Excursion 5

Krokskogen Lava Area

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This excursion will go through the stratigraphical sequence in the Krokskogen lava plateau and the neighbouring cauldrons. Stops are at places where contacts between lava flows can be demonstrated. The detailed map-picture of the area exhibits a tectonic pattern with normal faults (often N–S striking) and with dyke swarms along the more prominent fractures. The environmental character of the interflow sediments can be studied (careful pebble investigations have not yet been undertaken). The cauldrons Øyangen, Svarten, Heggelia and Oppkuven are also visited during the excursion.

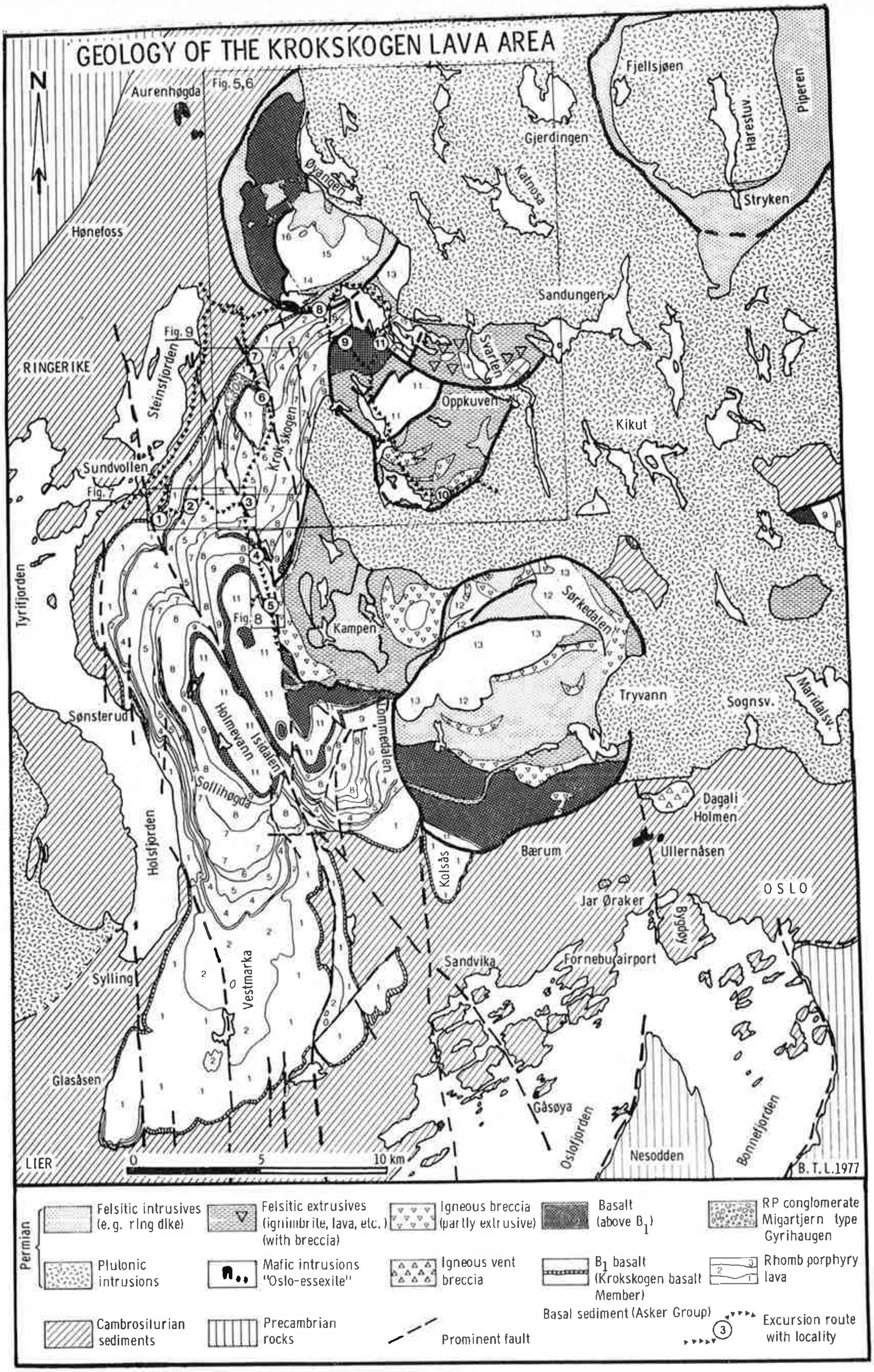
The aim of this excursion is to demonstrate some of the more important structural features as well as the rock-types, and to present problems in the relatively complicated volcano–tectonic history of the area. A warning must first be given: the area is currently being actively restudied, and in the descriptions no attempt has been made to separate the results (facts) from the interpretations (working hypotheses). (Both are preliminary and tentative, and more detailed studies are to be carried out in the future.)

The Krokskogen lava area, the second largest in the Oslo Region, covers about 400 km^2 and is situated just west of the city of Oslo in the central part of the Oslo graben (Fig. 1). In this area W. C. Brøgger and J. Schetelig around 1910 first worked out a lava stratigraphy for the Oslo Region. Their maps, on a scale 1:100 000, were published in 1917. Supplementary mapping has been undertaken by E. Sæther (1962) and in recent years by the author.

The Krokskogen lava area can be divided into two separate volcanological and tectonic units. In the west the *Krokskogen lava plateau*, and in the east a group of cauldrons: *Øyangen cauldron* (in the north), *Svarten*, *Heggelia* and *Oppkuven cauldrons*, and *Bærum cauldron* (in the south). (Fig. 1).

Northwest of the Bærum cauldron is an area of lava, felsite and breccia which could possibly represent a cauldron (Larsen 1975, Segalstad 1975). This has been named *Kampen cauldron* by Chr. Oftedahl (pers. comm. 1977) but the identification of this structure is still uncertain.

The general lava stratigraphy of the different lava areas in the Oslo Region is presented on page 58 (Ramberg & Larsen, this volume, Fig. 4). There the special location of the Krokskogen lava plateau and the nearby cauldrons is also discussed in the general tectonic context of the Oslo graben. More detailed stratigraphical columns for parts of the Krokskogen area are shown in Fig. 2. In the Krokskogen lava plateau the rhomb porphyry lavas make up about 85–90% of the total lava sequence. The rest consists of basalts of different types, with the addition of a single 2 m-thick ignimbrite flow of local occurrence. Inside the cauldrons the basalts and felsic volcanics are predominant, locally interfingering with stratigraphically young rhomb porphyry lavas.


GEOLOGY OF THE KROKSKOGEN LAVA AREA
N
Aurenhøgda
Fig. 5,6
Fjellsjøen
Piperen
Harestuv.
Gjerdingen
Øyangen
Katnosa
Stryken
Hønefoss
Sandungen
Fig. 9
RINGERIKE
Steinsfjorden
Svarten
Oppkuven
Krokskogen
Kikut
Sundvollen
Fig. 7
Tyrifjorden
Fig. 8
Kampen
Sørkedalen
Holmevann
Isidalen
Lommedalen
Tryvann
Sognsv.
Maridalsv.
Sønsterud
Sollihøgda
Dagali
Holmen
Bærum
Ullernåsen
Holsfjorden
Kolsås
Jar Øraker
OSLO
Bygdøy
Vestmarka
Sandvika
Fornebu airport
Sylling
Glasåsen
Gåsøya
Oslofjorden
Nesodden
Bonnefjorden
LIER
0
5
10 km
B. T. L. 1977
Permian
Felsitic intrusives (e.g. ring dike)
Felsitic extrusives (ignimbrite, lava, etc.) (with breccia)
Igneous breccia (partly extrusive)
Basalt (above B1)
RP conglomerate Migartjern type Gyrihaugen
Plutonic intrusions
Mafic intrusions "Oslo-essexite"
Igneous vent breccia
B1 basalt (Krokskogen basalt Member)
Rhomb porphyry lava
Basal sediment (Asker Group)
Cambrosilurian sediments
Precambrian rocks
Prominent fault
Excursion route with locality

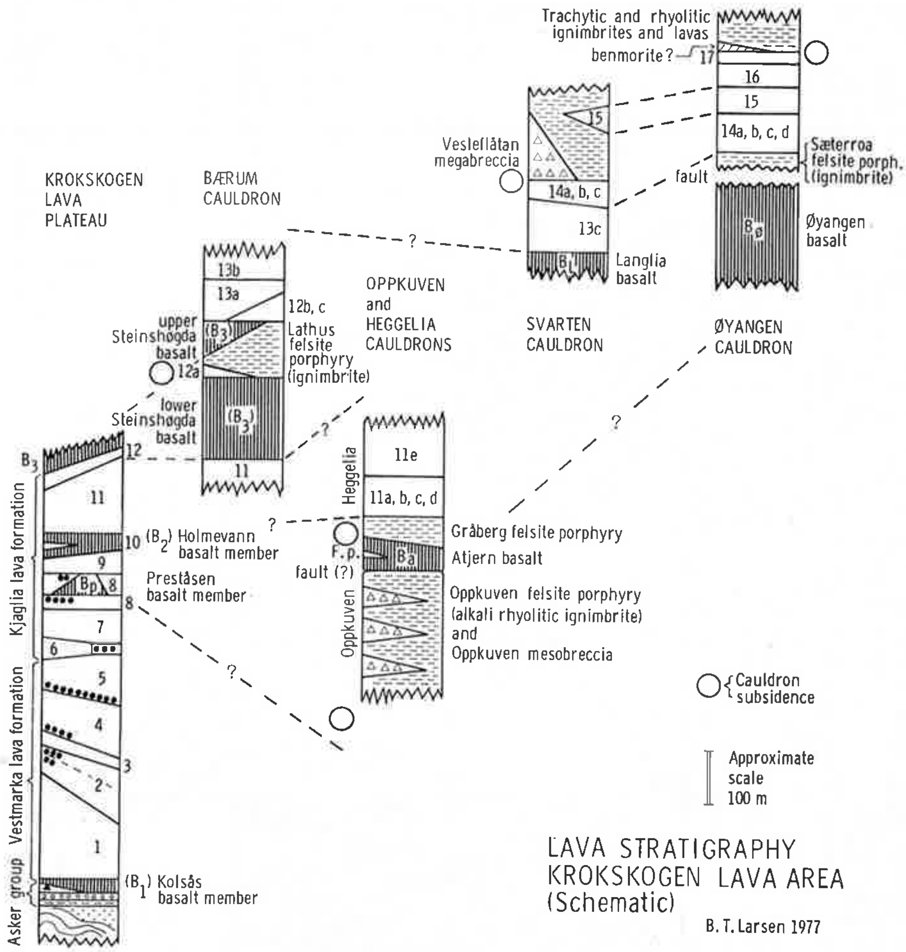


Fig. 2. Schematic lava stratigraphy, Krokskogen area. Data from Sæther (1962) and unpublished data from the author. Rhomb porphyry lavas indicated by figures corresponding to their No., 1 to 17. Approximate thickness of extrusives is indicated, although the basalt lavas high in the stratigraphy are too small relative to the RP-lavas. The possible time of cauldron subsidence of the different volcanoes is also indicated.

Rock-types

The *rhomb porphyry lavas* (RP) are intermediate in composition (Ramberg & Larsen, this volume, p. 60) with megacrysts of anorthoclase (or plagioclase) with crystal faces $\{110\}$, $\{1\bar{1}0\}$ and $\{20\bar{1}\}$ (Oftedahl 1948, Harnik 1969). Other minerals are clinopyroxene (microphenocrysts) and in the groundmass magnetite, apatite, alkali feldspar and pseudomorphs after (?)olivine. Based on variations in shape, size, composition and number of phenocrysts from one lava

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Fig. 1. Geological map of the Krokskogen area showing the Krokskogen lava plateau and the cauldrons. Excursion route and localities marked. Data from Brøgger & Schetelig (map 1917), Oftedahl (1952), Sæther (1962) and unpublished data from the author.

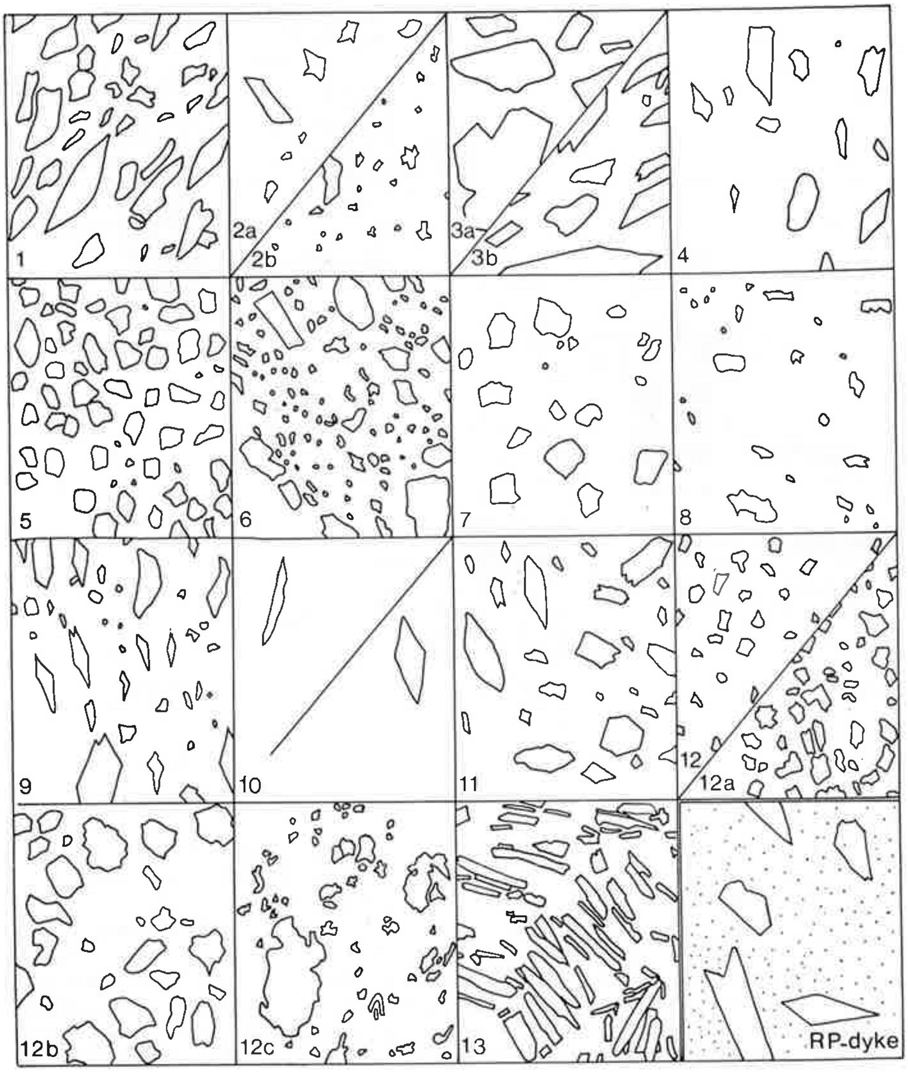

Fig. 3. Feldspar phenocryst patterns of the rhomb porphyry lava types of Krokskogen and the Tyveholmen dyke. Dons (1977), partly after Oftedahl (1952). 1 = RP_1, etc. Approximately ½ natural size.

flow to another (RP_1, RP_2, RP_3, etc.), it has been possible to work out a detailed lava stratigraphy for the area. Fig. 3 depicts the appearance of phenocrysts from the different rhomb porphyries at Krokskogen (Oftedahl 1952), and Fig. 4 shows some of the compositional differences in the RP phenocrysts after Harnik (1969), who found a rough compositional average for the phenocrysts to be $Or_{15}Ab_{75}An_{10}$. They are always highly zoned with Ca-rich cores and K-rich rims.

In the RP_{13}–RP_{14} stratigraphical unit (the so-called 'rectangular porphyry') are found the characteristic rectangular phenocrysts. This porphyry has a distinctly more basic composition than the normal RP lavas (Table 2, Ramberg

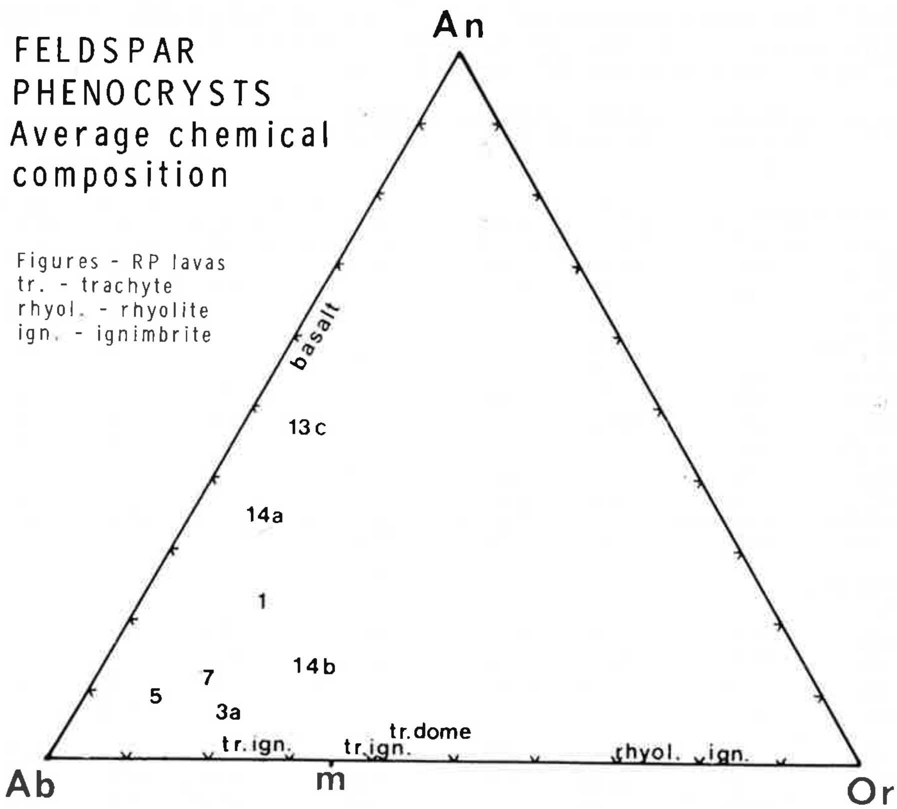

Fig. 4. Average chemical compositions of feldspar phenocrysts in rhomb porphyry lavas (partly from Harnik 1969), and in basalt, trachyte and rhyolites from the Øyangen cauldron.

& Larsen, this volume), as well as more basic feldspar phenocryst composition ($Or_{10}Ab_{45}An_{45}$).

Petrographically the *basalts* of the area are aphyric, plagioclase phyric, augite phyric or olivine (pseudomorph) phyric. Combinations of these also exist. Chemically they range from quartz tholeiitic (B_1 Kolsås basalt Member) to alkali olivine basalts, the latter predominating. Even basanitic types occur in the B_2 sequence (the Holmevann basalt Member). Alkali olivine basalts and olivine tholeiites dominate inside the cauldrons, and agglomeratic and tuffitic basalt types also occur. Basalt plots are shown in Ramberg & Larsen, this volume, Figs. 2 & 3. New chemical analysis of basaltic rocks from the northern Krokskogen area and the Øyangen syenite ring dyke are presented in Table 1.

The *felsic volcanics* (lavas, ignimbrites and tuffs) are both alkali rhyolitic and trachytic in composition (see Ramberg & Larsen, this volume, Table 2) with alkali feldspar phenocrysts. The age relations between the basalts and the felsic volcanics of the cauldrons, generally indicate that the basalts represent pre-caldera extrusions, forming huge basaltic central volcanoes. The felsic volcanics on the other hand formed during or after the caldera formation and represent caldera-filling material. Breccias are often genetically linked to the

Table 1. New chemical analyses of basalts from the northern Krokskogen area, and the Øyangen cauldron ring dyke. X.R.F. analyses, Na_2O by flame photometry. Norm calculations are on the basis of standard values for Fe_2O_3 (Fe_2O_3 $=TiO_2+1.5$) (Irvine & Baragar 1971). Analyst B. T. Larsen.

	Basalt Preståsen basalt	Basalt B_2	Hawaiite Frøysestykket	Basalt Gyrihaugen	Basalts Atjern basalt Member Heggelia cauldron			Mugearite Svarten cauldron	Syenite Ring dyke Øyangen cauldron
	K–1766B	K–1775	K–1512	K–1768	S–1573	S–1572	S–1582	S–1546A	Ø–61
SiO_2	48.97	46.72	52.59	43.29	40.99	42.90	44.87	53.19	61.42
TiO_2	2.28	2.37	2.61	4.31	4.12	3.24	3.56	2.01	0.92
Al_2O_3	17.01	17.12	17.28	13.57	13.49	14.36	14.72	16.91	17.60
Fe_2O_3 (tot.)	11.38	11.49	10.16	13.42	15.21	13.78	14.12	9.23	4.01
MnO	0.16	0.14	0.16	0.20	0.20	0.23	0.22	0.18	0.16
MgO	4.88	4.32	2.63	8.32	7.94	7.47	7.13	1.94	0.83
CaO	6.32	10.03	7.17	10.71	12.41	11.00	11.16	4.46	1.98
Na_2O	4.61	3.00	3.37	2.91	2.06	2.61	2.41	3.35	6.18
K_2O	2.32	1.20	2.42	2.12	1.38	1.34	1.03	5.39	5.66
P_2O_5	0.34	0.30	0.57	0.49	0.33	0.52	0.40	0.76	0.27
Total	98.27	96.69	98.96	99.34	98.13	97.45	99.62	97.72	99.03
Katanorm									
Q	–	–	5.58	–	–	–	–	1.33	0.04
OR	13.92	7.44	14.71	12.75	8.50	8.24	6.23	33.00	33.48
AB	33.76	28.27	31.14	11.04	6.08	15.07	22.17	31.17	55.67
AN	19.18	31.19	25.62	18.03	24.50	24.49	26.97	15.75	2.63
NE	4.97	–	–	9.33	7.92	5.60	–	–	–
HY	–	4.40	7.83	–	–	–	0.25	8.78	0.88
DI	8.33	15.18	5.73	26.24	29.95	23.03	21.67	1.63	3.35
OL	11.88	5.14	–	9.27	10.22	12.58	11.34	–	–
MT	4.01	4.25	4.42	6.18	6.12	5.16	5.42	3.80	1.36
HM	–	–	–	–	–	–	–	–	0.51
IL	3.23	3.47	3.74	6.11	5.99	4.70	5.08	2.90	1.21
AP	0.72	0.66	1.23	1.04	0.72	1.13	0.86	1.65	0.74
D.I.	52.7	35.7	51.4	33.1	22.5	28.9	28.4	65.5	90.5

felsic rock-types in the cauldrons, e.g. the *Vesleflåtan megabreccia** in the *Svarten cauldron* and the *Oppkuven mesobreccia** and *intrusive breccia* in the *Oppkuven cauldron* (Larsen, in prep.).

Stratigraphy of the Krokskogen lava plateau

The Krokskogen lava group can be divided, informally, into two formations. The name *Vestmarka Formation* is here proposed for the lowermost unit, which overlies the basal sediments (the Asker Group) and includes the basalt B_1 (Kolsås basalt Member) and RP_1 to RP_5. The upper formation, for which

* Nomenclature from Lipman (1976). *Mesobreccia,* in which numerous small clasts are visible within single outcrops. (Most clasts are 1 m or less i diameter.) *Megabreccia,* in which many clasts are so large that the fragmental nature of the deposit is obscure in many individual outcrops. (Many clasts are larger than 1 m.) Transitional types also occur. The breccias are intermixed with thick intracaldera ignimbrite flows that accumulated during caldera collapse.

the name *Kjaglia Formation* is suggested, is composed of RP_6 to RP_{12} as well as basalts alternating with the rhomb porphyry lavas (mainly B_2, Holmevann basalt Member). Beds up to 10 m thick of conglomerates, sandstones and lava detritus occur between several of the lava flows (and belong to the defined lava formations). In the Gyrihaugen area a coarse conglomerate approximately 150 m thick fills in an erosion valley which cuts through the lava sequence from RP_1 to RP_9 (see stop 6 in the road log).

The separation of the Vestmarka Formation from the Kjaglia Formation seems natural for two main reasons. First, the RP_5 is a relatively thick flow which represents a period of active eruptions, followed by (or simultaneous with) a period of intensive faulting that resulted, for instance, in the cutting out of RP_6 in central parts of the Krokskogen lava plateau. The second reason is that basalts are missing below RP_6 (except for B_1 at the base) whereas they occur at least at three levels in the upper formation. The three basalt lavas (see Fig. 2) are the *Preståsen basalt Member* (between RP_7 and RP_8/RP_9), the *Holmevann basalt Member* (previously called B_2, between RP_9 and RP_{11}) and the *Steinshøgda basalt Member* (previously called B_3, lying above RP_{11}). These names are new.

Structure of the Krokskogen lava plateau

The plateau, approximately 35 km from north to south, has the shape of a large trough or open syncline with an ENE–WSW axial trend (Plate 2). In the north (Stubdal) the B_1/RP_1 boundary is found at $\sim$500 m a.s.l. Near Sollihøgda the same boundary passes below the level of Tyrifjorden (64 m a.s.l.). It then rises again to reach 200 m a.s.l. at Glasåsen in Lier, in the south.

Two faults dominate the structure of the plateau. The NNW–SSE *Isidalen fault*, crossing from Sundvollen, follows the Isidalen and Kjaglidalen, through the Cambro-Silurian lowland of Bærum (Sandvika) and passes into the Oslo-fjord. It is marked by a prominent geomorphological feature, a 14 km long, c. 100 m deep gorge, which splits the Krokskogen lava plateau into two parts. The fault is of the hinge type with a 150–200 m downthrow of the western block in the south, but not more than 20–40 m for the same block in the north.

The other prominent fault is the *Fiskebekken–Mattisplassen fault*. This fault has a N–S trend with a downthrow of the eastern block of c. 50 m. In common with most of the other faults in the Krokskogen area the fault is synthetic to the graben formation, but there is also an antithetic element in the fault pattern represented by NNE–SSW striking faults with blocks dipping to the ESE, and with a relative downthrow of the WSW blocks. A diabase (dolerite) dyke swarm follows the Fiskebekken–Mattisplassen fault. Single dykes can be up to 20 m in width.

Over the area as a whole the Krokskogen lava plateau displays a grid-faulted pattern typical for rift floor faulting (e.g. Baker (1958), Baker et al. (1972) in the Kenya rift, and Ramberg & Smithson (1975b) in the Rio Grande rift). A gridded fault pattern has also been described on a larger scale both in the

Oslo rift and in the Rio Grande rift (Ramberg & Smithson 1975b, Ramberg & Larsen this volume). The distance between the faults at Krokskogen, which is the width of the blocks in the gridded pattern, is about 300–800 m, which is a similar figure to that recorded from the Kenya rift (Baker 1958, Baker & Mitchell 1976).

Stratigraphy of the lavas inside the cauldrons

Within the cauldrons a bimodal assemblage of basalts and felsic volcanics is typical. Local stratigraphical sequences can tentatively be established inside each of the cauldrons Bærum, Oppkuven/Heggelia, Svarten and Øyangen (Fig. 2). At present the first and the last are especially well known (Huseby 1963, Naterstad & Rui, pers. comm. 1976, Larsen unpublished data). The interdigitating rhomb porphyry lavas, which represent fissure eruptions, constitute logical and useful stratigraphical markers for inter-areal correlation rather than the basalts and felsic volcanics which represent central volcanoes and caldera filling material, but even the rhomb porphyries are sometimes of doubtful stratigraphic value.

According to Sæther (1962) the dominant rhomb porphyry lavas within the Heggelia/Oppkuven cauldrons are RP_{11} (five different types). In the Svarten cauldron RP_{13}–RP_{15} occur, in the Øyangen cauldron RP_{14}–RP_{17}, and in the Bærum cauldron RP_{11}–RP_{13}. The youngest cauldron, the Øyangen, has a ring fault and ring dyke which cut the Svarten cauldron and contain the highest rhomb porphyry lava (RP_{17}). However, the volcanics inside the Svarten, Heggelia and Oppkuven cauldrons have only been preliminarily reinvestigated by the author.

Structure of the cauldrons

The cauldrons lie along a line which is parallel to the numerous and important NNW–SSE striking faults of the Krokskogen lava plateau. The cauldrons, mentioned in order from south to north, are the Bærum cauldron, Oppkuven cauldron, Heggelia cauldron, Svarten cauldron and Øyangen cauldron. The last four can be regarded as having originated in one multicenter volcano with migration of the center from south to north. The Øyangen cauldron is the youngest, evolved from the probably youngest central volcano, and shows an elongated map picture with the longest axis aligned NNE–SSW, one of the major tectonic trends in the area. The Glitrevann cauldron, situated SW of the Krokskogen lava area, is also elongated in the same direction (see Fig. 5d, Ramberg & Larsen, this volume, p. 66).

The subsided central volcano basalts always strike parallel to the ring fault, and dip toward the center of the cauldrons. Both Øyangen and Bærum are very good examples, and they also have well-developed central trachytic domes, possibly caused by a resurgence in these cauldrons. Flow-banding is well developed along the border of the Ringkollen trachyte dome in the Øyangen cauldron (Larsen, in prep.).

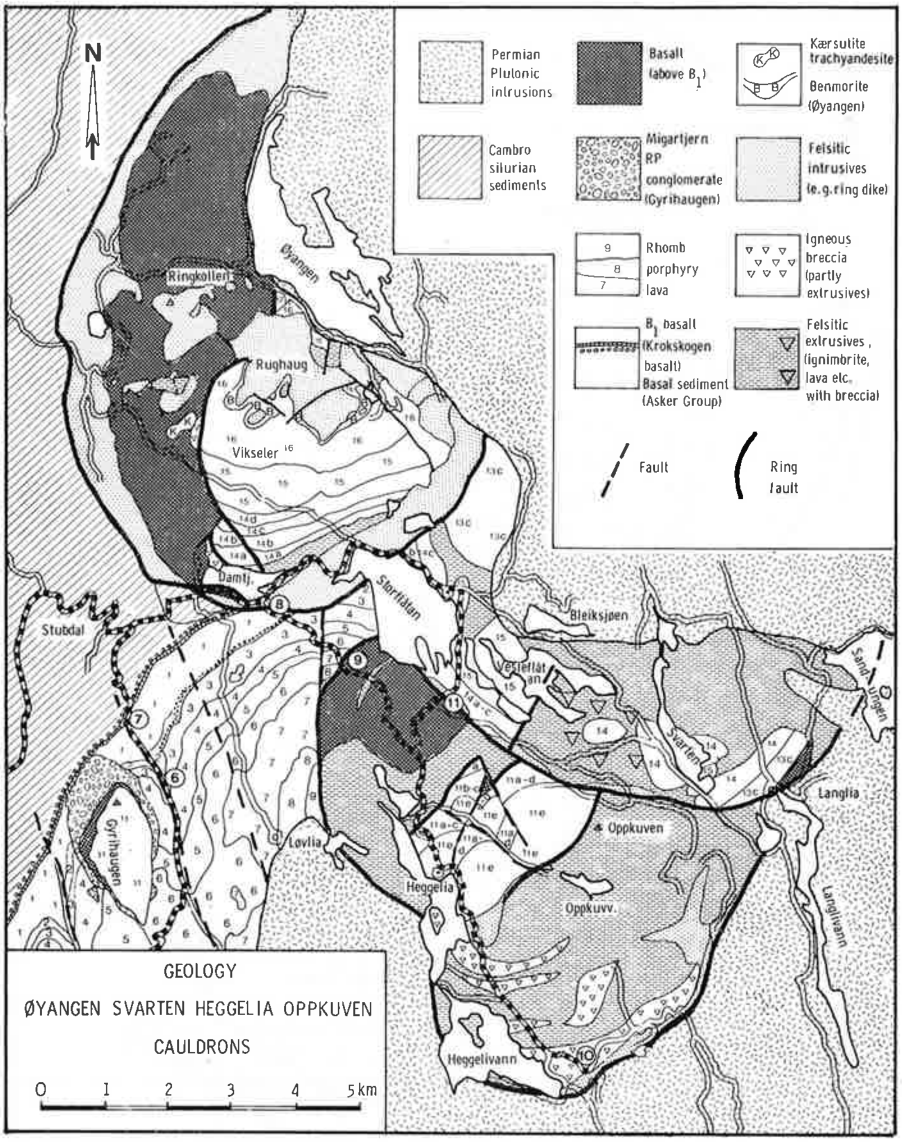

Fig. 5. Geology of the Øyangen, Svarten, Heggelia and Oppkuven cauldrons. Data from Sæther (1962) and unpublished data of the author.

Of the four cauldrons depicted in Figs. 5 & 6. the Øyangen cauldron has the best developed ring dyke which can be traced all the way round the preserved portion of the cauldron. It is up to 600 m wide and composed of relatively coarse-grained grey syenite. In the southwest, however, where double subsidence has taken place, the width is reduced to 10–20 m (Fig. 5). The red syenitic ring dyke of the Svarten cauldron is not continuously preserved but occurs in short lengths at frequent intervals along the boundary. The Oppkuven cauldron ring dyke is less well preserved while the Heggelia cauldron ring dyke is known from only one small area.

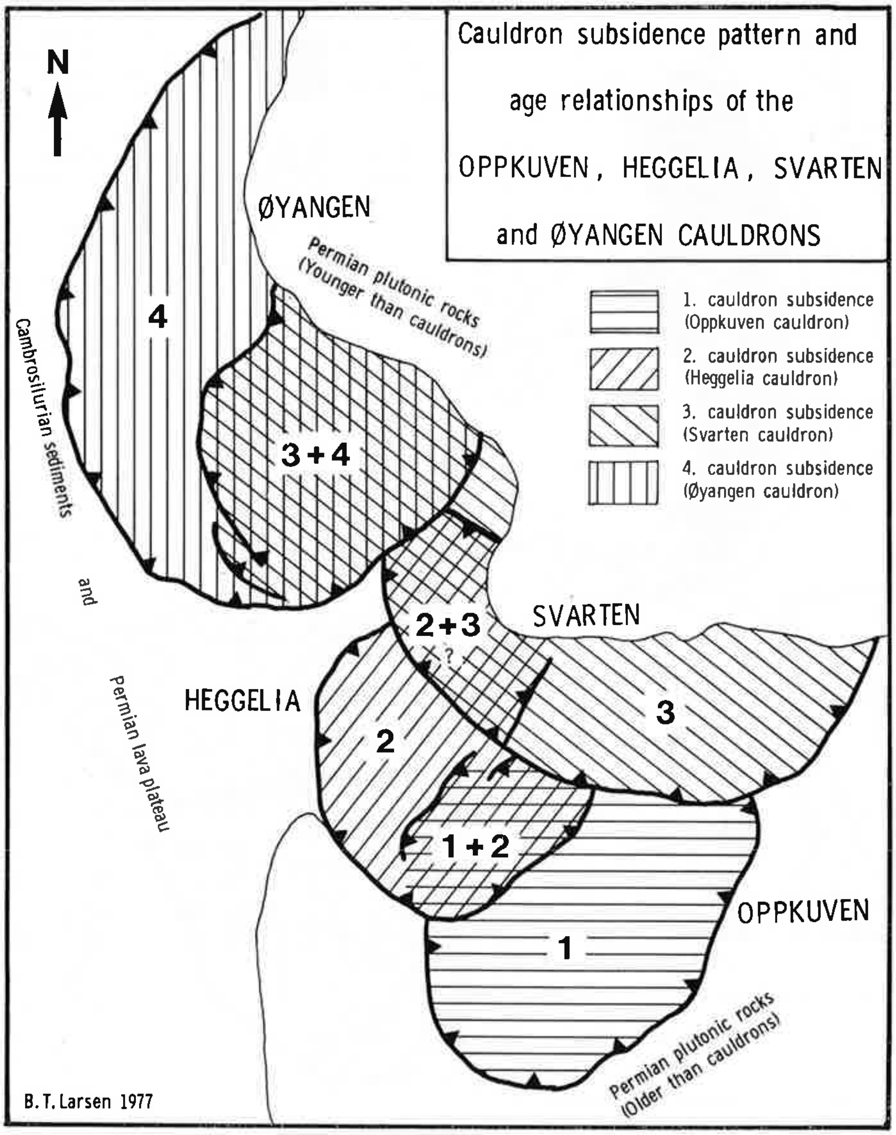

Fig. 6. Cauldron subsidence pattern of the Oppkuven, Heggelia, Svarten and Øyangen cauldrons, Krokskogen lava area.

The subsidence of the cauldrons in the area, estimated from the lava stratigraphy, is approximately 500–1000 m. The local thickness of the basaltic lavas of the central volcanoes (evolving into cauldrons) and the filling material in the cauldrons is difficult to calculate, but it is somewhere in the order of 1000 metres. Segments in the interdigitated cauldrons have also subsided in connection with more than one cauldron (Figs. 2, 5 & 6).

Fig. 6 shows the age relationships of the four cauldrons in the cluster; Oppkuven (1) is the oldest and Øyangen (4) is the youngest. Because the cauldrons have overlapping boundaries, certain areas (marked in the figure) have suffered double subsidence and may have undergone a total vertical movement of the order of 2000 m. The size of the cauldron is believed to be related to the size of the underlying magma chamber. The larger the cauldron, the larger the underlying chamber and thus the greater the possible subsidence. It is therefore assumed that the two small cauldrons (Oppkuven and Heggelia) subsided less than Svarten and Øyangen, and that the area of double subsidence marked 3 & 4 in Fig. 6 represents the area of greatest total subsidence. The stratigraphy indicates that the western part of the Heggelia cauldron has suffered very little subsidence (less than 100 m) and the steep dip of the lavas here suggests that there has been a hinge movement along the boundary between the cauldron and the lava plateau to the west.

The recognition of double subsidence influences the interpretation of the observed stratigraphy (Fig. 2). The Svarten cauldron is in this respect a key area and will be studied in greater detail in the near future.

Road log (excursion 5)

1. *Dronningveien, Sundvollen* (Fig. 7)

The road-cut gives us a nearly continuous section through the base of the Permian sequence at Krokskogen. The units represented are:

Top: *RP_1*
Kolsås basalt (B_1)
The Permian Asker Group: (See Henningsmoen, this volume)
Tanum Formation: Quartz sandstone with quartz pebbles, cross-bedding and graded bedding (channelling in other areas). Thickness varies fram 50 cm to 7 m. Local faulting tectonics were active before this sedimentation.
Rapid facies changes from a quartz sandstone to coarse (15 cm and less) quartz conglomerate over a distance of few hundred metres. The conglomerate facies is generally most prevalent.
Kolsås Formation: Red and grey/green mudstone, max. 10 m.
∿∿∿∿∿ Sub-Permian unconformity (often covered by scree).
Bottom: *Red Downtonian sandstone* (Ringerike Formation), often good primary structures, cross-bedding, ripples, mudcracks, etc., and trace fossils.

A single basalt flow generally 15–20 m thick and never exceeding 30 m starts the volcanic eruptions in this area. It is a fissure type eruption, aphyric and quartz tholeiitic in composition (distinguishing this Kolsås basalt Member B_1 from the other B_1 basalts in the Oslo Region, which are alkaline).

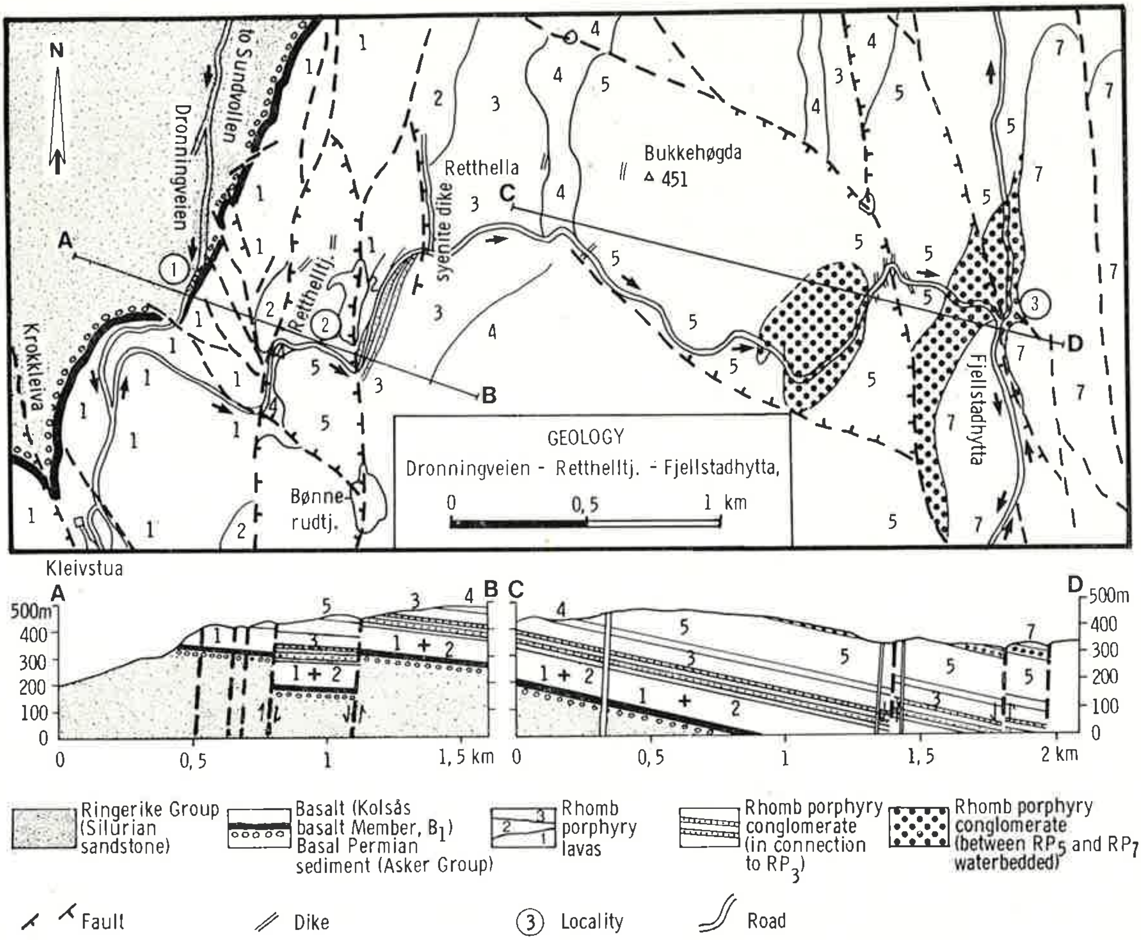

Fig. 7. Geological sketch map for localities 1, 2 and 3. Preliminary data from the author.

Rhomb porphyry RP_1

The first rhomb porphyry lava flow (RP_1, Kolsås type). More than 100 m thick, possibly composed of two similar flows. Globular structures of pillow type more than 1 m in diameter, with red sediments in between (Dons 1956a), indicate that the lava has flowed across a wet surface or into a small local shallow lake. These globular structures have only been found up to now in the western part of the Krokskogen area.

From the Dronningen view-point we see in the far west the Precambrian hills, and the Cambro–Silurian lowland with the Ringerike sandstone nearer to us. To the south we can see the Finnemarka granite and to the north the Øyangen cauldron with the Ringkollen trachyte dome.

2. *Retthelltjern* (Fig. 7)

Stratigraphically in the RP_1–RP_5 position of the lava sequence. Approximately 500 m walk along a road traverse, starting in one tectonic block with RP_1/RP_2, passing a small topographic depression and coming into RP_4 and the overlying RP_5. We have crossed a normal fault, typical for this part of the plateau, with a downthrow of more than 100 m to the east. During the walk to the southern end of the small lake Retthelltjern, we approach another fault, and now walk down again in the stratigraphy to RP_2–RP_3. The fault-block is a small slice 500 m wide, which was dropped and possibly formed a small narrow graben during the tectonically most active period.

East of Retthelltjern sedimentary layers occur between RP_2 and RP_3 (RP_{3a}, RP_{3x}, RP_{3b}). Above RP_{3a} (extremely large feldspar phenocrysts) is a 4–5 m-thick conglomerate, with well-rounded material of RP-lavas; pebbles 1–3 cm (up to 10 cm), good bedding, well sorted, deposited in water. Above the sediment is a thin (only 1.5 m) lava flow, RP_{3x}, and on top of this flow is a new RP conglomerate (1.5 m thick). Blocks bigger here than in the first conglomerate, unsorted, and with red sandstone matrix between the pebbles. This conglomerate is hardly water-deposited, and may represent a blocky lava surface with wind-blown(?) sand as infilling. The sediments are typical for the two main types between the RP lavas. On top of the sediment we have RP_{3b} with big feldspar phenocrysts.

A little further north along the road is a 6 m-thick N–S striking composite syenite dyke cutting RP_{3b}, following a N–S fault.

3. *Fjellstadhytta* (walk down to the road junction) (Fig. 7)
West of the stop we pass one of the more prominent faults of the Krokskogen lava plateau, the *Mattisplassen–Fiskebekken fault.* The fault is followed by a dyke swarm of larger and smaller (in this road-cut, 4 small) diabase dykes.

The stratigraphical position of the lava is RP_5, close to Fjellstadhytta. RP_5 is overlain by a RP conglomerate with small pebbles of RP-lavas, possibly 20 m thick and well bedded with rounded pebbles. This represents a relatively thick and extensive RP-conglomerate, water-deposited, with possible graded bedding.

Above the sediment follows RP_7, which means that RP_6 is missing in this part of the Krokskogen area. Further north (around Gyrihaugen) RP_6 is more than 30 m thick.

The occurrence of RP_6 or the sub-RP_7 conglomerate seems to be linked to certain fault blocks, with abrupt facies changes from one block to another. There seems to be a tendency for the sediments and the new lava flows to be thickest in the eastern part of each block. Extensive block-faulting must have taken place during and after the emplacement of the thick and extensive RP_5. Further south at Krokskogen RP_6 is also missing in some blocks.

4. *West of Plassdammen* (Fig. 8)
Stratigraphically above RP_7. Here RP_8 is split into two (RP_{8a} and RP_{8b}). RP_{8a} is thinner and has slightly larger phenocrysts than RP_{8b}. Between the two RP_8 flows is a basalt sequence. This basalt is also found further southwest at Krokskogen, southwest of the *Kjaglidalen fault* and is named the *Preståsen basalt Member.* The basalt is aphyric, and contains some large (up to 8 cm)

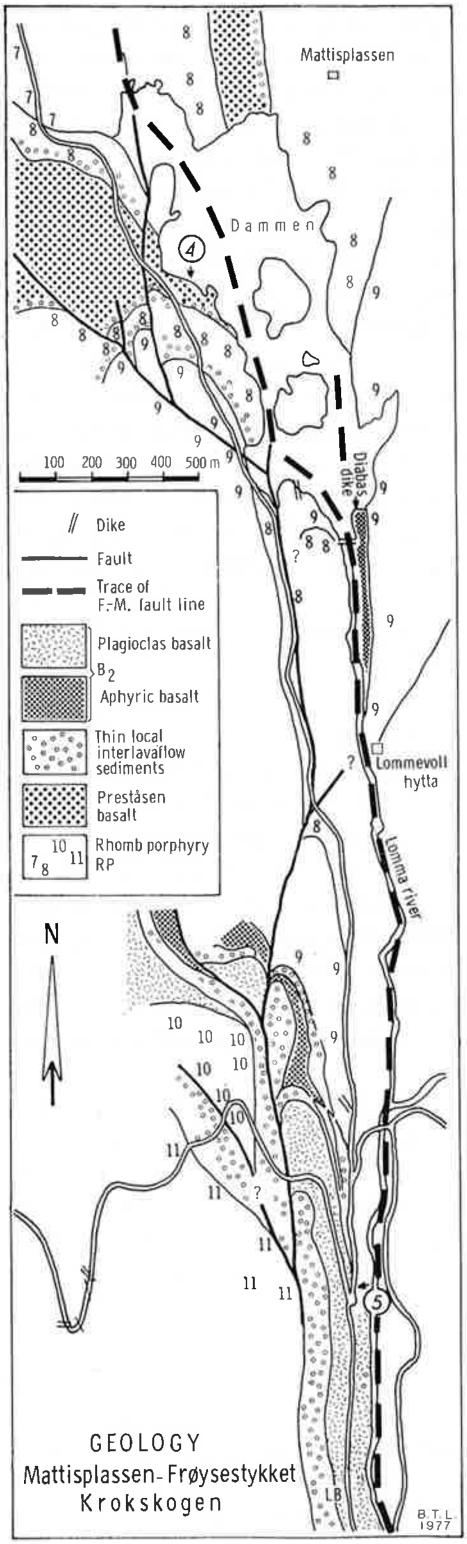

Fig. 8. Geological sketch map for localities 4 and 5. Preliminary data from the author. (F.–M. Fault line = Fiskebekken –Mattisplassen fault).

very scattered feldspar megacrysts. In the type-area at Preståsen the basalt sequence is approximately 50 m thick, and is composed of 6 separate flows.

At the Plassdammen locality the basalt is about 20–30 m thick, and has a vesicular and oxidized top. A conglomerate, 1–2 m thick, with boulders of oxidized basalt and red sandstone occurs above the basalt. Conglomerate beds are also found at the top of RP_{8a} and RP_{8b}.

5. *Frøysestykket* (Steep side-road to west, with turnpike) (Fig. 8)
Stratigraphically in the B_2 basalt sequence, now named the *Holmevann basalt Member*, RP_{10} and RP_{11}. At the turnpike is a thick hawaiitic alkaline plagioclase basalt which occurs in the upper half of the B_2 sequence. Walk from turnpike up to RP_{11}, mostly road-cuts. The detailed stratigraphy of the area is:

top	RP_{11}	
	Conglomerate/red sandstone, with mudcracks	3 m
	RP_{10}	appr. 10–15 m
	Conglomerate/red sandstone	3–5 m
(Turnpike)	Hawaiitic plagioclase basalt	25–30 m
	RP conglomerate, water-sorted much like the one below	50 cm
	Aphyric basalt (possibly two lavas in places)	$\geqslant 5$ m
	RP conglomerate, pebbles up to 3 cm (most RP_9)	10–?20 m
bottom	RP_9	

The total thickness is 50–70 m in this area.

The lowermost part of the sequence (from turnpike) can be seen northward from the road junction along the 'main road' (also passing the next road junction).

Some faults cut the area. Along the river Lomma to the east in the river gully, the *Fiskebekken–Mattisplassen fault* is traceable. East of this fault is a complicated volcanic sequence with different rock-types, mostly felsic intrusives and extrusives (breccias and ignimbrites). These volcanics have not been investigated by the author and will not be visited.

The Holmevann basalt Member (B_2) lavas occur in the central parts of the Krokskogen area, and vary in thickness from 10 to 70 m, thickest in the southern and central parts around Isidalen.

The B_2 basalts are alkaline in character, and some have a basanitic affinity. The RP_{10} is the least extensive of the RP flows at Krokskogen. It is also atypical in chemistry, more basic than the others, and should possibly not have been called a rhomb porphyry.

6. *Gyrihaugen* (Main stop) (Fig. 9)
Stop at Lommegård, climbing to the top of Gyrihaugen (682 m a.s.l.). Path straigth westward from Lommegård, stratigraphy from RP_{3a}, through RP_4 and into a conglomerate (after about 200 m walk).

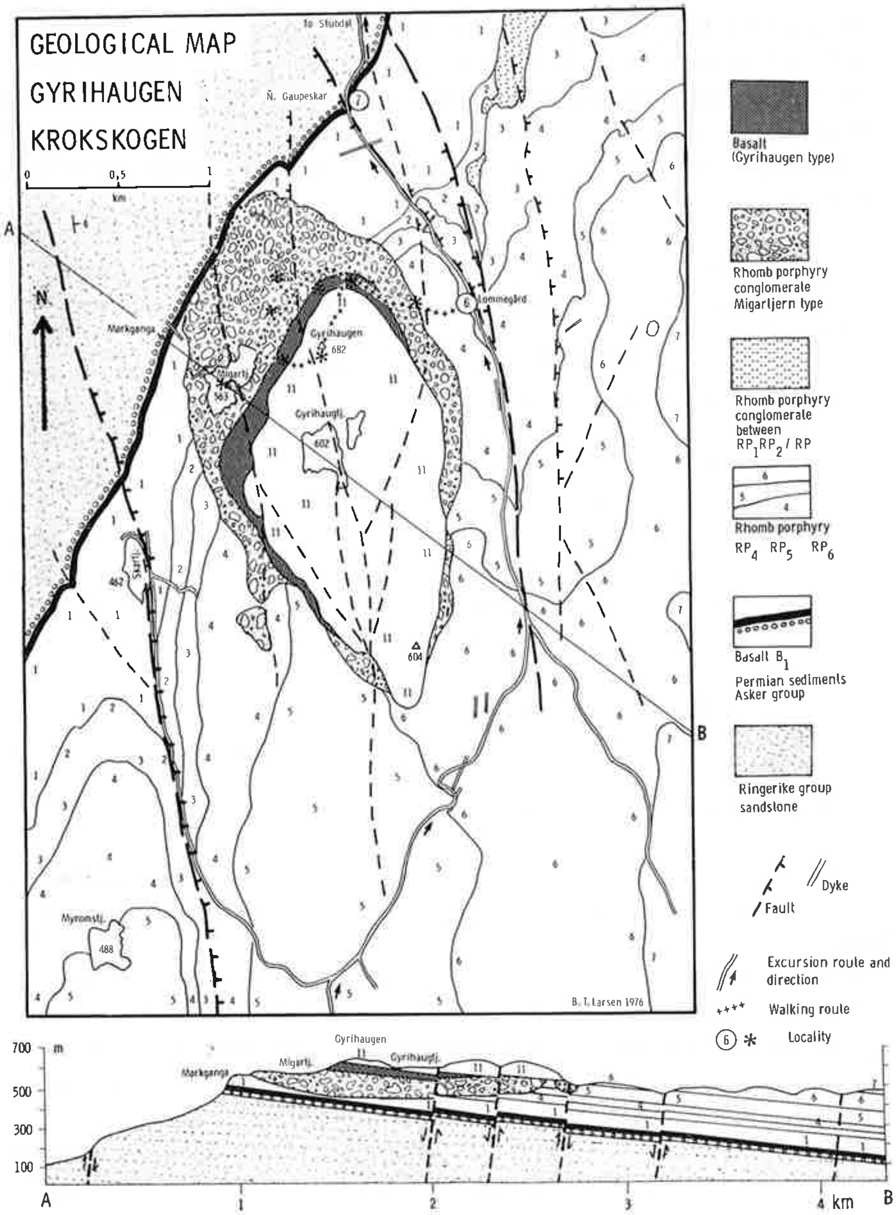

Fig. 9. Geological sketch map for localities 6 and 7. Walking route for locality 6 indicated. Preliminary data from the author.

This newly discovered rhomb porphyry conglomerate, named *Migartjern conglomerate*, covers a local area around the hill Gyrihaugen.

The Migartjern conglomerate (Fig. 10). Extremely coarse-grained, lava boulders up to 1 m in diameter, angular in shape; rounded pebbles can be seen among the smaller fragments. Bedding planes are absent or rare. The sediment consists exclusively of lava clasts. RP_1, RP_3, RP_5, RP_6 and RP_7 are positively

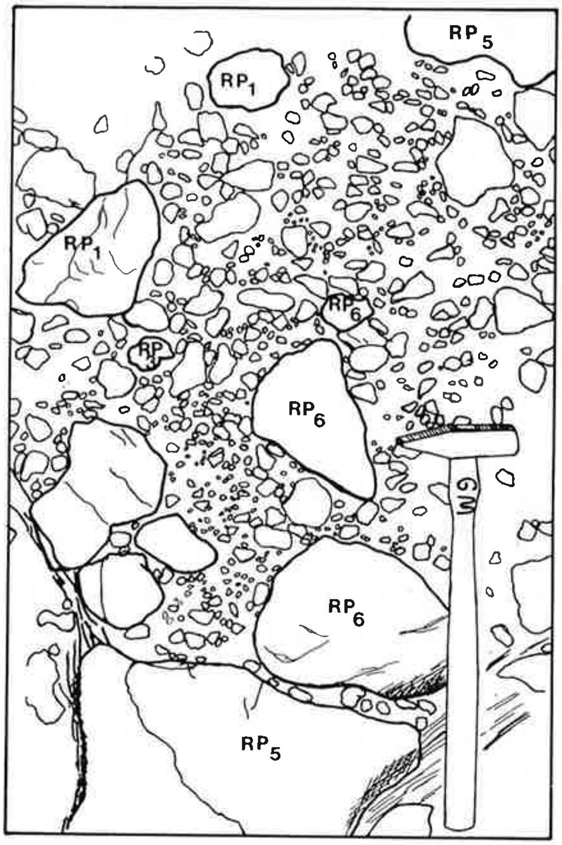

Fig. 10. Migartjern rhomb porphyry conglomerate. Hammer shaft around 50 cm.

identified, and a plagioclase basalt is locally found as boulders together with RP_9 on the eastern shore of Migartjern. The sediment looks unsorted with both large and small fragments. The plagioclase basalt is most likely at B_2 basalt.

The estimated thickness of the conglomerate is about 150 m, but the lower contact is not yet fixed (steep cliff towards west). It would appear that the conglomerate was deposited in a NNW-striking trough which shallowed off to the SSE. The trough most likely represents only a small remnant of a fault-bounded trough delimited by the Fiskebekken–Mattisplassen fault to the west and a parallel fault which runs along the river Lomma to the east. This 2 km-wide small graben seems to have subsided most rapidly in the NNW. The erosion of the lava plateau must have taken place over a certain period of time, as the entire rhomb porphyry sequence from RP_9 to RP_1 has been cut through. This 'new' conglomerate provides one of the best examples in the Krokskogen area of the rapid local variations in the tectonic and volcanologic environment.

Having passed through the conglomerate we encounter the *Gyrihaugen basalt*, which is aphyric and approximately 40 m thick. Between the Migartjern conglomerate and the basalt there is an unconformity. This emphasizes the fact that a more tectonically active period began with the B_2 basalt eruptions (here the Gyrihaugen basalt).

The Gyrihaugen basalt is always relatively highly oxidized, with alteration of most the primary minerals. The basalt looks more 'porous' than other aphyric basalts, with abundant gas cavities. This 'porosity' does not look like common vesicularity, and occurs throughout the lava flow. It is assumed that the basalt flowed across an area of wet sediment (Migartjern conglomerate), and has been penetrated by steam.

Above the Gyrihaugen basalt occurs the RP_{11} lava. This lava has mistakenly been identified as RP_5 (Brøgger & Schetelig 1917 map, Sæther 1962) or RP_6(?) (Oftedahl 1952).

7. *N. Gaupeskar* (Fig. 9)

Road-cuts where the road passes over the cliff to the west. Geological features are similar to those of stop 1, Dronningveien. Some differences should be mentioned. The basalt is thinner in this area, about 10 m; the underlying sediment (the *Asker Group*) is also thinner, and both these units thin to the north at Stubdal. The *Tanum Formation* (quartz conglomerate) is here much coarser than at any other locality known to the author. The rounded quartz boulders are up to 20 cm in diameter. Pebble imbrications have been observed in the conglomerate, and at the very top caliche(?) nodules some more than 1 m in size are found. The caliche nodules are irregular in shape, and often weathered out as caves and cavities.

One thin diabase dyke cuts the lavas at this locality, and the pass is occupied by a fault.

8. *South of Damtjern* (Road-cut on the road to Heggelia, approx. 100 m after the junction) (Fig. 5)

Border between the ring dyke of the Øyangen cauldron and the RP_1 of the Krokskogen lava plateau. The northernmost end of the lava plateau.

The rock-type of the ring dyke is a medium-grained homogeneous grey syenite with local steep flow-banding. The ring dyke is 500 wide, and grades into a plutonic rock, thicker and more coarse-grained than most ring dykes in the Oslo region. This rock-type was earlier named hedrumite by Brøgger. The feldspar (90% of the rock) is a microperthitic Na-rich alkali feldspar (norm. $Or_{35}Ab_{60}An_5$); plagioclase and quartz are absent. Dark minerals are pyroxene (Fe-rich augite), Fe–Ti opaques and apatite ($\pm$biotite and amphibole).

9. *Sandviksdalen* (Road-cuts south of Storflåten) (Fig. 5)

Stop in RP_8; 100 m back is the underlying RP_7. We cross the eastern of two parallel N–S striking hinged faults. Parts of the area are covered, and the results given below are preliminary.

East of the fault we walk into steeply dipping basalts (the Atjern basalt) (B_2 or B_3). Petrographically different types occur: plagioclase basalt (hawaiites(?)), aphyric basalts and ankaramites, with phenocrysts of clinopyroxene and olivine pseudomorphs. Strike is about 040° and dip about 30° to SE (local variations). Agglomerates and red oxidized scoriaceous lava tops can be seen.

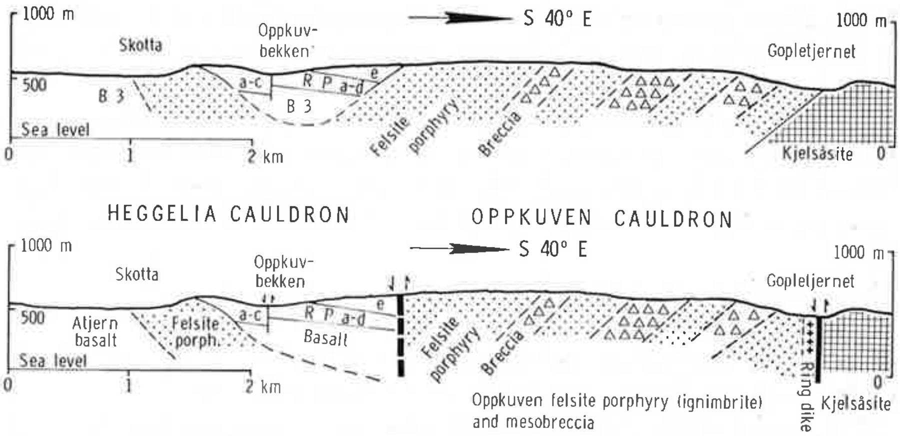

Fig. 11. Profile from Fig. 5 crossing the Heggelia and Oppkuven cauldrons. Upper interpretation from Sæther (1962, p. 86); lower profile the interpretation of the present author.

After about a 500 m walk we meet a porphyritic ignimbrite/breccia layer (breccia at the top?), then the basalts continue. We walk to an aphyric basalt/ankaramite contact with good examples of oxidation and sedimentation on a scoriaceous top.

The Sandviksdalen area is a key to the interpretation of the complicated RP/basalt/rhyolite area at northern Krokskogen. Sæther (1962) fixes the stratigraphical position of the basalt to B_3 basalts, implying a 1000 m displacement of the eastern block. There is evidence, however, that the basalt overlies RP_9, which implies that there is no abrupt faulting, and that the basalt is B_2. This gives a smaller displacement of the Heggelia cauldron.

10. *Heggelidammen* (300 m east of road-cut in the southernmost bend in the Heggelia–Pipenhus road) (Fig. 5)

Locality in the southern part of the Oppkuven cauldron, the oldest(?) and southernmost of the four cauldron-in-cauldron structures.

Oppkuven felsite porphyry (alkali rhyolite) and Oppkuven breccia, now classified as the Oppkuven mesobreccia and intrusive breccia (see above). The locality shows the contact between two flows, and a cracked or partly brecciated surface, overrun by new eruptive material (Figs. 5 & 11). Fragment-free felsite porphyries can be seen.

The boundaries between breccias and porphyries are mostly sharp, and fragments also occur in the felsite (ignimbrite). A massive felsite porphyry (100 m thick) has been described (Sæther 1952) at the contact to the kjelsåsite in the south, and is interpreted as a ring dyke.

The Oppkuven mesobreccia and Oppkuven felsite porphyry. The size of fragments is from 1 mm to several metres (Sæther 1962). The mesobreccia is composed of a multitude of rock-types: felsite porphyry, syenite porphyry, basalt, rhomb porphyry, 'rectangular porphyry' ($RP_{13a,b}$), kjelsåsite (monzonitic plutonic rock), fine-grained and porphyritic monzonite/syenite types (Sæther

1962). Planar structures in the breccia have a northerly dip and a strike more or less parallel to the ring fault. Breccia alternates with felsite porphyry (K-rich alkali rhyolite), mostly ignimbritic.

Sæther (1962) interpreted the porphyry breccia to be intrusive in character. Intrusives do occur, but most rocks are now regarded as effusives (after very limited field work in this area). The preliminary interpretation is that these rocks are mostly caldera-filling material formed in a syn- to post-caldera stage.

11. *South of Langtangen, Storflåtan* (Fig. 5).

(About 100 m east of road-section, along the road to Storflåtan)

Walk from basalts in the Heggelia cauldron, crossing the syenitic ring dyke(?) of the Svarten cauldron, and into RP_{14} of the Svarten cauldron.

The basalts of the *Atjern basalt Member* are represented here by a red oxidized tuff bed with 1 cm size clinopyroxene (green) phenocrysts.

The ring dyke(?) is about 100 m wide, red medium-grained syenite, quite unlike the Øyangen cauldron ring dyke (grey, stop 8). The ring dyke cannot be traced all the way round the ring fault and is probably discontinuous.

The RP lavas inside the Svarten cauldron represent RP_{14}, according to Sæther (1962).