensive travels abroad and in the Oslo Region, had a good knowledge of some of the peculiarities of the region by the time the famous German geologist *Leopold von Buch* (1774–1853) visited the town in 1806 and 1808. Through v. Buch's report the 'Christiania Übergangsterritorium' gained a world-wide reputation. The 'Übergang' (transition) refers to theories advanced in the conflict between neptunists and plutonists. Being educated in Werner's neptunistic school, v. Buch was surprised to see granites within layerd rocks; to him they should exist only at the base of the sediments. The name *rhomb porphyry* was introduced by v. Buch (1810) for a dyke rock

found at the harbour in Oslo (Tyveholmen), but he extended the term to include also the rhomb porphyry lavas.

B. M. Keilhau (1797–1858) became University professor in 1834, after Esmark. In his three-volume monograph 'Gæa Norwegia' (1838, 1844, 1850) he gives detailed and regional descriptions in German, and maps covering the whole country. His Oslo Region map and the accompanying text (1838) are extremely rich in good field data. He explained the change from shale to granite (syenite) by his own 'transmutation theory', a process corresponding to pseudomorphism among minerals. He spoke (1838) of a 'granitification process', but refused to take into account 'extraordinary heat, this great factor of the plutonists'. What he saw in the field were the metamorphic hornfels zones around deep-seated rocks, as well as semi-digested remnants of sediments in the same rocks. Even though his theory was easily rejected by contemporaneous German geologists, mainly on chemical grounds, he fought for it throughout his life.

Several famous European geologists visited the Oslo Region in these early days as well as in the years to follow. The German geologist *F. L. Hausmann* was here in 1806, and *C. Fr. Naumann* in 1821 and 1822. *Charles Lyell,* who came here for the first time in 1837, was much impressed by the clear manner in which granite intruded fossiliferous 'transitionals' near Oslo, (see Holtedahl 1963). Many of the visitors published reports which received a wider distribution than the Norwegian ones, and it is now often difficult to find out how much these visitors learned from their Norwegian colleagues and excursion leaders, and to what extent the visitors brought in new ideas. There is no doubt, however, that the geology of the Oslo Region and especially of the district near Oslo, has played an important role for the advancement of basic concepts in geology. Already more than 100 years ago Keilhau described Grefsenåsen (one of the hills surrounding the town) as 'a mountain, the classical value of which should never be forgotten in the history of geognosy, for it was here it was first seen that syenite (granite) could be younger than fossiliferous limestone'.

Th. Kjerulf (1825—1888), Keilhau's successor as professor obtained first-hand knowledge in modern quantitative analytical chemistry, especially through his studies in Heidelberg with R. Bunsen. Already in 1857, the year before he became professor, he reviewed and rejected former theories on the formation of the igneous rocks of the Oslo Region, and his presentation of new views seems sound even today. His 1855 publication 'Das Christiania Silurbecken'

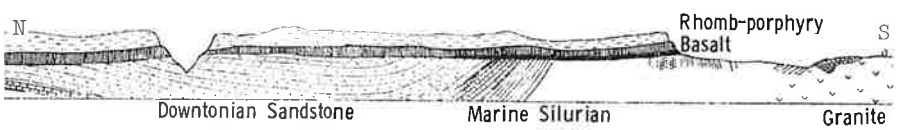

Fig. 1. Section along the Lier valley to the east side of Tyrifjord. Permian sediments below the lavas are not marked. A Permian sill of quartz porphyry (marked in black) is locally found below the lavas (after Kjerulf 1879, Holtedahl et al. 1934).

contains detailed stratigraphic tables of the Cambro-Silurian sequence and description of selected igneous rocks based on rock analyses, as well as block diagrams of high quality. A series of publications that followed shows that he was well aware of the angular unconformity between the folded Cambro-Silurian sediments and the lavas above, which at that time were regarded as Devonian in age (Fig. 1). This fact was rejected, until 1930, by his pupil and successor as professor, W. C. Brøgger. According to Kjerulf the plutonic masses were formed through assimilation of crustal material by a granite (syenite) magma. He was one of the founders of the Norwegian Geological Survey (1857) and as its first director (1857—1888) he published a series of geological maps, some of which cover parts of the Oslo Region on a scale of 1 : 100,000.

Professor *W. C. Brøgger* (1851–1940) will always be the great name in the history of geological research in the Oslo Region. His many hundred publications, mostly in German, were written during a period of more than 60 years; about 60 of these papers concern this region. They cover subjects in mineralogy, petrology, structural geology, stratigraphy, palaeontology, glacial (Quaternary) geology and even archeology. His first training was in zoology and Darwinism had a strong stimulating influence on his views. He thus naturally advanced very far in the study of genetic relationships in mineralogy and petrology and built up a special rock nomenclature with groups and families including more than 50 new rock names, of which 10–20 are still in daily use.

His co-worker for 20 years (up to 1933) in the mapping of the Oslo Region was professor *J. Schetelig* (1875–1935) whose name is easily forgotten in the shadow of Brøgger. Much of Schetelig's work is found in the papers of his master. He published very little on the Oslo Region himself, and much was lost on his death.

Brøgger had the opportunity in 1875–78, in addition to field work in the Oslo Region and elsewhere in Norway, to study abroad; in Germany he came in close contact and co-operation with Paul Groth and H. Rosenbusch. His first major contribution both to Cambro–Ordovician stratigraphy, and to igneous petrology and metamorphism was 'Die silurischen Etagen 2 und 3' (1882). In the following years (1883 and 1886) he published on the structural geology of the south-western part of the Oslo Region (Langesund–Skien) and of the whole Oslofjord region. Precambrian and younger fault breccias, marking displacements locally exceeding 1000 m, and their age relations to the intrusive dykes, are given special consideration in these papers as well as in a later one (1900) on the fault-controlled rhomb porphyry conglomerates at the south-eastern side of the Oslofjord.

When reading the papers of Brøgger one sees a year-to-year development of his views on a variety of questions concerning the Oslo Region. He believed he had proved that all the igneous rocks of the region had the same origin; a basaltic magma. Originally he assumed that the basaltic magma, which gave rise to the first basalt (his essexite-lava) and the corresponding subvolcanic Oslo-essexite (his essexite), changed gradually and completely to more acid

compositions by fractional crystallization. So convinced was he of this that when one of his field assistants, the later professor in geography W. Werenskiold, reported a basalt flow between the more acid rhomb porphyry lavas, Brøgger sent him out again with the command to change his mind by revised mapping. In his later publications, when speaking of the young diabase dykes, Brøgger discusses the possibility of a reversion to a local basic magma by some process of differentiation, or whether a basic magma may have existed at the base of a large magma chamber during the entire intrusion period. Brøgger could see no theoretical or field evidence for assimilation processes.

Cauldrons were not fully accepted by Brøgger, although as early as 1890 he described some of them as 'laccoliths of cauldron shape made up of concentric ringshaped intrusions'. We can see that Schetelig understood their mechanism, at least by 1916, when he described the Bærum cauldron. (The term 'cauldron subsidences' was introduced in 1909 by Clough, Maufe and Bailey for the Glen Coe cauldron in Scotland.) In 1933 Brøgger wrote of 'circular bounded intrusions' and single and multiple laccoliths; 'nordmarkite intrusions along caldera-boundaries' appear in the legend (1919) to some of the Brøgger-Schetelig maps (1 : 100,000).

Brøgger's masterpiece is the 1890 monograph published in Groth's Zeitschrift f. Kristallographie No. 16, 'The minerals of the syenite-pegmatite dykes of south Norway's augite- and nepheline syenite', written in German. Here he presents the main points in the geological history of the entire Oslo Region and the systematics of its igneous rocks, and defines new rock names such as larvikite, lardalite, nordmarkite, akerite and ekerite. The main part of the volume is a splendid description of the pegmatite minerals, of which about 20 were new. The monograph appeared in the same year as his appointment to the chair as professor in Oslo after a nine-year period as professor in Stockholm. He started his series of monographs 'Eruptivgesteine des Kristiania (Oslo) Gebietes' in 1894, and the last one (No. 7, 1933) contains a list of 331 rock analyses together with a general resumé and a geological map (scale 1 : 250,000) of the Kristiania region (printed 1923) based upon the Brøgger-Schetelig 1 : 100,000 maps (1917–26).

Professor *J. H. L. Vogt* (1858–1932) was professor at the University of Oslo from 1886, and from 1912 professor at the new Technical University of Trondheim. He is known for his pioneer study of crystalline slags and for his geochemical and ore-geology studies. (Beyslag, Krusch, Vogt: Die Lagerstätten der nützbaren Mineralen und Gesteine I–II–III (1910 and later) and Vogt (1914) Silikatsmeltzlösungen I–II). Many of his basic field observations come from the Oslo region.

V. M. Goldschmidt (1888–1947), professor at the University of Oslo from 1914, developed in his doctoral thesis 'Die Kontaktmetamorphose im Kirstiania Gebiete» of 1911 the concept of ten classes of hornfels. Each has its characteristic mineral associations depending on the chemical composition of the original rock, and all formed under low pressure, high temperature conditions. His work included extensive field studies of mineral deposits, and petrographic

studies. Goldschmidt is perhaps best known for his 'Geochemical laws for the distribution of elements (1–9)', and the posthumous textbook 'Geochemistry' (1954).

The first professor in palæontology at the University of Oslo was *J. Kiær* (1869–1931) appointed in 1909. One of his principal works is the monograph 'Das Obersilur im Kristiania-gebiete' (1906).

The German professor *H. Cloos* visited the Oslo region on the invitation of Brøgger and Goldschmidt in 1923. In 1925 he had a field course for his students in the Oslofjord region, where they mapped faults and fold structures in certain areas in very great detail. Some results were published (Cloos 1928, 1949) but most of the maps, etc., remain unpublished in Bonn, Germany.

With the permission of Brøgger, and after long experience in the study of the Cambro-Silurian sequence, Professor *O. Holtedahl* (1885–1975), appointed professor in 1920, started a new period in the systematic study of the Oslo Region in 1933. One of the reasons for this was the need for a new excursion map of Oslo and the surrounding district; another was the new perspective opened by the finding of Permian fossils at the base of the lava sequence (on a student excursion led by Holtedahl in 1931). Holtedahl is best known for his investigations in many parts of Norway and the Arctic regions. His 'Norges Geologi' in two volumes (in Norwegian) appeared in 1953, and 'Geology of Norway', which he edited, came out in 1960 in connection with the International Geological Congress in Norden the same year.

Holtedahl and Professor Barth initiated the co-operation with Great Britain and the USA and began writing about the Oslo Region in English instead of German. Holtedahl's 1935 publication in American Journal of Science, 'Tectonic disturbances connected with plutonic bodies in the Oslo region», was a beginning, and was followed by a comprehensive guidebook for the Oslo Region by Holtedahl et al. for the 1934 field meeting of The British Geologists Association. Emphasis was placed on lava stratigraphy, emplacement of the plutonic rocks by overhead stoping and the formation of cauldrons. The monograph series 'Studies on the igneous rocks of the Oslo Region' was introduced by Holtedahl in 1943 with 'Some structural features of the district near Oslo' and followed by Professor T. F. W. Barth's 'Systematic petrography of the plutonic rocks' in 1945. The succeeding numbers have been written by a great number of authors. Even though we will not mention in this introduction the work done by geologists who are still living, exception is made here for the most important contributors, Professor C. Oftedahl (feldspars, lavas, cauldrons) and Dr. Egil Sæther (dyke rocks, the geology of Nordmarka, etc.). As noted earlier the series has now (1977) reached 25 numbers.

Excursions for Norwegian students and foreign geologists have a 150-year long tradition in Oslo. The first excursion guide was published by Kjerulf in 1865. For the same purpose Holtedahl and his pupils compiled a new bedrock map, scale 1:50,000, for Oslo and the surrounding district which was published

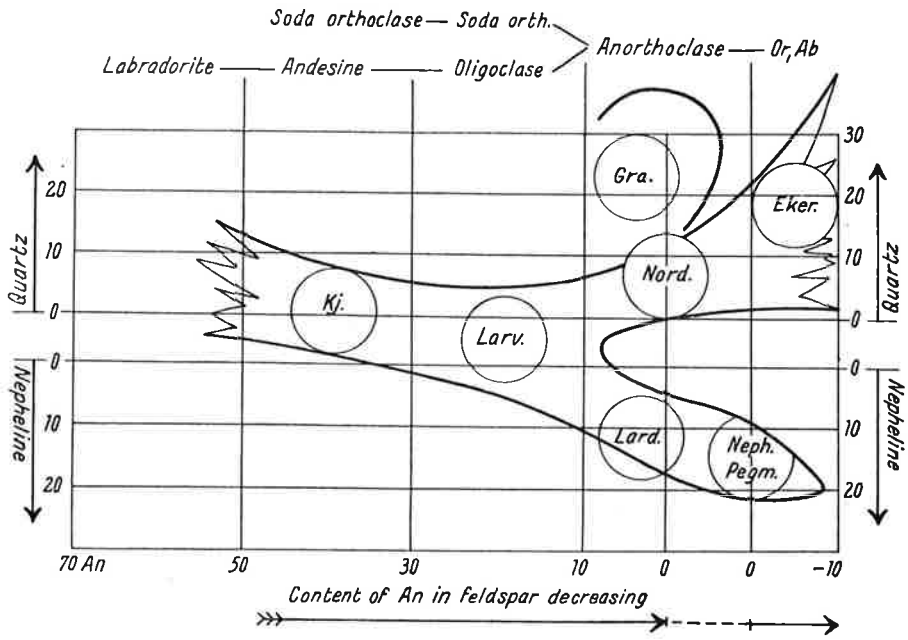

Fig. 2. 'Family Tree' showing the systematic position and mutual relationship of the principal Oslo rock-types (from Barth 1945a).

in 1952 together with excursion guides in English (1957 and 1966) and Norwegian (1955 and 1977).

Tom. F. W. Barth (1899–1971), professor at the University of Oslo from 1937, is probably best known through his textbooks 'Entstehung der Gesteine' (1939, Barth, Correns, Eskola), 'Theoretical Petrology' (1952) and 'Feldspars' (1970). Most of the present-day Oslo Region geologists regard him as their most important teacher. By a recalculation of Brøgger's analyses (1933) and the study of many of Brøgger's several thousand thin-sections, he re-evaluated the systematics of the igneous rock complex, distinguishing four principal rock series: A) Basic series (Oslo-essexite), B) Intermediate-acid series (kjelsåsite, larvikite, nordmakite, ekerite), C) Intermediate per-alkaline series (lardalite) and D) Acid series (granite). He postulated two sources of magma, one giving rise to the alkali basalt lavas and the subvolcanic Oslo-essexites, and the other giving birth to sialic rocks such as rhomb porphyry lavas and several bodies of plutonic rocks probably at shallow depth. The mineral reaction series in the rocks of categories B, C and D are shown in Fig. 2 (Barth 1945).

In his contribution 'Provenance of the Oslo magmas' (1954) he regarded the Permian Oslo graben as an active zone of degassing. In his view 'the emanations released by the general degassing of the Earth ascend along the main fissure zones in the Earth's crust. They carry enough energy to transfer the pre-existing rock prism into magma masses which, undisturbed by orogenic movements had time to differentiate in the liquid state by gravitation,

thereby generally producing alkalic rock types in the upper parts of the prism'. With all due respect for work done in the past by eminent geologists, a new generation has now taken over the study of the Oslo Region. Their viewpoints and results are included in the following introductory chapters and in the description of the excursions.