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Field work report

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Geological mapping and investigations in the
Susendal area, Hattfjelldal, Nordland

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enclosed:

- 1 generalized geol. map 1:50000, total area
- 1 detailed geol. map 1:20000, central area
- 6 geol./tect. maps on air photo base, ca. 1:50000, total area, including air photo interpretation
- 5 cross-sections
- 1 generalized tectonical map, 1:50000, total area
- 1 legend to the maps

1. Preliminary remarks

During summer 1982 (june - september) I mapped an area of about 80 km² in the Susendal region, south of Hattfjelldal, Nordland. The main purpose was to find out the stratigraphy and structure of the so-called Hattfjelldal nappe, which forms the highest unit of Köli rocks between Rössvatnet and the Börgefjell window. Thus, the overlying Helgeland nappe has not been studied in detail.

In addition to this work, I inspected other localities in the Hattfjelldal nappe and further Köli localities on both Norwegian and Swedish side, which led to an idea of the stratigraphical and structural development of the Hattfjelldal/Susendal area. This idea has only preliminary character and might be subject to changes after the rock samples have been investigated in detail and after next year's field work.

As the lithology of the mapped area was established by field work, the tracing of structures and the interpretation of structural elements was supported by air photo investigation. The enclosed cross sections could only be established by some interpretational work in addition to the field data.

Quaternary deposits were considered only, where they cover the ground rock over large, uninterrupted areas.

2. Stratigraphy

2.1 Stratigraphical order

The order of description of the stratigraphic units is based on the major tectonic units, which are a) the underlying Köli rocks (Leipikvatnet or Stikke nappe?), b) the Hattfjelldal nappe and c) the Helgeland nappe. The bulk of different sediments within the Hattfjelldal nappe makes it desirable to put them in the correct stratigraphical order. As no macro-fossils have been found (micro-fossils will be looked for), this can only be done by means of sedimentology.

Determinations of top and bottom sides of conglomerates or respective rocks are not directly useful for finding out

the way-up of the whole sequence because of its intensive isoclinal folding. The way-up direction changes so rapidly, that one can never be sure, if the determined top side of a conglomeratic layer belongs to the same side of an isoclinal fold, as the next bed boundary does.

However, the Hattfjelldal nappe stratigraphy is composed of two major stratigraphical units, which are clearly separated from each other. I will preliminarily call them the "phyllitic/quartzitic series" and the "carbonatic series". This division and a number of obvious sedimentary bed contacts led to a stratigraphic order of the whole sequence.

The remaining question - where are bottom and top of this ordered sequence? - could at least be answered by some sedimentological thinking about. A very clear up-and-down evidence is given by the graded dolomite conglomerate (14), which has been classified as a submarine canyon deposit (see 2.33). This is overlain by turbidity current deposits, becoming more distal in the upward direction. This fact indicates a basin deepening with simultaneous stepping-back of the steeper slope environments, into which the canyon must be cut. These slope sediments are not exposed. But by projecting the tendency of basin deepening into the further past, we have to look for a less deep marine facies that has to underlie the canyon deposits. This can easily be found with the sediments of the phyllitic/quartzitic series (8-12), which are interpreted as shelf environment.

Thus, the way-up direction of the sequence is indicated.

Following down the sequence, we find, as lowermost sedimentary unit in the Hattfjelldal nappe, the same calcareous psammitic phyllite that covers large areas of the underlying Köli nappe. The resulting stratigraphical order is summarized in the collective stratigraphical column (page 5).

2.2 Underlying Köli rocks

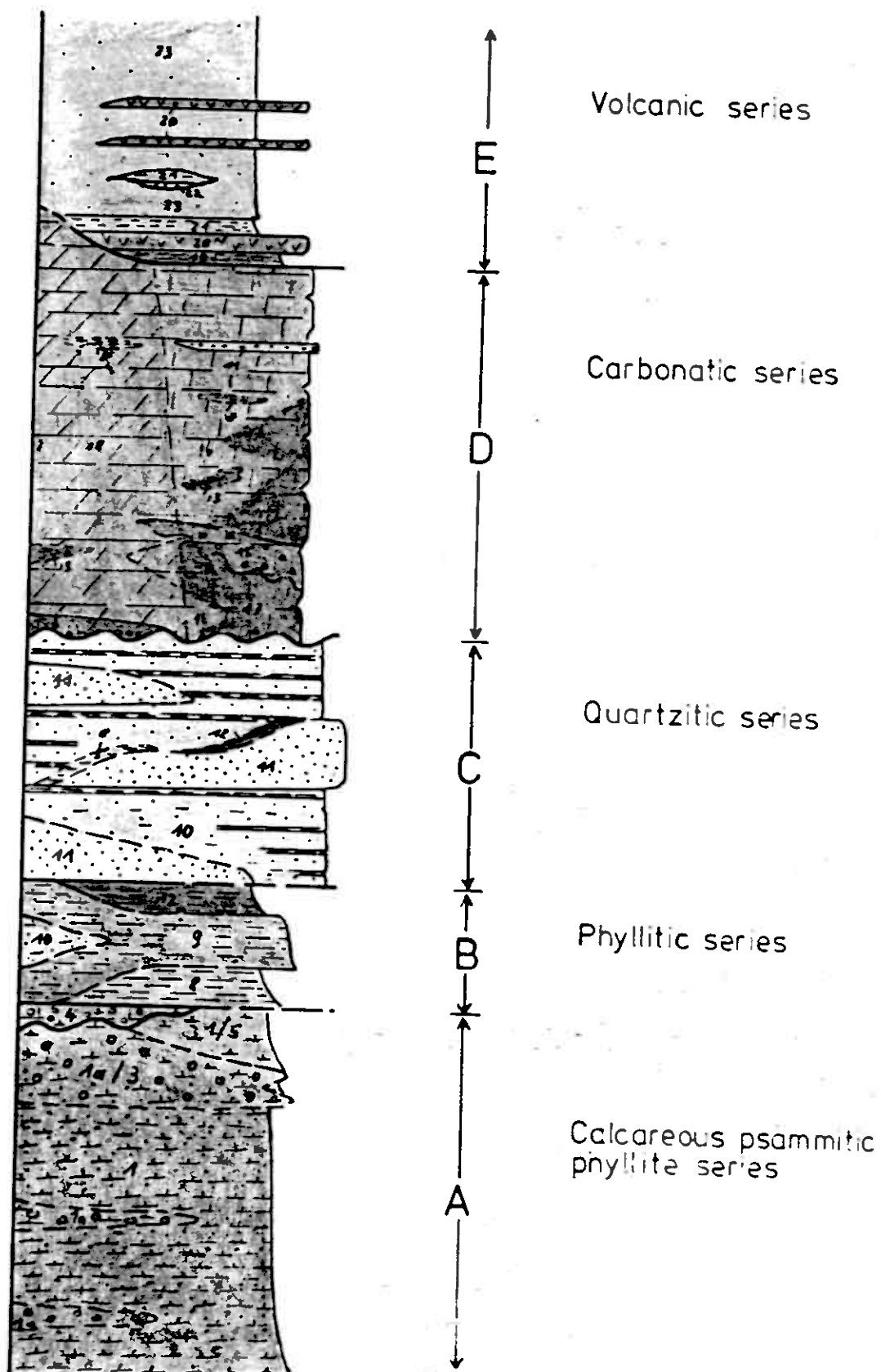
(1) Calcareous psammitic phyllite

- position:

The major part of the Köli rocks underlying the Hattfjelldal nappe within the mapped area is covered by a thick series of calcareous psammitic phyllites, dipping generally with angles

Schematic stratigraphical column for southern Hattfjelldal nappe

no scale implied



between 20° and 45° against the Hattfjelldal nappe. They strike N-S from Pantdalen to Storvardhögda, then turn into NE-SW direction from Lillevardhögda to Sandskarbekken.

- description:

The general feature of the sediment is a thin alternation of bluish-grey, phyllitic/chloritic layers and grey or white calcitic/quartzitic layers. The latter appear as horizontal laminae or lenses, often interrupted by phyllitic remnants of an older foliation. The grain size varies from coarse sandy to silty size without a general tendency.

Cross-bedding-like features are common, but could in some cases be recognized as pretended by tectonics, i.e. particularly crenulation cleavage and sheared folds.

In Orjedalen, some quartzitic intercalations could be found, which have a thickness of up to some meters. Outside of the mapped area, near the bridge over Elsvasselva (E' of Hattfjelldal), there is a calcitic/quartzitic bed exposed, which presents a turbiditic sequence (B-C-D-E).

At many places in Pantdalen, furthermore about 700 m east of the farm Orjedal and at some places near the upper thrust contact in the Ivarrud-Nervollen region, quartz-free and chlorite-richer beds could be traced over some hundred meters. They also have minor or no calcite contents.

- occurrence in Hattfjelldal nappe:

Beyond the Hattfjelldal thrust, the same type of sediment appears

a) pressed up and thinned between imbricated blocks E' of Kvalpskarakslen, and

b) between Kvalpskarelv and Möllebekken (E' of Skinnfjellet), where it contains isolated dolomite pebbles (1a) and grades into the calcareous phyllite (5) without a sharp boundary.

- (1a) "conglomeratic beds":

The central part of the area covered by the calcareous psam. phyllite (1) contains subrounded to well rounded pebbles of dolomite and quartzite, obviously of vein-, and possibly also of sedimentary origin, up to a size of 10 cm, but normally only of some mm to about 4 cm.

It is not a conglomerate in the sedimentological sense of the word. The pebbles are exclusively isolated, even where they occur concentrated in certain beds. The matrix does not differ from the pebble-free sediment. The distance between the isolated pebbles differs from many m or even tens of m to occasionally a few cm. The richer beds occur mainly in the southern part of the mapped area (Storbekken, Sandskarbekken), some also on top of Storvardhögda. They seem to attenuate laterally.

L. Barkey's maps of the Norwegian Köli area (1976, unpubl.) and the new NGU's map "Mosjøen" (1:250000, 1981) show this bed of "dolomite conglomerate" as a continuous layer all over this area. I could not confirm the connection between the thin occurrence in Örjedalen and the few beds on top of Sommerfjellet, and further on to Pantdalen. There probably is one, but not as thick as the mentioned maps show it.

As the "conglomerate" could be traced uninterruptedly in the southern part, it splits up on Storvardhögda into some thinner beds with dolomite pebbles, between which only quartzitic pebbles occur. Northward against Örjedalen, pebbles were only found in one bed of some meters of thickness. On Sommerfjellet and in Pantdalen, these beds are getting more numerous again, containing both quartzite and dolomite pebbles.

The splitting-up of several beds in the north and the thick outcropping in the south could be a repetition by isoclinal folding, which affected the whole series.

- greenish variations:

In Pantdalen occur chloritized, probably quartz- and calcite-free beds in this rock series, which can be called a chlorite phyllite. One 100 m thick bed is situated 3.5 km E' of the mouth of Pantdalselva, and another one appears 2 km further east, plunging beneath the swamps in the middle Pantdalselv valley. The continuation up to Sommerfjellet could not be traced.

In the region of Tözmerhaugen and Klembergan, the calcareous phyllite grades into a greenish, strongly weathered rock, which is chloritized and partly epidotized. At a place near Klembergan, it is rich in pyrite. I suppose both the forming of the green minerals and of the pyrite to be due to the imbricated thrust pattern, caused by the thrusting of the Helgeland nappe.

- conclusions and correlations:

The whole series provides the same appearance as the "conglomeratic calcareous psammite" (O. Lutro, 1979) in the Gjersvik area, south of the Borgefjell window, which belongs to the Limingen group and there is called "Litlfjelltang formation". The sedimentary structures are not as well preserved as in the Gjersvik area, but I hope to find out their comparability. Lutro suggests shallow water environment, probably river deposits.

Foslie (1923, 1924) called the same series in the Grong district, to which the Gjersvik area counts, "flysch formation", a term indicating some deeper marine environment.

Going with both interpretations, the pebble-containing beds could be designated as "pebbly mudstones" (Reineck & Singh 1975, S. 388, citing Stanley, 1969 and others), which are found near river mouths and can be transported by mass-flow movement into (continental?) slope and submarine fan environments.

Thus, the depositional environment has to be one on the way from an alluvial to a submarine fan. The high sand portion and the cross bedding suggest low water depth, but the turbidites exclude shallow water, so that shelf environment seems to be the most probable one. The carbonatic pebbles, which cannot be far transported, derive obviously from a carbonatic source area near to the depositional area - a continental environment (Helgeland nappe?) or, more to be expected, an island arc, from which the Gjersvik nappe could be a remnant (Lutro, 1979).

(2) Sommerfjell conglomerate

- position:

In the mapped area, this unit occurs only in the top region of Sommerfjellet, and can be traced 1 km in N-S direction, and 0.5 km in E-W direction. It is situated directly beneath the Hattfjelldal thrust.

North of the mapped area it appears again in the same tectonic position with a larger extension, running northward from Stortjønn. On L. Barkey's map, it corresponds to the eastern part of the eastern conglomeratic layer at Stortjønn (sheet Hattfjelldal).

- description:

This conglomerate is monomict, containing only dolomite pebbles. Unsorted, coarser layers sometimes show clast-supported texture, which may derive from tectonic deformation. The clasts range in size up to about 20 cm.

Better sorted, finer grained layers show mud-supported texture, the clasts generally not exceeding 4 cm.

The shape of the clasts is well rounded to subangular, which classifies the sediment to be immature, under consideration of the carbonatic material.

Graded bedding is rare and poorly developed, the mode of layering chaotic.

The matrix is partly calcitic, partly composed of calcareous phyllite, which can grade into chlorite phyllite. Chlorite phyllite also forms intercalated layers without clasts. Calcitic material can be found as boudins within the calcareous phyllitic matrix between the dolomite clasts, indicating zones of strong tectonical deformation.

- similar rocks:

At Sagbekken appears a very thin layer of a similar rock in the same tectonic position. The clasts are calcitic and more isolated, whereas calcitic boudins are very common. The matrix is calcareous phyllite.

- conclusions:

I consider the rock to be an olisthostrome, although a typical olisthostrome would be polymict and contain bigger clasts - except when there is no other material available. If the material is provided by rivers as suggested under 'conclusions' (page 8), it can scarcely be coarser than the observed grain size - provided, that the source conglomerate was not completely lithified. The well rounded and rounded pebbles are resedimented twice at least. The chaotically distributed matrix material and the lack of any bedding suggests mud-flow transport rather than mass-flow movement, which would result in the formation of pebbly mudstones (see 2.31, (4)).

Tectonically, the formation of this olisthostrome can be explained by basin deepening or slope steepening during the early stages of uplift or thrusting of the Hattfjelldal nappe.

(a,b,c,d) rocks of unknown stratigraphic position
S' of Örjevatnet

South of Örjevatnet occur phyllites, partly quartz-rich, graphite phyllites, quartzites and different types of greenstones, which has not been taken under consideration yet. They resemble the later described rocks of the phyllitic/quartzitic series of the Hattfjelldal nappe, except the quartz phyllite, which here resembles the calc. psam. phyllite (1), from which it can only be distinguished by the lack of calcite.

2.3 Hattfjelldal nappe

2.31 Calcareous psammitic phyllite series (3,4,5)

- position:

Within the Hattfjelldal nappe, calcareous phyllites with and without pebbly mudstones form the probable lowermost stratigraphical unit. They appear in the core of a fold (probably an anticline) running NNE-SSW approximately along the bottom of Susendalen and dipping softly towards the SSW. Thus, they form many outcrops on the river banks and in the road cuts of the Susendal road. They vanish about 200 m south of the mouth of Kvalpskarelven, cut by some faults, crossing the river valley.

They split up into several arms, which will represent the same horizon, repeated by a sequence of minor folds.

Between Kvalpskarelv and Möllebekken, the units (3) and (5) seem to grade into calcareous phyllites belonging to the carbonatic series. But tectonics in this area are very complicated and badly exposed, so that no conclusions should be made at the moment.

- description:

The whole sequence is bluish-grey in colour, which points to some chlorite portion in the rocks. They often appear as a fine laminated phyllite, with carbonate only in a few, silty laminae. Near the mouth of Kvalpskarelv, some pyrite contents has been observed.

Between Kvalpskarelv and Möllebekken, the sediment has

a more psammitic composition, resembling the calc. psam. phyllite (1) of the underlying nappe.

The unit (3) contains isolated pebbles, up to a few cm in diameter, of subrounded to well rounded dolomite and, rarely, well rounded quartzite. The distances between the pebbles vary from dm's to tens of meters.

Calcite-free layers of both (3) and (5) occur frequently.

The unit (4), in previous works called "dolomit-konglomerat" (Strand, T., 1953), is much richer in dolomite pebbles than is (3). The distances between the pebbles are in the order of cm or dm. I only found dolomite pebbles there, which reach a size of 10 cm. The matrix is rich in calcite, graphite and silty quartz; phyllite with a chlorite portion forms thin laminae which give rise to a slaty cleavage, coarser than in (3) and (5).

- greenish variations:

I suppose, that some of the greenstones, described under (6), are equivalent to the calcareous phyllite. In one of the chlorite phyllite layers in Pantdalen I found dolomite pebbles.

- conclusions and correlations:

All conditions are given to call the pebble containing units "pebbly mudstones" (Reineck & Singh, 1975), as they are found in the underlying Köli rocks, too. Both units, (1+1a) and (3-5) might represent the same stratigraphical unit, those of the Hattfjelldal nappe deriving from an area further west. This suggestion has yet to be proved by microscopical investigation.

2.32 Phyllitic and quartzitic series

- general remarks:

A typical feature of this rock series is the rapid change of facies in both space and time. The lithostratigraphic order given in the legend to the map only shows the main tendency of sedimentary development. The phyllitic rocks, and in the first place among them the graphite phyllite, occur in many stratigraphic positions, and are also found as squeezed-up lubricants in thrust zones.

The individual units of this series are not present at all places beneath the carbonatic series. Thus, the quartzite is lacking on the western side of Susna, north of Möllebekken. In the northern part of the Hattfjelldal nappe, outside of the mapped area, nearly the whole series seems to be absent.

The rapid change of facies appears also within some of the described units, so that only the normal features can be described here. Furthermore, the different types of phyllite change gradually, and the bed boundaries on the map cannot be a correct representation of reality.

(6, 7) Chloritized phyllitic and quartzitic rocks of
the Mikkelfjord area

- position:

Chloritized sediments occur all over the western slope of Sommerfjellet, and there are concentrated to its lower part. The terrain falls approximately along with the bed surfaces, which causes the broad outcropping on the map. The entire thickness of those sediments will not exceed an amount of some tens of meters. The boundary between (6) and (7) on the map had to be generalized.

- description:

The chloritic Phyllites (6) are light to dark, greenish-grey phyllites, never calcareous, but often quartzose with a fine slaty cleavage. Impregnation with iron-hydroxide is common, resulting in a brown weathering colour. Beds of nearly (?) chlorite-free variations occur. The rocks contain veins, which are rich in sulphides and probably magnetite, beside quartz, known as the Mikkelfjord deposits. I observed them, in solid rock, only running bed parallel, but loose blocks suggest, that they also are bound to $\pm$ E-W running gaps or faults, cutting the bedding planes.

The rock type (7) provides all stages between a quartzitic chlorite schist with a coarser slaty cleavage than it has (6), greenish-grey in colour, and a chloritic quartzite, which varies in colour, but allways containing a layered or diffusively distributed portion of chlorite $\pm$ other mica minerals. Ore containing gaps occur, as explained above.

- occurrence in other places:

Greenish quartzite occurs beneath the Helgeland thrust at Grublandselva. It also was observed between the carbonatic and the volcanic series at Sagbekken.

- conclusions and correlations:

The chloritic sediments of the Mikkelfjord region lie in the same stratigraphical position, as the phyllites do in other places. As some of the greenish rocks represent ancient calcareous phyllites (see p. 11), will the bulk of them represent rocks of the phyllitic and quartzitic series.

Chloritization and sulphidization has been facilitated by a well developed system of gaps and faults, caused by nappe imbrication and conjugation. The whole mountain slope at Mikkelfjord could be a minor thrust plane, the thrust unit being eroded. This suggestion is supported by the fact, that at Grublandselva, where phyllitic and quartzitic rocks underlie the Helgeland thrust, chloritization increases as well.

Furthermore, exactly south of the Mikkelfjord area, there is a minor thrust zone within a block of lower tectonic level, which falls nearly parallel with the terrain, as well, and which could be the continuation of the supposed thrust at Mikkelfjord. There, the present thrust line would be covered by the glacial deposits on the bottom of Susendalen.

(8, 9) Phyllite and quartz phyllite

- position:

As phyllites occur throughout the whole phyllitic/quartzitic series, they are not restricted to certain areas. The bulk of them lies stratigraphically above the calcareous phyllites (3-5) in Susendalen, but they appear in Pantdalen, Orjedalen and on the western side of the mapped area as well. The main beds in Susendalen vanish south of Nervollen, where the whole series is cut by faults, which cross the river valley, and then occurs again as very thin phyllitic layers near the Hattfjelldal thrust N' of Ivarrud.

- description:

The unweathered phyllite (8) has a typical sericitic lustre, possesses a very fine slaty cleavage, which sometimes is folded,

giving rise to a crenulation cleavage. The quartz-rich variations (9) may have quartzitic laminae of light colour up to a thickness of some mm (S' of the Pantdalselv mouth), or laminae of a dark, fine-grained, quartz containing mineral-mixture, which yet has to be defined microscopically.

The weathered variations are soft, brown, slaty rocks, in which remnants of sericitic planes may occur.

In some places I found intercalations of quartzitic layers. In the river bed of Kvalpskarelva at 480 m, at a waterfall, some of those dm-thick quartzites grade into phyllite, possibly representing turbidites.

No further conclusions.

(10, 11) Quartzite shist and quartzite

- position:

Quartzitic sediments occur interruptedly along a bow from the upper, western slope of Sommerfjellet, crossing the lower Orjedal, the river Susna at Klembergan and further south, then turning northward with several outcrops at the eastern sides of Kvalpskarakslen and Skinnfjellet. They nearly disappear further north in the Hattfjelldal nappe.

Pure quartzites (11) form larger beds only on the eastern side of this bow, in the west mostly local quartzite bodies are found within phyllitic or quartzite shist beds.

- description of (10):

The term "quartzite shist" is here used as a descriptive term for different types of alternating beds of quartzite and, more or less, phyllitic rocks, when quartzite dominates on the whole. These beds are varying in thickness, grain-size distribution and are most badly exposed, so that a detailed description is not possible at the moment. If sedimentary structures are present, they mostly consist of parallel lamination. One outcrop between Tømmerhaugen and Nervollen shows graded quartzitic layers, alternating with phyllites. One coarse-sand-sized quartzite body, probably transported by slumping, caused synaeresis in the underlying clay (phyllites).

- description of (11):

These are quartzites with different bank thickness, often parallel laminated, consisting of sand-sized quartz grains, mica (partly chlorite) and ore (pyrite + others?). Even within these banked sediments occur occasionally separated quartzite bodies, which are lacking any structural orientation (f. ex. on top of Skjerphaugen).

No further conclusions.

(12, 13) Graphite phyllite)

- position:

Graphite phyllite appears in the stratigraphical order mostly under the quartzitic beds, but in some cases above them, as well. It seems to replace stratigraphically some of the phyllitic beds on the eastern side of the main anticline. Furthermore, it often acted as lubricant for thrusting of the Hattfjelldal nappe, and can particularly be found in this position in Pantdalen and Ørjedalen.

This can be applied to the calcareous graphite phyllite (13) on top of Sommerfjellet. This rock type can seldom be found in its original stratigraphical position. It then forms small lenses within carbonatic or phyllitic layers, or is a transitional sediment between phyllites and carbonates with a graphite portion.

- description:

The graphite phyllite (12) is a fine slaty phyllite, consisting of fine-grained mica, graphite and quartz grains, plus a varying amount of pyrite. Crenulation cleavage can commonly be seen. The calcareous variation (13) can possess a varying portion of calcite and more or less lose its slaty cleavage. Colours are dark grey or nearly black.

No further conclusions.

2.33 Carbonatic series

- general remarks:

The map distinguishes dolomite and two different types of limestone. The latter are kept apart by their colour, that derives from the presence or absence of graphite contents. They could be classified by their structure as well: The light type normally having no preserved sedimentary structures, the dark one being distinctly bedded. However, this deviation does not exactly go along with the colour. The different types are grading into another, the deviation by colour being easier mappable. In the region of Ivarrud, even this had to be simplified.

Phyllitic, calcareous phyllitic, quartzitic and conglomeratic beds are intercalated with the limestones.

(14) Graded dolomite conglomerate

- position:

This rock type was only found north of Nervollen, where it is underlying dolomites and limestones of the carbonatic series. The lower boundary is cut by a fault. Exposures along the Susendal road.

- description:

The sediment is composed of graded conglomeratic beds. The graded units have a thickness of about 50 cm, starting with conglomeratic grain sizes (2-3 cm) and ending in coarse sand. The pebbles are subangular to subrounded, dolomitic, and show partly imbricated pattern. The whole sediment is grain-supported, the pores being filled up with phyllitic material. There is superimposed graded bedding within the sand- and grit-sized parts, the thickness of these units lies in the order of 5 cm.

Going upward, coarse-grained beds vanish. Finally, the sediment is followed by dolomite along the road cut, but further east by banded limestone (16).

- conclusions:

After R. Walker (1975), this conglomerate type is typical for the turbidite association (graded-stratified model) and there deposited in the lower parts or at the exit of submarine canyons. Therefore, inner submarine fan or canyon environment is suggested.

(15) Hattfjelldal conglomerate/breccia

- position:

In the mapped area it forms the core of a minor syncline north of Ivarrud. Limestone (17) is intercalated. Road cuts provide exposures.

Furthermore, small outcrops has been found on the SW slope of Sommerfjellet, where the boundary of dolomitization is running through it.

The largest area covered by this rock is situated at Stortjønn, and to the north of it, outside of the mapped area (N of Unkerelven).

- description:

The typical appearance is a mud-supported breccia. The pebbles, up to 0.5 m in size, consist of angular to subrounded dolomite or limestone (partly, (16) could be recognized), rarer quartzite, quartz shist and graphite phyllite. All of them can be found in the carbonatic series itself. Some beds with smaller (about 5 cm) pebbles, rounded to subrounded, exist, and even fine-grained, clast-supported breccias has been found at Stortjønn.

The matrix is an irregular mixture of different phyllites (+ chloritic or calcitic) and calcite or dolomite, respectively. No regular sedimentary structures occur.

One boundary of the breccias usually is sharp, the other is unsharp because of (overlying?) sediment mixed with the matrix of the breccia.

Frequently observed clast-supporting in the sediments is thought to be due to tectonical deformation. Pressure solution features between neighbouring clasts can be seen, as well.

- conclusions:

The observations point to a slow mud-flow transport of the sediment. Both pebbles and matrix seem to belong to the carbonatic series, in which the breccias are situated themselves. It can be called an 'olisthostrome' (Görler & Reutter, 1967), or more correctly: an intraformational olisthostrome. The source sediment was young and poorly lithified, which could be the reason for the lack of bigger clasts, which ought to be expected in olisthostromes.

(16) Dark limestone

- position:

The dark limestone variation is common all over the western side of Susendalen. Typical cross-sections can be seen at Kvalp-skarelva, Ytter-Djupdalbekken and Grublandselva. This rock type is rare in the east. It there shows transitional changes to the light limestone variation (17).

Mylonized and recrystallized limestones (marbles) appear commonly in thrust zones, acting as lubricant.

- description:

The typical features are medium to dark grey colour, often bluish, alternating layers of occasionally graded, arenitic layers of calcite (+ quartz) and thin phyllitic/qz.-siltose layers. The thickness of the single rhythmic units is between about 1 and 10 cm, but is thought to be diminished by tectonical deformation.

Within this unit occur phyllitic, graphitic and quartzitic beds, and some of the Hattfjelldal conglomerate, as well. Pyrite is a common postsedimentary mineral.

- conclusions:

Grading, grain-size distribution and rhythmic layering suggest clastic transport and deposition out of suspensions. This fact, and the association with the submarine fan conglomerate (14) makes it reasonable to consider this unit as being turbidity current deposits of distal character.

(17) Light limestone- position:

The light limestone variation is less common than the dark one. Its main occurrence is the region north of Ivarrud. Other localities are particularly found along the eastern side of the Hattfjelldal nappe. Transitional changes to dark limestone (16) are given.

- description:

This rock is a fine grained limestone with normally no sedimentary structures. Irregularly distributed dark, graphite containing areas are common. At one locality, SW' of Sommerfjell top, a light coloured (graphite-free) variation of the banded limestone (16) occurs.

In the contact zone of the gabbroic intrusion N' of Ivarrud, the rocks are altered by contact metamorphism and appear to be bedded.

- conclusions:

The distribution of the limestones (16) and (17) suggests a lateral facies representation.

(18) Dolomite- general remarks:

As the limestones can be dolomitized partly, the boundaries were mapped by means of reaction with HCl, dolomite being inferred when there was no distinct or quick reaction on unweathered surfaces. The irregular and complicated distribution of dolomites had to be mapped generalized.

- position:

Dolomite is a throughout common sediment in the carbonatic series, only lacking on the western side of Susendalen, north of Kvalpskarelva. It is intercalated with both limestone types.

- description:

The dolomites are mostly white, but may be light to dark grey, as well. Due to their graphite contents, diffusively spotted

variations exist. They are unlayered, but in some cases banded. The boundaries to the limestones can be sharp (tectonic?) or transitional (diagenetic dolomitization?).

No further conclusions.

2.34 Volcanic (?) series and other magmatic rocks

Between Sagbekken and Sandskarfjellet, a sequence of greenstones, brittle phyllites, spotted and banded shists, interbedded with some quartzitic rocks is exposed. Those greenstones are not bound to tectonic zones as most of the others (Mikkelfjord area) do. Their metamorphic grade is obviously higher than the one of the other series. The contacts to the carbonatic rocks are badly exposed and may be tectonic. In one case at 449.7/7255.0, I found a sedimentary interbedding of limestones and the fine-banded greenstones, which might be tuffites.

I suppose this series to be of volcanic origin, but this cannot be proved yet. Its assumed stratigraphical position on top of the carbonatic series is not sure, as well. A more detailed mapping and sampling in this region and further south, where the Hattfjelldal nappe attenuates, will be necessary.

Rocks of doubtless intrusive character within the Hattfjelldal nappe can be found as follows:

a) Sills of some dm or m of thickness, cutting the carbonatic series near the Helgeland thrust zone. They are fine-grained, dark grey rocks, often pyritized. They seem to be equivalent to boudins, occurring in the same zone.

b) Two limbs of a porphyroblastic, basic rock N of Ivarrud, probably a sill of originally gabbroic composition.

c) A foliated, diaphoritic, porphyroblastic meta-granodiorite (?) intrusion in the carbonatic series at Sagbekken.

At Ytter-Djupdalbekken, near the Helgeland thrust, some of the sills (a) occur together with an amphibolitic material, probably emplaced tectonically, deriving from the Helgeland nappe.

2.4 Helgeland nappe

The rocks of the Helgeland nappe have not been object of special consideration. Generally, they are of medium-grade metamorphism, but showing diaphthoresis near the thrust zones. There, rocks are mylonized, partly recrystallized and often strongly foliated.

Obvious magmatic rocks are almost restricted to different types of quartz diorite, both fine- and coarse-grained. Beside that, a minor area S' of Kvalpskarakslen is covered by a medium-grained, probably gabbroic rock, which is cut by fine-grained basic veins. Basic veins cut the quartz diorites, as well. Between Sagbekken and Sandskarelva, a pegmatite of granitic composition appears.

The remaining rocks of the Helgeland nappe, overlying the mapped part of the Hattfjelldal nappe, are different types of mica shists, banded gneisses and amphibolite. An interesting feature might be serpentinite bodies with chrysotile and talc growth at the boundaries. They occur abundantly in the top region of Sandskarvfjellet, each some meters in size. The biggest one is situated less high at 448.6/7256.5.

3. Tectonics

3.1 The Hattfjelldal thrust

The thrust contact between the Hattfjelldal nappe and the underlying Köli unit (Leipikvatnet or Stikke nappe?) is folded and faulted. As it follows the isoclinal folds of the Köli rocks, its thrusting must be an early event in the deformational history of the Köli rocks.

Some features of the thrust are listed here:

Sandskarbekken (at 680 m):

strongly deformed, probably recrystallized limestone (16), alternating with calcareous phyllite, upward followed by rocks of the volcanic series.

Sagbekken (at 600 m):

calcareous phyllite with pebbles of white, coarse crystalline limestone, which are mostly rolled out tectonically, forming boudins. Followed by some meters of chloritic quartz shist, rich

in pyrite, and finally a phyllitic variation of the dark limestone unit (16).

Myhaugen (road cut, 800 m N' of Ivarrud):

Phyllitic lenses of varying thickness separate the two nappes.

Örjedalen, N' side:

Thick layers of graphite phyllite form the thrust plane of the dolomites of the Hattfjelldal nappe.

Sommerfjell top:

Sommerfjell conglomerate, forming the thrust contact, where the pebbles are partly boudinized. Further east, the thrust zone is a calcareous graphitic rock, folded around thrust-parallel fold axes. The shear zones cutting the folds are younger.

Pantdalselva:

Partly recrystallized limestone mylonite, partly graphite phyllite as lubricant.

The described contact features suggest, that only minor thrust movement took place here, may be some few kilometers, but not attaining a nappe transport in the order of that of the Helgeland thrust.

3.2 The Helgeland thrust

The thrust contact between the Köli and Helgeland rocks is unfolded, but imbricated, and at some places faulted. Between Sandskarfjellet and Kvalpskarakslen, a dip of about 25° WNW could be measured on air photos.

The underlying Hattfjelldal rocks are strongly deformed, mostly boudinized limestones, partly mylonitic and recrystallized. Boudins in all sizes up to some meters are common, they consist of deformed sill material. Limestones also occur being squeezed up between harder rocks.

The upper part of the zone are strongly foliated or mylonized variations of the thrust rocks, showing shearing and diapnoresis.

3.3 The fault pattern

The observed fault pattern postdates the Hattfjelldal thrust and isoclinal folding, partly the Helgeland thrust, as well. It is presumed to have developed simultaneously with and after thrusting.

The faults derive from two major events:

a) Imbrication of the nappe pile. The imbrication faults in the Köli rocks, running in N-S direction down from Rössvatnet, turn into NE-SW direction within the mapped area. This is probably due to the Börgefjell massif, which is underlying the Köli rocks here in relatively low depth, and resisting to the thrust movement. This may be the reason for the more intense imbrication in this area, as well.

b) Conjugation pattern, developed by horizontal pressure affecting the rock pile and causing diagonal faults with lateral and vertical movement.

3.4 Folding and foliation

The main fold phase formed isoclinal folds with an axial plane foliation. Stratigraphic boundaries run approximately parallel with the foliation. Where they turn round, a crenulation cleavage can be observed, which proves the existence of an earlier foliation, about parallel with the bedding. The isoclinal folds exist in all orders of size, from km to cm.

A second phase of folding is widely bending the isoclinal folds. This can be observed in the southern part of the mapped area, is nearly lacking between Örjedalen and Pantdalen, but appearing again further north, near Unkerelvålen.

Folds, which are distinctly bound to thrusting of the Helgeland nappe, provide an increasing deformation towards the thrust plane. Fold axes of varying direction occur. As approaching the thrust plane, fold axes are getting more and more parallel with the shear direction of the mylonites.

It is not possible yet to say, if these two fold types represent one or two phases of folding. They may grade into one another without a remarkable break. A crenulation cleavage bound to these folds has not been found.

4. Sulphidization

As the whole area is strongly sulphidized, I am going to explain briefly my opinion about the origin of sulphidization. The most frequent mineral is pyrite; its occurrence seems to be due to three different reasons:

a) As many of the graphite containing sediments - graphite shist (12, 13), dark limestone (16), pebbly mudstone (4), partly dolomite (18) - are rich in pyrite, it is supposed to be of sedimentary origin, H_2S provided by rotting of organic material in euxinic environments. Later concentration and mineral growth took place during metamorphism. Examples: Graphite phyllite in road cut at 453.8/7259.5; dark limestone in ancient, overgrown quarries at 452/7260.5.

b) Basic sills cutting the limestones and dolomites near the Helgeland thrust, often contain pyrite $\pm$ other sulphides, where they are probably due to reduction of the iron (and other metals) by volcanic gases. Concentration and mineral growth by later metamorphism. Examples: Sills in dark limestone at Kvalpskarelva at 451.5/7259.7; sill in dolomite at 448.85/7255.5.

c) Pyrite and other sulphides can be found in all rocks, bound to the closer environment of fracture zones and quartz veins, due to hydrothermal activity. Thus, areas of intense fracturing are favoured in getting metallized. Examples: Mikkelfjord area, metallized chlorite-quartz rocks in an intensively conjugated fracture zone, possibly in combination with a minor thrusting (see p. 13, conclusions) at 454.9-455.4/7261.4-7262.5; metallization (pyrite, pyrrhotite and prob. others) in tectonically deformed dolomite (18) and fine-banded greenstone (23) in connection to the Helgeland thrust at 448.8-449.2/7255.0-7255.8.

5. Summary and Conclusions

The rocks of the Hattfjelldal nappe can be divided into five groups:

A: Calcareous psammitic phyllite series:

As this series forms the higher parts of the underlying nappe, as well, there cannot be a remarkable jump in stratigraphy between the two nappes. The depositional environment is supposed to be shelf environment with intercalated mass-flow deposits (pebbly mudstones), getting in from a higher topographic level (shore, delta?). Increasing mass-flow movement at the top of the sequence is probably caused by increasing tectonic activity.

B: Phyllite series:

The variety of euxinic/non-euxinic sediments and of the deposited grain-size and the rapid lateral changes in facies suggests the development of a threshold/basin pattern.

C: Quartzitic series:

As sedimentary structures in the quartzites are rare, a determination of the depositional environment has not been able until now. Some slumping, causing synaeresis, and probable graded bedding suggest a partly rapid sedimentation. As pure quartz bodies only appear as local incasts, a delta-like environment might be supposed. All corresponding sediments have been found.

D: Carbonatic series:

Here, a lateral facies representation of two limestone types is given, one of them being considered as turbidity current deposits, the other - with reservations - as shallow water limestone.

A graded conglomerate, being determined as a submarine fan conglomerate, indicates the way-up direction of the sediments, which is going along with basin-deepening. By applying this tendency to the whole facies distribution, the here applied way-up direction of the whole Hattfjelldal sequence can be presumed.

Furthermore, olisthostromes are interbedded in the limestone series, which is partly dolomitized.

For the whole series, a flysch-environment is supposed, possibly bound to the early stages of nappe transport.

E: "Volcanic" series:

This is a series of greenstones, whose volcanic origin has still to be proved. The assumed position on top of series D is unsure, as well.

Nowhere, low-grade metamorphism is exceeded, most of the area only shows chlorite zone. Biotite occurs occasionally, most frequently in the rocks of series E.

The tectonical deformation is dominated by isoclinal folding and by intensive nappe imbrication, going along with conjugated structures. The order of tectonic events is presumed as follows:

- 1) s_1 -foliation about parallel to bedding
- 2) Hattfjelldal thrust, local folding (f_0) at thrust plane
- 3) f_1 -folds, isoclinal, with axial plane foliation s_2 , giving rise to crenulation cleavage
- 4) f_2 -folds in the southern and northern parts
- 5) $f_{(2 \text{ or } 3)}$ -folds, increasing towards the Helgeland thrust, thrusting of Helgeland nappe, imbrication and conjugation faults
- 6) further faulting

Metallization (pyrite and other sulphides) is bound to:

- a) sedimentary sulphidization in euxinic environment, concentrated by metamorphism;
- b) volcanic veins;
- c) hydrothermal activity in fractured zones near thrust planes.

6. Bibliography

- | | | |
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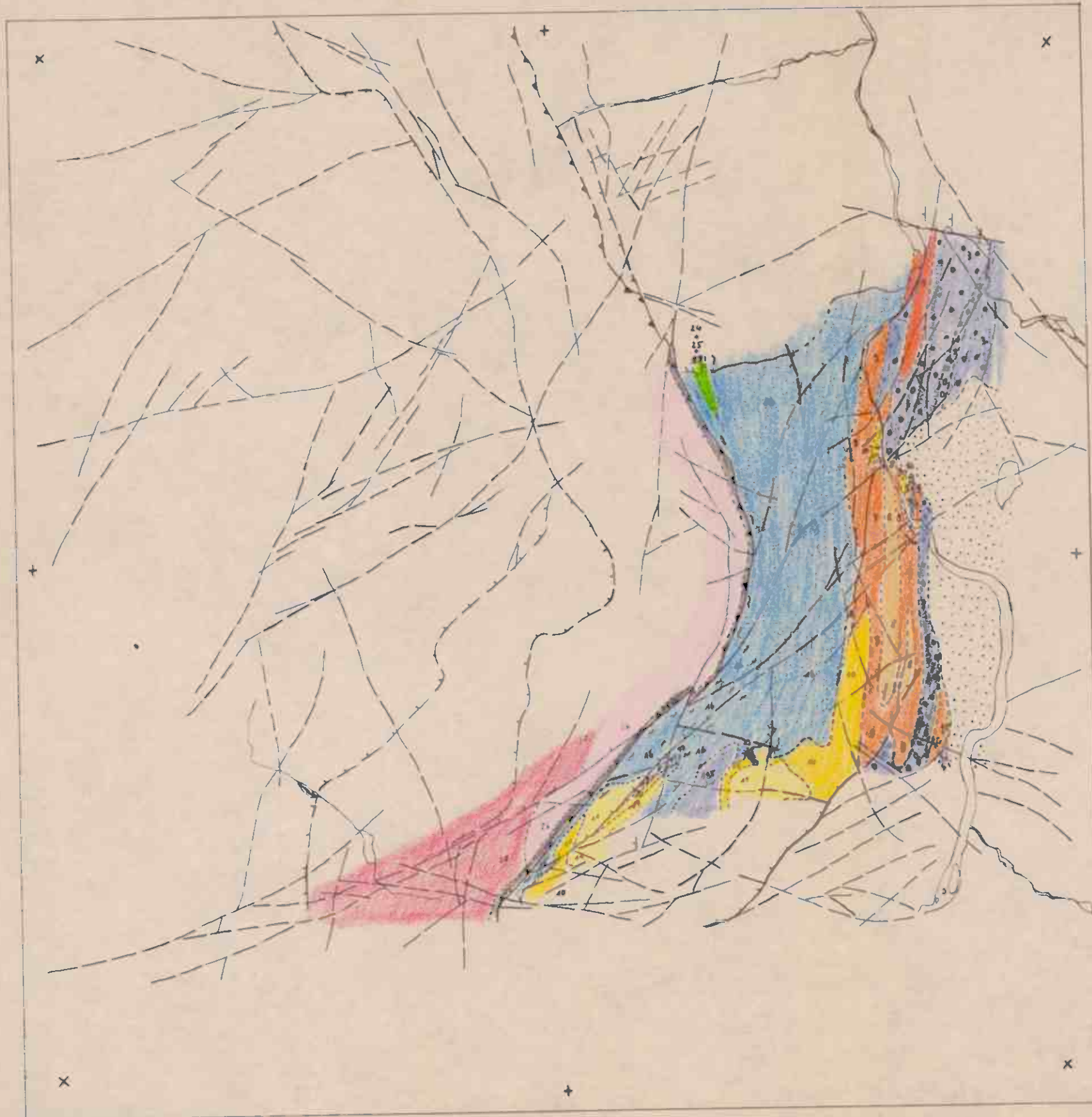
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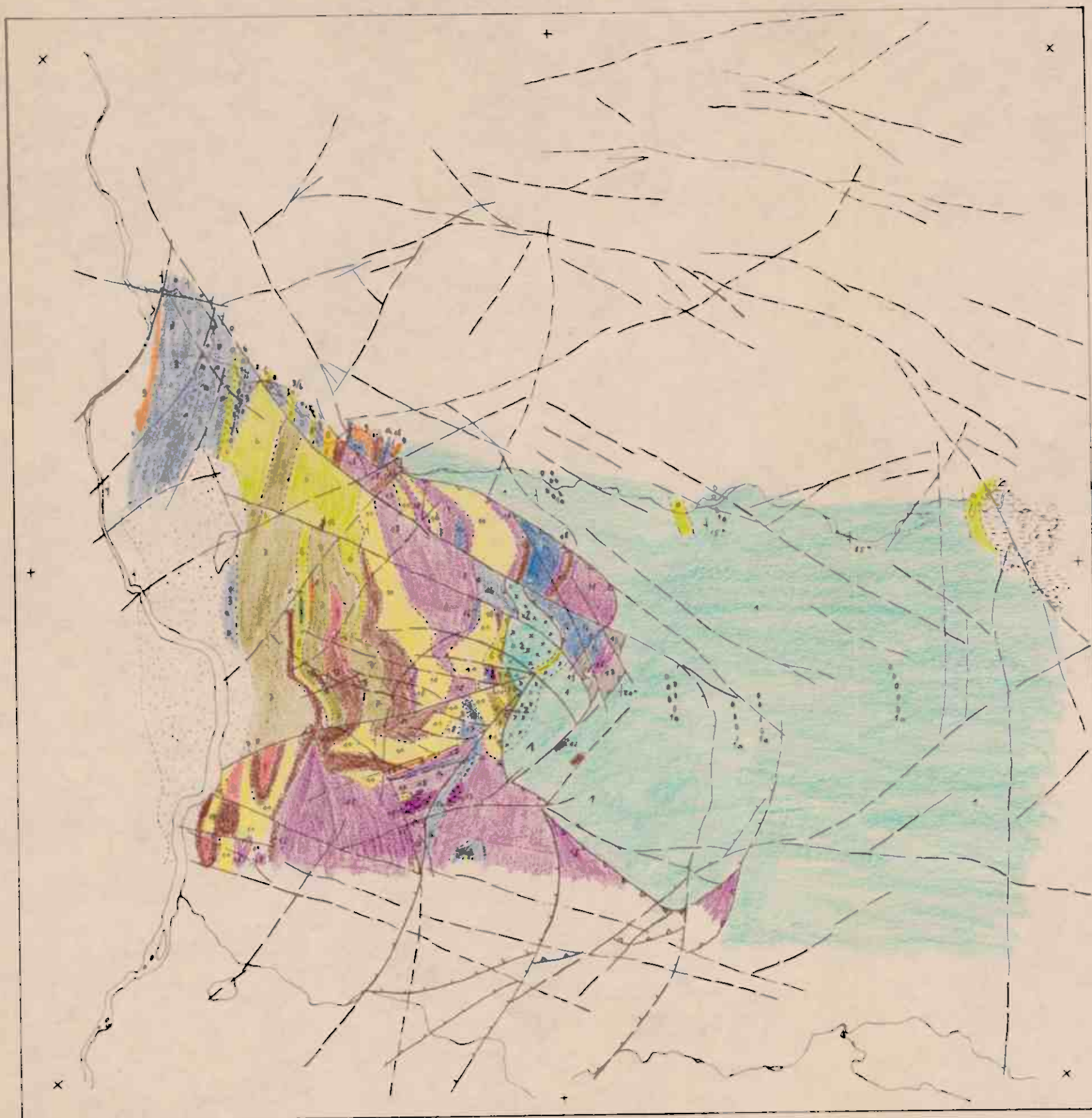
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interpretation

ca 1:30 000
parallax not corrected

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Preliminary legend see separate plate





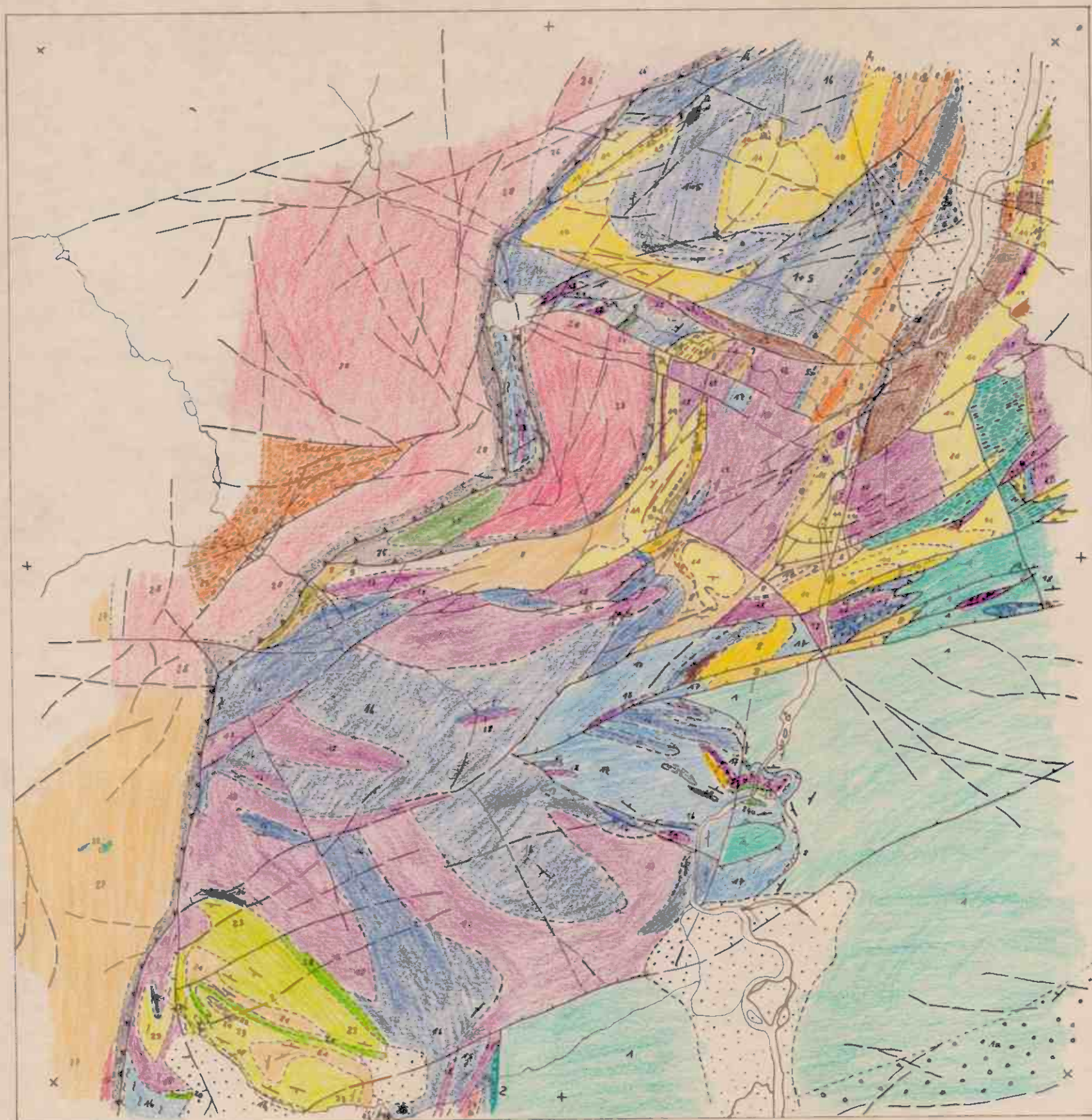
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Preliminary legend see separate plate



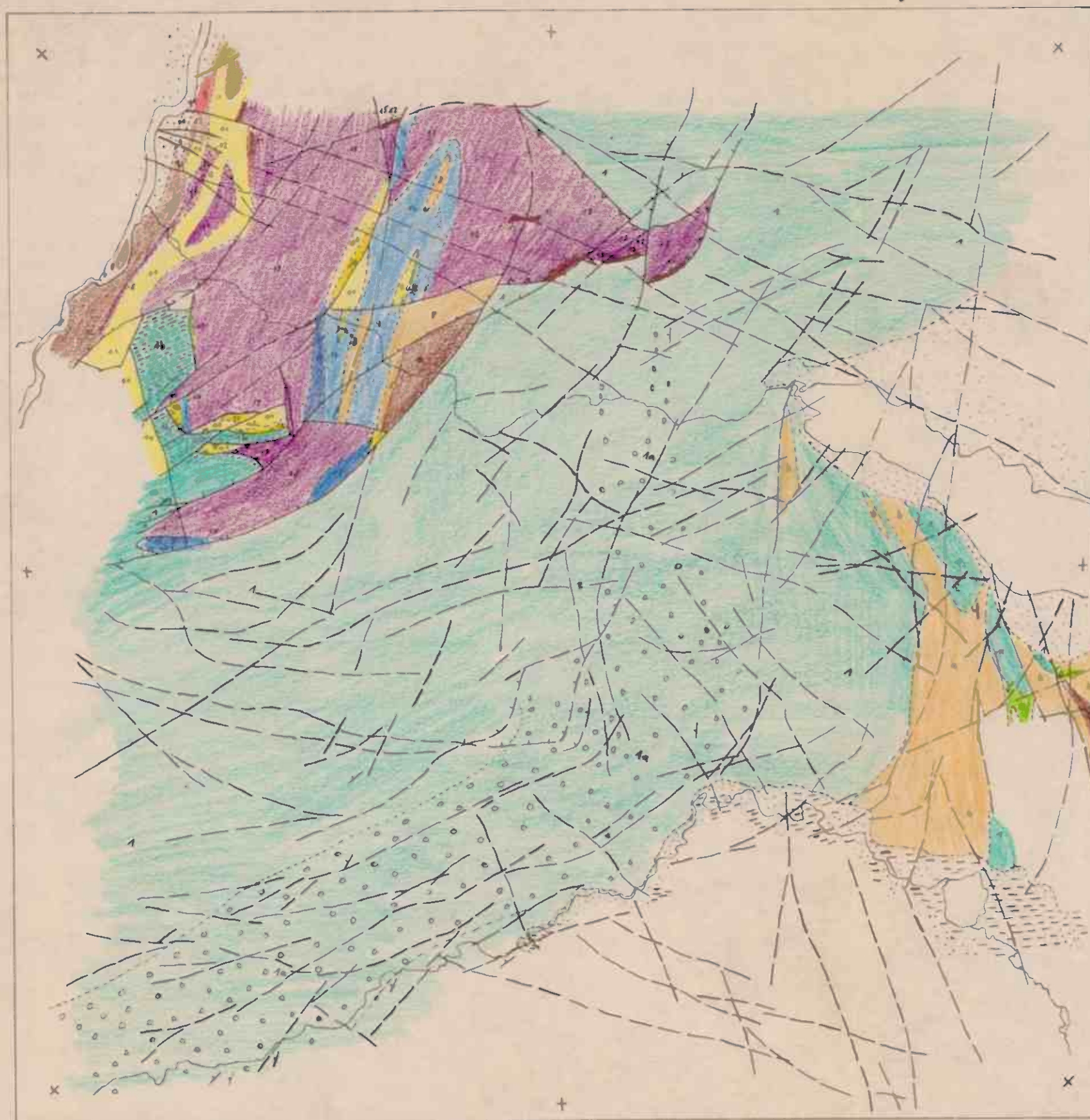
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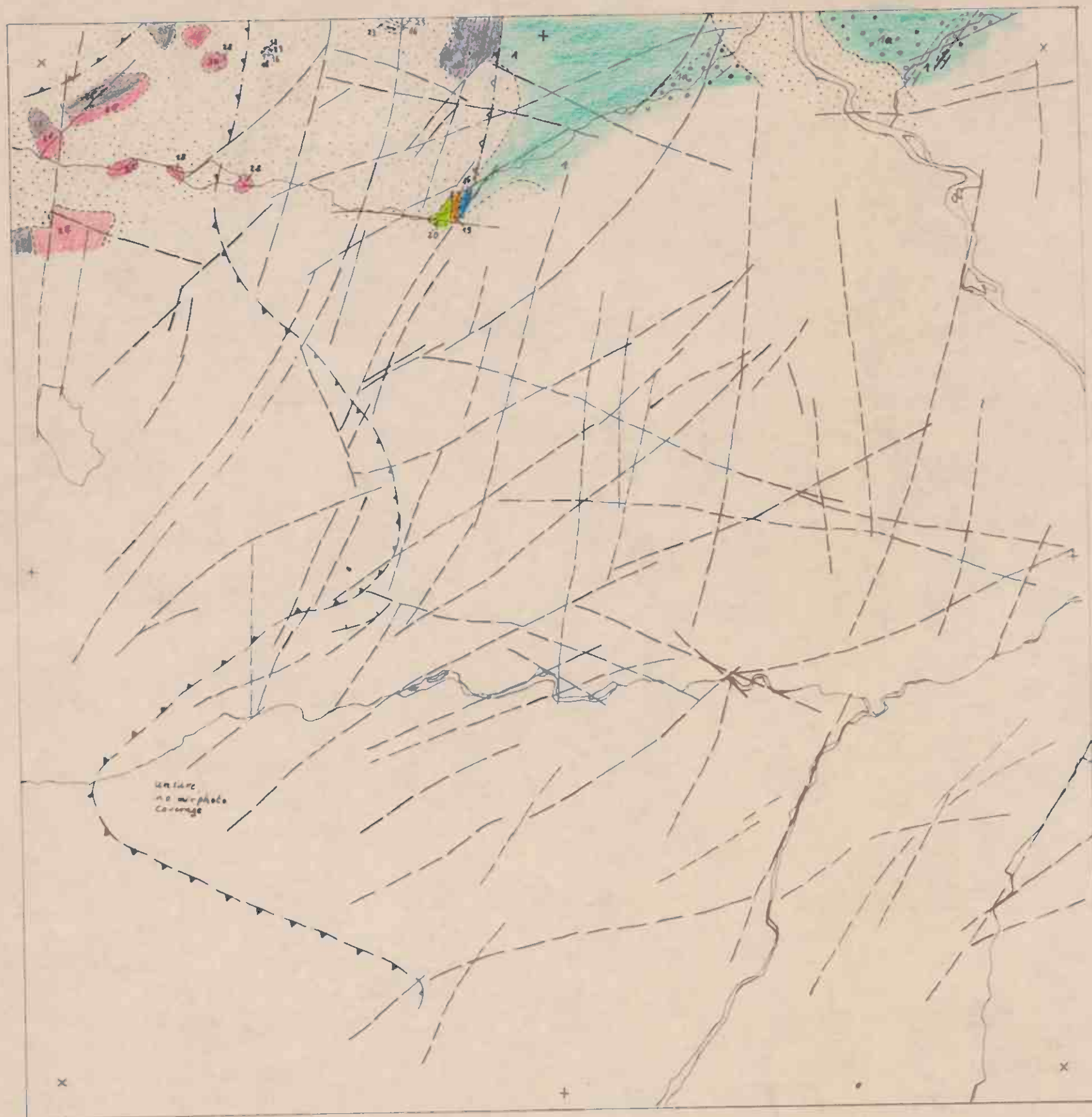
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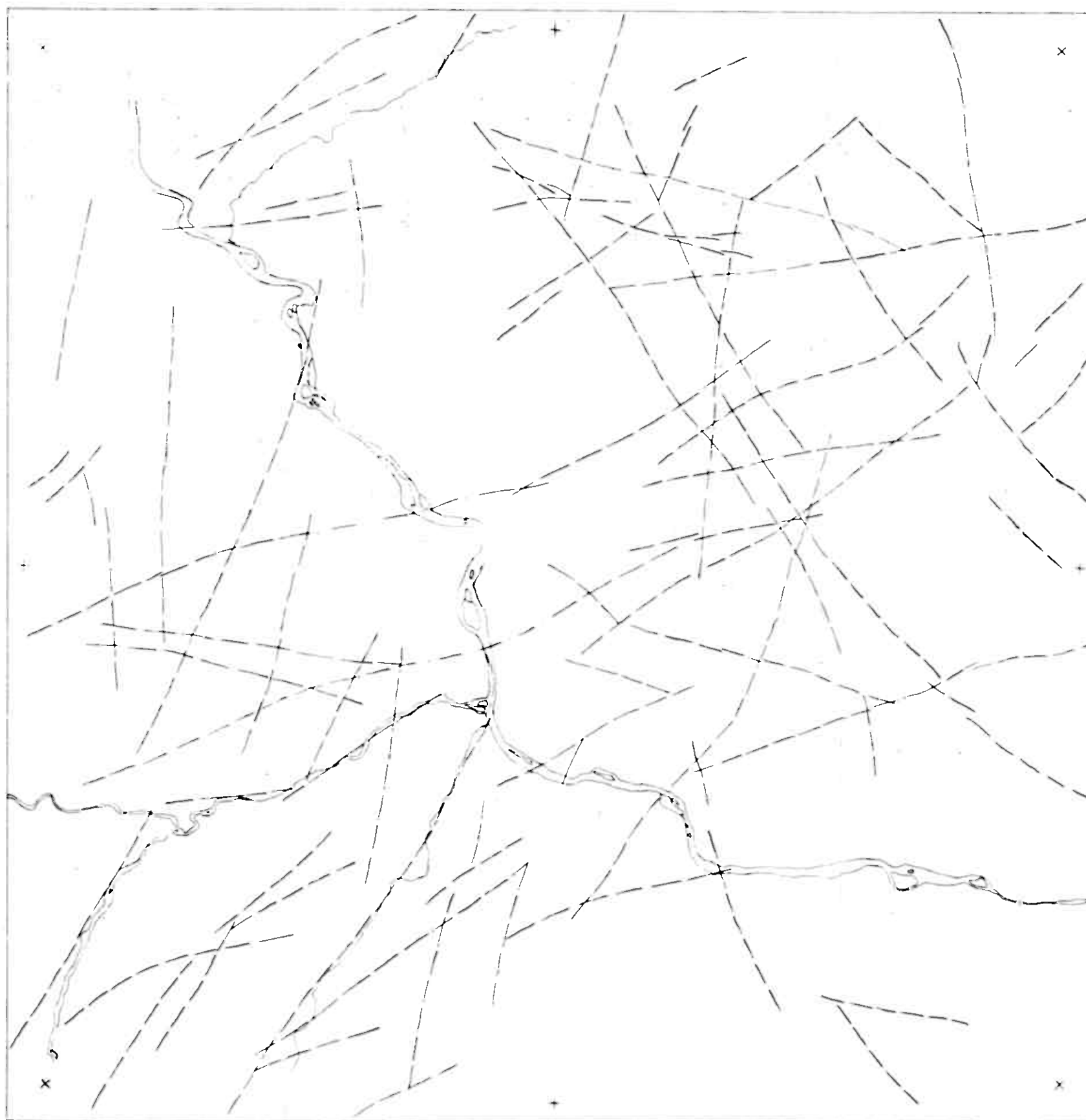
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Preliminary legend see separate plate



Overlay to air photo N3 (ser.4040)

photo lineations

complementary sheet to mapped area

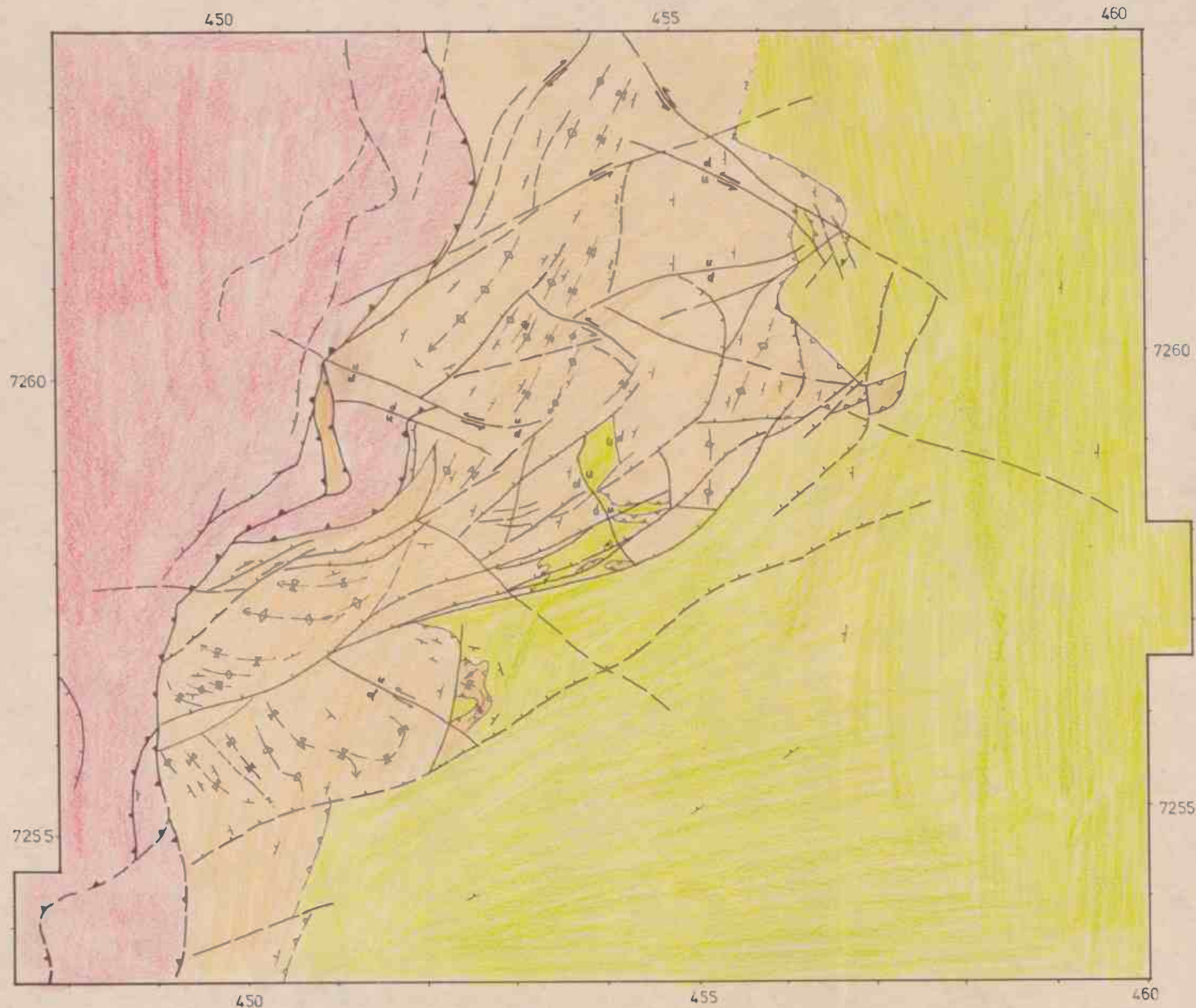
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STRUCTURAL INTERPRETATION MAP, SUSENDALEN, NORDLAND

LEGEND :

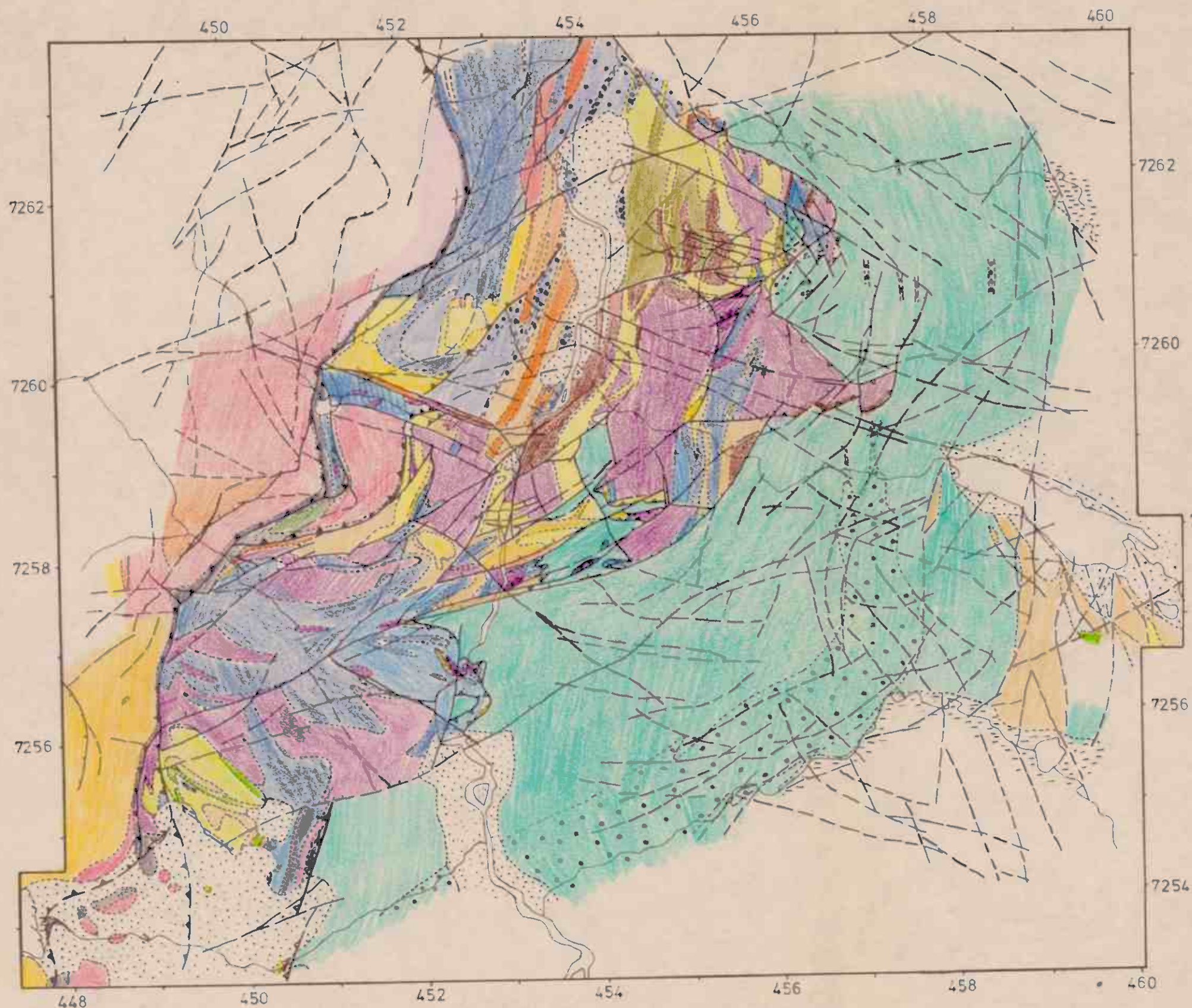


- Helgeland nappe
- Hattfjelldal nappe
- Leipikvatnet or Stikke nappe ?
- Helgeland thrust
- minor thrust
- horizontal displacement
- vertical displacement
up/down
- anticlinal structure
dip of axis
- synclinal structure
- strike and dip of main foliation
- Hattfjelldal thrust
- not specified struct. lineation

Scale 1:50000

0 1 2 3 km

GEOLOGICAL MAP OF SUSENDALEN, NORDLAND



LEGEND:

QUATERNARY

Helgeland nappe:

- basic rocks
- qz diorite & mica gneiss
- quartz diorite
- banded gneiss & amphibolite
- mica gneiss & -shist
- mylonitic rocks

Hattfjelldal nappe:

- basic/acid igneous rocks
- greenstone, light, finebanded
- greenstone, diff types, mostly dark
- banded & spotted shist
- dolomite
- light limestone
- dark limestone
- conglomerate / breccia
- calc. graphite phyllite
- graphite phyllite
- quartzite
- quartzite shist, fine banded qz rocks
- quartz phyllite
- phyllite
- quartz-chlorite-rocks
- chlorite phyllite
- calcareous phyllite
- " w pebbly beds

Middle Køli nappe:

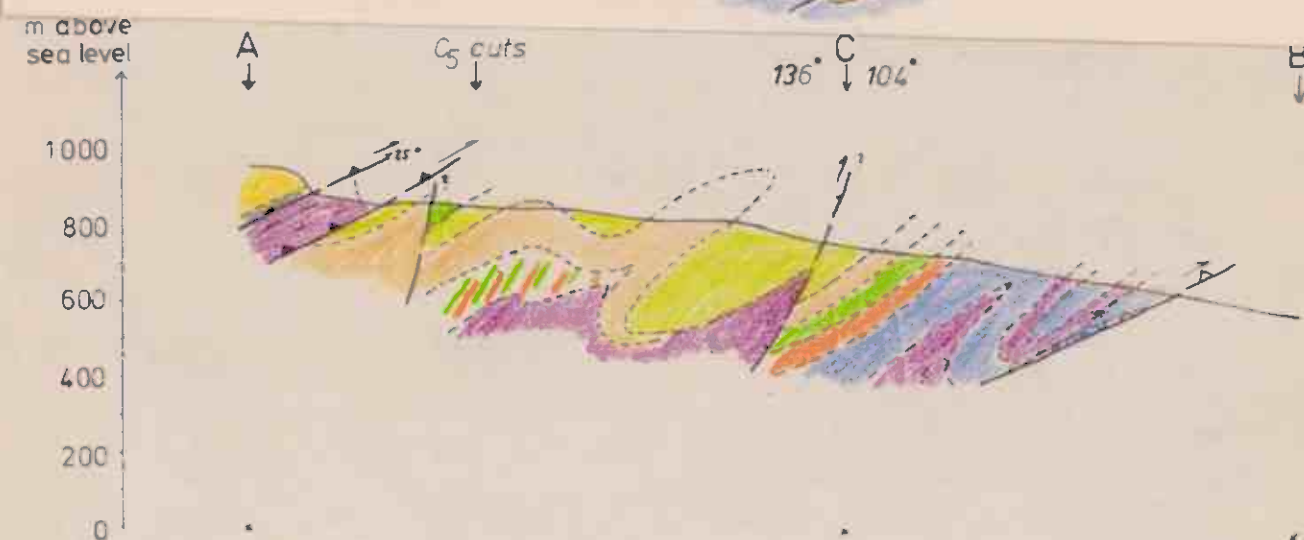
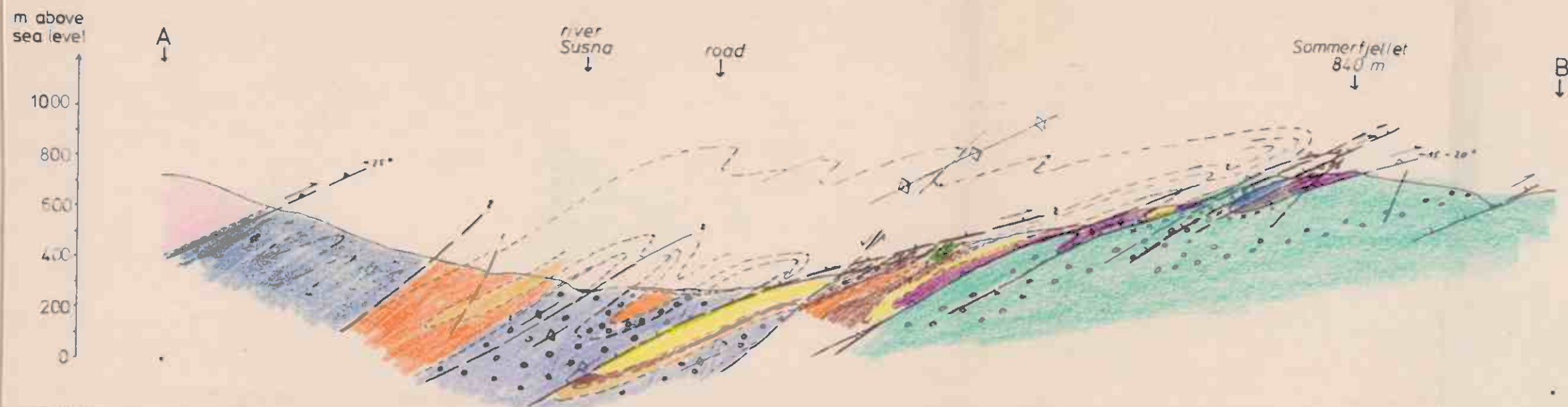
- breccia
- calcareous, psammitic phyllite
- " w pebbly beds
- qz, phyll, graph phyll, greenst of unknown stratigr. position

- fault, field confirmed
- air photo lineation
- minor thrust or uplift

Scale 1:50 000

0 1 2 3 km

Cross section C₁ Skinnfjell - Sommerfjell



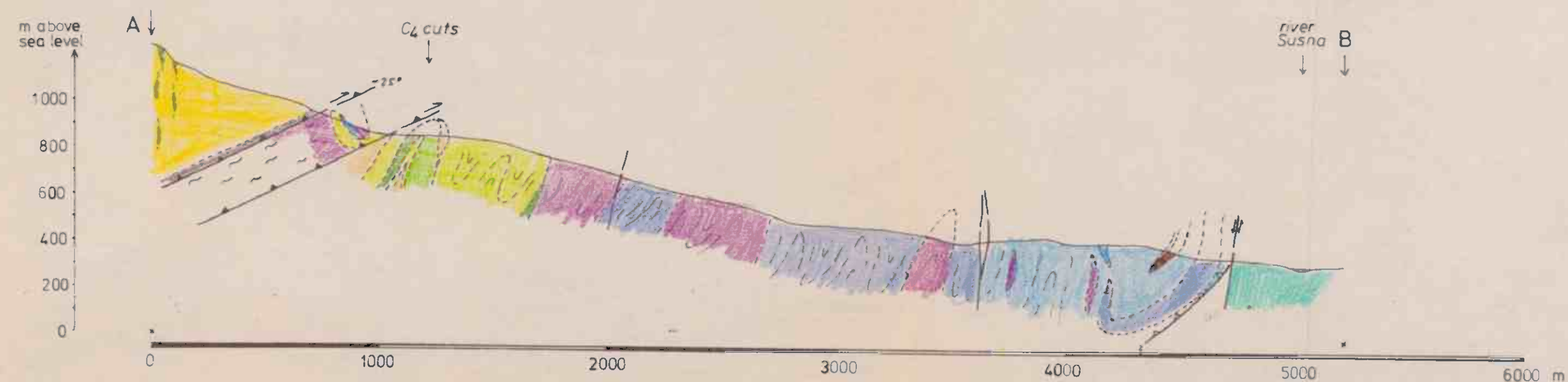
Cross sections of the
southern Hattfjelldal nappe

1 : 20.000

Appendix to geological map of
Susendalen, Nordland

W. Dallmann, 1982

Cross section C₅ Sandskarfjell - Nervollen



PRELIMINARY LEGEND TO GEOLOGICAL MAP SUSENDAL

by W Dallmann, 1982

this legend will be revised after microscopical determination of the rock samples

Quaternary  diluvial deposits  alluvial deposits

HELGELAND NAPPE

not in stratigraphic order

-  serpentinite
-  basic igneous rocks
-  coarse grained granitic rocks
-  quartz diorite & mica gneiss folded together
-  quartz dioritic rocks
-  banded gneisses & amphibolite
-  mica gneisses & shists
-  mylonites & phyllonites also in Koli

UPPER KOLI [HATTFJELLDAL] NAPPE

INTRUSIVE ROCKS

-  basic/acid intrusions
-  basic sills near Helgeland thrust, summarized

VOLCANIC / SEDIMENTARY SERIES, EASTERN SANDSKARFJELL (equiv. Gjersvik group?)

-  greenstone, light, fine banded
-  quartzitic rocks
-  phyllite
-  greenstone, diff. types, mostly dark
-  banded & spotted shists

CARBONATIC SERIES (Hattfjelldal group)

-  limestone mylonites, boudinized
-  dolomite

 light limestone

 dark limestone (interbedded phyllitic and quartzitic layers)

 Hattfjelldal conglomerate/breccia

 graded dolomite conglomerate

PHYLLITIC / QUARTZITIC SERIES (equiv. Limingen group?)

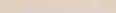
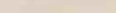
-  graphitic limestone & calc. graph. phyllite
-  graphitic phyllite in diff. stratigr. positions
-  quartzite
-  quartzite shist & fine banded quartzite
-  quartz (bearing) phyllite
-  phyllite
-  quartz chlorite shist and chlorite quartzite (prob. equiv. to 9-11)
-  chlorite shist or phyllite (prob. equiv. to 8+9)
-  calcareous phyllite
-  " rich in dolomite (± quartzite) pebbles
-  " poor in dolomite (± quartzite) pebbles

MIDDLE KOLI NAPPE

(Lingen group?)

-  Sommerfjell conglomerate (partly breccia)
-  chloritized and/or epidotized var. of 1
-  1 with isolated dolomite and quartzite pebbles
-  calcareous phyllite mostly quartz bearing with unknown stratigraphic position
-  quartzite
-  phyllite, partly rich in quartz
-  graphitic phyllite
-  greenstone, diff. var.

TECTONICS

-  fault, field controlled
-  air photo lineation
-  Helgeland thrust
-  Hattfjelldal thrust
-  minor thrust or uplift
-  doline
-  strike and dip
-  vertical dip

GEOLOGICAL MAP OF SUSENDALEN, NORDLAND

1 : 20.000

W. Dailmann, 1982

1km

this map shows the central mapping area as far as topographical
base maps 1:20000 are available
marginal areas see air photo overlays 1:30000

Preliminary legend see separate plate

appropriate limit of
mapped area

