COAL BLEND AND URANIFEROUS HYDROCARBON IN NORWAY

BY

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The word «kullblende» (coal blend) has been used during centuries at Kongsberg Silver Works as a designation for an anthracite-like «mineral». The workers there had a rule saying that where there is no coal blend or bituminous calcite there will be no native silver. In Sweden, where similar material occurs and is beeing thoroughly studied at present, it is called «bergbek» (mountain pitch), (HELLAND 1875, HEDSTRÖM 1923). A more general designation, also used is «anthracite».

It is a jet-black, brittle, amorphous, nonfluorescent mineral, see figures 3, 5, 6, 7. Spec.gr.: ~ 1.3, hardness: 2—3 (fracture surfaces give the idea of ~ 5), streak: black, fracture: conchoidal, lustre: vitreous. Composition in weight per cent: carbon 95—80, oxygen 6—2, hydrogen 3—1, nitrogen 0.7—0.2, sulphur 0.4, ashes 4—0.1. Chemically the specimens from some localities differ greatly from these figures. X-ray examination carried out on material from most of the 20 localities usually showed more or less pronounced graphite lines.

All known occurrences of coal blend in Norway are listed below, starting in the southern part of the map area fig. 1. Some of them have been mentioned and described in earlier literature, others are only known because collected material has been stored in this museum. A couple of new occurrences have been discovered by the author who also wishes to thank his colleagues for furnishing him with further information.

As shown by the map, all localities of coal blend are to be found in Southeastern Norway, near and inside the Oslo Region (graben area) in Precambrian, Cambro-Silurian and Permian rocks.

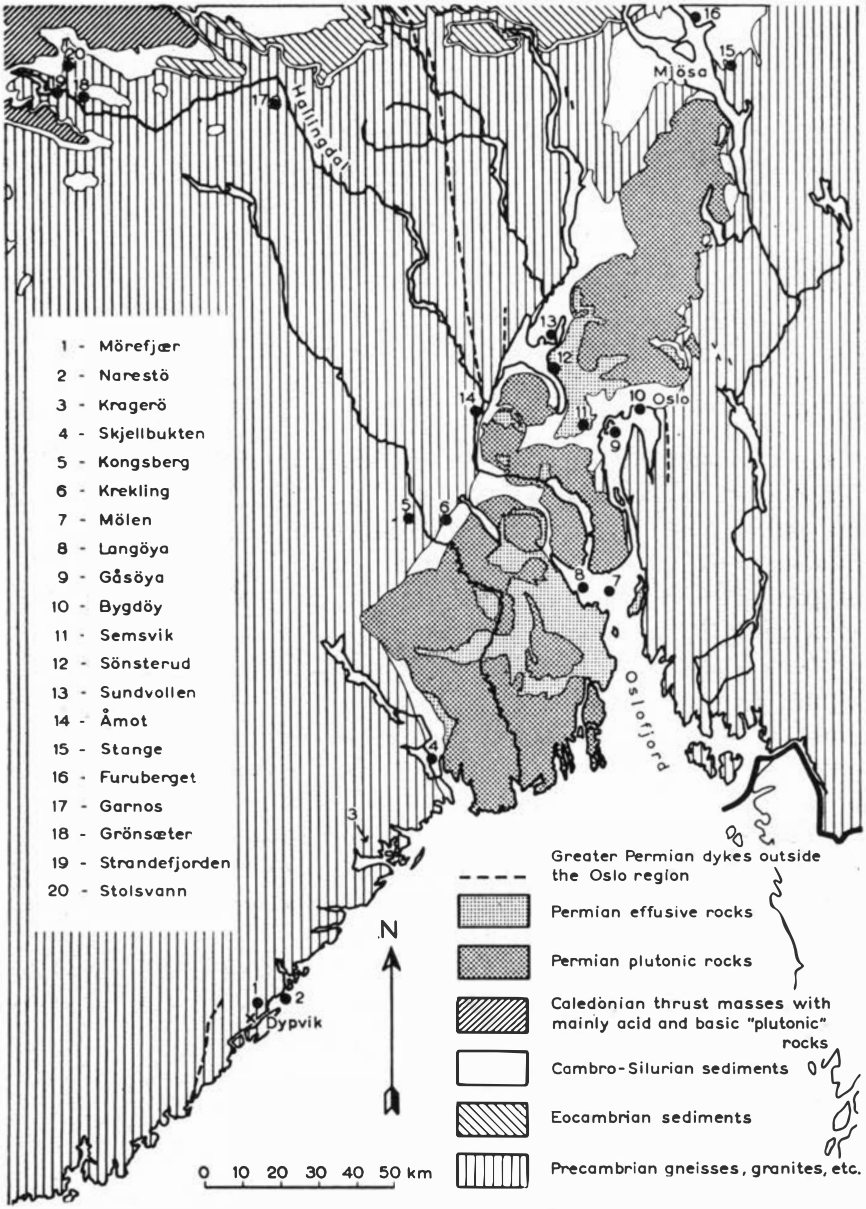

Fig. 1. Map showing the location of 20 occurrences of coal blend.

Loc. 1. Mörefjær, Arendal. Precambrian area.

In the skarn iron ore mines, the Mörefjær mine especially mentioned, (BUGGE 1954), small grains of coal blend have been observed in a mass of chlorite. It is considered to be a young mineral which occurs together with analcime, prehnite, heulandite, calcite and other hydrothermal minerals. The age of the hydrothermal activity is unknown.

Loc. 2. Narestö, Arendal. Precambrian area.

Specimens of coal blend from Narestö feldspar quarry (opened in 1792 on a granite pegmatite) were presented to this museum in 1909 by Christiania Minekompanie, and in 1936 by Mr. Suleng. The total amount of material at disposal was approximately 25 grams.[1] In the description of the quarry (ANDERSEN 1931) the following minerals are mentioned: alkali feldspars, quartz, biotite, plagioclase, magnetite. Also radioactive minerals such as orthite, monazite and xenotime are reported, but no coal blend. The museum specimens seem to indicate that the rock in which the coal blend occurs has been altered by hydrothermal solutions.

Beta (and gamma) - ray counts carried out in the Norwegian Geological Survey Laboratory on the whole material of coal blends from Southern Norway gave a radioavticity of $\sim$ 2 per cent equivalent U_3O_8 for the Narestö specimens and nothing for all the others.

An analysis, partly chemical, partly spectrographical, performed at the Institute for Atomic Energy gave the following result in weight per cent: 95 «organic» material, 1.8 U_3O_8 no ThO_2, appreciable amounts of B, Si, Mg; traces of Mn, Fe and Ca. No V_2O_5 is here reported but its presence has earlier been proven by Dr. H. BJÖRLYKKE.

This means that the coal blend of Narestö has an ash content of 5 per cent and that the U_3O_8 content of the ash is 36 per cent. As Th is lacking the designation thucholite is incorrect for this material. The name «ucholite» would be better. Also in the uraniferous hydrocarbon from Laxey, Isle of Man, thorium is not present in detectable quantity. (DAVIDSON and BOWIE 1951).

As seen in the table of analyses (fig. 2, first and second column) the Narestö coal blend also differs greatly from the others by its

[1] The author, visiting the quarry in July 1956, was unable to find any coal blend.

Fig. 2. Analyses of coal blend and other carbonaceous material.

Weight %	Loc. 2		Loc. 5			Loc. 11	Loc. 12	L. 14	L. 18				
	Narestö Arendal Helland 1875	Narestö Arendal New anal.	Kongsberg Helland 1875	Kongsberg Neumann 1944	Kongsberg New anal.	Semsvik Bugge & Neumann 1939	Sönsterud Kristoffersen 1939	Åmot Modum New anal.	Grönsæter Hol New anal.	Carbonites Brittle, non fusible Mueller 1954	Antracite coal Av. of 16 anal. Clarke 1920	Average of 4 Antraxolites. Dunn & Fischer 1954	Average of 4 Schungites. Inostrazef 1880
C	69.1	74.1	95.4	90.5	93.4	86.5	86.3	93.6	79.2			91.52	98.11
H	2.9	3.1	1.9	2.2	1.6	2.9	3.37	0.9	0.7			3.15	0.43
N	tr		tr	0.5		0.7	0.19					1.05	0.43
S	0.2			0.4		0.5	0.38					0.52	
indir. O	15.6		2.2	5.5		5.7	2.29					2.68	
H_2O-							1.17						
$CaCO_3$							6.3						
Ashes	12.2	5.0	0.4	0.9	1.8	3.7		0.1	16.2	0.51		1.08	1.09
Weight % without ashes:													
C	78.8	78.0	95.8	91.3	95.1	89.9	93.2	93.7	94.5	84.7	93.5	92.52	99.2
H	3.3	3.3	1.9	2.2	1.6	3.0	3.7	0.9	0.8	6.1	2.8	3.18	0.4
N	tr		tr	0.5		0.7	0.2			0.9	1.0	1.06	0.4
S	0.2			0.4		0.5	0.4			1.3		0.53	
O	17.7		2.3	5.6		5.9	2.5			7.0	2.7	2.71	
	100.0		100.0	100.0		100.0	100.0			100.0	100.0	100.0	100.0
Atom.prop.													
H/C	0.52	0.50	0.24	0.29	0.20	0.40	0.46	0.12	0.10	0.40—1.15	0.36	0.41	0.05
O/C	0.17		0.02	0.05		0.05	0.02			0.02—0.07	0.02	0.02	
Spec. grav.													
	1.64		1.38	1.49		1.3—1.4	1.2—1.37		1.8	1.21—1.25	1.65	1.38	1.84

low content of carbon and high content of oxygen and ashes. Microscopic investigations of a polished section reveals subangular mineral grains, probably uraninites (light grey to yellowwhite in plane-polarized reflected illumination) which make up about 5 per cent of the material which for the rest consists of normal coal blend (grey with no reflection pleochroism or effect of anisotropy) and pyrite.

It can probably be assumed that the coal blend mentioned in old literature from «granitiske Udskeidninger» (rocks derived from granite) by Arendal refer to the Narestö quarry. (WEIBY 1849).

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In this connection may be mentioned the so-called oil diabases (doleritic dykes) from the Arendal area which have been known to geologists for a century, but not mentioned in the literature. One of the dykes a couple of meters wide and nearly vertical is seen in the good road section on the NW side of the little bay Dypviken, 3 km NE of Arendal. When splitting up the rock so that the amygdales (up to 1 cm in cross section, coated with quartz and calcite) are disturbed wet patches grow out from the hollows. The liquid has the typical smell of petroleum, and some times one can succeed in getting it burning before it evaporates completely. It is reported that someone had the liquid analysed and it showed a close resemblance to Caucasian petroleum. The dyke rock shows no radioactivity.

Several diabase dykes have been mapped by Dr. J. A. W. BUGGE during his study of the Arendal area, a few of them being of the Dypviken oil-bearing type (oral communication). The diabase dykes are the youngest rocks in this Precambrian area. They may be of Permian age.

Loc. 3. Kragerö. Precambrian area.[1]

Coal blend has been reported from the Kragerö district (DAHLL 1861) and is said to occur in dykes and to be related to intrusions of gabbro. The exact location of this occurrence is unknown and no specimens exist any longer.

[1] In a new road section at Hullvann 7 km N of the town Kragery (Loc. 3 in fig. 1) cand. real. S. Skjeseth this summer found coal blend in a N-S-running breccia 2—3 m thick. This breccia forms a part of a greater and older breccia. The coal blend, mainly leafshaped, is found between the crystals of calcite and and quartz which fill the spaces between the partly round, partly sharpedged pre-Cambrian gneiss fragments. The coal blend is non-radioactive. The younger breccia may be of Permian age.

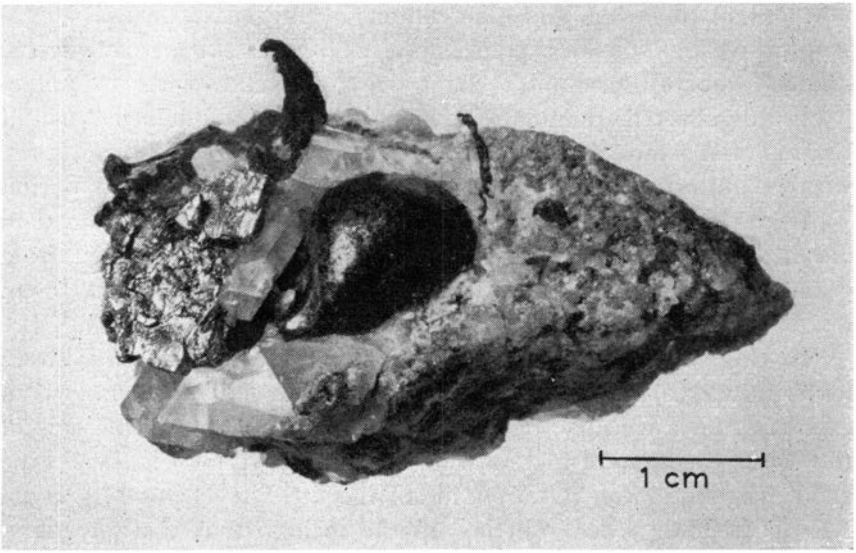

Fig. 3. Globule of coal blend in calcite. Threads of native silver. on the upper surface of the specimen, pyrite to the left. Kongsberg, loc. 5.

Loc. 4. Skjellbukten. Ordovician sedimentary area.

During a student excursion in 1949 the author found some handfuls of coal blend occurring together with calcite in a minor brecciated zone cutting vertically the Encrinite limestone (Ordovician). The material was taken to Finland for analysis.

Loc. 5. Kongsberg. Precambrian area.

The coal blend is tolerably common in the hydrothermal veins worked in the Kongsberg silver mines, (HELLAND 1875, VOGT 1899, LEITZ 1939, NEUMANN 1942). Dr. H. Neumann reports that botryoidal, spherical or globular forms are here the usual way of occurrence, their size being from almost nothing to more than that of a hen's egg (fig. 3). The minerals is found in vugs fixed to other minerals, as well as along cleavage planes of calcite, and even on the tip of «threads» of native Ag. Coal blend of irregular shape, and coal blend as fan-shaped leaves coating silver minerals has also been observed.

According to Dr. Neumann the hydrothermal vein minerals occur in three paragenesis, rather intimately connected with each other:

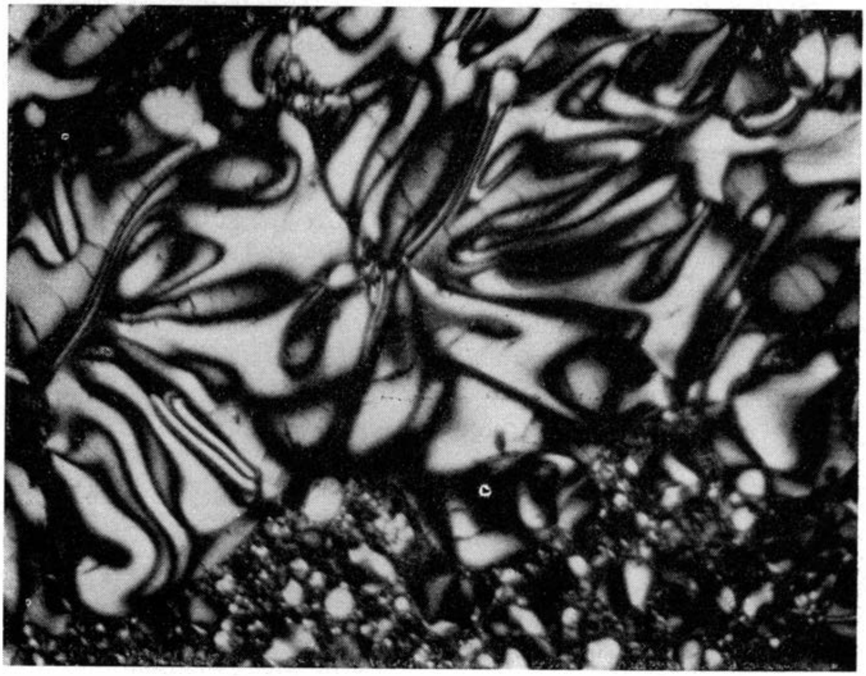

Fig. 4. Photomicrograph of the Kongsberg coal blend. Polished section, crossed polars. Side length of picture corresponds to 0,5 mm.

the older quartz- coal blend-fluorite- axinite-pyrite paragenesis, a middle calcite-barite-fluorite-sulphide-silver-Ni- Co-arsenide paragenesis, and a younger calcite-zeolite paragenesis. The age of the coal blend and its place in the paragenesis is difficult to decide because of the absence of crystallization. It seems to have been precipitated at various times. It is, however, usually very young.

All the veins are narrow and they cut east-west across a Precambrian series of rocks, mainly banded dioritic and granitic gneisses. A swarm of Permian diabases which crosses the area is closely connected with the older quartz veins as well as the calcite-native silver veins, and has the same direction. The veins are most probably connected with the younger igneous activity of the Permian Oslo Region. The pressure under which the minerals have been deposited must, according to Neumann, have been about 1000 atm. and the temperature has probably varied from about 400—500° C to about 200° C.

Both J. Leitz and H. Neumann observed that the coal blend, in polished section, showed a very great reflection pleochroism, a definite effect of anisotropy and a low reflective capacity. Coal blends from other localities in SE Norway show none of the above mentioned optical properties. Leitz has observed an intergrowth of parallel stripes, where the individuals of the anisotropic minerals are oriented approximately vertically to each other. Neumann states that the polished specimens of coal blend he has seen were built up from almost parallel, probably leaf-shaped individuals. Leitz stresses the similarity with graphite (Retort graphite). Neumann's Debye-Scherrer diagram of coal blend gave a few indistinct lines which did not coincide which any of those of graphite.

X-ray diagrams taken up for this investigation gave the lines for graphite, sphalerite and calcite.

A new polished section prepared from a globule of Kongsberg coal blend showed the optical properties mentioned above, but quite another pattern (fig. 4). However, this also resembles some of the types of «Retort graphite» (RAMDOHR 1928).

The chemical analyses are given in fig. 2. An x-ray spectrogram of the ashes from the Neumann analysis showed vanadium.[1]

As mentioned above the coal blend is found in the mines at Kongsberg even at great depth (~1000 meters below the surface). This will correspond to ~1500 m below the now denuded Cambrian alum-shale and ~2000 m below the Permian sediments. Coal blend has also been found outside the mine area, for example at Basserudåsen S. E. of Kongsberg, and at the small Tjennerud lake E of Kongsberg.

Loc. 6. Krekling, Eiker. Cambrian area.

In the core from a drillhole through alum-shale at Tangen a few, small grains of coal blend have been observed. Together with calcite and pyrite they form a thin vein cutting a nodule of black limestone. The exact stratigraphical situation is Parabolina heres-beds, 2 dε.

[1] The C_{12}/C_{13} ratio has been determined on Kongsberg material by Professor Wickman (Stockholm) with the following result: Calcite 89.69 89.58 89.24 88.73. Coal blend 91.16 91.12. No definite conclusion as to the origin of coal blend can be drawn from these results.

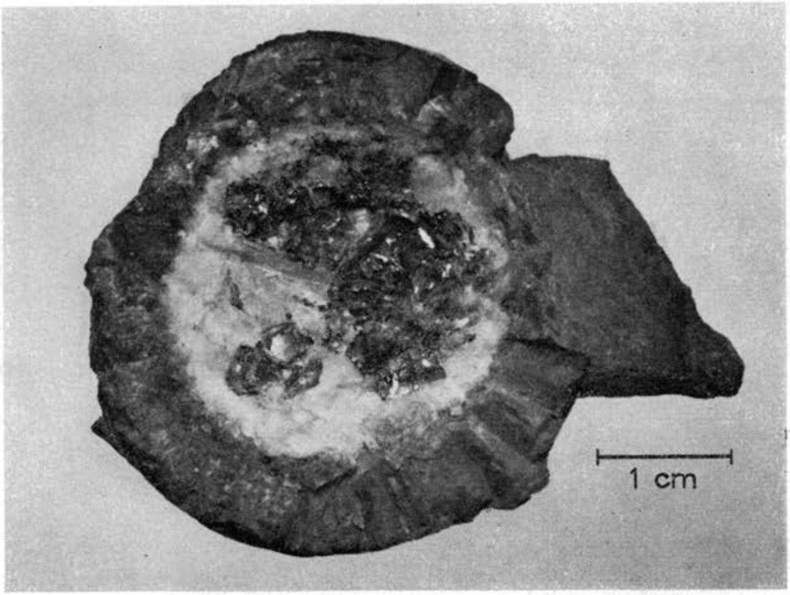

Fig. 5. Coal blend in calcite forming the central part of Echinosphaerites sp. Gåsøya, loc. 9.

Loc. 7. Mölen, Oslofjord. Precambrian area.

During an excursion in 1943 coal blend was found in thin calcite-fluorite-pyrite fissures which cut an amphibolite on the SE-side of the island. The coal blend is leafshaped.

Loc. 8. Langöya, Holmestrand. Silurian area.

The upper Silurian limestone (stage 9) building up the Langöya island is extensively quarried for use in the Portland Cement Factory at Slemmestad. The workers could at the author's request, confirm that coal blend which he found in a calcite vein, is quite frequently seen in the numerous crosscutting veins.

Loc. 9. Gåsöya, Oslofjord. Ordovician area.

A specimen of Echinosphaerites sp. was collected from the SW part of this island in shale between limestone beds (stage 4aβ — 4bα) by Dr. Örvig in 1941. The central part of the fossil is made up of calcite with some irregular grains of coal blend. Fig. 5.

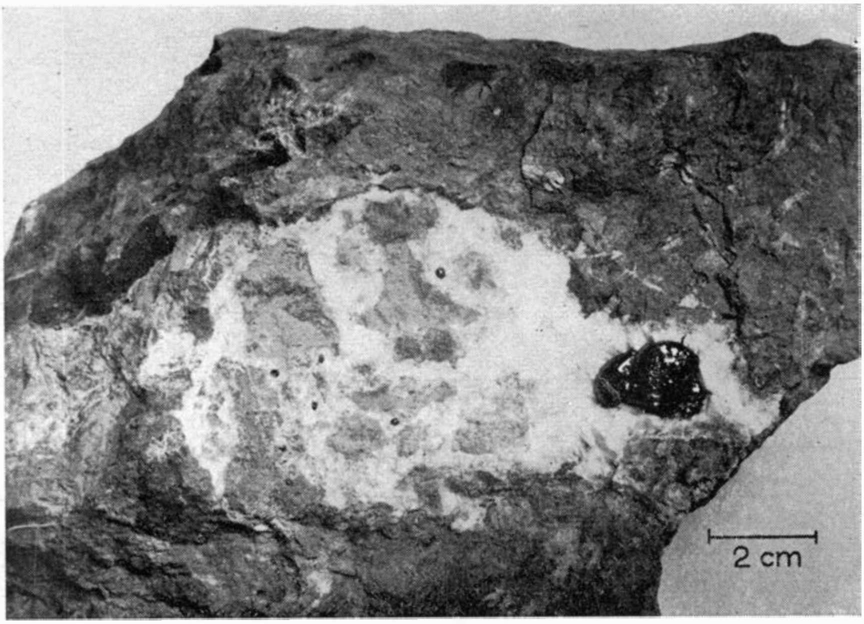

Fig. 6. Nodules of coal blend in calcite, Rhomb porphyry. Sønsterud, loc. 12.

Loc. 10. Bygdöy, Oslofjord. Ordovician area.

In the teaching collections of the University coal blend is represented by a specimen from Bygdöy sjöbad. Here it occurs together with calcite and pyrite as fine grains in a thin vein cutting black shale of lower Ordovician age.

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During his field studies of the Cambro-Silurian in Oslo and surroundings cand.real N. Spjeldnæs has often observed coal blend, in vertical calcite veins, especially where these cut across Cambrian and lower Ordovician sediments.

Loc. 11. Semsvik, Asker. Permian lava area.

The lower basalt, B_1, (the essexite lava E_1 of Brögger) overlaying the Permian fossiliferous beds at Semsvik contains cavities coated with small globules of coal blend as well as quartz, epidote, calcite and prehnite. (BUGGGE, NEUMANN 1939). Specimens have not been available to the author. The chemical analysis is tabled in fig. 2.

Loc. 12. Sönsterud, Tyrifjord. Permian lava and sandstone area.

Coal blend was discovered in 1938 in cavities and fissures of the lower rhomb porphyry lava RP_1 exposed in a road section near Sönsterud (KRISTOFFERSEN 1939). The mineral has the form of nodules (fig. 6) or fingershaped individuals and is always followed by calcite and locally also by fluorite. Chemical analyses are tabled in fig. 2. Spectrograms taken of the ashes show vanadium as a main component.

During detailed field investigations in this area the author happened to find small grains of coal blend also in the beds below the rhomb porphyry, viz. in a $^1/_2$—1 meter thick bed of sandstone and the underlaying basalt B_1 (DONS 1956).

Loc. 13. Sundvollen, Tyrifjorden. Silurian area.

It is related that coal blend has been found in road sections along the lake Tyrifjord between Sundvollen and Vik. Details are lacking, but it is assumed that the mineral occurs in narrow calcite veins intersecting upper Silurian shallow water sediments, stage 9.

Loc. 14. Åmot, Modum. Precambrian area.

A carbonaceous substance found by the workers in the quarry «Åmot pukkverk» was in the spring 1955 sent by the director of Åmot agricultural school, Mr. Heldal to this museum for identification. It proved to be coal blend. The quarry, which is worked for road material, was visited by the author May 1955. It is situated on the western side of the river Dramselven between the Åmot bridge and Embretsfoss factories at a distance of $1^1/_2$ km from the Cambrian alum-shales of the Oslo region. The steep hillside is built up of brecciated rocks forming a zone striking *N-S* in Precambrian amphibolite

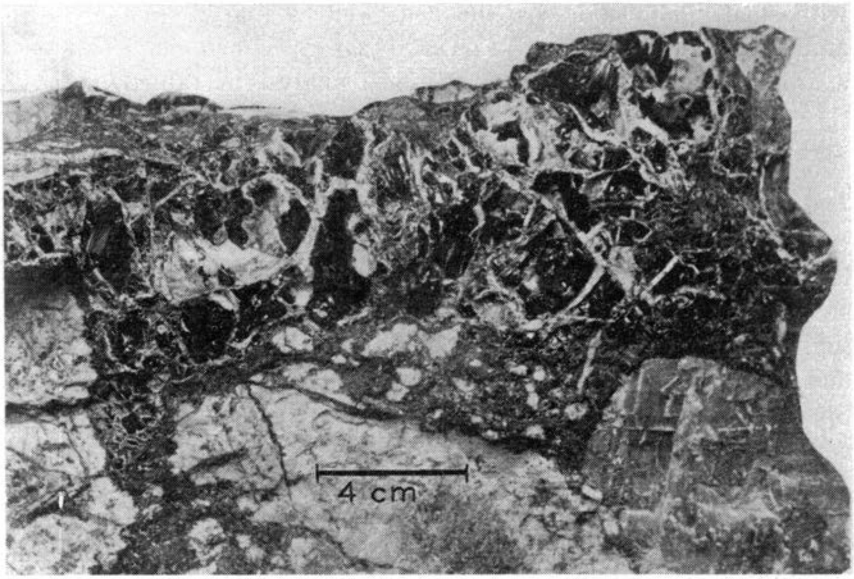

Fig. 7. Coal blend from Åmot, loc. 14. One great crystal of calcite is seen in the lower right part of the photo.

gneisses and quartz-mica-schists rich in actinolite. The breccia zone is believed by the author to be of Permian age, and may be regarded as a part of a faultsystem in the Precambrain area forming the western side of the graben of the Oslo Region. The base level of the quarry is situated 2—400 meters below the formerly existing sub-Cambrian peneplan and the Cambrian alum-shale.

The coal blend (fig. 7) is found in great amounts at one place in the breccia zone in the quarry. One gets the impression that the coal blend originally formed more or less horizontal layers, strings or clusters, 5—10 cm thick which later, due to shrinkage during consolidation, broke up in all directions, the interspaces being filled in with calcite etc. Great crystals of calcite 10—30cm across are often found close to the coal blend. Slickensides on planes of various directions are frequent within the breccia zone. One system of planes is nearly horizontal.

The quarry workings include two parallel Permian diabase dykes. They strike north-south, like the breccia zone in which they are found. The lack of coal blend in calcite fissures of the diabase dykes cannot be used for dating the formation of coal blend, because the occurrence of this mineral is limited to another part of the quarry. Thin sections show that there seem to be two generations of coal blend formation separated by an interval of slight movements, because dark parts of the rock, pigmented by rubbed coal blend, are cut by thin veins of undisturbed coal blend. The lighter parts of the breccia are composed of oligoclase formed secondarily, but prior to the coal blend.

The undisturbed greater masses of coal blend which suffered a shrinkage during consolidation became interwoven by hydrothermal veins composed of calcite, quartz (with undulating extinction!) chalcopyrite and chlorite. The latter mineral is pale-green in colour composed of fans and has an average refractive index of 1.61, weak birefringence and abnormal blue to violet interference colours. The birefringence and the interference colours are characteristic for penninite but that mineral has a lower index. The x-ray diagram also resembles that of penninite but is not absolutely identical. The chlorite is, as mentioned before, found in the coal blend, but it also occurs in the berccia rock in contact with the coal blend where it can be seen with a hand lens as laths or rectangular tablets.

The ore microscope reveals no inhomogenety in the coal blend like that observed in the Kongsberg material. The Åmot mineral shows thus no reflection pleochroism and no anisotropy. It has light grey smooth surfaces.

The chemical analysis performed on material previously treated with HCl-solution shows that the content of ash is very low, the results being 0.0 and 0.1 per cent.

A spectrographical analysis performed on material heated to 500° C gave the following content: Ca, Mg, Fe, Al, V ($^1/_2$—1 per cent) Ni, Mn, Mo and traces of Ag, Cu, Ti, Yt, Pb, Co. Another analysis of coal blend on unheated material gave: V, Ca, Fe, Si, Mg. The analyses show that vanadium is a typical element in the coal blend as was also the case with the Kongsberg and Sönsterud material. Many of the other elements, such as Ca, Mg, Fe, Si, Al etc., are derived from minerals found in microscopic veins in the coal blend. It is remarkable that no uranium lines could be identified, because one type of uranium bearing mineral (and ilmenite) was found at several places near the accumulations of coal blend.

Loc. 15. Stange. Precambrian area.

The second railway section south of Stange near the lake Mjösa crosses a Precambrian mylonite zone in which coal blend has been found, together with calcite and ankerite in thin fissures and veins (KJERULF 1885). No material is now available.[1]

Loc. 16. Furuberget. Ordovician area.

In the middle Ordovician «Mjösa Limestone» (zone 4bδ) 80 m thick, cand.real S. Skjeseth has observed local occurrences of coal blend in calcite veins. No mateiral is available at present.

Loc. 17. Garnos, Hallingdal. Volcanic breccia in Precambrian area.

The Permian (?) Garnos breccia which is composed of fragments of Precambrian rocks and Cambro-Silurian sediments has a groundmass pigmented and impregnated with carbonaceous particles (BROCH 1945). The microphotographs and the description show that the carbonaceous material is also found in narrow veins and scattered amongst the mineral-fragments of the groundmass. Pieces up to the size of a nut have been found. Broch concludes: «The coal may originate from volcanic gases — in that case being the only trace of them — or may be a distillation product of bitumen from Cambrian shales fallen to greater depths through the chimney». No detailed analysis of the material has been performed, but it is believed that the carbonaceous material has a composition which corresponds to the coal blend.

Loc. 18. Grönsæter, Hol, Hallingdal. Precambrian area.

«Coal» from this locality was in 1915 brought to the Geological Survey and the director visited the area the same year. (REUSCH 1920). In his publication (with English summary) he uses the expres-

[1] In Solör near the main road passing Rönåsmyren between Hukusjöen and Glomma (just outside the map area, fig. 1, 50 km SW of loc. 15) cand. real. S. Skjeseth this summer found coal blend in a NNW-running breccia in NNW-striking mylonitized pre-Cambrian gneiss. The breccia fragments are coated with small quartz crystals. Coal blend is found in the partly open space between the coated fragments. The coal blend is non-radioactive. The breccia most probably indicates a southern continuation of the important Permian Rendalen-fault, which in that case can be traced for a distance of 200 km. Also cand. mag. A. Hjelle found coal blend in pre-Cambrian rocks this summer. It occurs near the farm Östby 9 km S of loc. 15 in a N - S-running breccia zone.

sion carbonaceous substance, but the appearance and properties make it clear that it is coal blend. The mineral occurs scattered over a distance of 1 km in a 100—200 m thick bed of quartzite belonging to the Precambrian Telemark-formation. The coal blend is cut by veins of quartz, but no calcite can be seen. There is no sharp junction between quartzite and layers or patches of coal blend. Pieces as large as an apple have been observed in layers $^1/_2$ m long and 20 cm thick. Fig. 2 gives the chemical analysis characterized by a high content of ashes. The specific gravity is consequently high and variable, the average being 1.768 (4° C) and max. 1.950. Coal blend in our museum from this locality as from all the others will not burn, but people living at Grönsæter have said that some of this material really burned.

Loc. 19. Strandefjorden, Hol. Precambrian area.

This and the following occurrence of coal blend have been found by director Dr. C. Bugge while acting as geological adviser to Oslo Lysverker during the construction of water barrages and tunnels in this district for water-power. Dr. Bugge has kindly informed me that small grains of coal blend were found in a mica sandstone near the border of granite at the eastern end of Strandefjorden. These rocks belong to the Telemark-formation. The sandstone is porous and beautifully brecciated.

Loc. 20. Stolsvann, Hol. Precambrian area.

The coal blend was also here found at the place where the barrage was to be constructed. It occurs in cavities in the so-called «Dagali gneiss» near bedded sandstone.

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Hypothesis of origin and conclusions.

Coal blend is a complex of carbon-hydrogen-oxygen-compounds with traces of nitrogen and sulphur. The content of graphite, as well as other components, varies in the same occurrence and from one occurrence to another.

For considerations concerning the mode of formation it is to be noted: 1) that the Cambrian alum shale, which once covered the whole area where the coal blend is found, contains small quantities of carbon and vanadium; 2) that the Cambro-Silurian sequence is composed of fossiliferous limestones and shales and that parts of this sequence also covered the same area; 3) that the Permian sediments of insignificant thickness formimg the base of the lava series contain fossil plants; 4) that the Carboniferous epoch is not represented by any rocks in Southern Norway, and finally 5) that the Permian igneous activity can be traced by means of dykes etc. far outside the graben area itself, (see fig. 1 where also some of the most prominent dykes are indicated).

The Narestö coal blend looks like the material from the other 19 localities but differs by containing a uranium mineral. It is also the only occurrence of coal blend in pegmatite. The properties and mode of occurrence harmonize fairly well with that of the thucholites, Th is however lacking. Examples of such radioactive hydro-carbon aggregates are recorded in a most interesting paper by DAVIDSON and BOWIE, 1951, where also previous literature is summarized. It is believed that radiations from preexisting radioactive minerals have polymerized hydrocarbon compounds present in hydrothermal solutions, thus stopping further circulation of these compounds by a condensation around the nuclei of minerals. The chemical analysis of the Narestö material calculated as ash-free material shows a higher content of oxygen and a lower content of carbon compared with the other coal blends. This may be due to the bombardment of alpha and beta particles sent out by the radioactive mineral, a treatment which did not take place in the other cases. (Non-radioactive carbon material is described by DUNN and FISCHER 1954, and by MUELLER 1954).

All the occurrences of coal blend can be of hydrothermal origin. Concerning the Narestö (and Mørefjær?) material the hydrothermal activity may be of Precambrian or Permian age, for all the others a Permian age is supposed.

It is believed that the original hydrocarbon fluids had a reasonably constant composition and that the different properties now observed in the coal blends are due to the mode of polymerisation under varying conditions.

Most of the coal blends, if not all of them, have in all probability passed through the state of gels which became concentrated in zones of comparatively high porosity. Subsequent changes of the protocoal blend to a viscous mass led in some place to the globular structure, and elsewhere to more or less regular layers which suffered a decrease in volume when the viscosity gradually increased, producing a brecciated structure. The filling of fractures by hydrothermal minerals (calcite, quartz, chlorite, etc.) indicates that the whole process of solidification took place in the hydrothermal stage.

The hydrocarbon content of the hydrothermal solutions may have been juvenile in the Permian magmas, most probably in the granitic ones. The parent material may also be Cambro-Silurian sediments assimilated by these magnas. That the magmas may contain carbon-hydrogen-oxygen compounds is made probable by the occurrence of «petroleum» in the diabases in the Arendal area (described above under loc. 2).

It can be objected that the loc. 18, 19 and 20 are found at too great a distance from the Oslo region to have been influenced by hydrothermal solutions from Permian magmas. However, it must be remembered that breccia-zones of Permian age or reworked in Permian time, during the later years of study have been traced very far outside the Oslo region. (Broch 1950).

A few other hypotheses of origin mentioned briefly below may of course be considered, however, they all seem to be less probable. The coal blend could originate directly in the Cambrian (carbon bearing) alum-shales or other fossiliferous Cambro-Silurian (and Permian) shales. If there is only one source of material, which is believed to be the case, the hydrocarbon must have passed downwards at least to the deepest levels in the Kongsberg mine as well as upwards through the Permian lavas. A local reduction of limestone giving a hydro-carbon compound of the coal blend type seems improbable as the presence of such unknown reducing agents would have influenced the rest of the rock in a noticeable way.

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