

Metallogeny of the Elsjø area, northern Oslo Region, Norway

SVEIN OLERUD

Olerud, S.: Metallogeny of the Elsjø area, northern Oslo Region, Norway. *Norsk Geologisk Tidsskrift*, Vol. 64, pp. 325–334. Oslo 1984. ISSN 0029-196X.

The Elsjø area is situated in the northern part of the Oslo Region and consists of a 2 km² inlier of Palaeozoic metasediments. Cambro–Ordovician shales and limestones are enclosed in Permian intrusives and are contact metamorphosed and altered by metasomatic processes. The present investigation has defined three mineralisation types of interest: The heavy-metal content of the Alum shale, sphalerite-bearing skarn lenses within the Alum shale and molybdenite mineralisation in the underlying Permian granites.

The Alum shale of the Elsjø area has a maximum thickness of more than 150 metres as a result of overthrusting and folding during the Caledonian orogeny. The highest heavy-metal content is in Upper Cambrian strata. The greatest average content is in a 10.6 m thick layer with 160 ppm U, 200 ppm Mo, 930 ppm V, 11.6 % C and 2.8 % S. The Alum shale also contains lenses of hedenbergite-garnet skarn lenses with sphalerite mineralisation; these are alteration products of marble lenses in the shale. Similar sphalerite-bearing skarn mineralisation is also found in other stratigraphic levels and on shear zones. The Palaeozoic sedimentary rocks are underlain by three types of Permian granites. Molybdenite occurs as scattered disseminations in the phyllic alteration zones of the granites. Propylitic alteration is common in both the underlying intrusives and in the Palaeozoic sediments. The molybdenite mineralisation has similarities with porphyry molybdenum type occurrences, but can also be interpreted as a roof zone mineralisation in the granites.

S. Olerud, Norges geologiske undersøkelse, Postboks 3006, N-7001 Trondheim, Norway.

The Elsjø area is situated in Nittedal and Nanndal municipalities, 35 km north of Oslo (Fig. 1). Sphalerite showings were discovered in the area at about the beginning of this century. Mining activities took place between 1906 and 1921, and more than 1.5 km of adits and shafts were driven. The geology of the sphalerite-bearing skarn mineralisation was first described by Goldschmidt (1911). From 1976 to 1980 the project 'Undersøkelse av statens bergrettigheter' at the Geological Survey of Norway undertook new investigations of the zinc occurrences (Mathiesen et al. 1976, Ihlen 1978). The potential for extracting uranium, vanadium and molybdenum from the Alum shale and zinc from the skarn lenses was investigated later (Ihlen 1980, Olerud 1982a). This paper reports the results of these investigations, emphasising the geological setting, tectonics, the trace-element content of the Cambro-Ordovician shales and the hydrothermal zinc and molybdenum mineralisations related to Permian intrusives.

Chemical analyses were done at the Chemical Division of the Geological Survey of Norway. Uranium was analysed by gamma spectrometry, molybdenum and vanadium by X-ray fluores-

cence, sulphur and carbon by combustion methods. The estimates of the resources in the Alum shale given here are based on the chemical composition of the shales after elimination of the limestone layers.

Geological setting

The Elsjø area consists of hornfelsed Cambro-Ordovician sedimentary rocks which occur as a 2 km² xenolith in Permian intrusives of the northern Oslo Region (Fig. 1). The area is located on the eastern margin of the Stryken ring complex, interpreted as a cauldron root by Scott (1979), where syenite porphyry and felsites make up a system of ring dykes. To the north, a circular alkali granite intrusion occurs, with remnants of porphyric syenite along the borders forming an incomplete circular structure (Scott 1980). The Elsjø area is situated at the point of intersection of these two main ring structures (Fig. 1). The Cambro-Ordovician rocks are in contact with five different Permian intrusives (Scott 1979, Olerud 1982b) (Fig. 2) which have produced extensive contact metamorphism and skarn alter-

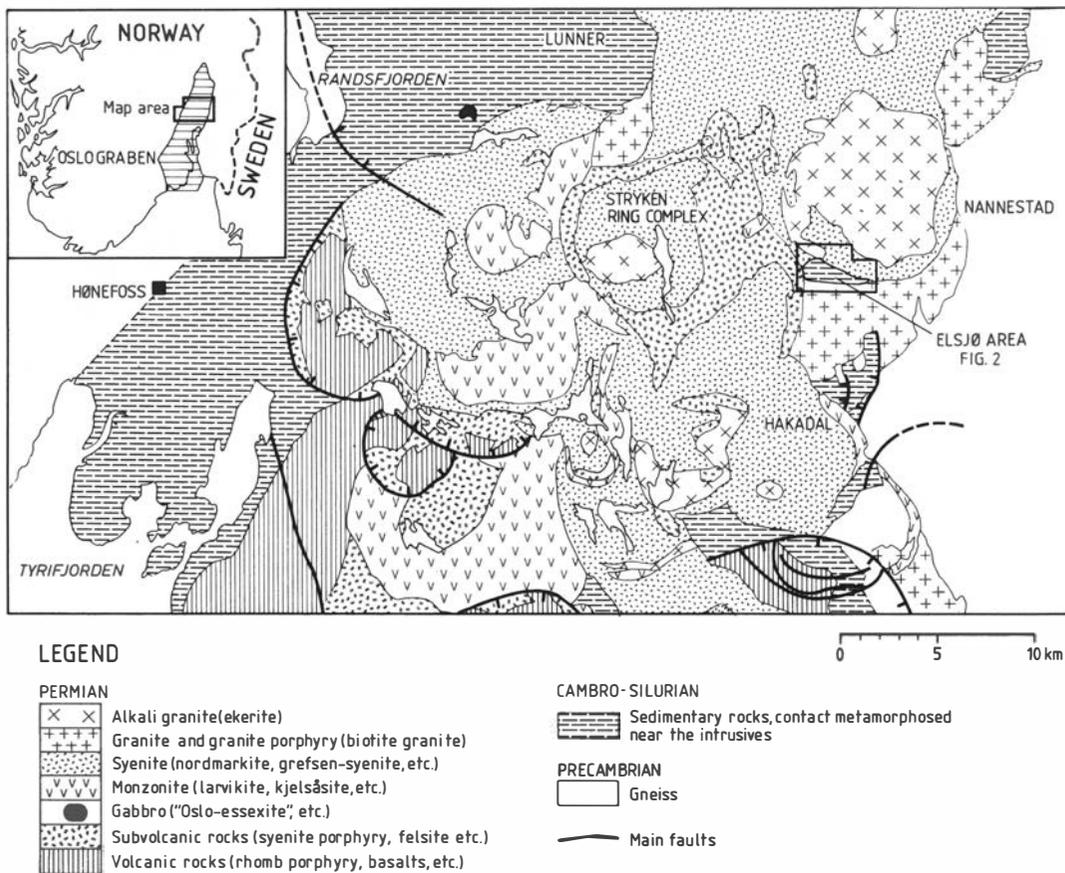


Fig. 1. Geological map of the northern part of the central Oslo Region compiled and simplified from Brøgger & Schetelig (1923), Sæther (1962), Larsen (1978), Scott (1980) and Olerud (1982b).

ation in the limestones. The area is underlain by Permian granites.

The Cambro-Ordovician sequence begins with a basal siltstone of probable Middle Cambrian age and a minimum thickness of 10.85 m, overlain by black shales with thin limestone layers or nodules of Middle Cambrian to Lower Ordovician age. The sediments of Lower to Middle Ordovician are grey calcareous shales with limestone nodules, black shales and nodular limestone as described by Bjørlykke (1974). The Alum shale has a thickness, determined by drilling, of more than 150 m (diamond drill hole no. 1, Fig. 2), caused by folding and thrusting during the Caledonian orogeny.

Sphalerite mineralisation occurs in skarn horizons replacing former limestone beds and also as vein occurrences related to fault zones. Scattered molybdenite mineralisation is found related to

hydrothermal alteration zones in the underlying Permian granites.

Tectonics

The marine sequence of Lower Palaeozoic sedimentary rocks in the Elsjø area was folded during the Caledonian orogeny along fold axes striking ENE-WSW to E-W and plunging 10–20° to the southwest. The strike is the same as in the neighbouring Cambro-Silurian areas of the Hadeland (Brøgger & Schetelig 1923) and Oslo-Nittedal areas (Holtedahl & Dons 1955), but the plunge is steeper.

The Cambrian rocks in the Elsjø area are in general nearly flat lying (dip 0–20°), while the Lower and Middle Ordovician rocks are steeply folded. According to several authors (Bockelie &

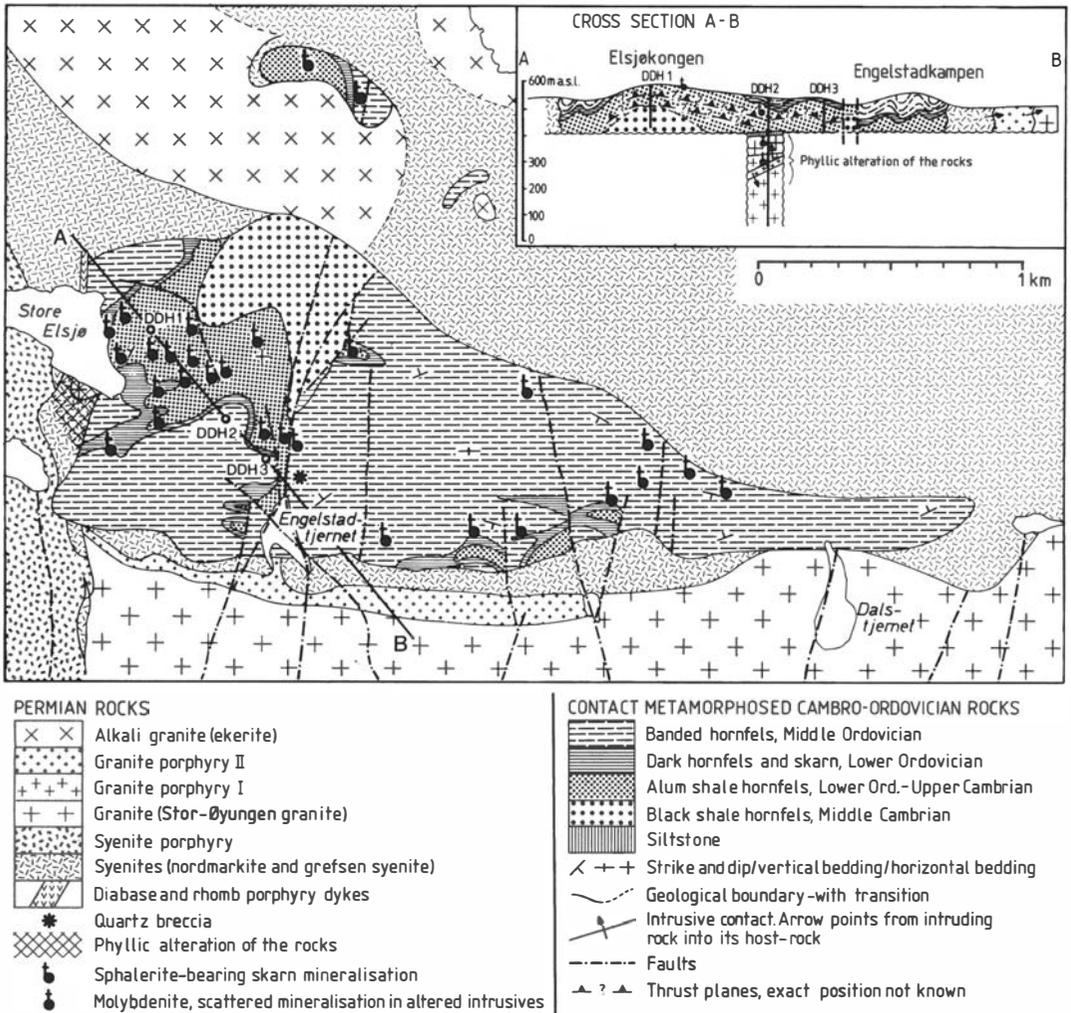


Fig. 2. Geological map of the Elsjø area. Geological boundaries in Permian intrusives north of the Elsjø area are based on Scott (1980), boundaries in the intrusives in the southwestern corner of the map are based on Gaut (1981).

Nystuen 1981, Bjørlykke 1983), the different fold styles between Cambrian and Ordovician rocks in the Oslo Region are separated by a thrust plane in the Cambrian black shales. The thickness of more than 100 m in DDH 3 of nearly flat lying uranium rich Alum shale (Olerud 1982a) suggests repetition by thrusting or overturned folds in the sedimentary sequence, which is normally about 45 m thick (Bjørlykke 1974). The exact location of the thrust planes is uncertain, since at least nine breccia zones and/or calcite veins could be thrust planes. The limestone beds contain fragments of surrounding rocks from slide movements along the beds.

The beds in DDH 2 and 3 are relatively flat lying (0–20°), while the shales in DDH 1 dip between 30° and 45°. In the Elsjøkongen area (Fig. 2) stratigraphically low levels in the Cambrian shales form the highest topographic point with Ordovician shales at topographic lower levels both in the north and south. This indicates folding of the Cambrian sediments into a major antiform.

All Cambro-Ordovician rocks except the basal series and a few metres of the overlying Alum shale are thought to be allochthonous because of the imbricate structure described above.

Nearly vertical faults with displacements of 50

Table 1. Selected chemical analyses of Cambro-Ordovician hornfelsed shales.

Stratigraphic level / rock type	ppm U	ppm Mo	ppm V	% S	% C	Sample type
Hornfelsed Ordovician shale	25	42	246			Av. of 3 hand specimen.
Hornfelsed Didymograptus shale	33	46	615	1.1	2.1	Av. of 3 m core, DDH 2.
Hornfelsed Ceratopyge shale	58	97	1400	1.3	4.2	Av. of 3.0 m core, DDH 2.
Hornfelsed Dictyonema shale	85	161	1650	1.3	5.9	Av. of 6.03 m core, DDH 2.
Hornfelsed Dictyonema shale	138	302	3400			Highest V content in hand specimen.
Hornfelsed Alum shale	137	202	765			Av. of 73.68 m core, DDH 3.
Hornfelsed Alum shale	160	204	933	2.8	11.6	Av. of 10.6 m core, DDH 2 (43.8–54.4m).
Hornfelsed Alum shale	239	242	1400			Highest U content in hand specimen.
Garnet-graphite rock	504	1500	1500			Highest U content, 0.06 m core, DDH 3, secondary enrichment?
Hornfelsed Middle Camb. shale	53	119	155			Av. of 7 hand specimen.

to 150 m divide the Elsjø area into two main parts, mainly Cambrian rocks in the west and mainly Ordovician rocks in the east (Fig. 2).

In the eastern part of the area several faults with downward movement to the east have a vertical displacement of some tens of metres. Detailed underground mapping of the sphalerite mineralisation in the Alum shale (Ihlen 1980) reveals a network of small faults in the Engestadtjern-Elsjøkongen area with vertical offsets of 2 to 3 m. The faults along with the southwest-plunging fold axis may be Permian deformation related to the emplacement of the underlying intrusives.

Trace elements in Cambro-Ordovician shales

Shale samples were taken from surface outcrops, old mine adits and shafts, and drill cores. The sampling and the results of the rock analyses are described in detail by Olerud (1982a). The main results are presented in Table 1 and as a drill core section of DDH 2 in Fig. 3. The stratigraphy of the section on Fig. 3 is compiled from lithologies described in the neighbouring areas of Hadeland and Oslo-Aker by Strand (1948), Spjeldnæs (1954), Henningsmoen (1960) and Bjørlykke (1974) and based on the trace element pattern of the shales as reviewed by Bjørlykke (1974). The strong contact metamorphism of the shales and limestones has resulted in the formation of hornfelsed and marbles. Fossils are hard to recognise. Table 1 shows selected average values of U, Mo, V, S and C in different shale types and stratigraphic levels and some maximum values found in hand specimens and drill cores.

The highest uranium average value obtained in

the Alum shale over 10.6m of drill core is 160 ppm U. The drill cores were mostly analysed in 3 m sections. Because of local variations, hand specimens or thin beds from drill cores give higher values, see Table 1. In the Alum shale, the highest uranium values obtained for one hand specimen was 239 ppm U, while in a supposed hydrothermally enriched garnet-graphite rock the highest value found was 504 ppm U. The Dictyonema Shale contains a high vanadium content, the highest average content over 3 m of drill core being 3400 ppm V in addition to 138 ppm U, and 302 ppm Mo.

Intensive investigations on the Alum shale were carried out in the Oslo Region in the 1950's. Skjeseth (1958) showed that the *Leptoplastus* and *Eurycare* (Stage 2c) and the *Peltura* layers (Stage 2d) in the Upper Cambrian have the highest uranium contents. The highest average content was found to be 50–100 ppm in beds of 5–15 m with a maximum value of 170 ppm in thin layers. The Geological Survey of Norway recently re-analysed some of the drill cores from this investigation. The drill core from Stablum near Kongsberg (Skjeseth 1958) shows average values of the *Peltura* shales of 129 ppm U, 215 ppm Mo and 1077 ppm V over a 14.6 m thickness. The maximum U content in this sequence is 213 ppm U. The highest vanadium value is 5600 ppm, recovered from the Dictyonema shale. The stratigraphic interpretation is based on fossils (pers. comm. G. Henningsmoen 1979).

Investigations on the U-content of the Alum shales in Sweden (Armands 1972, Andersson et al. 1982) show that the maximum uranium values are found in the *Peltura* *scarabaeoides* zone (Upper Cambrian). At Ranstad in Billingen the richest part is a 2–4.5 m thick layer with an aver-

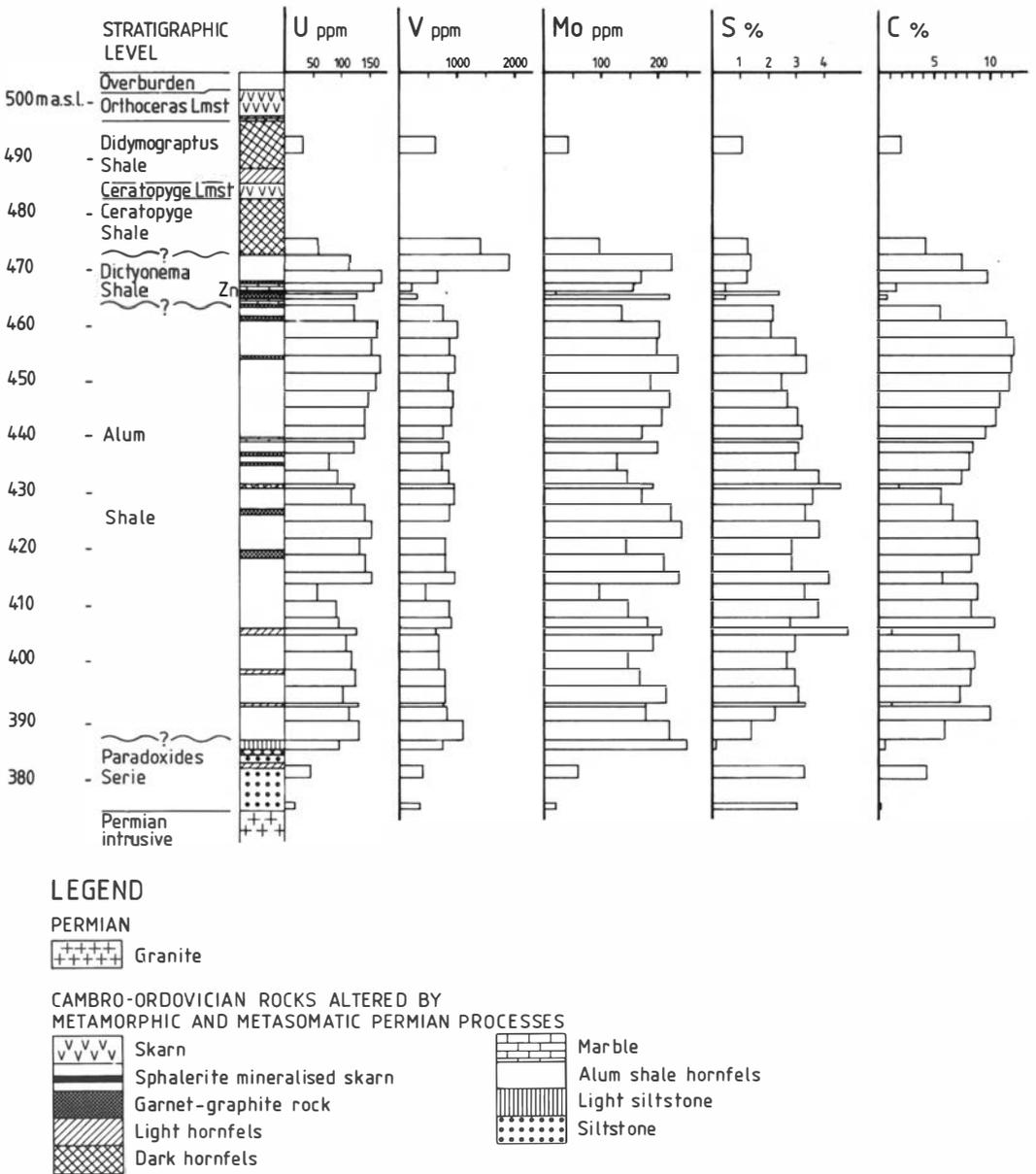


Fig. 3. The content of uranium, vanadium, molybdenum, sulphur and carbon in the Cambro-Ordovician hornfelses in DDH 2 in the Elsjø area.

age of 290 ppm U, including the kolm unit (Edling 1974) containing organic matter up to 70 % and uranium up to 0.7 %. The average during mining was 306 ppm U (Andersson et al. 1982). The maximum vanadium content is found in the Dictyonema shales.

The sulphur content of the Alum shale (3.1 %

on average) in the Elsjø area is lower than the values found by Bjørlykke (1974) in the Oslo-Aker district (average ca. 6 %). The sulphides in the hornfelses are mostly pyrrhotite and smaller amounts of pyrite. A part of the sulphides occurs as mm-thick pyrrhotite-enriched laminae in the Alum shale. A large share of sulphide material is

Table 2. Correlation coefficients between elements in hornfelsed Alum shale, DDH 2.

	U	Mo	V	S	C
U		0.67	0.43	-0.19	0.25
Mo			0.61	0.15	0.02
V				-0.01	0.13
S					-0.52

mobilised in a pyrrhotite-bearing stockwork which is found throughout the Cambro-Ordovician rocks. Analysis of the drill core (Fig. 3) suggests that the Alum shale is depleted in sulphur compared with primary values found by Bjørlykke (1974), while skarn horizons and some silicious interbeds of the shale are enriched.

Analyses from 30 samples from DDH 2 containing Alum shale were selected and the U, Mo, V, S and C contents were treated statistically. Table 2 shows the correlation coefficient between the elements. Uranium correlates well with molybdenum ($R=0.67$) and vanadium ($R=0.43$), while the uranium against sulphur ($R=-0.19$) and carbon ($R=0.25$) show no correlation. Edling (1974) found the correlation coefficient of uranium and carbon in the high-grade kolm unit in Ranstad, Sweden to be $R=0.98$ while in the Alum shale itself U and C showed no correlation ($R=-0.07$).

The levels of U, Mo, V and C and the correlation pattern between them are in accordance with values of the Alum shale in the Oslo Region (Bjørlykke 1974) and Sweden (Edling 1974, Andersson et al. 1982). These patterns indicate that the trace-element abundances are only slightly affected by contact metamorphism and hydrothermal alteration. The U, Mo and V contents are interpreted as being very close to the abundances in the primary sediment. Hydrothermally derived uranium and molybdenum are found only in two localities as irregular enrichments of a few cm width. No evidence has been found for secondary enrichment of vanadium.

Until now the kolm unit with a uranium content up to 0.7%, as in Sweden, has not been found in the Norwegian Alum shale. New analyses of previously investigated Alum shale show higher values of U, Mo and V than earlier investigations by Goldschmidt (1954), Skjeseth (1958) and Bjørlykke (1974). The Elsjø field has the highest uranium values in Alum shales in Norway known until now, but this rock unit has not been system-

atically sampled and analysed by modern laboratory equipment, so higher values may exist.

Sphalerite mineralisations

Underground mapping done by Ihlen (1980) shows that the most important zinc mineralisations in the western part of the Elsjø area are related to limestone lenses at a single stratigraphic level in the Alum shale. The U, Mo and V content of the surrounding shales (Olerud 1982a) also suggests that the lenses are from one stratigraphic level. This level is interpreted as the lower part of the Dictyonema shale and/or the uppermost part of the Peltura shale (see Fig. 3). The limestone lenses have irregular shapes from small nodules to discoid-formed lenses with maximum sizes of $2 \times 40 \times 50$ m (Ihlen 1980). This size is unusual as the limestone nodules and lenses seldom exceed 1 m in these strata (Henningsmoen 1960).

The zinc mineralisations were described by Goldschmidt (1911) and recently in more detail by Ihlen (1980). Sphalerite occurs in a medium-grained skarn rock dominated by hedenbergite, garnet and small amounts of calcite, amphibole and sulphides. Between the skarn rock and the surrounding Alum shale there is always a zone of garnet-graphite rock. This characteristic zonation is shown all over the Elsjø area. The Zn content of the skarn lenses seldom exceeds 10%, and the average is estimated to be 5% (Mathiesen et al. 1976).

Underground mapping and drilling show that only a small share of the limestone lenses is altered to skarn. The Zn-mineralised skarn lenses are too widespread and low grade to be recoverable even with an economic process for total extraction of the Alum shale.

Other sphalerite occurrences in the eastern part of the Elsjø area are described as mineralized fault zones and as thin skarn-altered limestone beds (Goldschmidt 1911, Mathiesen et al. 1976, Ihlen 1978).

Permian rocks, alteration and molybdenite mineralisation

Core drilling through the Cambro-Ordovician rocks (Olerud 1983) showed that the Elsjø area is underlain by Permian intrusives, granite and granite porphyry I and II (Fig. 2). These rocks

are hydrothermally altered and brecciated and carry low grade molybdenite mineralisation locally.

Permian rocks beneath the Cambro-Ordovician rocks

Three main types of granite intrusion occur in DDH 2 (cross-section, Fig 2). The oldest intrusion is a granite found in the uppermost part of the Permian rocks in the drill hole. This granite is known as the Stor-Øyungen granite and outcrops south of the Elsjø area (Figs. 1 and 2). The granite porphyry I, which is not found in outcrops, intrudes the Stor-Øyungen granite. The granite porphyry II intrudes granite porphyry I in DDH 2 and is found as dykes and irregular bodies inside the Stor-Øyungen granite (Gaut 1981, Olerud 1980). The relationships between the intrusives are shown on the cross-section in Fig 2. South of the Elsjø area the Stor-Øyungen granite and granite porphyry II are cut by younger syenites of the Nordmarka batholith (Gaut 1981). Two other types of dyke of lesser importance are found in DDH 2.

Breccias occur at four localities in the upper part of granite porphyry I and in the lower part of the granite. The breccias have angular to rounded fragments mainly of feldspar and quartz from the wall rock. The fragments are less than 4 cm across and are cemented by rock flour. Infill of hydrothermal minerals is minor.

The Stor-Øyungen granite south of the Elsjø area is described by Gaut (1981) as a coarse-grained biotite-bearing subsolvus granite with hypidiomorphic granular texture. This rock is found in DDH 2, but is always slightly altered by late hydrothermal processes.

Granite porphyry I has phenocrysts which make up more than 40 % of the rock. The alkali-feldspar grains are 3–10 mm across, hypidiomorphic, partly rounded crystals, often zoned or plagioclase-mantled. The plagioclase grains are hypidiomorphic, partly rounded with a grain size of 2–6 mm. The quartz occurs as partly rounded and corroded grains less than 3 mm. The matrix is dominated by quartz and plagioclase with grain sizes less than 0.1 mm.

Granite porphyry II is an allotriomorphic granular rock with grain size 0.1–1.0 mm. It occurs both with and without phenocrysts of partly rounded quartz or hypidiomorphic alkali-feldspar and often shows granophyric texture with irregular intergrowths of quartz. The rock is

characterised by red spots, which are halos around disseminated pyrite grains in the rock.

Molybdenite mineralisation

Molybdenite occurs scattered in Permian granitic rocks in DDH 2 between 370 and 265 m a.s.l. (Fig. 2) and between 170 and 150 m a.s.l. The mineral is spatially connected to areas with intensive phyllic alteration and is deposited in the following ways:

1. Molybdenite as a dissemination in zones with phyllic alteration.
2. Molybdenite coatings on fissures.
3. Molybdenite in veinlets of quartz, epidote and pyrite.

The molybdenite mineralisations are too low grade to be of economic interest.

Hydrothermal alteration

The Permian rocks in DDH 2 are hydrothermally altered by three main types of alteration.

Phyllic alteration is encountered in the granite intrusions beneath the Cambro-Ordovician part of the area in DDH 2 and in granite and syenite on the western shore of Store Elsjø on the western border of the Elsjø area (Fig. 2). In DDH 2 the phyllic veins are spread along the whole length of the core. They are most abundant in the upper part of the intrusives between 370 and 265 m a.s.l., where approximately 20 % of the rock volume is altered. Between 230 and 142 m a.s.l. the rock is more weakly altered, approximately 6–8 % of the rock volume. In other parts of the core, phyllic alteration is sparse.

Phyllic alteration occurs as a vein stockwork and is only seen in the intrusives. The thickness of the veins is commonly 2–20 mm, but more pervasively altered zones with thicknesses of several m also occur. The typical vein is developed on both sides of a seam of pyrite. Near the centre of the vein nearly all the feldspar is altered to sericite and quartz. The proportion of altered feldspar decreases outwards and the rock gradually changes to a fresh-looking rock. The quartz is unaffected. In thicker veins the altered rock takes on a light grey colour and a massive and fine-grained appearance, but the original intrusive texture is still preserved as ghost-like feldspar grains. The feldspar is altered to sericite and quartz and the rock now consists of quartz and

sericite with lesser amounts of pyrite, fluorite, chlorite, carbonates and molybdenite.

Argillic alteration occurs as a bleaching and slight green colouring of the rock in the uppermost part of the Permian intrusions in DDH 2, between 351 and 328 m a.s.l. In other parts of the core argillic alteration is scattered. This alteration is characterised by a clay mineral alteration of the plagioclase and a precipitation of hydrothermal minerals such as pyrite, carbonates and fluorite on grain boundaries in the rocks. The biotite is altered to aggregates of chlorite, pyrite and carbonates. This alteration is classified in the drill logs as a weak pervasive argillic alteration. Clay minerals also occur as vein-filling in the DDH 2. Dickite and montmorillonite are the main clay minerals according to x-ray diffraction analyses.

Propylitic vein alteration is common in the whole Cambro-Ordovician Elsjø area and in the underlying Permian intrusions, except for the 40 m in the lowermost part of DDH 2. In the surrounding intrusives, veins with propylitic mineral assemblages are seldom found. Propylitic alteration occurs as a stockwork of veinlets, mostly less than 2 mm thick. Locally they can swell out to a few centimetres. The veins consist of epidote, pyrite and/or pyrrhotite, quartz, chlorite, carbonates, fluorite and garnet. These hydrothermal minerals are restricted to the veins, and no alteration of the wall-rock minerals can be seen. In the Cambro-Ordovician hornfels, pyrrhotite is the most common sulphide, while pyrite is the only iron-sulphide which occurs in the intrusive rocks. The propylitic veinlets cross-cut both the phyllic and argillic altered rocks.

As an approach towards a solution of the problem of the origin of the zinc-skarn mineralisation and the propylitic alteration of the hornfels, it is necessary to review some field observations. South of the Elsjø area a syenite dyke intrudes the granite porphyry I; it can also be seen that it is unaltered and cuts the propylitic veins in the Cambro-Ordovician hornfels at the border. On the shore of Store Elsjø (Fig. 2) a similar syenite is altered by phyllic alteration. This suggests that the propylitic alteration of the hornfels and the phyllic alteration of the intrusives are two different events. Chronologically the granite is the oldest rock type followed by the propylitic alteration of the hornfels and the zinc-mineralisation in skarn. Later, the granite porphyry I and II, the syenite and the phyllic alteration and

molybdenite mineralisation followed in succession.

Evaluation and conclusions

Three main types of ore-mineral occurrence are found in the Elsjø area. The Alum shale with U, Mo and V, along with Zn from the skarn lenses in the most radioactive part of the shale, are of economic interest. Beneath the sedimentary sequence, there is also a potential for hydrothermal molybdenite occurrences.

During recent decades the Alum shale of the Oslo Region has been evaluated as a possible uranium source. The IUREP mission (Wilson et al. 1983) found that favourable features of the Alum shale were its large volume and its association with other metals, while unfavourable features were the low grade and the lack of mobilisation. The Alum shale of the Elsjø area has the highest uranium content in the Oslo region known to date, but even with the vanadium and molybdenum content, exploitation is not economic at current metal prices. Underground mapping and drilling have shown that only small areas of the limestones are altered to sphalerite-bearing skarn.

The shape of the molybdenite mineralisation is not known in three dimensions, but the characteristic features may be compared to porphyry molybdenum systems in general (White et al. 1981) or to the occurrences in the Glitrevann and Hurdal areas in the Oslo Region, described by Schönwandt & Petersen (1983). Similarities with these porphyry occurrences are:

1. The presence of several shallow granite intrusions.
2. The Mo mineralisation in phyllic altered rocks placed in the uppermost part of a granitic intrusion and in the overlying rocks.
3. The existence of a local phyllic and argillic alteration zone.
4. The existence of a local propylitic alteration zone. The propylitic alteration and contact metamorphism are very strong in the Cambro-Ordovician rocks, but this is a well-known regional phenomenon in the contact areas in the Oslo Region (Goldschmidt 1911) and cannot be used as a local alteration pattern related to the mineralising system. The intrusives beneath the Elsjø area have a strong propylitic vein alteration, which is not common for the surrounding areas and is therefore

thought to be related to a local hydrothermal system.

Important distinguishing features are the lack of high temperature K-alteration and the irregular and very low Mo content. The importance of these is hard to evaluate as the shape of the mineralisation and alteration pattern is not known. Einaudi et al. (1981) summarise that porphyry-related skarns tend to consist of fine-grained to massive aggregates of calc-silicates. The skarn types in the Elsjø area are medium-grained and dominated by hedenbergite and garnet, which according to Einaudi et al. (1981) should be a skarn type formed near a batholith and not related to a porphyry system.

In the Skrukkelia molybdenite deposit in the Oslo Graben, Olerud & Sandstad (1983) interpreted the Mo mineralisation in the sialic gneisses either to be a roof zone above a postulated Permian granitic intrusive or a weakly developed porphyry molybdenum system. Compared to the Skrukkelia deposit the Elsjø area has more intense propylitic and phyllic alteration; both have very low grade Mo mineralisation.

The relationship between the Mo and Zn deposition is difficult to outline because the hydrothermal alteration of the rocks gives very different results in the intrusives and in the hornfelses. In the intrusives the results are phyllic alteration partly with molybdenite, and propylitic vein alteration with pyrite. In the hornfelses the results are a replacement of the limestones with skarn and a deposition of skarn veins along fracture zones, both types with sphalerite and other sulphides. The propylitic vein alteration in the hornfelses carries both pyrrhotite and pyrite.

In the Drammen granite, molybdenite-bearing veins with different kinds of alteration envelopes occur within and in apical positions to the main intrusives (Ihlen et al. 1982). These roof zone molybdenite mineralisations and their related alterations are comparable to the Elsjø molybdenite mineralisation. The field observations suggest that the Mo mineralisation and the hydrothermal alteration phenomenon in the intrusives are related to late phases of the granite porphyry I or II or to other unknown granitic rocks, while the propylitic alteration and zinc mineralisation in the Cambro-Ordovician rocks are related to the intrusion of the granite.

The molybdenite mineralisation and the related alteration types have similarities with porphyry molybdenum occurrences, but they are more likely a roof zone mineralisation of the granite intrusions.

phyry molybdenum occurrences, but they are more likely a roof zone mineralisation of the granite intrusions.

Acknowledgements. – The author wishes to thank the NGU project 'Undersøkelse av statens bergrettigheter' for financing this study. The manuscript greatly benefited from discussions with P. M. Ihlen. Thanks are due to P. W. Scott, who provided new information about regional geology, and to J. Staw who drew the figures. Valuable corrections and improvements to the text were made by R. Boyd, J. S. Sandstad and two anonymous referees.

Manuscript received April 1984,
revised December 1984

References

- Andersson, A., Dahlman, B. & Gee, D. G. 1982: Kerogen and uranium resources in the Cambrian alum shales of the Billingen-Falbygd and Närke areas, Sweden. *Geol. För. Stockh. Förh.* 104, 197–209.
- Armands, G. 1972: Geochemical studies of uranium, molybdenum and vanadium in a Swedish alum shale. *Stockh. Univ. Contr. Geol. XXVIII: 1*, 1–148.
- Bjørlykke, K. 1974: Depositional history and geochemical composition of lower Palaeozoic epicontinental sediments from the Oslo Region. *Nor. geol. unders.* 305, 81 pp.
- Bjørlykke, K. 1983: Subsidence and tectonics in Late Precambrian sedimentary basins of southern Norway. *Nor. geol. unders.* 380, 159–172.
- Bockelie, J. F. & Nystuen, J. P. 1981: The southeastern part of the Scandinavian Caledonides. *Terra Cognita 1*, 1, 35.
- Brøgger, W. C. & Schetelig, J. 1923: Geological map, sheet Hønefoss. *Nor. geol. unders.*
- Einaudi, M. T., Meinert, L. D., & Newberry, R. J. 1981: Skarn deposits. *Econ. Geol. 75th Anniv.*, vol. 1, 317–391.
- Edling, B. 1974: Uranfördelningen i överkambrisk alunskiffer från Ranstad, Billingen Västergötland. *Publ. Paleont. Univ. Uppsala, Spec. vol. 2*, 118 pp.
- Gaut, A. 1981: Field relations and petrography of the biotite granites of the Oslo Region. *Nor. geol. unders.* 367, 39–64.
- Goldschmidt, V. M. 1911: Die Kontaktmetamorphose in Kristianiagebiet. *Skr. Norske Vidensk.-Akad. i Oslo, Mat.-naturv. Kl. 1911*, No. 11, 405 pp.
- Goldschmidt, V. M. 1954: *Geochemistry*. Oxford Univ. Press, London. 730 pp.
- Henningsmoen, G. 1960: Cambro-Silurian deposits of the Oslo Region. In Høltedahl, O. (ed.), *Geology of Norway*. *Nor. geol. unders.* 208, 130–150.
- Høltedahl, O. & Dons, J. A. (eds.) 1955: *Geologisk fører for Oslotrakten*. (With map 1:50 000). *Det norske Vid. Akad. i Oslo. Dybwads forlag*, 122 pp.
- Ihlen, P. M. 1978: Malmgeologisk undersøkelse og kartlegging av Kongens, Sulitjelma, Røros, Øvre og Nedre Grubelien og Dalstjern Gruver i Elsjøfeltet, Nannestad, Akershus. *Unpubl. NGU-report 1575/16B*, 8 pp.
- Ihlen, P. M. 1980: Geologisk kartlegging av Kongens og Røros gruve i Elsjøfeltet, Nannestad, Nittedal, Akershus. *Unpubl. NGU-report 1650/16C*, 18 pp.
- Ihlen, P. M., Trønnes, R. & Vokes, F. M. 1982: Mineralization, wallrock alteration and zonation of ore deposits associated with the Drammen granite in the Oslo Region, Norway. In Evans, A. M. (ed.), *Metallization Associated with Acid Magmatism*. John Wiley & Sons Ltd. London. 111–136.
- Larsen, B. T. 1978: Excursion 5. Krokskogen lava area. In Dons, J. A. & Larsen, B. T. (eds). *The Oslo paleorift. A*

- review and guide to excursions. *Nor. geol. unders.* 337, 143–162.
- Mathiesen, C. O., Olerud, S. & Eidsvig, P. 1976: Geologiske og geofysiske undersøkelser i Elsjøfeltet, Nannestad/Nittedal, Akershus. *Unpubl. NGU-report 1430/16A*, 39 pp.
- Olerud, S. 1980: Oppfølging av bekkesedimentanomalier på Romeriksåsen, Geologisk kartlegging av Øyungengranitten, Nannestad, Nittedal, Lunner, Akershus og Oppland. *Unpubl. NGU-report 1650/49C*, 25 pp.
- Olerud, S. 1982a: Elsjøfeltets geologi, tektonikk og innhold av sporelementer i kambro-ordovisiske skifre. Nannestad/Nittedal, Akershus. *Unpubl. NGU-report 1650/16D*, 49 pp.
- Olerud, S. 1982b: Berggrunnskart Nannestad 1915 III, 1:50 000. Foreløpig utgave. *Nor. geol. unders.*
- Olerud, S. 1983: Molybdenmineraliseringer under Elsjøfeltet. Geologisk logging av borhull 2, 129,30–216.40 m. Nittedal, Akershus, *Unpubl. NGU-report 1900/16F*, 10 pp.
- Olerud, S. & Sandstad, J. S. 1983: Geology of the Skrukkelia molybdenite deposit, northwestern margin of the Oslo Graben, Norway. *Nor. geol. unders.* 387, 1–20.
- Scott, P. W. 1979: Geologisk kartlegging på Romeriksåsen i Oslofeltet. Nannestad / Nittedal / Lunner, Akershus og Oppland fylker. *Unpubl. NGU-report 1750/49G*, 13 pp.
- Scott, P. W. 1980: *Geological map of the Stryken ring complex and adjacent area, Oslo Region, Norway*. Unpubl. map. Univ. of Hull.
- Schønwandt, H. K. & Petersen, J. S. 1983: Continental rifting and porphyry-molybdenum occurrences in the Oslo Region, Norway. *Tectonophysics* 94, 609–631.
- Skjeseth, S. 1957: Uran i kambrisk alunskifer i Oslofeltet og tilgrensede områder. *Nor. geol. unders.* 203, 100–111.
- Spjeldnæs, N. 1953: Middle Cambrian stratigraphy in the Røyken area, Oslo Region. *Nor. Geol. Tidsskr.* 34, 105–121.
- Strand, T. 1948: On the Middle Cambrian of Hadeland. *Nor. Geol. Tidsskr.* 27, 89 pp.
- Sæther, E. 1962: Studies of the igneous rock complex of the Oslo Region. XVIII. General investigation of the igneous rocks in the area north of Oslo. *Skr. Norske Vidensk. Akad. i Oslo, Mat.-naturv. Kl. Ny Serie, No. 1*, 184 pp.
- Wilson, M. R., Cuney, M. & Taylor, D. M. 1983: *IUREP orientation phase mission. Summary report. Norway*. Report from IUREP orientation phase by OECD, NEA, 23 pp.
- White, W. H., Bookstrom, A. A., Kamilli, R. J., Ganster, M. W., Smith, R. P., Ranta, D. E. & Steininger, R. C. 1981: Character and origin of Climax-type molybdenum deposits. *Econ. Geol.* 75th. *Anniv. vol.*, 270–316.