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PRELIMINARY REPORT ON THE REGIONAL GEOLOGY OF THE TOSEN-MOLDVIKA AREA.

by

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PART I. THE REGIONAL GEOLOGICAL PATTERNS OF THE HELGELAND NAPPE COMPLEX.

There has been little detailed work carried out on the geology of the Helgeland Nappe Complex with the exception of the various works by Gustavson (1975, 1976, 1978, 1979), Myrland (1972, 1974) and Kollung (1967) together with earlier works from the beginning of the century by principally Rekstad (1902, 1910, 1915 & 1917) and a number of minor articles on more specific topics. There is a principal difficulty in interpreting the geology of the region in the complete lack of attempts to provide either a lithostratigraphy or a chronostratigraphy. As a result the interpretation of the existing map-sheets i.e. 1:250.000 Mosjøen and 100.000 map-sheets Bindal, Velfjord, Helgelandsflesa and Vega provide only information regarding rock-types and lithology distribution. In some instances the identifications are erroneous and the lithological information provided is either not in sufficient detail or with adequate distinction to enable more than preliminary models for stratigraphical and structural patterns to be established. As a result it is necessary to a make a re-mapping and reinterpretation of the region. Naturally before the overall structural patterns and events sequences can be constructed a reasonable working model must be established for the stratigraphy. Detailed mapping of the metasedimentary sequence has been carried out on Leka (Sturt with others), Terråk area (Husmo and Norgulen), Rødøy and Hultøy (Bang) with reconnaisance over considerable areas by Sturt and Ramsay and by Sulfidmalm geologists in connection with their regional prospecting programme.

The metasedimentary rocks show considerable variety both in their lithologic character and in their degree of metamorphism through the area; their strain-state is also variable on the areal scale. The dominant metasedimentary lithologies include a range of mica-schists both pelitic and semi-pelitic, meta-sandstones, quartzites, substantive developments of limestones, calc-silicates and calc-phyllites/schists together with much conglomerate. In the main the metasediments appear to represent shallow to moderate depth marine sediments, though that in some areas continental conditions pertained is indicated by the considerable development of braided stream clastics on Leka and the preservation of sub-aerial weathering profiles developed on the surface of the ophiolitic substrate to these sediments. Minor developments of oceanic sediments also occur in relation to ophiolite terranes e.g. in the Leka and Terråk areas. No fauna has yet been recovered anywhere in the Helgeland Nappe Complex and reliable sedimentary structures are infrequent. The metasediments are traditionally assumed to be of Cambro-Silurian age but this is based on inference and lithological comparison with other areas - no direct evidence being yet at hand.

During the course of investigations in the last three years it has become apparent that many of the ultramafics, gabbros and greenstones of the nappe complex represent dismembered portions of one or several ophiolite slabs. Ophiolite fragments varying from virtually complete to dismembered parts have now been recognised on Leka (V.C.), at Terråk (V.C), 2 km. north of Sorenskogen (U), Lyngstad south of Sausvatn Velfjord (U), Rødøy (U + G), Haltøy (G) and in the Skålvær island group (G + P.L.)[x]. In the latter case Gustavson (1 suggests an ophiolite affinity based on the almost ideal MORB geochemistry of the greenstones. From the patterns of regional geology and rock types present further ophiolite fragments can be predicted on the 1:250.000 map-sheet Mosjø at Aunvatnet near Oppland; Mosjøen; 2 km. east of Grane; at Jengelvatnet in the southeastern most part of the map-sheet, in the island complex of Bolvær/Risøen/ Flæøen west of Brønnøysund and possibly at Kjertan in the mouth of Velfjor

The significance of these complexes all representing p of a dismembered ophiolite slab(s) has considerable stratig raphic and structural implications for the interpretation of the 1:250.000 map-sheet Mosjøen, and more specifically for unravelling the complicated tectono-stratigraphic package of the Helgeland Nappe Complex. The implication of this green stone/gabbro/ultramafic association representing ophioliti materials is that they formed as the result of an oceanic spreading mechanism, and thus represent part of the oceanic crust of either the major Iapetus Ocean or of a back-arc basin related to this ocean. In either instance they are n compatible with the essentially shallow marine and in part continental metasedimentary rock associations with which th are now juxtaposed. At Leka, Breivika west of Terråk, Lyng south of Sausvatn, Velfjord, Rødøy and Haltøy clearly defin primary sedimentary contacts are to be observed between dif

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x) V.C. - virtually complete, U = ultramorfic cumulates/ultr morfic undifferentiated, G = Gabbro, P.L. = Pillow lava wi MORB geochemistry.

parts of the ophiolitic substrate and an overlying cover sequence. This latter can be seen, at these localities, to rest with profound unconformity on the respective ophiolite fragment. Thus, for the first time in this region, it is possible to begin the task of establishing a viable stratigraphy for the metasedimentary rocks where the base of the succession is clearly defined.

Well preserved fossil weatering profiles are present, in the ophiolitic substrate beneath the unconformity, in spite of their subsequent deformation and metamorphism on Leka, Rødøy and Haltøy. The presence of caliche in these fossil weathering profiles, and on Leka also as cementing plugs with Ordovician braided-stream deposits furthermore implies a sub-tropical/semi-arid climate at this time (Sturt et al. 1981).

The initial deposits above the unconformity show considerable differences on the regional scale from continental fluviatile conglomerate dominated braided stream deposits on Leka, shallow marine limestone dominated sequences at Terråk, Velfjord and Rødøy to conglomerate (of as yet uncertain milieu) dominated sediments in the Sorenskogen area. The detailed mapping of the Skei Group on Leka reveals the existence of a considerable palaeo-relief at the unconformity. The regional variation in the basal sediment type may well be a reflection of such palaeo-relief, though in this near-shore to continental environment rapid lateral facies changes can also be expected to have significance.

It is obvious that the ophiolitic substrate was expose at various levels in the ophiolite pseudo-stratigraphy prior to deposition of the cover sequence. This is presumably th result of and interplay between two factors:

a) The depth of pre-Skei Group (and its equivalents) erosion,

and b) The pre-unconformity structural state of the ophiol fragments consequent upon folding and faulting.

For example on Leka the immediate substrate to the cover sequence (Skei Group) is gabbro with dykes and in part sheeted diabase dykes with trondhjemite; at Bindalseid it is pillow lava; at Breivika gabbro with dykes; at Lyngstad and Velfjord ultramorfic cumulates and on Rødøy and Haltøy it is gabbro. Further on Rødøy it is possible to distingui major folding of cumulate gabbro layering, now cut by the unconformity, so that the cumulate layering may make virtual any angle with the unconformity.

A feature which distinguishes the ophiolite fragments o the Helgland Nappe Complex, from those further south, is the extensive preservation of ultramafic rocks. These are dominantly thick cumulate sequences, though later intrusive phases and deformed residual upper mantle peridotites can also be distinguished. The ultramafic cumulates contain major zones of chromite-bearing dunites (Leka, Terråk, Velfjord, Rødøy). The chromite may be present as banded ore, disseminated ore or may be in part podiform. Although no major area of high concentration has yet been identified one is in the type of environment where major podiform deposi could be expected to occur.

Thus the immediate carapace to the granitic rocks of the region would appear to be of oceanic crust (ophiolite) with an unconformable or Palaeozoic cover sequence. The latter by correlation being almost certainly of Ordovician-Silurian age. The pre-unconformity folding of the ophiolite substrate implies that the ophiolite(s) had been subjected to orogenic deformation prior to uplift and deep erosion. It will be recalled from the descriptions of the Karmøy Ophiolite (Sturt and Thon 1978, Sturt et al. 1979, 1981), that the ophiolite had been obducted onto continental crust prior to the intrusion of the West Karmøy Igneous Complex and the deposition of the Skudeneshavn Group metasediments. The latter are of certainly Upper Ordovician age (Ashgill) though they probably extend downwards into the Middle Ordovician and upwards into the Lower Silurian. Of central importance in our discussion is that the oceanic sediments of the Torvastad Group, that conformably cap the ophiolite, had been subjected to polyphasal deformation and metamorphism into the high temperature part of the greenschist facies, prior to deposition of the Skudeneshavn Group and also earlier than emplacement of the West Karmøy Igneous Complex. If the Scandinavian ophiolites represent dismembered parts of one great ophiolite slub i.e. of the scale of the Oman Ophiolite they can thus be assumed to have been emplaced by obduction onto continental crust fairly early in Ordovician times. It is very difficult to be precise regarding the timing of ophiolite obduction though there are a variety of reasons which demand or suggest an earliest Ordovician timing: -

(i) The Støren ophiolite appears to have been obducte[d] prior to the upper part of the Arenig, based on the age of the basal deposits of the unconformably overlying Lower Hovin Series.

(ii) The little to non-deformed trondhjemites, of Sul fidmalms drill-cores at Kvitne, which cut two cleavag[es] in phyllites correlated with the Naudandevoll Mica Schist (Dictyonema-bearing i.e. Tremadoc) give U-Pb ages on zircons as old as 485 m.y. (Klingspoor & Gee 1[9..]

(iii) The metamorphism and deformation of the Torvast Group on Karmøy is highly significant as the only oro phase to which this can be equated is Finnmarkian D-2 i.e. at approximately 500 m.y.

In the Helgeland Nappe Complex, as defined by Gustav (1978), continental crustal material as a substrate to the cover sequences is not known. However, reconnaisance inves tigations indicate difficulties in defining the western boundary of the Helgeland Nappe Complex, and in the writers opinion this boundary is something which requires re-investigation. Indeed to the west of the traditional wester boundary, of the Helgeland Nappe Complex, there are cover sequences of rather similar lithology to those within the Helgeland Nappe Complex which apparently sit in synclines on a sialic basement - though no detailed investigations ha been attempted on such contacts. If this is the case we may be looking at a tectono-stratigraphic pile in which oceanic basement appears only in the upper part. To this should be added that there is very little modern information available from the region of the 1:250.000 map-sheet Namsos, and that the existence and form of the great basement culmination which is traditionally accepted, in the Namsos area, is at best uncertain.

Of interest in this context is the unit in the south-eastern portion of the Mosjøen 1:250.000 map-sheet referred to as the Susendal Nappe. Here metasedimentary rock associati reminiscent of the Finnmarkian/Sparagmite/Särv Nappe lithologi are present beneath rocks identified as Seve-Köli: The sedimen of the latter (especially Köli) must at least in part correlat with the metasedimentary cover-sequences within the Helgeland Nappe Complex. However, it is difficult at this stage to state how far such correlations can be justified in detail as the stratigraphic concepts of the Seve-Köli are in a state of flux. One feature of difference between the Köli lithostratig raphy and that of the cover sequences in the Helgeland Nappe Complex is the abundance of volcanic rocks, of possible island arc affinity, in the Köli. The reason for this difference is not yet known.

The results of reconnaisance studies on the tectono-stratigraphy of the Helgeland Nappe Complex itself, reveal that several major thrust nappes must be present within the confines of the Mosjøen 1:250.000 map-sheet, and which have been subsequently folded. This can be demonstrated from a consideration of basement-cover relations i.e. of ophiolitic sub-strate to unconformably overlying cover sequence. In many cases ophiolite is both overlain and underlain by metasediments of the cover sequence. This is impossible to interpret as a natural relationship and only two possible explanations are permitted:

(i) That the lower contact of the ophiolite is a thrust-plane.

(ii) That the ophiolite fragments form the cores of recumbent anticlines.

Our studies to-date favour the first of these possibilities. This is well-illustrated by the apparently one-sided nature of the unconformity, well-exemplified in the mapping of Husmo in the Terråk area. In the latter a series of thrust-slices can be distinguished with mylonitic soles. These slices conta mainly gabbro and in one case also pillow lava capped by an unconformable cover-sequence, and each slice shows the same stratigraphic polarity.

At the present state of knowledge it would appear that at least 3 major nappe units can be suggested in the section from Kollstrømmen Bridge to Tosenbotn. These are in ascendin order: -

(i) The Breivika Nappe. This comprises most of the area mapped by Husmo, and contains a series of slices as indic above.

(ii) The Osan Nappe. This contains a thick sequence of metasediments i.e. limestones, calc-silicates, mica schi and metasandstones in which the internal stratigraphic patterns have not yet been established. Whether or not this is a separate tectonostratigraphic unit to (i) is not certain and a limiting contact to the Breivika zone cannot yet be drawn.

(iii) The Tosen Nappe. The base of this unit is defined as the lower contact of a series of small ophiolite fragments now present as impersistent lenses. In spite of the impersistence of the ophiolite lenses the lower part of the lithostratigraphy of the cover sequence is instantly recognizable by a persistent and extensive major conglomerate horizon whose clast content is dominated by ophiolite derived material (gabbro, gabbro gneiss, diabase, greenstone, trondhjemite, serpentinite, epidote nodules, and occasional chert/jasper fragments). This horizon can be traced from Overbygd (Husmo and Norgulen pers. comm. 1982), across Tosenfjord northeast of Finskjærodden and thence to the north-west of Nord-fjellmarken. On the Bindal 1:100.000 map sheet this horizon is shown as Hetrogeneous Hornblende Schists and on the Mosjøen 1:250.000 map sheet is denoted as unit II. Small lenses of ultramafic rocks have been observed beneath the western contact of this conglomerat at Sorenskogen and to the south of Tosenfjord (Mjelde and Michaelson pers.comm. 1982). Recent work by Sulfidmalms geologists shows mylonites to be present close to the western contact of the conglomerate on Tosenfjord and these will be important in precisely locating the nappe base. It is obvious that further wor must be carried out along this contact to search for ophiolite fragments and for mylonitic rocks allowing for the definitive positioning of the thrust plane. The most spectacular development of this conglomerate is seen in the river section at Nordfjellmarken where an easterly-dipping sequence of conglomerate dominated clastics at least 600 metres thick occurs in the section east of the waterfall. Whether this is a true thickness or one repeated by folding has not yet been determined. Exactly how the ophiolite fragments at Sausvatn and Velfjord tie-in to this nappe base has not yet been established.

There are indications that the Tosen Nappe may have to be revised into two or more separate nappes:

a) West of Barstad, near the split in unit II, spectacular blasto-mylonites are developed from the metasediments and similar rocks to these are encountered more or less along strike, to the east of Nordfjellmarken. In the latter instance it is of interest to note that the conglomerates at the eastern end of Markavatn have a very different provenance to these described above. Conglomerates of similar provenance are encountered again in Tosenfjord just to the south of Tosen where the Cable comes on land. These latter conglomerates are separated from the ophiolite dominated conglomerates and associated sandstones, near Bjørnebekk, by a high strain zone in psammitic and amphibolitic rocks which often have mylonitic textures. This upper or eastern conglomeratic unit can be traced northwards as far as the southwestern side of Langfjord where it is misidentified as 'hetrogeneous hornblende schist' on the 1:100.000 map-sheet Velfjord. This mis-identification characterizes both conglomerate horizons and they are consistently referred to unit II, on the Mosjøen 1:250.000 map-sheet, from Langfjord to Overbygd.

b) Taking these features into consideration and if 'unit II' is similarly mis-identified throughout the map-sheet a yet higher nappe may be present in the area centred on Langskardnasen.

It is obvious that much work must be done to confirm these reconnaisance results. They provide, however, the first basic framework for establishing models not only for the stratigraphy of the region but also for it's structural development and of the distribution of metamorphism.

Let us now speculate on the regional relationships implied via this framework. It can be noted that, on the western part of the 1:250.000 map sheet Mosjøen, the established and projected ophiolite complexes together with their cover sequences all have a stratigraphic polarity or facing towards the east. The projected ophiolites on the eastern side of this map sheet, via consideration of the distribution of 'unit 8' and 'unit 11', on the other hand would appear to have a stratigraphic polarity or facing towards the west. If this is correct it would imply that the major nappe units, proposed in the Tosenfjord area, should be expected to project throughout the Helgeland Nappe Complex. This would mean that the nappe units occur in a complexly folded structural basin whose axial trace centres on Langskardnasen. If this is the case it would demonstrate a repetition of stratigraphies in a series of packages bounded by thrust planes. This naturally has considerable consequences for any strata-bound or stratigraphically related mineral deposits. It will only be through a detailed investigation of the tectono-stratigraphic patterns that the true form and distribution of such deposits can be established.

PART II. DETAILED TRAVERSE ACROSS THE MOLDVIKA PROSPECT.

A. General Aspects.

It was requested that a tectono-stratigraphic assessment be made of the zone, on the northern shore of Tosen Fjord, across the Moldvika Prospect. We decided to make a logged section from the main granite/metasediment contact 250 m north of Kråkhaugen to the metasediment/diorite complex contact just SW of Dagslaatt; details of this traverse are given in Table 1.

The lithologies although, in many cases, not particular distinctive can be subdivided into a series of logable units with a number of more distinctive marker horizons. With the exception of the quartzose migmatites at Moldvika, containing scheelite-bearing scarns, which lie in the core of an F-3(?) antiform, the other units all appear to be two-sided i.e. in lithostratigraphic continuity; and hence major repetition in terms of folding are precluded. The entire sequence has gone through fairly high-grade metamorphism i.e. high in the amphibolite facies and, in lithologie of favourable composition, migmatitic anatexis has occurred with the variable production of neozomal material.

The rocks have been polyphasally deformed and a minimum of three major deformation phases are recorded in the rocks. The latest or F-3 folding is responsible for the obvious macroscopic and large scale structures and hence controls the major disposition of the units. In the ensuing text fold phases will be referred to as F_1, F_2, F_3 etc; deformati phases as D_1, D_2, D_3 etc where F_1 and D_1 represent the earli phases which we have managed to establish in 1982.

The D_3 deformation produces a semi-penetrative strain-slip foliation (crenulation clearage) which is parallel to the axial planes of F_3 minor folds. The F_3 folds can further be logged into these with S, Z or M profiles which allows distinction between limbs and fold hinge-zones. Considerable retrogression of higher temperature mineral assemblages can be related to the D-3 deformation: A possibly later phase of folding F_4 can be observed locally e in the calcareous rocks at Dagslaatt, though their disposition is controlled by pre-existing F_3 structures. The F_2 structures fold the earliest identifiable foliation (S_1) and parallel to their axial planes is a marked penetrative crenulation-schistosity (S_2) which strongly transposes previous layering (S_0)/foliation(S_1). The observable F_2 folds are relatively small structures and do not appear to have significant influence on the overall disposition of units. Due to the high degree of transposition in both D_2 and D_3 very little information was found regarding D_1 structures, except for the penetrative foliation (S_1) which is parallel or sub-parallel to the lithologic banding (S_0). Zones can be distinguished where the pre-D_3 strains were obviously of considerable magnitude as F_3 folds could be found that folded rocks with already formed mylonitic to sub-mylonitic fabrics. Although no major folds of D_1 and D_2 generation were detected on the scale of the traverse this does not preclude their existence or the more regional scale, but on the basis of present information it is not possible to comment further.

It is difficult at this preliminary stage to make precise statements on the timing of metamorphism relative to deformation. The peak of regional metamorphism, however, appears to consistently pre-date the fold-structures (F_3) and foliation (S_3) produced during the third phase of deformation (D_3):-

(i) Al_2SiO_5 minerals are flattened and oriented in the crenulation clearage (S_3) and they are extensively pseudomorphed by white mica.

(ii) Large diopside and hornblende crystals, in calc-silicates, are frequently folded, broken, augened and boudinaged as the result of D_3.

(iii) Already formed boudins, as the result of D_2, of calc-silicates and amphibolites are folded by F_3 fol

(iv) The migmatitic neozomes are partially to strongly transposed by D_3 structures. The precise dating of migmatization relative to D_2 has not been possible to establish, at this stage, though it appears to overlap this deformation phase.

(v) The general structural aspect of the section is one where the high-grade mineral parageneses relate to the S_2 foliation, which is consistently folded by F_3 structures or transposed by S_3.

Thus it is possible to propose the following preliminary model for the timing of the main metamorphism i.e. that it's maximum expression was pre-D_2, syn-D_2 and post-D_2 but pre-D_3.

Ignoring for the moment the innumerable minor bodies, sheets and veins of granitic rocks it is possible to see that the metasedimentary lithologies possessed considerable variation in internal competence differences. This has had quite marked influence on the deformation mode. During deformation, particularly D_2, extensive boudinage of the more competent horizons is a characteristic structural style. As the result of steep disposition, due to F_3 folding, the D_2 boudins have steeply plunging long axes, except near the crest of larger F_3 structures. This may be one of the reasons for the apparently steeply plunging lensoidal form of the scheelite-bearing calc-silicate scarns at Moldvika.

B. Minor granitic bodies.

Within the profile minor bodies of granitic rocks have a complex series of relationships in the polyphasal structural evolution, and extremely variable strain-states are to be observed in these rocks. This is dependent upon a number of factors:-

a) The orientation of granite[1] sheets within the respective stress-fields during the different deformation phases.

b) The position of emplacement of granite during the deformation timing sequence.

c) The relative viscosity contrasts between granitic and host-rocks.

d) The petrological features of the granites especially their grain-size and mica contents.

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1) The term granite is employed in the general field-sense i granitic rocks.

e) The variations in local strain regimes.

The combination and interplay of these factors over short distances produces an apparently bewildering pattern of structural styles. However, it is possible by detailed study, particularly by employing strain-ellipsoid concepts, to resolv such patterns but this is often a very time-consuming exercise. Albeit it would appear that the minor granitic bodies have the following general relationship:-

(i) Pre-D_2 granites. These have several generations as can be seen from cross-cutting relationships. They variably bear the S_2 foliation, and they are folded and/or boudinaged by both D_2 and D3 structures. In D_2 high strain zones the granitic sheets are often reduced to small platy lenses and pegmatites show all stages of disruption from lenses to isolated porphyroclasts in the mylonitic folation.

To this set of intrusions belong prominently developed muscovite granite sheets which often contain or have associated muscovite bearing pegmatites. The latter contain muscovite books up to 10 cm in diameter and often contain sporadic and variable amounts of tourmaline. In one instance small crystals of beryl were observed.

(ii) Syn-D_2 granites. A number of granite sheets were observed parallel to F2 fold axial planes, which in many cases bear an S_2 foliation and have been variably affected by D_2 boudinage. Some of these sheets were also observed to be muscovite-bearing and occasional small needles and clusters of tourmaline crystals noted.

(iii) Post D_2 granites. Innumerable granitic net-vein of variable composition and texture which are affect by the full sequence of D_3 strains. Those vary fro fine-grained aplites with saccaroidal textures throu medium grained rocks to pegmatites. They are charac-terized by a low to variable mica content.

(iv) Syn D_3 granites. These granites form large sheet and net-vein complexes which though cutting D_3 stru are still affected by late D_3 and post D_3 strains. In rare cases (Fig.) the granite sheets may be i part involved in F_3-folds though apophyses may foll F_3 axial planes or even cut the F_3 structures implyi the essential syn-tectonic nature of such bodies. This suite of granites have singularly low mica contents.

(v) Post D_3 granites. Some minor granite sheets cut through D_3 structures and show very little signs of deformation and are apparently post D_3.

The large granodiorite body which cuts the metasediment some 250 m north of Kråkhaugen comprises essentially massive rocks of medium grey colour and is of medium grain-size. It appears to be composed of quartz, grey-white feldspar (albite-oligoclase), biotite and often with small flecks of sulphide. Foliation development is variable and its strike ranges from 125 - 005 with sub-vertical disposition. The granodiorite truncates the metasediments and also apparently the F_3 structures as it cuts the northern limb of the Moldvi Antiform. It is difficult to assess, from an essentially tw dimensional traverse, how far the foliation in the granodior represents a primary granite flow-structure or to what exten it is a result of post-crystallisation deformation. The cro cutting pegmatites, however, are remarkable free of deformation structures which perhaps favours the first of these possibilities. The granodiorite also contains very few xeno

It is perhaps of interest, at this stage, to consider these observations, made on the granitic rocks of the profile, with respect to the scheelite mineralization at Moldvika. The Moldvika scheelite bearing calc-silicate scar are apparently folded by the F_3 Moldvika Antiform. Further scheelite grains in specimen are often in elongated streaks and large crystals can sometimes be observed to have an aug form in a steeply disposed crenulation cleavage. This would imply that scheelite mineralization was essentially pre-D_3. On the other hand, at No. 8 showing, some large scheelite gr have apparently grown as porphyroblasts across the steep crenulation cleavage, implying post-cleavage recrystallisati The major granodiorite body to the east, however, truncates the Moldvika Antiform and appears to be a 'dry' granite. When these observations are viewed together it would appear highly unlikely that the scheelite mineralization was relate to the emplacement of the granodiorite. It would be more logical to consider that the scheelite mineralization was assiciated with one or more of the earlier (Pre D_3) generati of granite rocks. The most likely candidates would be the muscovite-tourmaline bearing varieties.

C. The Major Granites.

A brief traverse was made into the main development of granitic rocks eastwards and into Tosenfjordbotn, where the rocks can be examined in a combination of good road and coast-sections. These rocks were found to form a series of intrusive bodies of variable composition and texture. The variety of rock types was found to exceed those shown on the published 1:100.000 map-sheet Bindal. The plutonic rocks vary from hornblende bearing tonalites and quartz diorites, dark-coloured monzonites, and a variety of granodioritic and granitic types. Intrusive contacts are well preserved in a number of cases and from those and evidence based on zenoliths it should be possible to establish a fairly detailed intrusion sequence. From our brief inspection it appears that the more basic varieties are invariably the oldest in the emplacement sequence, and appear to exhibit the greater degrees of deformation: On the basis of this brief two-dimensional traverse it is not possible, however, to comment on the form of those intrusive bodies.

D. The Dioritic Rocks.

A number of preliminary observations were made on the diorite complex between Dagslaatt and Tosen. This intrusive complex contains rock types and intrusive phenomena, in part, quite unlike those observed in the rest of the traverse. The complex is made up of a variety of dioritic (basic-acid) and more acidic rocks with a complicated series of internal relationships. At the localities visited the host-rock is a foliated biotite-hornblende diorite which contains xenoliths of more basic gneisses. This is fairly coarse grained rock of relatively uniform appearance and is variably to strongly foliated. It is the subsequent intrusive history, however, that makes the dioritic complex so distinctive. The dark dioritic host is cut by a myriad of later,post-foliation, minor intrusions of dioritic and more granitic character. These form a bewildering plexus of highly zenolithic dykes and sheets which often have the appearance of intrusive breccias, net-vein complexes and less regular intrusive bodies. One unusual feature is the presence of xenoliths exotic to the local rock complex and which presumably have been brought up from depth. The net-vein complexes are remarkable in the abundant evidence for melt-phases of different composition having utilized the same conduit and in some instances for the co-existence of two imiscible magmas.

The net-vein complexes are made up of fine-grained dark (hbl)diorites, pale diorites and variety of more acidic rock types. Most of the basic rocks are occurring in net-vein suites either as:-

(i) Where pale diorite internally net-veins dark diorite and where delicately fritted margins are often preserved between the two phases. This implies no long time-gap between the phases and allows for only two possibilities:

a) That the first melt had not completely crystallised prior to the ingress of the second melt,

or b) That the two melts were imiscible liquids and were intruded simultaneously.

(ii) Either dark og pale diorite internally net-veined by fine-grained acidic material, which also forms independent net-vein complexes in the foliated host diorite.

(iii) Combinations of (i) and (ii).

The acidic rocks often show well marked flowbanding, implyin viscous flow during their emplacement.

On the peninsular west of Dagslaatelva a series of spectacular diorite breccia dykes are to be observed. These contain a great variety of igneous xenoliths, which are often exotic to the complex, including hornblendites. There is good evidence for gas-coring in these breccia dykes and one is probably dealing here with magmas which contained a highly pressurised gas-phase.

The rocks of this diorite complex have many of the attributes of the diorite/appinite suite which is usually a characteristic late associate of batholithic plutonism.

E. The Moldvika Antiform.

It would appear from the air photograph BI/3402 that the Molvika scheelite showing i.e. Peter zonen lies on the eastern flank of a fold; indeed this was suspected by Nixon and Sivertsen of Sulfidmalm. It was decided to investigate this structure, in profile and to ascertain if possible the relative age of its development.

The lithology in which the scheelite showings occur has been termal Migmatitic Psammitic Gneisses in Table 1. This lithology is flanked both east and west by rocks of the Striped Gneisses (or Dark Banded Group) and appears to be a one-sided formation, implying repetition of the Striped Gneisses. The boundary between the two units is quite distinctive and there is a transition zone of only some 20 m in thickness. The boundaries are located at road level on the map and projected inland according to the features on air photo BI/3402. It is obvious that these boundaries be mapped in detail as the scheelite showings appear to occupy horizons which can be located with respect to this contact.

The dips of foliation ($S_0/S_1/S_2$) are fairly constant across the structure except at fold-closures, and the S_3 crenulation cleavage bears a constant steep easterly dip across the structure and is axial planar to the more obvious macroscopic folds. The implication being that the structure is essential on F_3-fold which is folding a composite layering ($S_0/S_1/S_2$). The F_3 minor folds were studied in particular with respect to their style in profile i.e. as to whether they were folds with S, M or Z profiles. As can be seen from Fig. 1 as one traverses from NNE to SSW the minor folds have consistent S profiles across the contact and through the Peter zone showings until they change for a short distance to M profiles and then to Z profiles through the eastern scheelite showing and consistently through the contact into the striped gneisses. This shows that the Moldvika Fold is an antiform. Indeed when we were carrying out this investigation we were unaware of the eastern scheelite showing and on the basis of the structure were able to predict its position to within $\pm$ 20 m. This prediction was checked by ultraviolet lamp the scheelite showing located and marked in the field as Locality II and a series of samples collected for assay. The F_3 minor structures have variable plunge, and appear to represent incongruous folds in the sense of Ramsay and Sturt (1973). They thus do not provide a reliable guide to the plunge of the overall structure. An inspection of Air Photo BI/ 3402 indicates that the plunge is probably gentle to the north. During the general traverse F_3-minor folds showed considerable plunge variation and a number of markedly non-cylindrical folds were encountered. This implies that fold plunge at depth is not liable to be constant on any scale, and the Migmatitic Psammitic Gneisses may well be expected to re-occur to the north.

CONCLUSIONS.

It is now possible to attempt the establishment of a regional stratigraphy within the Helgeland Nappe Complex. This is dependent upon the interpretation of ophiolites and the unconformably overlying cover sequences. The results of this work indicate that there are possibly at least four major basement(ophiolite)-cover thrust complexes which are developed throughout the Helgeland Nappe Complex. This naturally produces a series of repetitions of lithological units within a vertical stack and will be highly significant in producing repetitions of stratabound mineralized horizons. Internally the nappe units show a complex of deformations and three major episodes of deformation producing folds and fabrics have been recognized. The peak of metamorphism pre-dates the third (D_3) deformation phase.

The Moldvika scheelite deposit pre-dates the D_3 deformation and indeed it is folded by a large F_3-fold the Moldvika Antiform.

TABLE I

STRATIGRAPHIC LOG - NE/SW ALONG ROAD SECTION THROUGH MOLDVIK

START AT GRANITE CONTACT 250m NORTH OF KRÅKHAUGEN.

UNIT	LITHOLOGIES	HORIZONTAL MAP DISTA	
Striped Gneisses or Dark Banded Group	Biotite-Qz-Plag Gneiss Diopside bearing calc-silicates Garnet-Biot-Qz segregation gneiss Impersistent Calc-silicat/Quartzite Deformed basic sheets	440m	
			Råfosen Bridge
Migmatitic Psammitic Gneisses	Psammitic migmatites with occasional quartzite and thin pelite horizons with calc-silicates. Scheelite-bearing scarns both close to NE and SW margins	750m	
			Målfos Bridge
Striped gneisses or Dark Banded Group	Varied Group: Calc-silicates, Psammitic gneisses, Dark Q_2-Biot Schist Quartz-Biot gneisses with calc-silicates and psammites Striped Biotitic migmatites with calc-silicate layers	950m	
			Finnes
Rusty-weathering Schist Group	Biot-Qz dominated gneisses and schists with abundant pseudo-morphs after Al_2SiO_5 (sillimanite and/or kyanite). Contains biotitized amphibolites.	200m	
Striped Gneisses	Dark banded biotite gneiss with calc-silicate bands and lenses	75m	
Rusty-weatering Group	Rusty-weathering quartzose gneisses, migmatitic in part. Rusty Biot-Schist w. Al_2SiO_5 pseudo-morphs. 50m thick garnetiferous amphibolite	250m	

Quartzose Gneisses	Quartzose gneisses with quartzite and thin pelite partings migmatic in part.		ENGESKJÆRET
Calc-Silicate Gneisses	Banded diopside-actinolite-plag. gneisses	25m	ENGEOSEN
Quartzose Migmatites	Quartzose gneisses variably migmatic, some interbanding with rusty-weatering. Biot-schist, many lenses of amphibolite	275m	150m SW of
Marble	Foliated Blue-grey-buff marble	1m	
Quartzose Gneisses	Quartzose gneisses with bands of rusty schist and calc-silicate.	100m	
Calcareous Group	Banded calc-silicate gneisses with prominent 1m white marble band.	25m	JUVIKA
Quartzose Gneisses	Quartzose gneisses variably migmatitic, with bands of rusty-weatering schist and calc-silicate	1050m	
Calcareous Group	Marbles, calc-silicate gneisses, calc-schists and amphibolites	300m	
Quartzose Migmatites		10m	DAGSLAATT
Diorite	Complex		

End of Log

Note that these f
represent map-dis
in the general NE
traverse and do n
represent thickne

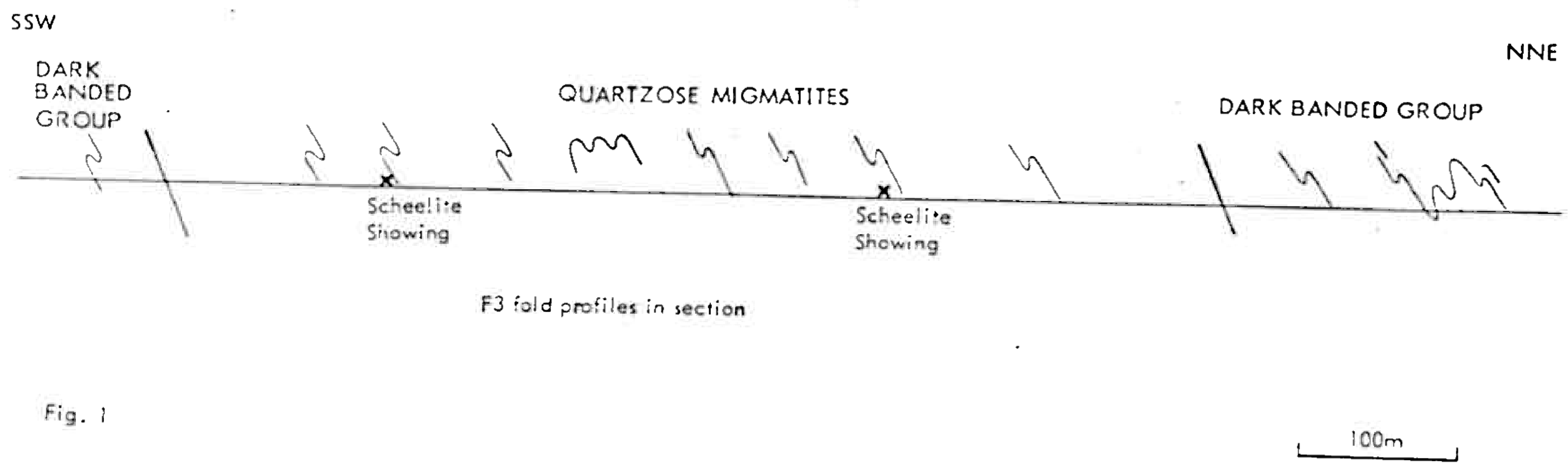
SSW
NNE
DARK BANDED GROUP
QUARTZOSE MIGMATITES
DARK BANDED GROUP
Scheelite Showing
Scheelite Showing
F3 fold profiles in section
100m

Fig. 1