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Rules and recommendations for naming geological units in Norway

by the Norwegian Committee on Stratigraphy

Editor: Johan Petter Nystuen

Translator: Richard Binns

Universitetsforlaget

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Preface to the Norwegian edition

At a meeting on May 5th, 1982, the Norwegian Council of Geology passed a resolution for the establishment of a Norwegian Committee on Stratigraphy (Norsk stratigrafisk komite, NSK). The status, mandate, composition and working methods of the committee were defined at the same meeting (Appendix 1). On December 16th, 1982, the Council appointed the committee members, and on January 15th, 1983, the committee held its statutory general meeting electing Anna Siedlecka (Geological Survey of Norway – Norges geologiske undersøkelse – NGU) as chairman with Tore Torske (University of Tromsø – Universitetet i Tromsø – UiT) as her deputy. The other members during the 4-year period of 1983-86, were Svein Gjelle (NGU), Atle Mørk (Continental Shelf Institute, Norway – Institutt for kontinentalsokkelundersøkelser – IKU), Rolf Sørensen (Agricultural University of Norway – Norges landbrukshøgskole – NLH), Jan Vollset (Norwegian Petroleum Directorate – Oljedirektoratet – OD) and David Worsley (Saga Petroleum), with Arne Solli (NGU), Jenö Nagy (University of Oslo – Universitetet i Oslo – UiO), Johan Petter Nystuen (NLH), Eiliv Larsen (NGU), Jan Mangerud (University of Bergen – Universitetet i Bergen – UiB), Arild Andresen (UiT), Per Blystad (Åse Moe – OD) and Audun Hjelle (Norwegian Polar Research Institute – Norsk polarinstitutt – NP) as deputies.

Atle Mørk and David Worsley took the initiative for setting up a body to attend to questions concerning Norwegian stratigraphy. In a written proposal sent to the Norwegian Council of Geology (Norsk geologiråd) they emphasized the need for a stratigraphical committee and outlined the tasks and working methods of such a body. As a result of this approach the Council, in a letter dated December 19th, 1979, appointed a committee consisting of Anna Siedlecka, Jan Vollset and David Worsley (chairman) charged with formulating a proposal for the working methods, responsibilities, terms of reference and members of a Norwegian Committee on Stratigraphy. The committees proposal of April 14th, 1980, formed the basis for the terms of reference and guidelines which the Council subsequently adopted for NSK.

The work of the Norwegian Committee on Stratigraphy is an extension of that performed by a previous stratigraphical group under the auspices of the Norwegian Geological Society. This group, with Professor Gunnar Henningsmoen as chairman, was active from the mid-1950s to the end of the 1960s. Its results included formulation of rules for Norwegian stratigraphical nomenclature (Henningsmoen 1961). The group also worked on approval and registration of stratigraphical units in Norway and Svalbard for a projected new version of the Norwegian section of the International Stratigraphical Encyclopedia (Major et al. 1956, Strand & Størmer 1956). To achieve uniform stratigraphical nomenclature in each country, stratigraphers in Finland and Sweden were approached with a view to cooperation. The activities of the group stagnated towards the end of the 1960s because the initiators had other pressing tasks.

An increasing need for advice on the use of stratigraphical terminology and for rules for erecting stratigraphical and other geological units has been clearly apparent in recent years. This is connected with the geological mapping of the country, earth science research in general, and, not least, the explosive advance in geological research and oil prospecting in the North Sea, Norwegian Sea and Barents Sea. Because of this need, the Norwegian Committee on Stratigraphy has, throughout the 4-year period, placed priority on formulating a Code for naming geological units in Norway (Appendix 1).

The sections dealing with lithological, biostratigraphical, chronostratigraphical and morphostratigraphical units, along with that on climatostratigraphy, formed the basis for the preparation of "Rules and recommendations for naming geological units in Norway". Responsibility for compiling these sections was assigned to the following members of the committee (in alphabetical order): Eiliv Larsen, Atle Mørk, Anna Siedlecka and Tore Torske – lithological units; Atle Mørk and David Worsley – biostratigraphy and chronostratigraphy; Eiliv Larsen, Jan Mangerud and Rolf Sørensen – climatostratigraphy and morphostratigraphy; Per Blystad contributed the section on seismostratigraphy.

There has throughout been broad agreement within NSK about the great need for recommendations and advice concerning nomenclature and erection of units in the fields of structural geology and tectonostratigraphy. The committee therefore decided to extend the Code to include these non-stratigraphical entities. In spring 1984, NSK appointed a committee to work specifically on structural and tectonostratigraphical units. This committee, consisting of Johan Petter Nystuen (chairman), Roy Gabrielsen (Saga Petroleum) and Johan Naterstad (NGU), prepared the sections on these units. Sylvi Haldorsen (NLH) contributed the material concerning terminology relating to ice-contact deposits. The Norwegian Committee on Stratigraphy extends its gratitude to these for their work.

While the Code was being prepared, its content, scope and related language problems were discussed at several full meetings of the committee. Valuable comments and suggestions for improvements were sent to the committee by many Norwegian geologists in response to notes about specific points and to the entire code when it was sent out on hearing in the winter of 1985/86. NSK also had assistance from the Norwegian Language Council (Norsk språkråd), and received valuable advice and comments from the State Adviser on Geographical Names (Statens navnekonsulent). The committee offers its thanks to all the individuals and institutions who have contributed constructive criticism.

At the meeting of the Norwegian Committee on Stratigraphy on March 25th, 1985, it was proposed that Johan Petter Nystuen should be the editor of the Code, and he accepted the task. He has put a great deal of effort into the job of editing and has also supplemented the work with, for example, the introduction, sections concerned with pedostratigraphy and magnetostratigraphy, diachronous units and deformational-diachronous units, and the illustrations. Thanks to his invaluable work the Code has achieved consistency in content and language. The Norwegian Committee on Stratigraphy hereby expresses its heartfelt thanks to Johan Petter Nystuen for this time-consuming task. He has shown professional skill, a realistic outlook and an ability to give the text clear wording. NSK also wishes to thank Marie-Louise Falch and Aslaug Borgan at the Department of Geology at the Agricultural University of Norway for, respectively, word processing the manuscript and doing the final draughting of the illustrations. Eiliv Larsen is thanked for the work he carried out on final preparation of the manuscript for printing.

The Norwegian Committee on Stratigraphy is grateful to Norsk Hydro A/S, Saga Petroleum a.s. and Statoil for financial support enabling the Code to be printed in Norsk Geologisk Tidsskrift. NSK would also like to thank Snorre Olaussen and Statoil for permission to use Statoil's Geological Time-scale; the cost of reprinting this for the Code was met by Statoil.

Finally, NSK would like to thank all those institutions and firms who have permitted employees to devote valuable working hours to the task of preparing the Code.

This Code is the first work of its sort and size to be published in Norwegian. Using the Code in practice is the only way any weak points, deficiencies and ambiguities will be revealed. NSK is publishing "Rules and recommendations for naming geological units in Norway", which is a result of valuable cooperation between representatives of various branches of the Norwegian geological fraternity, in the hope that the product will help many geologists in their everyday work.

Trondheim, June 18th, 1986

Anna Siedlecka

Preface to the English edition

The Norwegian edition of "Rules and recommendations for naming geological units in Norway" was published under the title "Regler og råd for navnsetting av geologiske enheter i Norge" (Nystuen 1986). The need for the Code has been proved by the broad response it has received and by the wide application of its recommendations by geologists concerned with defining, naming and erecting geological units in Norway, not least on the continental shelf.

Soon after the Norwegian edition was published, the Norwegian Committee on Stratigraphy (NSK) decided to have an English version. One important reason for this is that there are many geologists working in Norway and in Norwegian territories who use English as their technical language and who have a very poor or no knowledge of spoken or written Norwegian. NSK would also like to see such foreign geologists following the Norwegian recommendations, and an English version of the Code would naturally further the achievement of this aim. Foreign companies, research institutions and universities should also have ready access to the Code. Furthermore, the Norwegian Committee on Stratigraphy, being affiliated to the International Subcommission on Stratigraphic Classification of the IUGS Commission on Stratigraphy, is aware that the Norwegian code should also be known to the international geological community in general.

This English version is largely an *in extenso* translation of the Norwegian edition. Only minor sections dealing with terminological problems specific to the Norwegian language have been omitted; a few that specifically relate to English language terminology have been added by the translator. If there are any discrepancies in meaning or interpretation of definitions, rules or recommendations between the Norwegian and English texts the Norwegian text has priority. However, a footnote has been added to Section 3.5.1 of the English version regarding the practice of using reworked fossils for defining biostratigraphical units in Quaternary stratigraphy. Moreover, Sections 3.4.2.8, 3.9.8.7, 3.9.8.8 and 3.9.8.9 were inadvertently omitted from the Norwegian edition; these are included in the present one. A number of minor errors in the Norwegian edition have also been corrected during the translation process.

The Norwegian edition was funded by the three major Norwegian petroleum companies, Norsk Hydro A/S, Saga Petroleum a.s. and Statoil. The cost of translating and printing the English version has been met by Norsk Agip A/S, Amerada Hess Norge A/S, ARCO Norway Inc, BP Petroleum Development (Norway) Ltd, CONOCO Norway Inc, Elf Aquitaine Norge A/S, Fina Exploration Norway, A/S Norske Shell, Total Marine Norsk A/S and Unocal Norge A/S. The Norwegian Committee on Stratigraphy gratefully acknowledges the financial contributions from these companies.

The translation has been carried out by Richard Binns, Trondheim. He has also prepared the Index of the English version, as well as word processing and proofreading the text. The Committee thanks Richard Binns for this work and the effort he has put into finding appropriate English expressions to cover even small variations in meaning in the Norwegian text.

NSK thanks the Continental Shelf and Petroleum Technology Research Institute A/S (IKU) for its secretarial function while this version was being translated and published, the Geological Survey of Norway (NGU) for technical assistance, and Norsk Geologisk Tidsskrift and its editor Eiliv Larsen for their collaboration. The editor of the Code would like to thank all present members of the Committee for taking part in the work of achieving publication of the English version: Arild Andresen (University of Oslo), Per Blystad (Norwegian Petroleum Directorate), Svein Gjelle (Geological Survey of Norway), Morten Hald (University of Tromsø), Audun Hjelle (Norwegian Polar Research Institute), Marit Hovdenak (Norwegian Language Council), Atle Mørk (IKU), Snorre Olaussen (Statoil), Hans-Petter Sejrup (University of Bergen), Anna Siedlecka (Geological Survey of Norway), Morten Thoresen (Geological Survey of Norway) and David Worsley (Saga Petroleum a.s.).

Atle Mørk, Per Blystad and Snorre Olaussen are thanked for their work in obtaining financial

support for the project. Special thanks are due to Atle Mørk for his contribution towards solving practical and administrative tasks. The editor would also like to thank Saga Petroleum a.s. for technical assistance in retexting figures for the English version.

Høvik, November 21st, 1988

Johan Petter Nystuen
Editor and Chairman of the Norwegian Committee on Stratigraphy

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Rules and recommendations for naming geological units in Norway
By the Norwegian Committee on Stratigraphy

JOHAN PETTER NYSTUEN (EDITOR)

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The Norwegian Committee on Stratigraphy was established in 1982 by the Norwegian Council of Geology. In Article 1 of the mandate the committee was authorized to "Draw up a Code for Norwegian stratigraphical terminology". The present Code, resulting from this work, should be used for classifying and naming geological units in Norway, on the Norwegian continental shelf and in Norwegian territories and claims in the Arctic and Antarctic. The general chapters deal with definitions of basic concepts, such as the meaning of formal and informal units, rules for naming geological units and how to write names in Norwegian and English, as well as procedures for erecting, registering and changing the definition, rank and name of formal units. Emphasis has been placed on defining and naming subsurface units on the continental shelf. The Code expresses the principles of the International Stratigraphic Guide of 1976 (ISSC 1976) and has also adopted several of the stratigraphical categories introduced in the North American Stratigraphic Code (NACSN 1983). It also includes 6 new formal categories of geological units: geomorphological and structural form units, linear structural units (lineaments), planar structural units (joints, fractures, faults), morphostratigraphical units, tectonostratigraphical units and diachronous units defined by deformation events. Climatostratigraphical units are included in the category of diachronous units. The sections dealing with the 17 categories of geological units include basic definitions and terminology in English and Norwegian, the rank and position of the units in the classification systems along with their dimensional properties, mappability and methods used in identifying them, material or time content and other properties, nomenclature principles, comments on their variability and their relationship to other units, examples and key references.

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1 Introduction

1.1 Background and purpose

The volume of geological knowledge has increased greatly in recent years. This applies to our knowledge of geological processes and their results as well as to our understanding of the geological evolution of continents and oceans. In the case of Norway, investigations of the continental shelf have produced a particularly large volume of data.

An important prerequisite for exchanging, presenting and putting to practical use the ever-growing mass of information is that the language employed by specialists is used as unambiguously as possible. Much of the geological knowledge disseminated and exchanged through geological maps, scientific publications, and technical and economic reports is connected with definitions and descriptions of named geological units. Such geological units may be rocks and sediments, nappes, landforms, geological time units, etc. To avoid misunderstanding and confusion arising regarding the meaning of such nomenclature, the geological units must be classified and given names and a content in accordance with guidelines about which there is general agreement.

The tradition has developed of using geographical names for geological units. This has led to an almost explosive increase in the numbers of geographical names in use for geological units on Norwegian territory in publications in recent years. However, there is an unfortunate tendency for geographical names to be used also when definitions and descriptions are inadequate, particularly as regards such important properties as boundary relationships and geographical distribution. To avoid misunderstanding, it is important that the publication of such names takes place first after the units have been adequately studied, enabling them to be defined in accordance with international and national rules pertaining to formal units. Place names are part of our cultural heritage. This, along with geological criteria and guidelines, should be taken into account when they are being chosen for naming geological units.

Rules for naming geological units in Norwegian were last published by Henningsmoen (1961). In 1976 the International Subcommission on Stratigraphic Classification published the "International Stratigraphic Guide" (ISSC 1976). This standard work has formed the pattern for geological nomenclature in Norway in recent years. In 1983 the North American Commission on Stratigraphic Nomenclature published the "North American Stratigraphic Code" (NACSN 1983). The Norwegian Committee on Stratigraphy (NSK) has drawn up the Norwegian code presented here in accordance with the main principles in these two Codes.

NSK has also formulated rules for classifying and naming geological units which have not been covered previously. These are geological form units (Section 3.7), linear structural units (Section 3.8), planar structural units (Section 3.9), morphostratigraphical units (Section 3.10), tectonostratigraphical units (Section 3.11) and deformational-diachronous units (Section 4.8).

The objective in having a separate, comprehensive Norwegian code was to obtain recommendations, in the Norwegian language, for how geological units are to be (a) understood, with content and limitations, (b) named in Norwegian and English, (c) defined, erected, registered and, if necessary, changed. Additional objectives were (d) to be able to direct attention to special features shown by the individual geological units, which are specially valuable for providing additional clarification of their distinctive character, and (e) to make it easier to present geological knowledge in *Norwegian.* To achieve the last-mentioned aim, a number of new Norwegian words were coined to replace foreign technical terms, where that was thought desirable.

The need to inform geologists who use English as their technical language about the Norwegian Code has led to this Code now being published in English (see also the Preface to the English edition).

Only the use of the Code will show whether it will fulfil its objectives. NSK believes that the geological fraternity will benefit from giving broadest possible support to the rules which are proposed. This must not hinder the Code from being revised and improved. NSK therefore welcomes comments and suggestions for improvements as experience of using it is obtained. Such reactions will provide a basis for its complete or partial revision.

The Code has been written with a view to it being used as a *reference work.* To make the rules for the individual categories and units as complete as possible there have had to be some repetitions. This concerns, for example, some general rules and properties which are relevant to many of the geological units dealt with. All users are therefore recommended to study the generally applicable provisions found in Chapter 2.

1.2 Definitions

Geological unit – In this Code, the term geological unit is used to signify a body of rocks or superficial deposits, a form element, geological structure, or geological time unit which requires a special, recognizable name for use on geological maps, in scientific articles, and in technical or economic reports. Formal *unit terms* are those used in formal classification systems. Examples are formation, group, suite, biozone, etc.

Rock, bedrock, superficial deposit, type of superficial deposit, etc. – The term *rock* is used in this Code for a solid, coherent material consisting of (a) minerals formed by precipitation, crystallization, recrystallization, or cementation of older mineral and rock fragments, (b) glass formed by solidification of magma, and (c) organic material (e.g. coal). A rock constitutes part of the *bedrock* (berggrunnen). The bedrock is the solid fundament beneath the superficial deposits. In this Code, *superficial deposits* embody all kinds of loose, incoherent deposits such as clay, sand, gravel, organic material and the like, as well as the weathered, fractured and fragmented uppermost surface of the bedrock. Portions of more or less compacted and cemented material may be found within superficial deposits. A gradual transition from bedrock to superficial deposit is feasible. The term "superficial deposit", as used here, is synonymous with *regolith* (Bates & Jackson 1980). *Type of superficial deposit* corresponds to rock and designates a superficial deposit having special characteristics, e.g. a sand deposit, clay deposit, moraine, peat, and the like. *Sediment* is material which is transported and deposited by ice, water, air, sliding and mass movement, chemical and biochemical precipitation or biological growth. The term sediment is mostly used in connection with unconsolidated deposits, but also when dealing with coherent deposits and sedimentary rocks.

Category – A category is one or more geological unit(s) having one or more special trait(s) in common. For example, all units of stratified rocks or superficial deposits which are deposited with younger layers above older ones belong to the category of lithostratigraphical units. The Code comprises 17 main categories (see the summaries in Section 1.3 and Table 1).

Class – A class embodies types of rocks, superficial deposits, form elements, structures or geological time units that are distinguished from other types by having a fundamentally different character or mode of formation. For example, the three classes of rocks are igneous, sedimentary and metamorphic rocks, and the classes of form elements are erosional forms, depositional forms and forms of mixed origin.

Lithology – Lithology is the combined expression of all the physical properties on the basis of which a rock or sediment can be identified: composition, texture, grain orientation and structures. In an extended sense, lithology also embodies *derived* properties registered with the help of various measuring techniques: porosity and permeability, chemical, magnetic, electrical, thermic, seismic, gravimetrical and radiological properties.

Lithological units – Lithological units are geological units that are classified on the basis of their lithological properties. Lithological units comprise both rocks and superficial deposits. Categories of lithological units are lithostratigraphical, lithodemic and pedostratigraphical units.

Stratigraphy – Stratigraphy is used here as in ISSC (1976), as a science that treats rocks and superficial deposits as *beds*: their original sequence, absolute age, relative age relationship, form, extent, lithology, fossil content, geophysical and geochemical properties, interpretation of mode of formation and geological history. All classes of rocks and superficial deposits are described and classified stratigraphically.

Stratigraphical division, classification – Stratigraphical division is the systematic organization of rocks and superficial deposits, as they occur in their stratal successions, into units distinguishable from each other on the basis of their properties and/or boundary relationships. There are many types of stratigraphical division, according to which properties and relationships form the basis for the division.

Stratigraphical unit – A stratigraphical unit comprises one or more beds distinguished as a distinct unit on the basis of any property or group of properties found in rocks and superficial deposits. The unit constitutes, together with other units, part of the systematical organization of stratal successions on the Earth. The basis for the definition of the unit determines to which category of stratigraphical units it belongs.

Stratigraphical terminology – Stratigraphical terminology is concerned with terms for types of stratigraphical units. There are usually different unit designations for the individual stratigraphical categories. Such terms can designate the *rank* of the unit in the classification system and perhaps which position the unit occupies in a *hierarchical classification system*. Examples of such unit designations are formation, group, biozone, system and stage.

Stratigraphical nomenclature, naming – Stratigraphical nomenclature is used here to embrace naming of geological units in general, irrespective of category. Nomenclature has to do with the full name of the unit, consisting of a characterizing name and the unit term. There are formal and informal categories of names (see Sections 2.2 and 2.3).

Correlation, comparison – To correlate is, in a stratigraphical sense, to be able to demonstrate agreement in properties and stratigraphical position between two or more stratigraphical units. Correlations can be made on the basis of lithology (lithostratigraphical correlation), fossils (biostratigraphical correlation), morphology (morphostratigraphical correlation), time (chronostratigraphical correlation) and other properties.

System – "System" is a formal unit term in the chronostratigraphical classification system. The term is also used in combination with geological type designations in other categories, e.g. fault systems, joint systems and nappe systems. In this Code, "system", used in this wide sense, characterizes a geological unit which embraces rocks, superficial deposits, form elements or structures that are related in mode of formation within a limited time period.

Complex – "Complex" is a formal unit term in the lithodemic classification system. The term is also used in combination with geological type designations in other categories, e.g. fault complex, joint complex and nappe complex. In this Code, "complex", irrespective of category, characterizes a geological unit which embraces rocks, superficial deposits, form elements or structures, and which is a heterogeneous collection of dissimilar individual elements. The individual elements have either a different age and/or mode of formation, or their relative age relationships are uncertain or unknown.

1.3 Categories in the Code

The categories of geological units included in the Code are those containing units that can be defined formally and be given separate names (Table 1). A few categories and units which NSK recommends be used only in informal contexts, are also included. When the individual categories are dealt with, rules may be given for one or more geological unit(s). Some units are divided into subtypes.

There are two fundamentally different kinds of categories. One comprises categories consisting of units defined on the basis of *material content or other physical properties* (Chapter 3). Common for these is that they denote distinctive geological units that can therefore be given *special names* or *proper names*.

The other main group consists of units defined on the basis of *time* or *age* (Chapter 4). Such units are either a division of time, or material units that are formed within a specific time span. They are collective types and are given *characterizing names that are to be looked upon as collective names*.

Categories of material units and units defined on the basis of physical properties (dealt with in Chapter 3):

Lithostratigraphical units – Lithostratigraphical units comprise stratified rocks and superficial deposits that are defined on the basis of special lithological properties and boundary relationships. Lithostratigraphical units are units deposited in compliance with the "Law of Superposition", i.e. younger beds are deposited above older ones (Section 3.2).

Lithodemic units – Lithodemic units were introduced as a new category in the NACSN stratigraphical classification system (NACSN 1983). Lithodemic units are rocks that are defined on the basis of their lithological properties alone. These are generally non-stratified rocks such as plutonic or minor intrusive rocks, or strongly metamorphosed and deformed rocks (Section 3.3).

Magnetostratigraphical units – These are units that are defined on the basis of their remanent-magnetic properties (Section 3.4).

Biostratigraphical units – Biostratigraphical units are distinguished on the basis of fossil content, particularly from the viewpoint of biological evolution in the course of Earth history (Section 3.5).

Pedostratigraphical units – A pedostrati-

A. Geological units defined on the basis of material content or other physical properties

Litho-strat. units	Lithodemic units	Magneto-strat. units	Biostrat. units	Pedostrat. units	Geological form units	Linear structural units	Planar structural units	Morphostrat. units	Tectonstrat. units
Supergroup	Supersuite				Unconformity*		Joint zone	Morpho-supersuite	Nappe system*
Group	Suite	Polarity superzone			High*	Lineament zone	Joint	Morphosuite	Nappe complex*
					Ridge*				
Formation	Lithodeme	Polarity zone	Biozone	Palaeosol	Spur*	Lineament	Fracture zone	Morphodeme	Nappe
Member	Complex	Polarity subzone	with main types		Fault block*		Fracture	Morpho-complex*	Thrust sheet
Bed, Flow					Horst*				Small thrust sheet
					Dome*				
			Range zone		Anticline*		Fault system*		
					Plateau*		Fault complex*		
			Assemblage zone		Platform*		Fault set*		
			Abundance zone		Escarpment*		Fault zone*		
					Depression		Fault		
					Basin*		Thrust fault*		
					Trough*				
					Graben*				
					Syncline*				

B. Geological units defined on the basis of time and age

Chronostrat-igraphical units	Geochronological and geochronometrical units	Polarity-chronostratigraphical units	Polarity-chronological units	Diachronous units	Deformational-diachronous units
Eonothem	Eon	Polarity superchronozone	Polarity superchron		
Erathem	Era				
System	Period	Polarity chronozone	Polarity chron	Episode	Deformational episode
Series	Epoch			Phase	Deformational phase
Stage	Age	Polarity subchronozone	Polarity subchron	Span	Deformational span
Chronozone*	Chron*			Cline	Deformational cline
				Diachron*	Deformational diachron*

Fundamental units in hierarchical classification systems are underlined with unbroken lines

Fundamental units in non-hierarchical classification systems have broken underlining

* Units without rank or ranking equally within the category

Table 1 Categories of major geological units dealt with in the Code.

graphical unit is a body of sediment that represents a former soil or zone of weathering (palaeosol) (Section 3.6).

Geological form units – This category embraces present-day and buried landforms and form elements of structural origin; they need never have been topographical landscape features (Section 3.7).

Linear structural units – This category only embraces linear elements that are classifiable as lineaments, i.e. marked linear features in the landscape of uncertain, unknown or composite origin (Section 3.8).

Planar structural units – This category embodies fractures, joints and faults (Section 3.9). Other kinds of planar elements that have once been topographical surfaces, or that define structural form elements, are dealt with in Section 3.7.

Morphostratigraphical units – Morphostratigraphical units are geomorphological elements that show a geological evolutionary sequence, such as a series of ice-marginal deposits (Section 3.10).

Tectonostratigraphical units – Tectonostratigraphical units are bodies of rock that are distinguished as units because they are located above or between thrusts, i.e. nappes, thrust sheets and the like (Section 3.11).

Seismostratigraphy – Seismostratigraphy is the study of stratigraphy and depositional facies as they can be interpreted from seismic data (Section 3.12). Terms used in seismostratigraphy are briefly mentioned, but no rules are proposed for seismostratigraphical units.

Categories of units defined by time or age (dealt with in Chapter 4):

Chronostratigraphical units – Chronostratigraphical units are bodies of stratified rock that form reference units for all rocks formed during the same period of time; they have synchronous boundaries (Section 4.2).

Geochronological units – Geochronological units are time units embracing divisions of time defined on the basis of boundaries of chronostratigraphical units (Section 4.3).

Geochronometrical units – Geochronometrical units are time units, and are convenient direct divisions of geological time whose boundaries are expressed in years; they lack material referents (Section 4.4).

Polarity-chronostratigraphical units – This category consists of lithological units that have preserved an "imprint" of the original magnetic polarity that existed at the time the unit was deposited or crystallized (Section 4.5).

Polarity-chronological units – These are time units representing divisions of time when specific polarity-chronostratigraphical units were formed (Section 4.6).

Diachronous units – Diachronous units were first defined by NACSN (1983). They are time units that comprise the unequal periods of time when stratigraphical or geomorphological units with non-synchronous boundaries were formed (Section 4.7). Climatostratigraphical units are included in this category (Section 4.7.6).

Deformational-diachronous units – This category comprises diachronous time units delimited by deformational events, both within and outside orogenic belts (Section 4.8).

2 General rules for naming and defining geological units

2.1 Formal and informal units and names: definition

The Code distinguishes between *formal* and *informal geological units.* These have *formal* and *informal names*, respectively. Formally defined units are given protected status, affording priority to the specific proper or characterizing names used for them. Names of informal units do not have such protection, but can be protected following evaluation by NSK. Protection can be lifted if names are not in practical use. Formal and informal names can be distinguished in various ways in writing and orally (see Sections 2.2 and 2.3).

The following demands have to be fulfilled before geological units occurring on Norwegian territory, i.e. the Norwegian mainland, the Norwegian continental shelf, Svalbard, Jan Mayen and Norwegian claims in the Antarctic, can be given or have *formal status* and thereby a formal, protected name: (a) the unit has to be defined, erected and named in accordance with the requirements of this Code (Section 2.4); (b) the erection of the unit has to be reported to, and the proposed names approved by, NSK *prior* to publication; (c) old-established names of geological units can be approved by NSK as formal names when the units are unambiguously understood; if necessary, they can be defined in accordance with the Code at a future date; (d) any changes in the definition, rank, category and name of an established geological unit are to be reported to NSK along with applications for approval of a new name.

Informal names are names given to geological units that have not been erected in accordance with the rules given in this Code for definition of formal units (Section 2.4), and which have not been approved as formal names by NSK. Informal names also include *trivial names* (popular names), i.e. traditionally-used descriptive names of the sort that do not conform with the rules for formal nomenclature. After examining individual cases, NSK may also give protection and priority to geographical names used in long-established trivial names. Both formal and informal names are registered by NSK. Lists of those filed in this register of stratigraphical names are obtainable.

2.2 Names of formal units

2.2.1 The reason for having formal units

Formal geological units are to be defined with the aim in view that the names given to them will be able to function for *a long time retaining a stable, unambiguous geological significance.* The name is to be used (a) on official geological maps, (b) in published scientific works and technical reports, and (c) in other reports and documents connected with business, public administration and administrative bodies of a political nature. The practical need for a unit, and a certain level of knowledge about it, will need to be demonstrated before the unit can be formally defined and erected.

2.2.2 Construction of formal names

Names of formal geological units are compound terms, usually made up of two or three parts. In the case of geological units that are looked upon as *single, physical entities* the first component of the name is the *proper name.* For geological units of a *collective nature* (see Section 1.3), such as a period of time, this is a *distinguishing collective name.* It may be a geographical term or some other sort of name (see Sections 2.2.3 and 2.2.4) representing the type section, type locality or type area/area of distribution (Section 2.4.5). The second component of two-part names may denote (a) the rank of the unit in the classification system (e.g. group, formation, lithodeme, biozone, etc.), (b) the principle lithology of the unit (e.g. sandstone, basalt, conglomerate, etc.), or (c) the rank and/or distinguishing character of the unit (e.g. nappe, fault, basin, plug, syncline, etc.). In three-part names, the middle part can be a descriptive name placed between the proper or characterizing name and the part signifying rank or lithology. Such three-part names should be used as little as possible.

As a guiding principle, the same proper or characterizing name should not be given to more than one geological unit. Exception may be made for units derived directly from other geological units that have been established. This applies to rootless palaeobasins (Sections 3.7 and

3.7.14.7), escarpments (Section 3.7.12.6), thrusts (Sections 3.9 and 3.9.9.6), geochronological units (Section 4.3), geochronometrical units (Section 4.4), polarity-chronological units (Section 4.6), chronozones (Section 4.2.7) and, in part, diachronous units (Section 4.7).

2.2.3 Naming geological units on land

Geological units exposed on land are given a proper or characterizing name. This is a geographical name from the type section, type locality or type area for the unit (see Section 2.4.5). The geographical name should preferably be on an official topographical map and is to be written as it is spelt on the map except when this conflicts with rules for spelling compound names (cf. Sections 2.2.6 and 2.2.10). However, the guiding principle when spelling geographical names should be that the long-standing, local pronunciation should form the basis for the spelling, as is the case in the rules for spelling official geographical names (NOU 1983, no. 6, p. 65; the Crown Prince Regent's Decree of May 31st, 1957). Two geographical names linked by a *dash* may be used in exceptional cases. This may, for example, be required for far-ranging structural units and form elements. If doubt arises concerning the spelling of a name, advice should be sought from the Norwegian Language Council (Norsk språkråd) and the State Adviser on Geographical Names (Statens navnekonsulent).

2.2.4 Naming geological units on the continental shelf

Geological units which occur on the continental shelf may be given proper or characterizing names which are (a) geographical names of places and areas on the shelf within the type area or distribution area for the individual units, (b) names given to petroleum-bearing fields on the shelf, (c) geographically neutral names, and (d) geographical names from part of the *outermost coast* that is *close to* the relevant area on the shelf.

When geographical names are being chosen for geological units on the continental shelf the general principle (Section 2.2.2) that the name is to be derived from the type section (well, core), type locality or type area/distribution area should as far as possible be implemented. Names should preferably be chosen from categories a and b, above. If a field has been given an official name, this is to be looked upon as a geographical name and should be available for the unit that is geologically best defined within the field, assuming that the field is suitable as a type locality or type area for the unit. A unit that is named after a petroleum field should preferably be economically important. A unit that is defined and erected within a field, and named after that field, is to retain this name in other fields in which it can be proved (e.g. Statfjord Formation, named after Statfjord Field, is used throughout the northern North Sea area).

Category (c), other names than geographical names, offers a rich choice of names for applying to lithological and other units: (c1) Norwegian names of fish, birds, other animals and plants belonging to Norwegian waters or neighbouring land areas, (c2) names from Norse mythology, and Norwegian fairy tales and legends, (c3) other literary names from Norwegian writings about the coast and sea, (c4) names from maritime, business and cultural history related to the continental shelf and coastal areas. When names from category (c) are being used it is recommended that names that are associated with each other are used within a single field or neighbouring fields.

Names of places and districts on the coast (category d) can be used for lithostratigraphical and lithodemic units on the continental shelf when the locality is situated within or close to the area in which the unit occurs. This principle should be followed (1) to avoid misunderstandings with regard to the area in which the unit occurs and the location of the type section, type locality or type area, (2) to avoid conflicts with units on land that have already been named, and (3) to avoid geographical names that might predictably be used for formal or informal names of units on land being used for units lacking direct geological association with the place or area denoted by the name (cf. ISSC 1976, p. 42). Names of counties, parts of the country, large islands, large fjords, towns and large villages, and the like, are *not* to be used for stratigraphical units on the continental shelf. Units on land are to be given precedence for such names (see Sections 2.2.2 and 2.4.5).

Geological form units (Section 3.7), linear structural units (Section 3.8), planar structural units (Section 3.9) and morphostratigraphical units (Section 3.10) can be given names from areas on or near the coast which are structurally or morphologically related to the area in question on the continental shelf.

For definition and erection of units on the continental shelf see Sections 2.4 and especially 2.4.12, and ISSC (1976, pp. 17, 42).

2.2.5 Naming biological, chronological and geochronological units

A few units in these categories are given formal names after fossils. Such names are to be written in accordance with the orthographical rules for the Latin names of the taxa. See also the rules for the respective categories.

2.2.6 How to write formal names in Norwegian

Formal names are to be written in Norwegian in accordance with the rules for pronouncing and spelling compound Norwegian words (cf. NOU 1983, no. 6, p. 65; the Crown Prince Regent's decree of May 31st, 1957). Compound names which can be pronounced as one word are also to be written as one word, using an initial capital letter and without hyphenating the individual components of the name. Even long compound names should preferably be written as one word, but may exceptionally be divided into their several parts using an initial capital letter for the proper name, only. Such long compound names may, for example, consist of two geographical names and a final unit or type term. The geographical names are to be linked by a dash, and the last component is to be added using a hyphen, e.g. Peru – Chile-grøfta (the Peru – Chile Trench), Fongen – Hyllingen-gabbrokomplekset (the Fongen – Hyllingen Gabbro Complex), Hardanger – Ryfylke-dekkekomplekset (the Hardanger – Ryfylke Nappe Complex).

It is important to note that the definite articles -en, -a, -et, -ene at the end of geographical names are *usually* omitted in compound names. A genitive s can be inserted between the components of the compound name.

Even though the general rule is that the definite article of a geographical name is omitted when names are compounded, this should not be followed if the compound name thereby becomes unrecognizable as being related to the original geographical name. Such abbreviations may also lead to direct misunderstanding as regards the origin of the part formed by the geographical name. The -en ending of some geographical names is not the definite article, but a derivative of the old ending -vin, as in Løten, Løken, Farmen, Sinsen, Bleiken, Horgen, Hverven, Bergen, etc. In such words the -en ending is to be retained in compound names.

Hypothetical cases: A formation named after Roa should be called Roaformasjonen (the Roa Formation) and *not* Roformasjonen; a granite at Grua should be called Gruagranitten (the Grua Granite) and *not* Grugranitten; a gabbro on Leka is best referred to as Lekagabbroen (the Leka Gabbro) and *not* Lekgabbroen; an ice-front stage at Dalen should be called Dalentrinnet (the Dalen Stage) and *not* Daltrinnet, since Daltrinnet derives its name from Dal; a gneiss named after Fana should be called Fanagneisen (the Fana Gneiss) and *not* Fangneisen, and so on. On the other hand, we have Rendalsformasjonen (the Rendalen Formation) and *not* Rendalenformasjonen, Oslofjordforkastningen (the Oslofjorden Fault) and *not* Oslofjordenforkastningen, and so on. Other examples are given in Section 2.2.10.

If doubt arises concerning how names are to be spelt, advice should be sought from the Norwegian Language Council (Norsk språkråd) and the State Adviser on Geographical Names (Statens navnekonsulent).

2.2.7 How to write formal names in English and other foreign languages

In English, formal names must conform to English orthography and the rules given in ISSC (1976). The proper or characterizing name is to be written in full as it is spelt according to official Norwegian orthographical rules and approved forms of names. In contrast to the Norwegian way of writing the name, the Norwegian definite articles -en, -a, -et and -ene are to be retained if they are part of the official name (when the definite article "the" is used in front of the unit name it signifies that the *entire* unit name is to be understood in a definite form). In two-part or three-part unit names each part is written as a separate word with an initial capital letter. Rendalsformasjonen is therefore written in English as "the Rendalen Formation" and Sjodekket as "the Sjoa Nappe". See other examples in Section 2.2.10. If the formal name is to be written in other languages the way of writing it should be adapted in a corresponding manner to the national orthographical rules in question. The Norwegian letters æ, ø and å are, however, to be retained when the name is written in English or other languages. Exceptions can be made for typographical reasons. For naming of biological, chronological and geochronological units, see Section 2.2.5. Units which have been named after international waters or other large regional areas, can be spelt according to the rules of Norwegian, English or other desired languages, according to what is most appropriate. An example here is the Barents Sea Group (Barentshavsgruppen).

2.2.8 Formal names and political boundaries

Formal units that have already been defined and named in accordance with ISSC (1976) or corresponding national rules on ground belonging to other countries, and which continue into Norwegian territory, can be approved by NSK as the formal name for use in Norway (see ISSC 1976, p. 21).

2.2.9 Changes in the official way of writing proper names

If a change takes place in the official way of spelling a geographical or other name that is being used as a proper or characterizing name for a formal geological unit, the new version is to be used provided the change is insignificant and will not lead to misunderstanding. If the type section, type locality or type area is given an entirely new name on new editions of topographical maps, the name originally assigned to the unit is to be retained.

2.2.10 Examples of ways of writing formal names

Examples of some formal names are given below to show the fundamentally different ways of writing these in English and Norwegian (in brackets):
the Barents Sea Group (Barentshavsgruppen), the Biskopåsen Conglomerate (Biskopåskonglomeratet), the Digermulen Group (Digermulgruppen), the Skinnerbukta Formation (Skinnerbuktformasjonen), the Elvevika Member (Elvevikleddet), the Ringsaker Quartzite Member (Ringsakerkvartsittleddet), the Nordland Ridge (Nordlandsryggen), the Bjørnøya Basin (Bjørnøybassenget), the Hornsund Fault Zone (Hornsundsforkastningssonen).

2.3 Names of informal units

2.3.1 The reason for having informal units, their use and status

Informal units can be introduced for temporary use (a) when carrying out geological mapping, (b) during ongoing scientific, engineering or economic investigations, (c) when preliminary research results are being published, (d) when writing internal reports, theses, etc., that are not going to be published, and (e) for more lasting use when for various reasons it is not practical to erect formal units.

Informal units need not be erected in the manner required for formal units in this Code (Section 2.4) or in ISSC (1976).

Irrespective of how they are defined or documented, all names given to geological units that are described and named in internal reports, unpublished undergraduate or doctorate theses, compendiums, textbooks, circulars, guide books (except those published in large editions), etc., are to be looked upon as being informal (see Section 2.4.14).

2.3.2 Types of informal names and designations

There are many ways of informally designating geological units, both orally and in writing. This may be done using (a) a lithological or other descriptive designation alone, e.g. the mica schist, the grey shale, the anticline, laminated limestone, etc., (b) rank or unit designations from the formal terminology, or combined with a lithological or other descriptive designation, e.g. the formation, the quartzite member, the nappe series, the moraine ridge, etc., (c) an informal unit designation alone or combined with a lithological or other descriptive designation, e.g. the unit, the division, the limestone unit, the basaltic portion, the sandstone sequence, the greenstone belt, etc., (d) a number and/or letter code combined with formal or informal rank or unit designations, or together with a lithological or some other kind of descriptive designation, e.g. formation A, B-division, moraine c, 3c-stage, 1st conglomerate member, nappe pile 3, etc., position designations such as lower, middle and upper, in conjunction with designations for rank, unit, lithology and so on, e.g. lower sandstone unit, middle tectonostratigraphical unit, upper biozone (if these adjectival designations are used in conjunction with a formal unit name the sub-units are nonetheless informal, e.g. the upper Landersfjorden Formation (øvre Landersfjord-formasjonen)), (f) designations from engineering and economic geology, e.g. the ore layer, the oil shale, the quickclay horizon, the lead formation, etc., (g) geographical names (or alternative names on the continental shelf) along with an *informal* designation for unit, lithology or some other characterizing property, e.g. the Ågotnes sand, the Årungen beds, the Tuddal lava, etc. Such names will structurally resemble formal formation names written by combining a geographical name and the principle lithology (see Section 2.2.2). Because of this, informal names of this nature should be used as little as possible, and their informal status *must* be emphasized.

Names of informal units are not to be constructed by combining a geographical name with a designation for a fundamental, more highly ranking unit in hierarchical classification systems. This limitation applies to all geological units defined on the basis of time or age (see Table 1 and Section 1.2). Such combinations are to be reserved for formally defined units (see Sections 2.2.2, 2.2.3 and 2.2.4, and ISSC 1976, p. 35). Examples: the Valdres sparagmite (Valdressparagmitten) is an informal designation, but the Valdres Group (Valdresgruppen) is a formal one. The Biri limestone (Birikalken) is an informal designation, but the Biri Formation (Biriformasjonen) is a formal one. The terms the Lathus flow (Lathusstrømmen) or the Lathus member (Lathusleddet) can be used for an informal unit, but not so the Lathus Formation (Lathusformasjonen).

2.3.3 Ways of writing informal names

Informal names are written in Norwegian according to usual orthographical rules. If the name is understood and used as an ordinary type designation it is a collective name and is to be written with a lower-case initial. If the informal designation is understood and used as the name for a specific entity (unit), it is a proper name and is to be written with an upper-case initial (see Section 1.3). For example, the informal name Grefsensyenitt (the Grefsen syenite) which, when written in this way, is the proper name for a specific body (lithodeme) of syenite at Grefsen. The petrographic variety of this syenite is also found in other places and may then be called grefsensyenitt as a collective name (in English the collective name should include the word type' – Grefsen syenite-type), i.e. with a lower-case initial letter in Norwegian, but not in English.

Informal names are written in English according to English orthographical rules. Names which are understood as proper names are written with upper-case initials for the first part of the name and lower-case for succeeding parts. Informal designations which are understood as collective names are written with lower-case initials.

2.4 Rules for erecting formal geological units

The erection of any formal geological unit must always be based on certain fundamental information about the unit. This is crucial if unambiguous definitions are to be achieved. NSK advises authors to follow the recommendations listed in Sections 2.4.1 to 2.4.14, when erecting a formal unit.

2.4.1 Objective

The reasons and practical need for erecting a new formal geological unit, changing the rank and definition of an existing unit (Section 2.5.1), or completely rejecting an already defined and named formal unit (Section 2.5.2) should be clearly stated.

2.4.2 Historical background and previous investigations

When a new formal unit is being erected, previous investigations and any informal designations of the unit are to be referred to. If the introduction of a new name is desired, reasons are to be given for why the old name of the unit should be changed.

2.4.3 Category and rank

The category and rank of geological units are to conform with the main definitions given in this Code. It is very important that the unit is investigated sufficiently thoroughly to enable it to be erected in the correct category, class and type, and with an appropriate rank. The areal extent of the unit is particularly important in this respect. This also applies to units on the continental shelf.

2.4.4 Name

The choice of name must conform with the rules given above (Sections 2.1 and 2.2) and, if necessary, with the special rules relating to the category and unit in question, and those applicable for units on the continental shelf (Section 2.2.4). Responsibility for ensuring that a proposed proper or characterizing name has not been used previously, rests with the proposer. Previous usage will be checked prior to any approval of the name by NSK.

2.4.5 Type section, type locality, type area, reference section

The definition of a formal geological unit should be based on its occurrence in one or more type sections, a type locality or a type area (its stratotype). The occurrence of the unit here has to be as far as possible representative for that found throughout its area of distribution.

The *type section* or *stratotype* (typesnitt) comprises the *unit stratotype* (typesnitt for enheten) and *boundary stratotype* (typesnitt for grensen). The stratotype contains the entire unit, including its lower and upper boundaries. Stratigraphical units of limited vertical extent can be readily defined on the basis of such stratotypes. In the case of thicker stratigraphical units, e.g. a group or supergroup, it will often be difficult to locate a representative section covering the whole unit. The unit can then be defined using a *composite stratotype* (sammensatt typesnitt) which consists of a boundary stratotype and one or more reference sections (which may also include a unit stratotype). A type section may be a mountain slope, stream section, roadcut or some similar section which it may be assumed will remain generally accessible far into the future. Drill cores, drill logs and excavated sections can form stratotypes for subsurface units (see Section 2.4.12).

The *type locality* (typelokalitet) is the geographical area containing the boundary stratotype and one or more sections through all or part of the unit. Many well-established units have been given names from type localities or type areas without a stratotype having been defined and described. A reference section (see below) can be erected for such units.

The *type area* (typeområde) is the more wide-ranging geographical area within which a geological unit has been defined and which may contain the type section and/or type locality. A type area will often be more suitable for defining lithodemic, geomorphological, structural and morphostratigraphical units than one or more type sections. The type area for subsurface units can be defined by a set of drill cores, drill logs and seismic profiles (Section 2.4.12).

A *reference section* or *hypostratotype* (referansesnitt) may constitute the unit stratotype for lower-ranking stratigraphical units which, together with a boundary stratotype, defines a higher-ranking stratigraphical unit in a composite stratotype. Reference sections may also be sections that are suitable for (a) demonstrating variation and heterogeneity in a unit, beyond that shown by the type section, (b) replacing a type section that has been destroyed, and (c) describing old-established and named, formal units which lack a type section. A reference section need not be located within the type area of the unit.

ISSC (1976, p. 26) gives specific designations for various kinds of type section.

2.4.6 Description

A formal unit should be defined and described sufficiently clearly to enable any subsequent investigator to find it geographically and identify it geologically. Features which characterize a unit may be composition, texture, structures, fossils and organic remains, distinctive minerals, geochemistry, geophysical properties, structural occurrence and properties, three-dimensional form and geomorphological expression. Geological time units should be defined and described on the basis of physical referents (specific rock sequences or bodies), or defined geochronologically with reference to standardized methods for numerical age determination.

2.4.7 Boundaries

The boundaries of a geological unit are to be defined and described. The various criteria used for delimiting a unit must match the category into which the unit falls and the degree of exposure in the area. For litho-, bio- and chronostratigraphical units it is particularly important to define the lower boundary, since the upper boundary will often be defined by the lower boundary of the succeeding unit.

2.4.8 Dimensions and extent

The best possible information is to be given on stratigraphical thickness, tectonostratigraphical thickness, vertical, horizontal and lateral extent, and the spatial relationships with adjoining geological units. This also applies to non-exposed, subsurface units, such as units on the continental shelf. (N.B. It is *not* necessary for the complete extent of the unit to be known before it can be formally defined.)

2.4.9 Age

Knowledge about their age plays no direct role in definition and erection of formal geological units, other than time units. The age of a geological unit will nonetheless be of considerable interest and should be mentioned.

In the case of a metamorphic lithodeme, the metamorphic age should be kept distinct from the age of formation of the primary rock (protolith). The basis for age assignments is to be given. The relative age of movement and deformation forms the basis for distinguishing between complexes and systems in the structural and tectonostratigraphical categories (see Section 1.2).

2.4.10 Mode of formation

The mode of formation has no decisive significance for the definition of most categories of geological units, even though it forms part of the definition of various lithodemic, tectonostratigraphical, structural and morphostratigraphical units. It is, however, very important for understanding the evolution of a unit in time and space, and should therefore, if possible, be offered attention when the unit is being erected.

2.4.11 Correlation

For the sake of clarity newly-erected geological units should be correlated with corresponding units outside the type area. The basis for the correlation is to be given.

2.4.12 Special procedures for units on the continental shelf

A lithostratigraphical unit on the continental shelf, which it is desired to erect as a formal unit, should preferably be defined on the basis of one or more cores that constitute a type section (stratotype) for the unit, a boundary stratotype or perhaps a composite stratotype (see Section 2.4.5 for definition of stratotype). Core material provides the most direct expression of the lithology of a unit that is not exposed on land. It should therefore be given priority as the basis for defining the unit. Such cores should be specially protected under storage, and preferably be easily accessible.

A unit that has been proved by well logs and seismic profiling will often not be documented by drill cores. Such a unit can be defined on the basis of one or more well logs, but when it is subsequently core drilled, *representative* drill cores should be given the status of stratotypes or reference sections for the unit.

It is essential that structural form elements and planar structural units (faults, fracture zones, etc.) on the continental shelf are *formally* defined and named on the basis of seismic profiles, perhaps in combination with well data and drill cores (see Sections 2.4.6, 2.4.7 and 2.4.8).

It should be noted that the other requirements stated in Section 2.4 also apply when formal geological units are being erected on the continental shelf. Before a lithostratigraphical unit is formally defined and named, considerable emphasis should be placed on obtaining a reasonable regional knowledge of its extent and stratigraphical development (see Sections 2.4.3 and 2.4.8). If a unit is only known from one well, or from several closely spaced wells and a few seismic profiles, it should be given a provisional informal designation until adequate regional data are available as a basis for formal naming (see Figs. 2-4).

To ensure that formal stratigraphical division of the succession on the continental shelf is as permanent and useful as possible, it is important that geologists working on a relevant portion of the shelf are in broad agreement about ways of dividing the stratigraphy and the basis for defining new units.

2.4.13 Approval by the Norwegian Committee on Stratigraphy (NSK)

When formal geological units are being erected, the basis for their establishment is to be reported to NSK (see Sections 2.4.1 to 2.4.12) to provide the grounds for possible approval of the proposed name. The purpose of this requirement is to ensure that the unit is (a) adequately defined according to the rules laid down by ISSC (1976) and this Code, (b) given an unambiguous name which is constructed and written according to the rulings of this Code, (c) recorded in the register of names at the Norwegian Committee on Stratigraphy, and thereby secured priority, protection and status as a formal name.

Authors can apply to NSK for approval of formal unit names at the time of their publication, either by filling in an application form (Appendix 2), or by sending the manuscript direct to the committee or through the editor of the journal, book or map in which the establishment of the unit will be published. Application for approval of formal names should constitute part of the natural process of work on a manuscript. To avoid publication delays authors should apply for approval at an early stage in manuscript preparation. It is emphasized that NSK is not empowered to check the scientific basis for erecting a unit, but merely ensures that the rules for erection are followed.

2.4.14 Publishing

For a unit to become valid as a formal unit it must be defined in a publicly available scientific journal, map description, published well description, or a guidebook printed in a large edition. All such publications must be obtainable through ordinary library services. Geological units that are introduced on official geological maps before being published in map descriptions or in some other way, can be approved by NSK provided it can be shown that they are defined in accordance with the requirements of this Code. Formal units erected in this way must, however, be defined in line with the Code in a later publication, or alternatively the documentation forming the basis of the definition must be available from the institution responsible for publishing the map.

2.5 Amendment and rejection of formal units

2.5.1 Amendment of formal units

Formally erected geological units can be redefined or revised.

Redefinition involves giving a new description of the content of a unit without changing its boundaries, rank or category. A formation, for example, may originally have been characterized as shale, whereas more recent investigation has shown that the unit chiefly consists of limestone. In the formal compound formation name, ”shale” can be replaced by ”limestone” without the proper name (geographical term) needing to be changed.

Revision involves (a) minor changes in the definition of one or more boundaries of the unit, (b) change in rank, (c) change in category, or (d) changes in two or more of a-c.

Minor changes in definition of boundaries may be desirable following new investigations. If such revision only alters a small portion of the original unit, its name can be retained. See Chapter 4 for time units.

A unit can be changed in rank without needing to have its boundaries redefined or the geographical part of its name changed. A unit can be revised in this way both within and outside its type area, or only outside it.

A unit can be changed in category, in which case its proper (geographical) name usually has to be changed. If a unit is redefined to a closely related category, for example from a metamorphic lithodemic unit to a metamorphic lithostratigraphical unit, the original proper name can be retained.

If a unit is divided into two or more units having the same rank as the original one, the original proper name must not be used for any of the new ones. The proper name of the original unit may be retained if the rank of that unit is raised following the new division.

2.5.2 Rejection of formal units

A formal unit may be rejected, or its use abandoned, if it proves to (a) be equivalent to a previously formally defined unit, (b) be defined in the wrong category, (c) not have any application, and (d) be used in many different ways. The proper name of a formal or an informal unit that has been rejected may be used for a subsequently newly erected unit if a long period has passed after the name was used in its original meaning.

2.5.3 Approval

Amendments and rejections of formal unit names are to be approved by NSK prior to publication.

3 Geological units defined on the basis of material content or other physical properties

3.1 General properties and arrangement of the rules for the units

All categories of geological units in this chapter are defined on the basis of various material properties (lithology, fossils, magnetism) and/or other physical properties (boundary and contact relationship, form, structure). The categories dealt with are lithostratigraphical units (Section 3.2), lithodemic units (Section 3.3), magnetostratigraphical units (Section 3.4), biostratigraphical units (Section 3.5), pedostratigraphical units (Section 3.6), geological form units (Section 3.7), linear structural units (Section 3.8), planar structural units (Section 3.9), morphostratigraphical units (Section 3.10) and tectonostratigraphical units (Section 3.11), (see Table 1 and Figure 1). Seismostratigraphy is briefly described (Section 3.12). Each unit is dealt with under 9 main headings:

1. Basic definition
2. Rank, and the position of the unit in a hierarchical system of division, if any
3. Dimension and extent
4. Mappability and methods of identification
5. Content and other properties
6. Nomenclature
7. Variants of the unit, relationship to other units, supplementary comments
8. Examples
9. Key references

3.2 Lithostratigraphical units

3.2.1 General properties and rules

Lithostratigraphy is concerned with the description and organization of sediments and sedimentary and volcanic rocks on the basis of their lithological properties and superposition relationships.

A lithostratigraphical unit is a body of sedimentary, volcanic, metamorphosed sedimentary or metamorphosed volcanic beds delineated on the basis of characteristic lithological properties and stratigraphical position. Lithostratigraphical units conform to the "Law of Superposition", i.e. younger beds are deposited on older ones.

Lithostratigraphical units are defined independently of inferred geological history, mode of genesis or biological development. Their boundaries are in principle independent of time horizons, and most are time-transgressive. The lower boundary of a unit formed by a sudden, brief catastrophic event may, nonetheless, be nearly synchronous throughout the area in which the unit is found, e.g. a volcanic ash deposit or a bed deposited by a major flood or storm.

Boundaries between lithostratigraphical units may be lithologically sharp and mark an unconformity surface (Section 3.7.2), but gradual transitions may also occur. These are particularly common where lateral facies changes take place. Lithostratigraphical units may wedge into each other in this manner.

Lithostratigraphical units often have a three-dimensional shape such as a sheet, slice, lens, wedge, ridge, finger or tongue. Various lithostratigraphical boundary relationships are shown in figures 2, 3 and 4. In addition to having lithostratigraphical boundaries, lithostratigraphical units may be delimited by secondary boundary surfaces of intrusive, tectonic or metamorphic origin (Fig. 1).

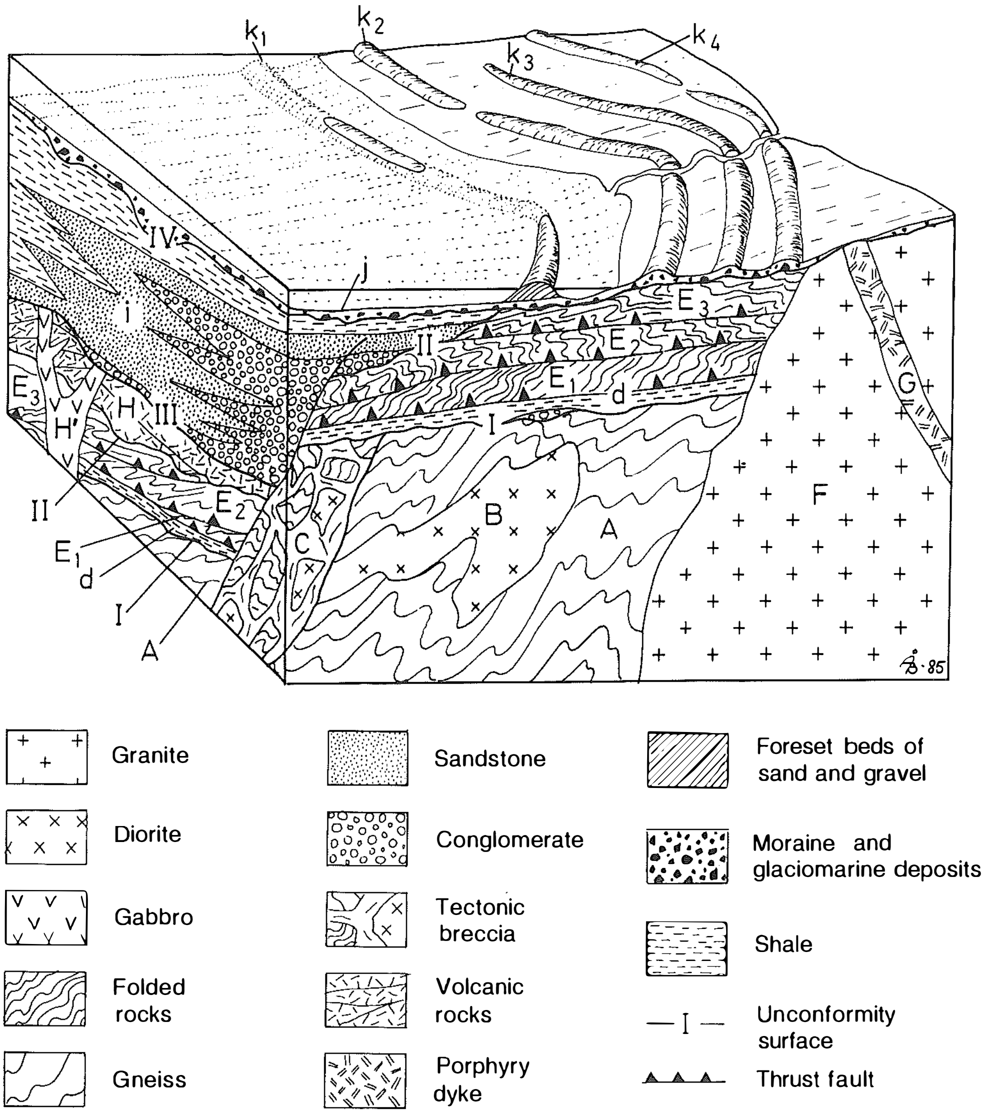
Lithostratigraphical units serve as units when geological mapping is being carried out. They are used in the field and when writing descriptions, elucidating the geological history and assessing economically exploitable deposits (oil, ores, minerals, gravel, groundwater, etc.).

Lithostratigraphical units are, in decreasing order of rank, *supergroup, group, formation, member and bed/flow*. The formation is the fundamental unit.

3.2.2 Formation (Formasjon)

3.2.2.1 A *formation* is a body of rock or superficial deposits occurring as part of a succession. It is characterized by its stratigraphical position in the succession and by a set of characteristic lithological properties that distinguishes it from adjacent units of rock or superficial deposits. Formations often have a three-dimensional shape such as a sheet, slice, lens, wedge or tongue (Figs. 2, 3 and 4).

3.2.2.2 Formation is the fundamental formal unit for lithostratigraphical classification and nomenclature. Formations have a practical use when geological maps are being made and when



Lithodemic units: A, B, C, F, G, H, H'

Tectonostratigraphical units: E_1, E_2, E_3

Lithostratigraphical units: d, i, j

Morphostratigraphical units: k_1, k_2, k_3, k_4

Order of age: A-B-C-I-d-E_1-E_2-E_3-F-G-II-H-H'-III-i-IV-j-k_1, k_2, k_3, k_4

Fig. 1 Various categories and types of geological units which can be defined on the basis of material content or surface properties. Unconformity surfaces I, II, III and IV are geological form elements, whilst thrust faults and normal faults delimiting structural complex C and lithostratigraphical units *i* are planar structural units. Faulting took place along the basin margin whilst sequence *i* was being deposited. Morphostratigraphical units k_1-k_4 are ice-marginal deposits formed when a glacier snout retreated.

the geological, geophysical and geotechnical properties of an area and its geological history are being described. A formation can be subdivided into *members*, and two or more formations can be defined as a *group*.

3.2.2.3 No limitations are placed on the dimensions of a formation, except that it must be mappable or be traceable in the subsurface (Section 3.2.2.4). Its thickness can vary from less than one metre to several kilometres.

3.2.2.4 A formation must be mappable at the surface or traceable in the subsurface. A formation exposed at the surface has to be mappable on ordinarily available base maps (official topographical maps, land-use maps, or privately produced, but openly available maps). A formation must also be capable of being portrayed on specially constructed maps, or sections on the same scale, intended to show its extent and three-dimensional form in the subsurface. A particularly thin formation can be portrayed as a single, thin line on maps and sections. A formation is mapped on the surface and recorded in the subsurface by ordinary field geological methods, excavation of sections, drilling and geophysical measurements.

3.2.2.5 A formation may consist of (a) a single type of rock or superficial deposit, (b) repetitions of two or more types of rock or superficial deposit, or (c) an inhomogeneous lithology which in itself constitutes a unit relative to adjacent units of rock or superficial deposit. A formation is recognized by at least one lithological property, such as mineral composition, chemical composition, fossil content, structures, grain size and other textural features. The boundaries of a formation may be lithologically sharp, or they may need defining by a change in at least one lithological property if there is a gradual transition between two adjacent lithostratigraphical units (Fig. 2). A formation may be characterized by electrical, thermic, magnetic, radiometric, hydraulic, seismic and other physical characteristics which derive from lithological properties. It may contain two or more unconformity surfaces (Section 3.7.2), which may, for example, be reflected by a lack of continuity in fossil content. The fossil content of a formation may define one or more biozones (Section 3.5.2).

3.2.2.6 A formation is given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2). The proper name (Section 2.2.2) is placed between the words "the ... Formation" in formal names, e.g. the Kistefjellet Formation, the Frigg Formation, the Båtsfjord Formation (in Norwegian, Kistefjellformasjonen, etc.). Instead of "Formation", the second part of the name can be a brief descriptive designation of the dominant lithology in the formation, for example, "Sandstone", "Clay", "Basalt", "Tuff", "Phyllite", as in, for example, the Moelv Tillite, the Stokkvola Conglomerate (in Norwegian, Moelvtillitten, etc.). These two forms of nomenclature can be used for one and the same formation as formal designations of equal standing. The combination using "Formation" is recommended when it is desirable to emphasize the formal status of the unit.

3.2.2.7 A formation can change character regionally to such a degree that in an area beyond its type area it may be most practical to designate the unit as a member or group (Fig. 4). The proper name of the originally defined formation can be retained there even though its stratigraphical rank is changed. It can even be retained if the lithic component of the name is changed as a result of the rock changing from a non-metamorphosed to a metamorphosed state, e.g. from shale to phyllite (see Section 2.5).

3.2.2.8 *Examples*: Many formation names are in use in Norwegian geological literature. Many of these are traditionally-used names for units that are more or less well defined on the basis of a type area. Examples of modern, formally defined formations are found in Siedlecka & Siedlecki (1971), Mørk et al. (1982), Nystuen (1982), Pharaoh et al. (1983) and Worsley et al. (1983).

3.2.2.9 *Key references*: ISSC (1976), NACSN (1983).

3.2.3 Group (Gruppe)

3.2.3.1 A *group* is a stratified body of rock or superficial deposits comprising two or more formations, or a corresponding number of informal lithostratigraphical units.

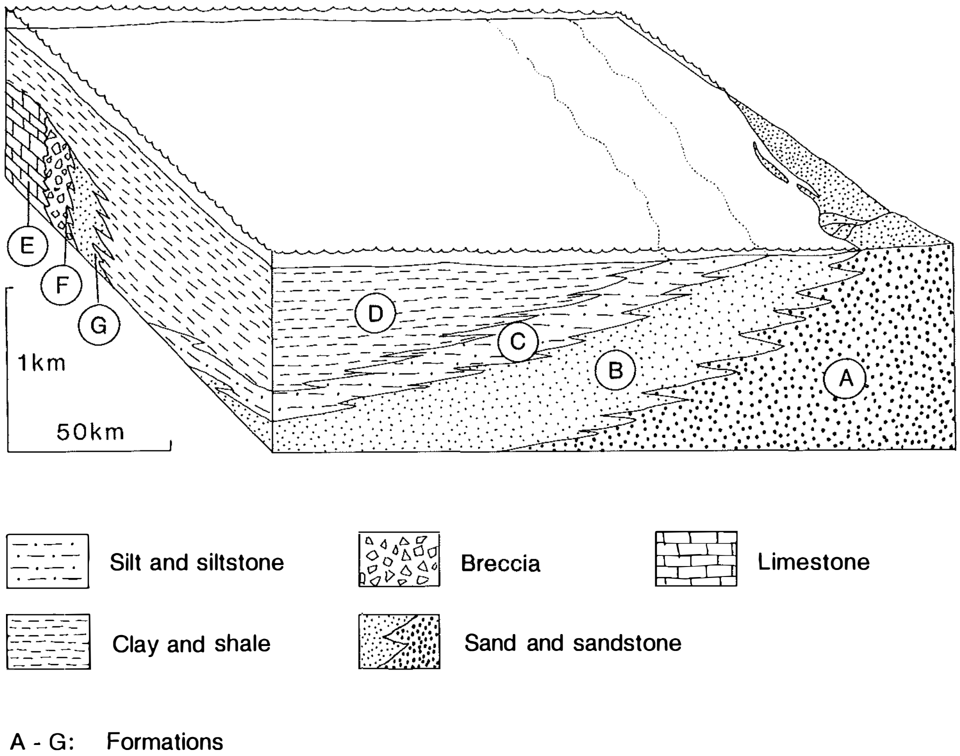


Fig. 2 Lithostratigraphical units. The figure shows lateral facies variations between major lithological units which are definable as formations. Formations A and B wedge into each other basinwards. Formation C is defined as a characteristic transitional facies between formations B and D. Limestone formation E is part of a carbonate platform which is laterally bounded by slump deposits in formations F and G. Note changes in facies and lithostratigraphy from the basin margin into the basin.

3.2.3.2 Group is the formal lithostratigraphical unit next in rank above formation. Two or more groups can be defined as a *supergroup*.

3.2.3.3 The thickness and extent of a group is determined by the total thickness and regional extent of the formations or informal lithostratigraphical units constituting it. A group need not consist of the same formations throughout its area of distribution (Fig. 4).

3.2.3.4 A group is mappable at the surface and traceable in the subsurface with the help of geological and geophysical methods. It is usually a practical lithostratigraphical unit for portrayal on small-scale regional maps.

3.2.3.5 A group may consist of (a) formally defined and named formations, (b) formally defined, named formations along with at least one undefined and informal lithostratigraphical unit, and (c) informal lithostratigraphical units alone, with or without a name or designation, which it may be assumed can be ranked as formations at a later date. The formal or informal lithostratigraphical units in a group are closely related as regards geological evolution and mode of genesis. There may also be a certain similarity in lithology, but this is not essential. The group can be defined as an entity from one or more type section(s) (see Section 2.4.5), without any formations having previously been defined. When the group is erected as an assemblage of already defined formations, its lower and upper boundaries are determined by the lower and upper boundaries of its lowermost and uppermost formations, respectively.

3.2.3.6 Groups are only named formally, this being done in accordance with the "general rules for naming and defining geological units" (Chap. 2). The proper name (Section 2.2.2) is placed

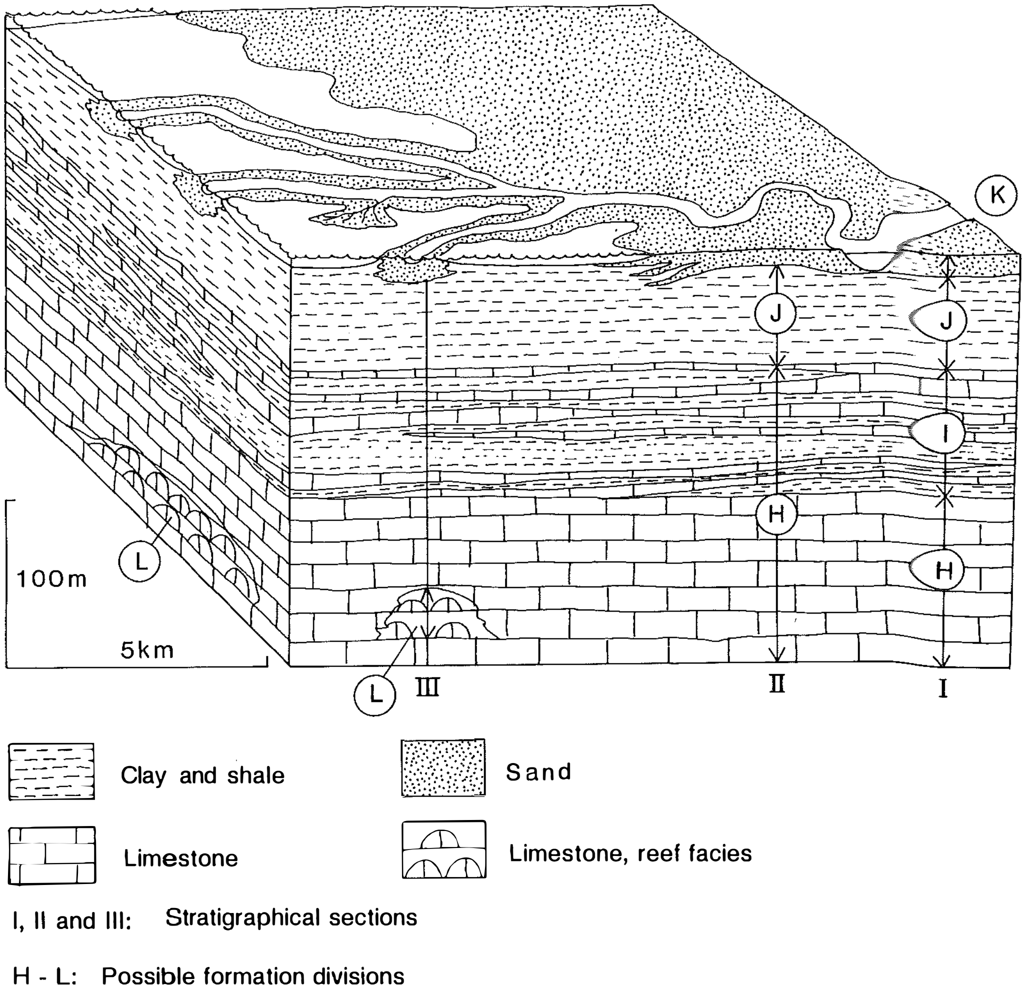


Fig. 3 Lithostratigraphical units, their form, boundary relationships and possible classification. The figure shows a hypothetical succession on a continental shelf, consisting mainly of sheet- and lens-shaped units. Sections I and II (wells) show alternative divisions of the succession into formations. Unit L, a ridge-shaped reef facies, is found in well III. It can be defined as a separate formation, or as a member in formation H. K is a sand formation formed by progradation of a delta and the coastline. It is partly a sheet deposit, partly wedge-shaped and partly finger-shaped.

between the words "the ... Group", as in the Sassendalen Group, the Løkvikfjellet Group, the Bandak Group (in Norwegian, Sassendalgruppen, etc.). A lithic designation describing the main lithology can be placed between the proper name and the word "Group", but this is not customary. A group that is defined in an area where the formational stratigraphy is established retains its name in areas where formations have still not been formally erected.

3.2.3.7 A group may change character regionally, making it more practical to designate it as a formation in an area away from its type area. The proper name of the originally defined group can be retained even though the stratigraphical rank in such areas is changed to formation. In certain cases it may be desirable to divide the group into *subgroups* (undergrupper). These can be formal having their own names, or informal having designations such as "lower", "middle" and "upper" (Section 2.3.2).

3.2.3.8 *Examples*: Examples of modern, formally defined groups are to be found, for example, in Siedlecka & Siedlecki (1971), Mørk ided the Late Precambrian Ifjord Formation in Finnmark into three formal members, the Gozavarre, Loavdajavarre and Elvevika Members.

3.2.5.9 *Key references*: ISSC (1976), NACSN (1983).

3.2.6 *Bed (Lag), Flow (Strøm)*

3.2.6.1 A *bed* is the smallest formal lithostratigraphical unit in sedimentary sequences. A *flow* is the correspondingly smallest unit in volcanic rocks and deposits formed by flowing lava or ash.

3.2.6.2 Beds and flows have lithostratigraphical rank next beneath members, but may also be formally erected in formations lacking formally erected members.

3.2.6.3 Beds and flows usually have limited lateral persistence within the distribution area of the higher lithostratigraphical unit of which they form a part.

3.2.6.4 Beds and flows are usually not mappable other than on special, particularly large-scale maps. They can be portrayed on sections of suitable scale. They may be traceable in the subsurface using geological and geophysical methods.

3.2.6.5 A bed usually represents a *single* depositional event in a sedimentary sequence and is characterized by composition, structure and texture. A flow is a volcanic extrusive rock formed during a *single* eruption. It is characterized by composition, structure, texture, palaeomagnetism and other properties, e.g. such as the various rhomb porphyry flows of Permian age in the Oslo Region. Beds and flows may contain laminae (singular: lamina); these are not named.

3.2.6.6 Beds and flows are given formal or informal names in accordance with the "general rules for naming and defining geological units" (Chap. 2). The proper name is placed between the words "the ... Bed" or "the ... Flow" in formal names. A lithic designation may be added between the proper name and the term "Bed" or "Flow". Formal names for beds and flows should only be erected when this will have particular stratigraphical or practical value. It may often be practical to apply informal designations to beds and flows (Section 2.3).

3.2.6.7 A *key bed* (nøkkellag) or *marker bed* (ledelag) is a particularly prominent and easily recognizable bed or member of large lateral extent (Fig. 4). Such units are of practical importance when structural patterns are being correlated and resolved. Key beds may be given formal or informal names.

3.2.6.8 *Examples*: Formally defined beds from Svalbard are the Skilis Bed, the Brevassfjellet Bed, the Blanknut Bed, the Verdande Bed (Mørk et al. 1982) (in Norwegian, e.g. Skilislaget) and the Marhøgda Bed (Bäckström & Nagy 1985). The Brentskardhaugen Bed is an important marker bed in the Jurassic succession on Svalbard. The name was first used by Parker (1967) who did not define the unit formally. Since a description which satisfies requirements for formal definition has subsequently been given by Bäckström and Nagy (1985), the Brentskardhaugen Bed is *now* a formal name. The Vedde Ash Bed (Veddeaskelaget) is a formally defined marker bed from the Quaternary succession in West Norway (Mangerud et al. 1984). The subdivision of the Permian lava sequence in the Oslo Region using the alphanumerical system B1, RP1, RP2, etc., is an example of informal classification of flows (Oftedahl 1960).

3.2.6.9 *Key references*: ISSC (1976), NACSN (1983).

3.3 Lithodemic units

3.3.1 *General properties and rules*

A lithodemic unit consists of one or more bodies of igneous rocks which may be plutonic, intrusive or extrusive rocks and/or strongly metamorphosed and deformed rocks (Figs. 1, 5). The unit is defined entirely on the basis of lithological character. In contrast to lithostratigraphical units, the classification of lithodemic rocks does not follow the principle of younger rocks being formed above older ones. Lithodemic units are therefore erected in areas where rocks do not succeed one another in compliance with the "Law of Superposition", or where it is very difficult to prove such a relationship.

Lithodemic units serve as units when geological mapping is being carried out in areas where the bedrock lacks unequivocal stratification. They are used during field work, when writing descriptions, elucidating the geological history and assessing economically exploitable deposits. Contacts with other geological units may be sedimentary, intrusive, metamorphic or tectonic in origin.

Lithodemic units are, in decreasing order of rank, *supersuite, suite* and *lithodeme*. The lithodeme is the fundamental unit. *Complex* is not ranked, but will usually correspond in size to suite or supersuite.

It has not been customary in Norway to use formal lithodemic names on geological maps and in map descriptions. Petrographical designations have usually been used for lithodemic units. However, in regional and petrographical descriptions, informal geographical names have often been applied to plutonic rocks, intrusive breccias and similar bodies. A few such designations, such as the Drammen granite and the Grefsen syenite, have been used partly as lithodemic proper names, partly as petrographical collective names. *Double* usage of this sort should be avoided. If one wishes to use a lithodemic proper name as an ordinary petrographical designation it should be written with lower-case initials as a collective name in Norwegian, but place names retain the upper-case initial in English. The type meaning can be emphasized by adding the word "type", e.g. "Drammen granite-type", "Grefsen syenite-type".

Formal lithodemic units should only be defined and erected if they serve a practical purpose. Names of informal lithodemic units are *not* to be constructed using a geographical name (or an alternative name in the case of the continental shelf) and a formal hierarchical unit designation (cf. Section 2.3.2).

3.3.2 Lithodeme (Litodem)

3.3.2.1 A *lithodeme* is a body of intrusive, volcanic or highly metamorphosed and/or thoroughly deformed rock that lacks primary structures. It is characterized by having a set of lithological properties that distinguishes it from adjacent geological units.

3.3.2.2 Lithodeme is the fundamental formal unit in lithodemic classification and nomenclature. Two or more lithodemes of the same class can be defined as a suite.

3.3.2.3 No limitations are placed on the dimensions of a lithodeme except that it must be mappable at the surface or traceable in the subsurface.

3.3.2.4 A lithodeme should be mappable at the surface or traceable in the subsurface using geological and geophysical methods. It should be mappable on ordinarily available base maps (official topographical maps, land-use maps, and privately-produced, but openly available maps).

3.3.2.5 A lithodeme consists of a rock that can be identified by its lithological properties using field geological methods. It may consist of (a) a single rock type, (b) two or more rock types showing a characteristic repetition or pattern, or (c) a heterogeneous lithology which in itself constitutes a unit that is distinct from adjoining rock units. A lithodeme may be an intrusive rock occurring, for example, as a pluton, diapir, stock, laccolith, sheet or plug, a body of volcanic rocks which have mutually complex boundary relationships, or a body of strongly metamorphosed rock. The boundaries of a lithodeme may be lithologically sharp, or may need to be defined by a change in at least one lithological property if there is a gradual transition to one or more adjoining geological unit(s). A lithodeme may be characterized by electrical, thermic, magnetic, radiometric, hydraulic, seismic and other physical characteristics derived from its lithological properties (see Figs. 1, 5).

3.3.2.6 A lithodeme is given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and according to the provisions in Section 3.3.1. The most common formal type of name is a geographical name (or an alternative name on the continental shelf) combined with a relevant lithological designation ("the ... Granite", "the ... Syenite", "the ... Breccia", "the ... Gneiss", etc.), or with a structural/genetical designation ("the ... Plug", "the ... Sheet", etc.). Such types of name may also be informal, e.g. "the Leka ophiolite", "the Gardnos breccia", "the Lofoten intrusives", "the Nesodden dyke", etc.

3.3.2.7.a Lithodeme corresponds in rank to formation in the lithostratigraphical classification system, also when used informally on maps or in descriptions.

3.3.2.7.b A lithodeme may change its character regionally. It may therefore be more practical to designate the unit as a suite beyond its type area; the original proper name may then be retained (see Section 2.5.1).

3.3.2.7.c A lithodeme that has been defined in a metamorphic succession can be redefined as a formation if it can be proved that the unit has a definite stratigraphical position within a succession of originally sedimentary and/or volcanic rocks. When this kind of redefinition takes place the original proper name is retained (see Section 2.5.1).

3.3.2.8 *Examples*: Many named bodies of intrusive rock have lithodemic-type names, even though the bodies have not been formally defined as lithodemes. Several examples of this are to be found among names of plutonic rocks from the Oslo Region in Sæther (1962) and Gaut (1981).

3.3.2.9 *Key reference*: NACSN (1983).

3.3.3 Suite (Suite)

3.3.3.1 A *suite* is a lithodemic unit consisting of two or more lithodemes, or informal lithodemic units. Individual lithodemes in a suite must belong in the same class, i.e. be either igneous or metamorphic rocks.

3.3.3.2 Suite is a formal lithodemic unit ranking next above lithodeme. Two or more suites of the same or a different class can be defined as a *supersuite*.

3.3.3.3 A suite usually has a regional extent, or consists of a few distinct units which together have a regional extent.

3.3.3.4 A suite is mappable at the surface and traceable in the subsurface using geological and geophysical methods.

3.3.3.5 A suite consists of formal lithodemes and/or informal, unnamed lithodemic units that belong to the *same class of rocks*. These may be either igneous or metamorphic (including metasomatic and highly deformed rocks). A suite may therefore be, for example, a plutonic, intrusive, dyke or metamorphic suite. The individual formal or informal units in a suite have one or more characteristic features in common that often unite them in a common geological history or mode of origin. See figures 1 and 5.

3.3.3.6 Suites are only given formal names, this being done in accordance with the "general rules for naming and defining geological units" (Chap. 2). The name may consist of a geographical name (or an alternative name in the case of the continental shelf) between the words "the ... Suite", but a descriptive term, such as "Intrusive" or "Metamorphic", may in addition be placed in front of "Suite" (Fig. 5).

3.3.3.7.a Suite corresponds in rank to group in the lithostratigraphical classification system.

3.3.3.7.b A suite may change in character regionally, making it more practical to designate the unit as a lithodeme in areas beyond its type area. The proper name of the originally defined suite can be retained even though the lithodemic rank is changed to lithodeme (see Section 2.5.1).

3.3.3.7.c The term "suite" has previously been used for a lithostratigraphical unit ranking next above group, e.g. the Telemark Suite. Such a unit should now be called a supergroup (see Section 3.2.4). In accordance with the definition given for suite in this Code, volcanic suites that are included in a thick sequence of sedimentary rocks can be defined together with these as a supergroup (see Section 3.2.4.1).

3.3.3.8 *Examples*: The plutonic and minor intrusive Permian rocks of the Oslo Region have been assigned to "series" (Brøgger 1933). Used in this sense, a "series" can be defined as a "magmatic suite".

3.3.3.9 *Key reference*: NACSN (1983).

3.3.4 Supersuite (Oversuite)

3.3.4.1 A *supersuite* is a lithodemic unit comprising two or more suites or complexes having a natural relationship to one another, either in the lateral or vertical sense.

3.3.4.2 Supersuite is a formal lithodemic unit ranking next above suite.

3.3.4.3 A supersuite has a regional extent.

3.3.4.4 A supersuite is mappable at the surface and traceable in the subsurface using geological and geophysical methods.

3.3.4.5 A supersuite may consist of lithodemic units belonging to the same and/or different class(es) of rocks.

3.3.4.6 A supersuite is only named formally, this being done in accordance with the "general rules for naming and defining geological units" (Chap. 2). The name consists of a geographical name (or an alternative name on the continental shelf) between the words "the ... Supersuite".

3.3.4.7.a Supersuite corresponds in rank to supergroup in the lithostratigraphical classification system.

3.3.4.7.b A supersuite should only be erected after a thorough assessment of whether it will have any practical value. Considerable mapping and scientific documentation is required prior to its erection.

3.3.4.8 *Examples*: So far no supersuite has been defined on Norwegian territory. It could, for example, be feasible to use the term for the magmatic lithodemes of the Oslo Region, and for major assemblages of plutonic lithodemes in both the Precambrian basement (grunnfjellet) and the Caledonian mountain chain.

3.3.4.9 *Key reference*: NACSN (1983).

3.3.5 Complex (Kompleks)

3.3.5.1 A *complex* is a lithodemic unit consisting of a mixture or assemblage of rocks belonging to two, or all, of the classes of rocks, i.e. igneous, sedimentary and metamorphic rocks.

3.3.5.2 Complex has no rank in the lithodemic classification system.

3.3.5.3 No limitation is placed on the dimensions of a complex, but it generally has a regional extent.

3.3.5.4 A complex is mappable at the surface and traceable in the subsurface using geological and geophysical methods.

3.3.5.5 The individual, associated bodies of different rock units making up a complex may be formally named lithodemes, lithostratigraphical units, and/or informal and unnamed lithological units. They have often been deformed together to form a complicated structural pattern, but this is not a prerequisite. A complex of large regional extent may contain other complexes of smaller areal distribution.

3.3.5.6 A complex is given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2). Names made up of a geographical name between the words "the ... Complex" should preferably only be used for formally defined complexes (see Section 2.3.2).

3.3.5.7.a A complex is a practical mapping entity in areas where it is difficult or impractical to distinguish individual lithodemic or stratigraphical units on the map scale in question.

3.3.5.7.b A complex is often comparable in size to a suite or supersuite.

3.3.5.7.c A *volcanic complex* is an assemblage of different kinds of volcanic rocks and associated intrusive and weathering products (Fig. 1). Volcanic complexes or intrusive-volcanic complexes that are included in a thick sequence of sedimentary rocks can be defined together with these as a supergroup (see Section 3.2.4.1).

3.3.5.7.d A *structural complex* is an assemblage of different kinds of rocks intermixed by tectonic processes (Fig. 1).

3.3.5.7.e Except for c and d, geological units consisting of assemblages of different rocks of *a single class* should *not* be designated as a complex, but as an intrusive suite or a metamorphic suite, for example.

3.3.5.7.f The term "complex" is also used in connection with joint complex (Section 3.9.3), fault complex (Section 3.9.7) and nappe complex (Section 3.11.5) (see Section 1.2).

3.3.5.7.g The term "series" has often been used for lithodemic and lithostratigraphical units corresponding to suite, supersuite, complex, group and supergroup. "Series" is *not* to be used in for-

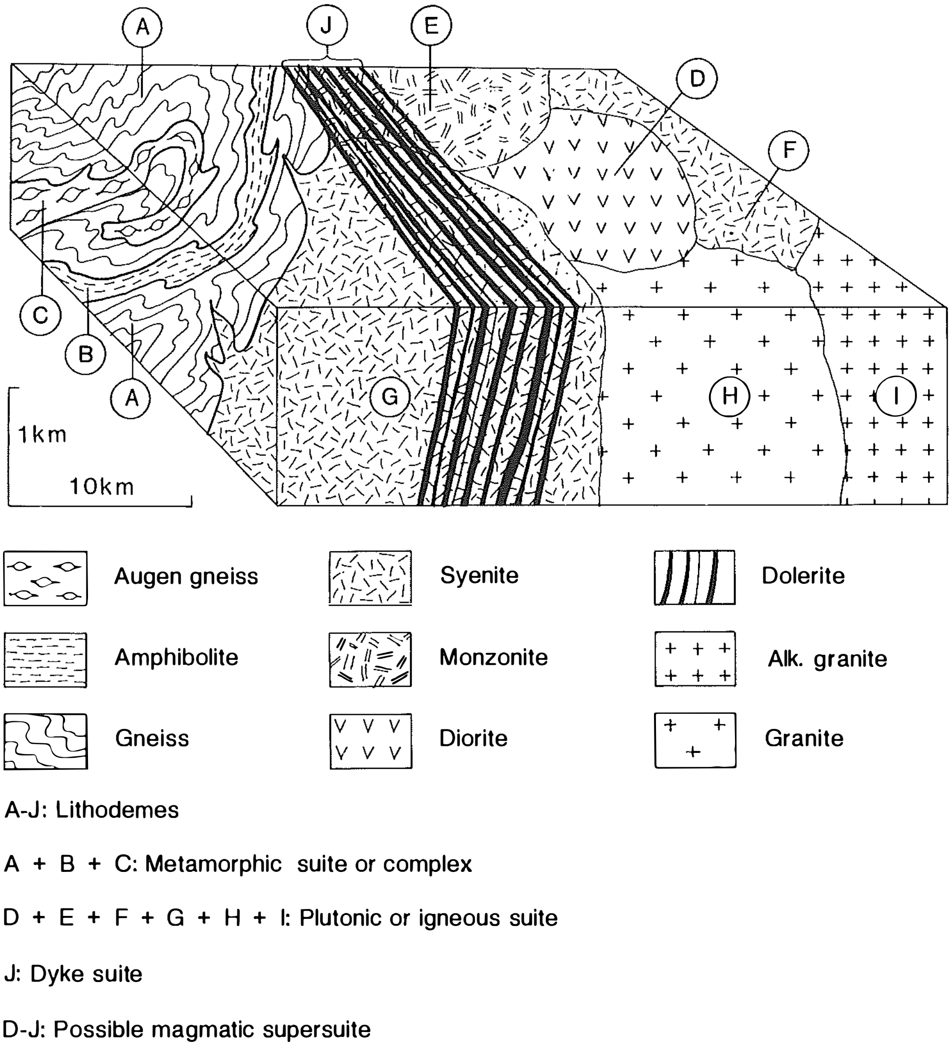


Fig. 5 Lithodemic units and their possible classification. The individual bodies of rock are lithodemes. It is natural to group the metamorphic lithodemes at a higher-ranking level as a suite or complex, the plutonic lithodemes as a plutonic suite and the dyke lithodemes as a dyke suite. If plutonic and dyke rocks are genetically related they can be grouped as a magmatic supersuite.

mal names, i.e. names containing a geographical name (or an alternative name in the case of the continental shelf), for any geological units of this sort, nor for tectonostratigraphical units (see Section 2.3.2).

3.3.5.8 *Examples*: The term "complex" has been used for many lithodemic units in Norway, mostly informally. Not all of these are complexes according to the above definition. "Gabbro complexes" are, for example, either a gabbro lithodeme or a gabbro suite. The assemblage of strongly metamorphosed gneissic and plutonic rocks in West Finnmark (Krauskopf 1954, Roberts 1974) may be defined as a complex. Ring structures (as in the Oslo Region) consisting of several bodies of plutonic and minor intrusive rocks will be ring suites. If they also contain volcanic and perhaps sedimentary rocks they will be ring complexes or cauldrons.

3.3.5.9 *Key reference*: NACSN (1983).

3.4 Magnetostratigraphical units

3.4.1 General properties, magnetopolarity units

Magnetostratigraphical classification is based on the characteristic remanent-magnetic properties of rocks and superficial deposits. Four basic types of palaeomagnetic phenomena can be determined or inferred from remanent magnetism: (a) polarity, (b) dipole-field-pole position (including apparent polar wander), (c) the non-dipole component (secular variation), and (d) field intensity.

Many palaeomagnetic signatures in a rock reflect earth magnetism at the time the rock was formed. Physical and chemical changes in the rock may have led to one or more of the remanent-magnetic components in the rock reproducing the magnetic field of the Earth at a time subsequent to when the rock was formed. To be capable of interpretation the palaeomagnetic properties must therefore be relatable to the geological history of the rock.

In accordance with NACSN (1983), only *magnetopolarity units* are here considered to belong to this category. Magnetopolarity is the "imprint" in the rock or superficial deposit of changes and variations in the polarity history of the Earth's magnetic-dipole field. A magnetopolarity unit is defined on the basis of a type section in which the lithostratigraphical and/or biostratigraphical units are specified (see Section 2.4).

Definition of a magnetopolarity unit does not require knowledge of the time at which the unit acquired its remanent magnetism; this magnetism may be primary, dating from when the rock was formed, or secondary. Demonstration of the primary origin of the magnetopolarity properties entails the use of petrographical criteria and of correlations using biostratigraphy and numerical age determinations. Magnetopolarity units can therefore not be used as an independent basis for chronostratigraphical classification, even though their boundaries are considered to be synchronous (see Sections 4.5 and 4.6).

The fundamental magnetopolarity unit is the *polarity zone.*

3.4.2 Polarity zone (Polaritetssone)

3.4.2.1 A *polarity zone* is a body of rock or superficial deposits that is characterized by its distinctive remanent-magnetic polarity, which differs from that of an adjacent magnetopolarity unit. If there is a risk of confusion with other types of polarity, the term *magnetopolarity zone* should be used instead of polarity zone.

3.4.2.2 Polarity zone is the fundamental formal unit for magnetopolar-stratigraphical classification.

3.4.2.3 In principle, no limitation is placed on the thickness and extent of the body of rock or superficial deposits that defines a polarity zone, nor on the time period represented by the zone.

3.4.2.4 A polarity zone is identified and mapped on the basis of its distinctive remanent-magnetic polarity, using palaeomagnetic analytical methods.

3.4.2.5 A polarity zone is defined by a lower and an upper boundary, each of which marks a change in the polarity of the remanent magnetization. These boundaries may represent a break in deposition or a change in the magnetic field. Such boundaries may be of two main types: (a) *polarity-reversal horizon* (polaritetsrevers horisont), which is either a clearly definable surface or a transitional interval of 1 m or less, (b) *polarity transition zone* (polaritetsovergangssone), which is a boundary where the change in polarity takes place over a stratigraphical interval of more than 1 m.

A polarity zone should possess a certain degree of inner homogeneity. It may contain rocks and superficial deposits that are characterized by a single polarity or a mixed polarity.

3.4.2.6 A polarity zone is given a formal name in accordance with the "general rules for naming and defining geological units" (Chap. 2). The name consists of a geographical name from a type section or type locality and the term "the ... Polarity Zone" (polaritetssonen). A descriptive designation for the polarity (normal, reverse, mixed) can be inserted between the proper name and the unit designation.

3.4.2.7 A polarity zone can be divided into *Polarity Subzones* (polaritetsundersoner). Two or more polarity zones can be grouped in the higher-ranking *Polarity Superzone* (polaritetsoversone) (Table 1).

3.4.2.8 *Examples*: No polarity zones have been defined on Norwegian territory.

3.4.2.9 *Key reference*: NACSN (1983).

3.5 Biostratigraphical units

3.5.1 General properties and rules

Biostratigraphy is concerned with describing and classifying sediments and sedimentary rocks on the basis of fossil content. A biostratigraphical unit is a body of sediment or sedimentary rock which is defined solely on the basis of its fossil content.

Fossils that define a formal biostratigraphical unit must be of the same age as the horizon or sequence in which they occur. Reworked fossils that were originally deposited in older beds must not be used in formal biostratigraphical classification. Great care must be taken when studying well material, where risk of contamination is high.*

Biostratigraphical units are defined on the basis of criteria that are essentially different from those used for lithostratigraphical classification. The boundaries of these two categories of stratigraphical unit may or may not coincide. Biostratigraphical and lithostratigraphical units are completely independent of one another.

The stratigraphical and geographical limitations of a biostratigraphical unit also represent the boundaries for the distribution of the fossils defining the unit, based on the observed evolutional appearance or extinction of the fossil taxa. The boundaries of most biostratigraphical units will therefore be diachronous, in contrast to those of chronostratigraphical units. Biostratigraphical units are therefore also in principle independent of chronostratigraphical classification. Biostratigraphical units will nevertheless usually be the most effective aids for interpreting chronostratigraphical relationships between different successions.

The fundamental biostratigraphical unit is the *biozone* (abbreviation for biostratigraphical zone). There are three main types of biozone: *range zone, assemblage zone* and *abundance zone.*

3.5.2 Biozone (Biosone)

3.5.2.1 A *biozone* is a body of sediment or sedimentary rock that is characterized and defined by a specified fossil content.

3.5.2.2 Biozone is the fundamental formal unit for biostratigraphical classification and nomenclature.

3.5.2.3 The vertical extent of a biozone can include anything from a single bed to units several thousands of metres thick. The lateral extent may be local, regional or worldwide.

3.5.2.4 A biozone is mappable at the surface and traceable in the subsurface with the help of geological and palaeontological methods. Excavated sections or drillings are required to obtain samples for biostratigraphical classification of successions that only occur beneath the surface.

3.5.2.5 A biozone can be defined on the basis of various criteria for the occurrence of fossils, resulting in three main types of biozone: range zone (Section 3.5.2.5.1), assemblage zone (Section 3.5.2.5.2) and abundance zone (Section 3.5.2.5.3).

3.5.2.5.1 *Range zone* (forekomstsone) – A range zone is the body of strata between two specified, documented lowest and/or highest occurrences of one or two fossil taxa (Fig. 6). The use of "interval zone" is not recommended since interval zone is defined in different ways in ISSC (1976) and NACSN (1983). There are three main types of range zone:

3.5.2.5.1.a The interval between the documented lowest and highest occurrences of a single taxon – the *taxon range zone* (Fig. 6A).

3.5.2.5.1.b The interval between the lowest occurrence of one taxon and the highest occurrence of another taxon. If the two taxa partially overlap one another in their stratigraphical oc-

*) Reworked fossils may be difficult to distinguish from indigenous ones. This is particularly true in the case of micro- and nannofossils where an individual fossil specimen may behave like a single grain of sediment and pass through one or more cycles of sedimentation with little evidence of wear. ISSC (1976, p. 47) also opens for the possibility of using reworked fossils as a basis for biostratigraphical zonation by stating "however, because of the difference in their significance with respect to age and environment, fossils that can be identified as reworked should be treated apart from those believed to be indigenous". The use of reworked fossils is mostly practised in Quaternary biostratigraphy for assemblage zones or remanie zones.

currence, the zone can be looked upon as a special type of *Oppel zone* or *concurrent range zone* (Section 3.5.2.5.2.b) involving *only* two taxa (Fig. 6B). If the occurrences of the two taxa do not partially overlap one another, but are used to divide the range of a third taxon, the interval is a *partial range zone* (Fig. 6C).

3.5.2.5.1.c The interval between documented successive lowest occurrences or successive highest occurrences of two taxa. When this interval is between two successive lowest occurrences in an evolutionary lineage it forms a *lineage zone* (Fig. 6D).

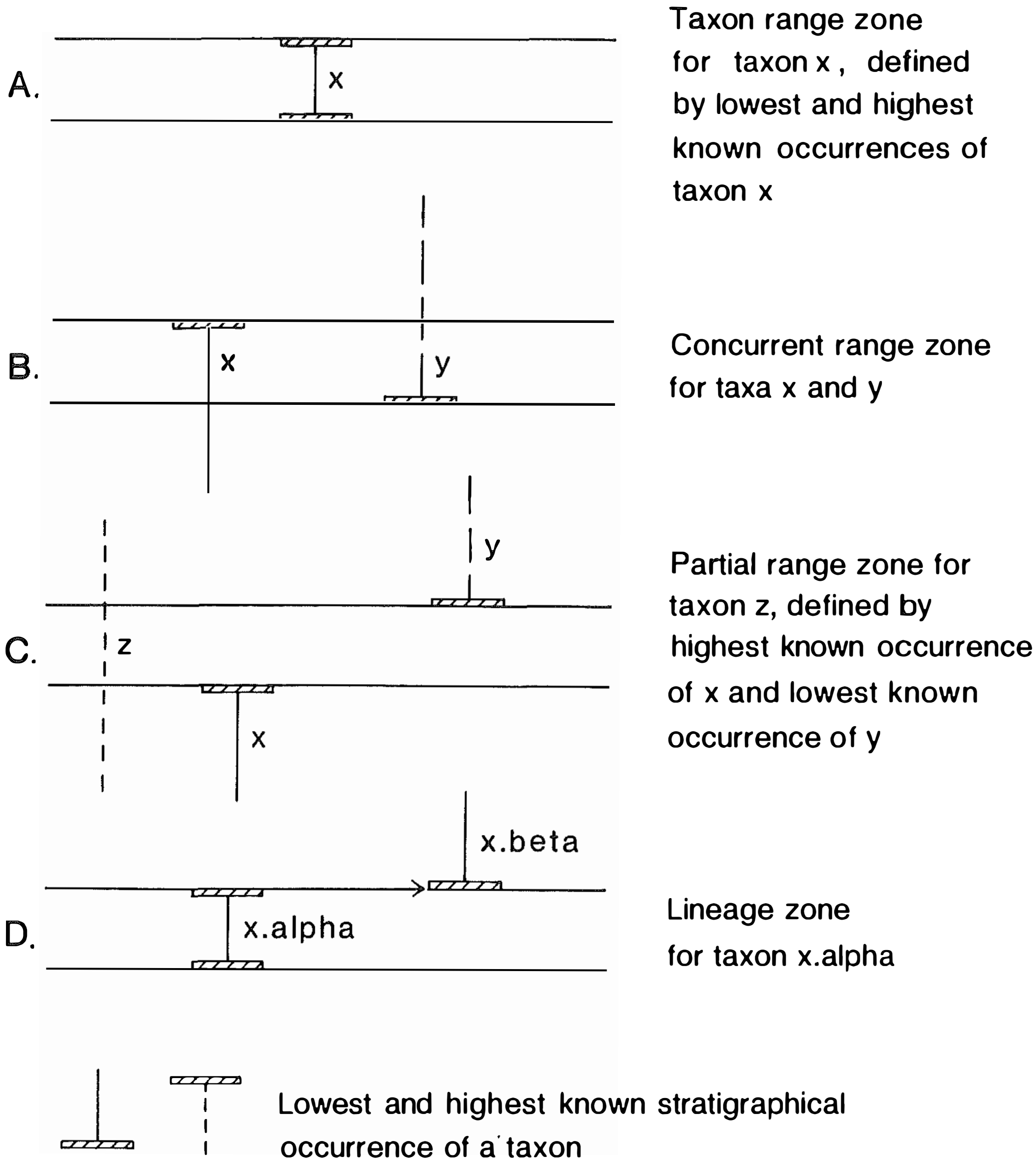


Fig. 6 Biostratigraphical units. Biozones defined as various types of range zones: A. taxon range zone, B. concurrent range zone or Oppel zone, C. partial range zone, D. lineage zone. Modified after NACSN (1983).

3.5.2.5.2 *Assemblage zone* or *cenozone* (samlingssone) (ISSC 1976, p. 50). An assemblage zone is a sequence that is defined by a natural assemblage of three or more taxa, without strict attention being paid to the distribution limits of each single taxon. The zone can be based on all the fossils present, or on only certain taxa (Fig. 7). Types of assemblage zones are:

3.5.2.5.2.a An assemblage zone may either contain *one* stratigraphically limited assemblage or *two or more* contemporaneous assemblages with shared characterizing taxa. The latter is a *composite assemblage zone* (sammensatt samlingssone) (Fig. 7A).

3.5.2.5.2.b An *Oppel zone* or *concurrent range zone* (ISSC 1976, pp. 55-57) (fellesforekomstsone) is characterized by more than two taxa. The zone boundaries are defined by two or more documented first and/or last occurrences of characterizing taxa (Fig. 7B).

3.5.2.5.2.c A *cenozone* (kenosone), as defined by ISSC (1976, p. 50), is characterized by a specified quantitative relationship between several taxa without any regard to the total stratigraphical distribution of the individual taxon (Fig. 7C). A definition of this nature will usually call for a precise quantitative specification of the characterizing taxa in the zone.

3.5.2.5.3 An *abundance zone* (maksimumssone) – acme zone of ISSC (1976, p. 59) – is a biozone defined by a quantitatively marked peak in the frequency of one or more taxa. The boundaries of the abundance zone are defined by significant changes in the frequency of the taxa present.

3.5.2.6 Formal erection of a biozone follows the "general rules for naming and defining geological units" (Chap. 2).

3.5.2.6.1 The name, which must also denote the type of zone, may be based on one or two characteristic and/or common fossils which either (a) are limited to the biozone, (b) reach their maximum frequency within it, or (c) have concurrent stratigraphical ranges within it. Such names will normally be based on genus or subgenus names, or full species or subspecies names (e.g. "the *Exus (Protexus) taxon distribution zone*" or "the *Exus (Protexus) albus taxon distribution zone*"). The genus and subgenus names can be abbreviated, but trivial species and subspecies names cannot be used alone (e.g. "the *E. (P.) albus taxon distribution zone*", but not "the *albus taxon distribution zone*").

3.5.2.6.2 The name can also be based on a combination of letters derived from the names of taxa which characterize the biozone (e.g. "the EPA taxon distribution zone").

3.5.2.6.3 The character of the biozone is to be clearly stated in the first formal definition of a biostratigraphical unit. When this has been done, it can be referred to more simply afterwards, e.g. "the *Exus albus* zone" instead of the more cumbersome "the *Exus albus* taxon distribution zone".

3.5.2.6.4 Alphanumerical divisions constructed on the basis of numbers and letters (e.g. as in the stage classification of the Oslo Region), or divisions based only on simple series of numbers or letters (1,2,3, or A,B,C) may be used for informal biostratigraphical units.

3.5.2.6.5 *Changes of name.* The biozone can be modified on the basis of new information. Its boundaries can be redefined or described in greater detail, and new characteristic taxa can be accepted, or existing taxa replaced. If substantial changes in the definition of the biozone are undertaken a new zone name should be proposed to avoid misunderstandings in later references. The zone name should also be changed if the taxa used in the name are given new names (see Section 2.5).

3.5.2.7.a A biozone can be completely or partly divided into formally defined sub-biozones or subzones (underbiosoner/undersoner) if such divisions serve a useful purpose.

3.5.2.7.b Unfossiliferous intervals between or within biozones are *barren interzones* (fossiltomme intersoner) and *barren intrazones* (fossiltomme intrasoner), respectively.

3.5.2.7.c Fossil taxa in certain assemblage and abundance zones may reflect dominant local ecological control. Biozones defined by such assemblages are to be considered as informal *ecozones.*

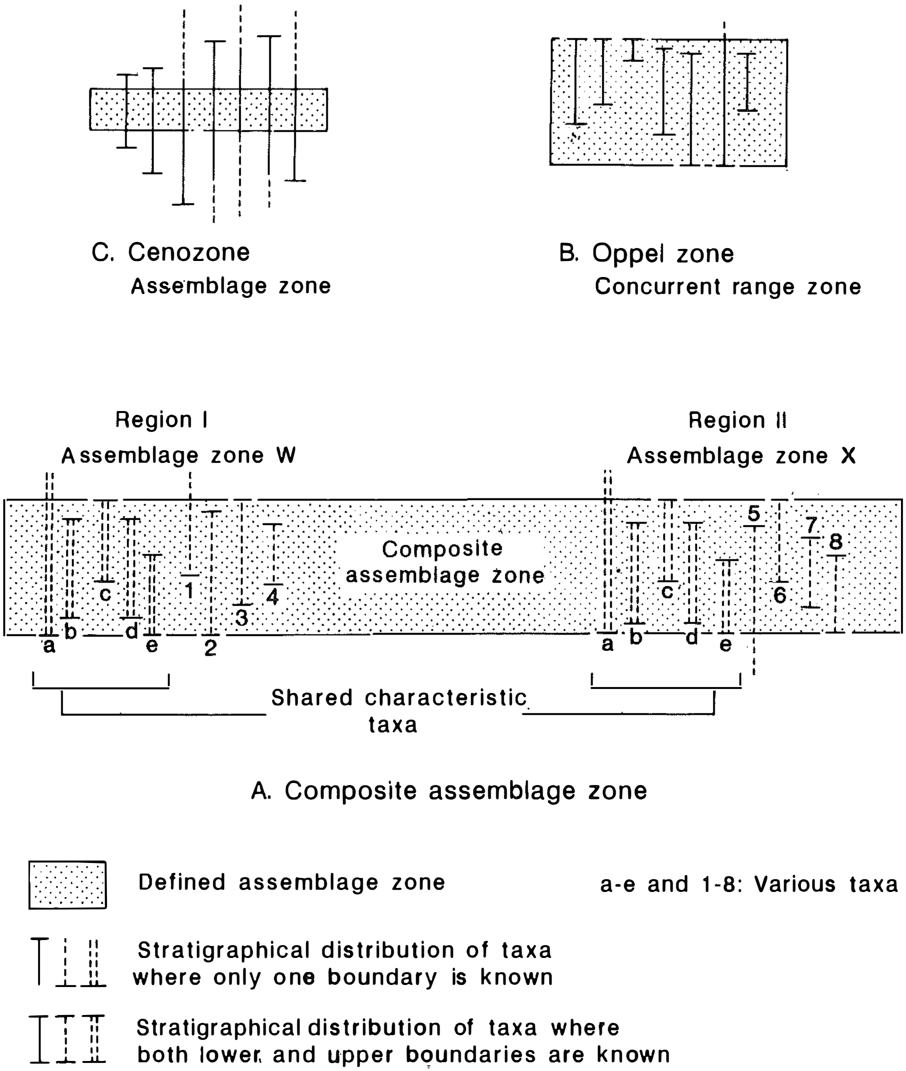


Fig. 7 Biostratigraphical units. Biozones defined as: A. composite assemblage zone, B. concurrent range zone or Oppel zone, and C. cenozone. Modified after NACSN (1983).

3.5.2.7.d *Biohorizon* (biohorisont). A biohorizon is a surface where a biostratigraphical change takes place, or that has a distinctive biostratigraphical character. It is therefore useful for correlation. Biohorizons are often used to define biozone boundaries, but can also occur within biozones. The term biohorizon is also sometimes used for thin, distinctive biostratigraphical zones. Examples of biohorizons are the first appearances and last occurrences of a taxon, changes in its frequency and abundance, evolutionary changes, and changes in its character.

3.5.2.8 *Examples*: On Norwegian territory there are few biozones where the zone type has been clearly defined. The zones in the Cambrian, based on trilobites (Henningsmoen 1957), can largely be looked upon as assemblage zones. The well-known evolutionary lineage in the genus *Stricklandia*, recently described in detail by Baarli (1986), may form a basis for defining lineage zones in the Llandovery. Many abundance zones that have been introduced into biostratigraphy reflect ecological conditions rather than processes controlled by evolution.

3.5.2.9 *Key references*: ISSC (1976), NACSN (1983).

3.6 Pedostratigraphical units

3.6.1 General properties and rules

Pedostratigraphy deals with the stratigraphical classification of ancient, buried horizons that contain soil profiles formed by pedological processes. Pedological processes comprise chemical weathering, biogenic reworking and activity, and formation of secondary minerals. A vertical soil profile is characterized by various pedological horizons. The most common terms for these, from the surface downwards, are: the A horizon, which is a mixture of organic material and weathered mineralogical material; the B horizon, which consists of redeposited material and/or concentrations of residual material; and the C horizon, which is weathered parent material. The C horizon usually shows a gradual transition downwards to unweathered parent material. There may be a layer of organic debris above the soil profile, the O horizon.

A *pedostratigraphical unit* is a body of rock or superficial deposits consisting of one or more pedological horizons developed on a surface made up of one or more lithostratigraphical and/or lithodemic units. It is overlain by one or more formally defined lithostratigraphical units.

The upper boundary of a pedological unit is defined by the top of the uppermost horizon formed by pedological processes. The O horizon, which is not formed by such processes, is not included in a pedostratigraphical unit. (Any organic top-layer present can be classified as a litho- or biostratigraphical unit.)

The lower boundary is placed at the lowest level that is *clearly* affected by pedological processes (usually the lower boundary of the B horizon).

The physical properties of a pedological unit are clearly distinguished from both the parent material below and the lithostratigraphical unit above. The physical properties of a single pedological unit, such as colour, texture, content of organic material, mineral content or concretions, can change laterally as a function of variations in, for example, parent material, drainage conditions and vegetation.

The boundaries of a pedostratigraphical unit are time-transgressive. Identification and lateral tracing of a pedostratigraphical unit are accomplished on lithological criteria and stratigraphical correlation with the help of the underlying and overlying litho- and/or biostratigraphical units, and perhaps by numerical age determinations.

The fundamental and only pedostratigraphical unit is a *palaeosol* (paleojord). A palaeosol is defined and named after a type locality or a type area in accordance with the "general rules for naming and defining geological units" (Chap. 2).

Pedostratigraphical classification has so far not been used on Norwegian territory, but it could perhaps find application within the succession on the continental shelf.

Key reference: NACSN (1983). (NACSN calls the pedostratigraphical unit a geosol.)

3.7 Geological form units

3.7.1 General properties and rules

3.7.1.1 *Definitions* – In studies of both Quaternary and older deposits it is necessary to define and name *geological form units*. These are geomorphological elements and form elements related to structural geology (Fig. 8).

Geomorphological elements are present-day and ancient, buried landforms that can be distinguished on the basis of distinctive physical characteristics. Geomorphological units may be (a) depositional forms, such as a moraine ridge, a delta or a beach ridge; (b) erosional forms, such as a canyon or a marginal meltwater channel; (c) forms produced by both deposition and erosion, such as a beach terrace or a kame terrace; and (d) structural landforms produced by tectonic movements, such as a horst or a graben.

Form elements related to structural geology comprise present-day and former structural landforms (group d, above) and structural form elements that have not been reflected at the surface as landforms, or about which nothing is known concerning whether they have at any time found expression in the surface topography. Such structural elements may be an anticline, syncline, dome, diapir, horst or graben.

Geological form units can be classified as *positive* (upstanding) or *negative* (depressed) (Fig. 8). Geomorphological form elements are directly visible on the surface, while structural form elements in ancient stratal sequences are seen in vertical section. Unconformities may define positive or negative forms, but are in themselves neither positive nor negative (Figs. 9, 10).

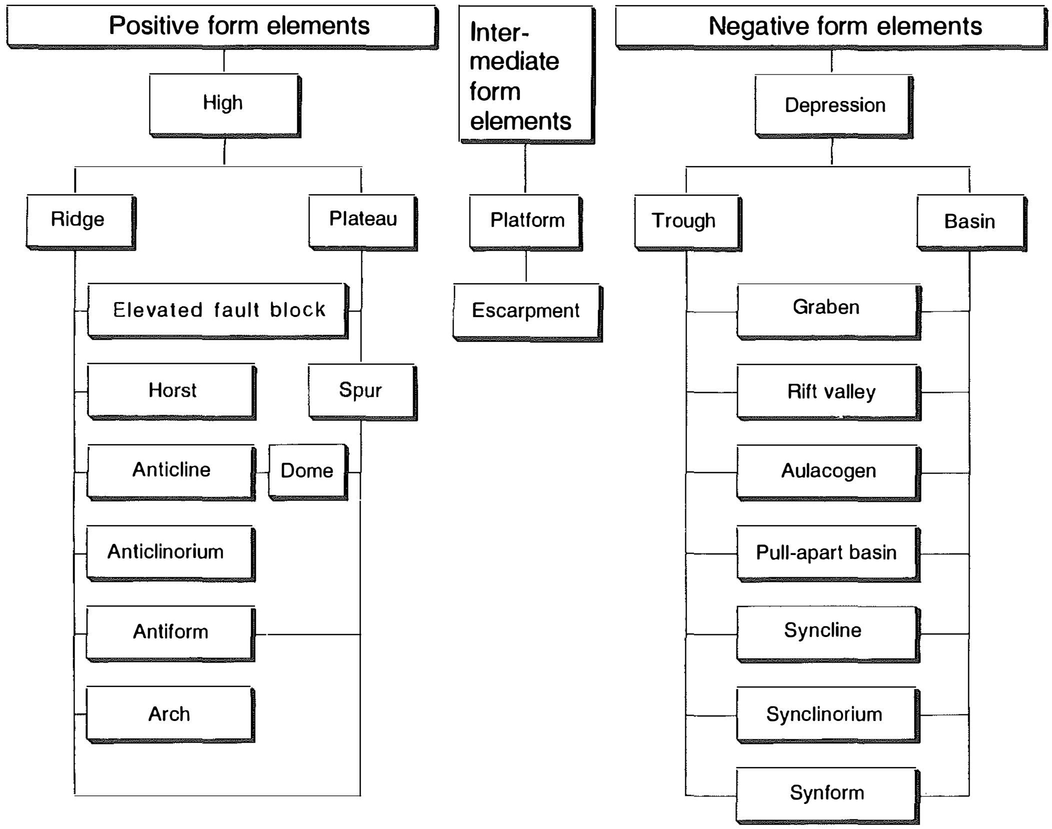


Fig. 8 Main types of geological form units.

3.7.1.2 *Identification and mapping* – Geological form elements are identified and mapped in several ways: (a) surface mapping of geomorphological form elements; (b) using geological and geophysical methods to record structural form elements in stratal sequences exposed on land; and (c) using geophysical methods to record subsurface geological form elements on land and on the continental shelf (Figs. 9, 10).

When exploring for economically exploitable subsurface ore and mineral deposits, not least petroleum on the continental shelf, the identification and regional tracing of structural form elements is particularly important. These will be revealed as geophysical anomalies (e.g. magnetic or gravimetric) or be identified in relation to a specific geological or seismic surface by, for example, reflection seismic mapping.

There may also be a need to define and name geological form elements that no longer exist, either at or beneath the surface. These may be former sedimentary basins or ocean basins that are indirectly reflected in a sequence. A distinction is made here between "rooted" and "rootless palaeobasins". Rooted palaeobasins with their infilled sequences are located in the same areas as they were when they formed active sedimentary basins. Rootless palaeobasins are expressed by sequences in the nappes of a mountain chain. Such basins are no longer directly connected to the area in which they existed as active basins.

3.7.1.3 *Nomenclature* – The most general terms in the following non-hierarchical system for naming geomorphological and structural form elements are non-genetical (Fig. 8). For example, a "high" is the fundamental designation for a positive geomorphological or structural form element of non-specified origin and shape. An elongate high of undetermined origin can be termed a "ridge". If a ridge is laterally delimited

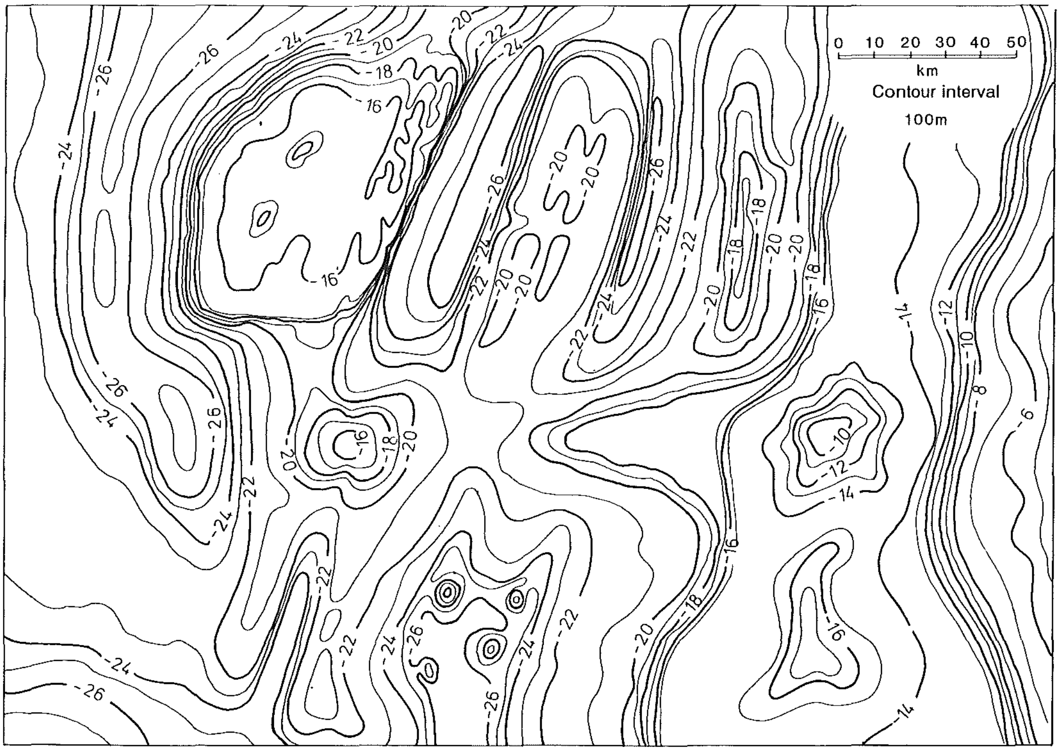


Fig. 9 Structural form elements shown as depths down to an unconformity surface (seismic reflector) on an idealized subsurface map of a continental shelf. The form elements are identified and given unit designations in figure 10.

by faults, the origin is clear and it can be called a "horst" (Figs. 9, 10). An "ice-marginal ridge" is another example of a genetical ridge term.

When choosing nomenclature, care should be taken to use the term which gives most geological information. If, for example, it has been shown that a certain structural feature has been formed as a horst, the term "horst" and not "high" should be used. Structural form elements can therefore be redefined during ongoing investigations (Section 2.5.1) as new knowledge about the structure is forthcoming (see also Section 2.4).

Naming takes place according to the "general rules for naming and defining geological units" (Chap. 2). It should be emphasized that the principle that more than one geological unit should not have the same proper name (Section 2.2.2) also applies to this category, except for escarpments (Section 3.7.12) and rootless palaeobasins (Section 3.7.14). An escarpment can be given a proper name after the named structure which it delimits or follows. In the case of rootless palaeobasins, the proper name of the lithostratigraphical unit defining the palaeobasin is also to be used as the proper name for the rootless basin. The proper name of a geomorphological unit which forms an integral part of a morphostratigraphical classification system can also be used for the derived morphostratigraphical unit (Section 3.10.1.3).

Geological form units are given formal status with protected proper names when they are defined according to the rules for formal units in Section 2.4.

3.7.1.4 *Units* – This category comprises the following geological units: unconformity, high, ridge, spur, fault block, horst, dome, anticline, plateau, platform, escarpment, depression, basin, trough, graben and syncline.

3.7.2 Unconformity (inkonformitet)

3.7.2.1 An *unconformity*, or surface of unconformity, is a surface representing a substantial

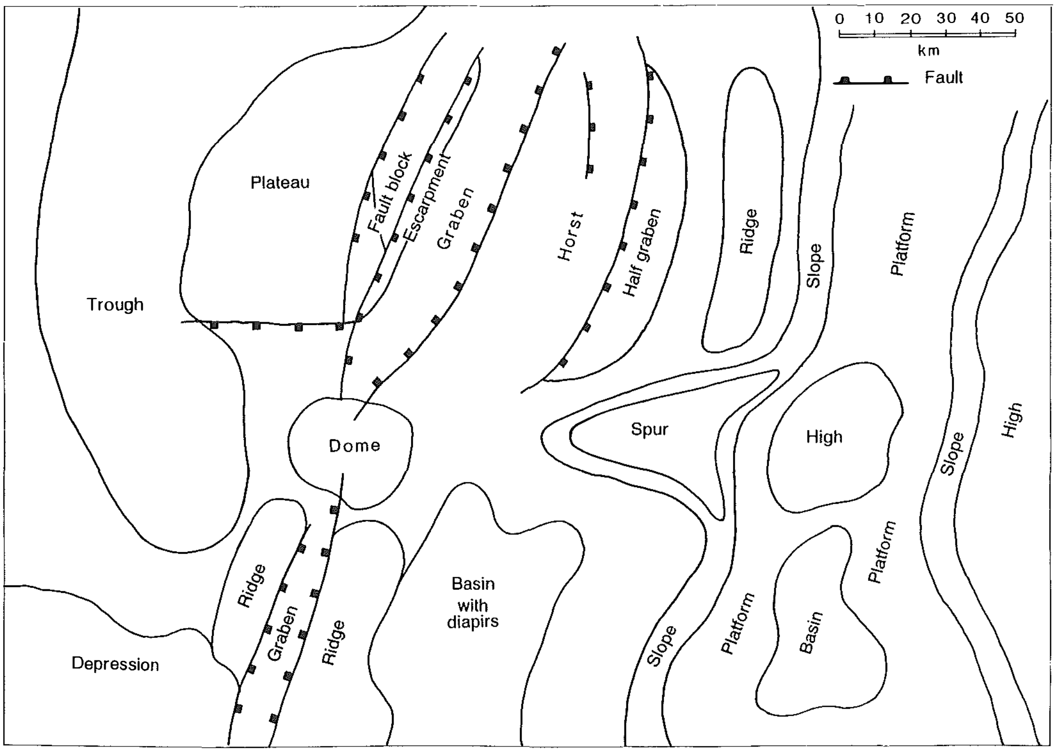


Fig. 10 Structural form elements in an idealized continental shelf succession, identified on the basis of the contour map of the unconformity surface shown in figure 9.

break in the geological record. It is the boundary surface between two stratigraphically adjacent units the younger of which was *not* deposited as part of a continuous geological process extending from the deposition of the older, underlying unit. An unconformity may reflect (a) an interruption in the depositional process leading to non-deposition of part of the sequence, or (b) uplift and erosion of bedrock (Figs. 11-13).

3.7.2.2 An unconformity often reflects a structural event (see deformational-diachronous units, Section 4.8).

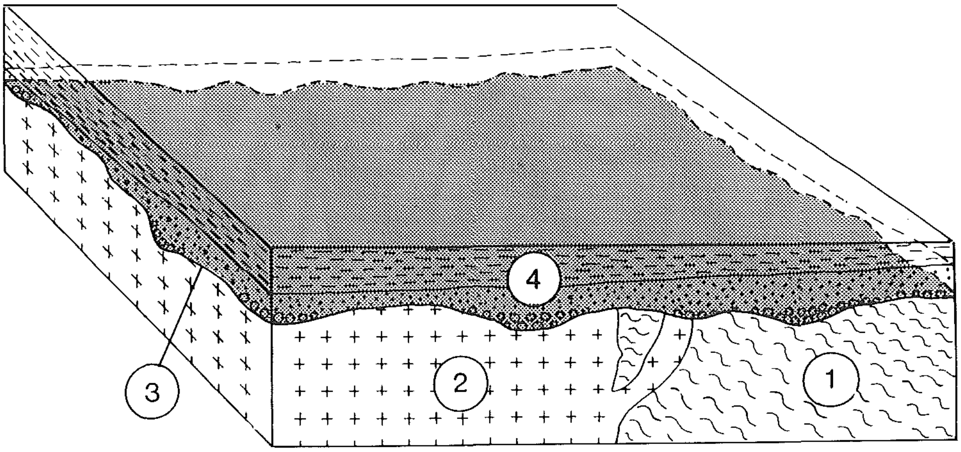
3.7.2.3 An unconformity may be of local or regional extent.

3.7.2.4 An unconformity is mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.2.5 A single unconformity can be expressed in different ways within the area in which it is developed. A surface of unconformity can be defined by a time-transgressive or time-regressive stratigraphical succession.

3.7.2.6 An unconformity is given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). The name consists of a geographical name (or an alternative name in the case of the continental shelf) from the type section, type locality or type area (Section 2.4.5), placed between the words "the ... Unconformity" (formal). The term distinguishing the type of unconformity (Section 3.7.2.7) may be used instead of "the ... Unconformity". Informal names may consist of the prefix "sub" used with the overlying lithostratigraphical unit or succeeding chronostratigraphical unit (e.g. the sub-Cambrian peneplain). Informal names may also contain the name of a deformational event that gave rise to the unconformity (e.g. the Late Kimmerian unconformity).

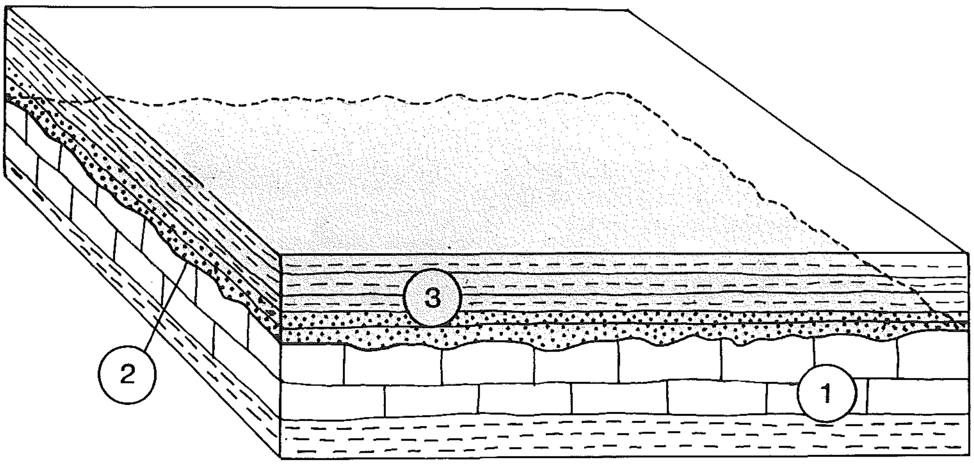
3.7.2.7 In British terminology the term unconformity (inkonformitet) is used for a structural



4: Younger sequence above nonconformity 3
3: Nonconformity surface, shaded

2: Granite lithodeme
1: Gneiss lithodeme
} Older basement to sequence 4

Fig. 11 Unconformity surface developed as a *nonconformity* (3) formed by erosion of an older crystalline basement (1 and 2) which is overlain by a younger succession (4).



3: Younger sequence above disconformity surface 2
2: Disconformity surface, shaded
1: Older sequence beneath disconformity surface 2

Fig. 12 Unconformity surface developed as a *disconformity* (2) formed by erosion of an older succession (1) which is overlain by a younger conformable succession (3).

discordance rather than a time gap. American terminology differentiates four types of unconformity: nonconformity, angular unconformity, disconformity and paraconformity. Apart from the last-mentioned term, which signifies an uncertain or doubtful unconformity between parallel beds (Dunbar & Rodgers 1957), it is recommended that these are used in Norwegian geological terminology.

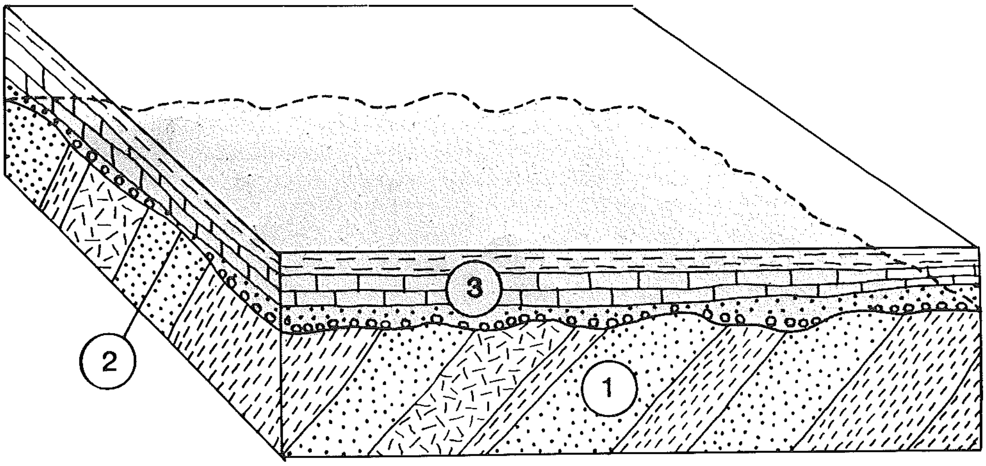
3.7.2.7.a A *nonconformity* (ikke-konformitet) is a surface of unconformity separating an older lithodemic unit (plutonic or massive metamorphic rock) from an overlying, younger sedimentary or volcanic sequence. The older lithodemic basement (underlag) was exposed to erosion prior to deposition of the younger, superposed sequence (Fig. 11) (Dunbar & Rodgers 1957).

3.7.2.7.b A *disconformity* (diskonformitet) is a surface of unconformity where the rocks beneath and above the stratigraphical break are essentially parallel. A disconformity surface reflects a prolonged break in deposition and perhaps considerable erosion during which time the older beds remained horizontal (Fig. 12). The term disconformity should preferably be used for stratigraphical breaks separating units ranking at least as high as a formation (Stokes & Varnes 1955).

3.7.2.7.c An *angular unconformity* (vinkeldiskordans) is a surface of unconformity where the rocks beneath and above a stratigraphical break are *not* parallel; the underlying unit has been tilted or folded prior to erosion and deposition of the younger, superposed unit (Fig. 13).

3.7.2.7.d Terms used for unconformities must not be confused with terms for periods of time reflected by a stratigraphical break. Whereas *hiatus* is the period of time represented by an unconformity, *diastem* is a still shorter period during which sedimentation was interrupted.

3.7.2.8 *Examples*: In Norwegian literature it has not been customary to formally name surfaces of unconformity. In several cases they have, nevertheless, been used as the basis for defining deformational-diachronous units, even though the unconformities themselves have not been named (see Section 4.8), e.g. the "Trysil uplift" and the "Ekne orogeny" (Vogt 1928). The "sub-Cambrian peneplain" and the "sub-Permian peneplain" are informal terms for unconformities. In the North Sea area the Late Kimmerian unconformity has been used as a term for unconformities of both regional and local extent (Rawson & Riley 1982). The term has been ascribed varying content and meaning, and should be used informally.



3: Younger sequence above angular unconformity 2
2: Angular unconformity, shaded
1: Older sequence beneath angular unconformity 2

Fig. 13 Unconformity surface developed as an *angular unconformity* (2) formed by erosion of an older, tilted succession (1) which is overlain by a younger succession (3).

3.7.2.9 *Key references*: Stokes & Varnes (1955), Dunbar & Rodgers (1957), Tomkeieff (1962), Bates & Jackson (1980).

3.7.3 High (Høyde)

3.7.3.1 A high is (a) a present-day or former positive geomorphological and/or structural feature of non-specified origin and shape, and (b) a positive geophysical anomaly.

3.7.3.2 High is a general term for (a) a geological or geomorphological feature that stands up relative to surrounding areas or structures, and (b) a positive geophysical anomaly.

3.7.3.3 No limitations are placed on the dimensions of a high.

3.7.3.4 The structure is mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.3.5 A high will frequently be capable of being divided into (a) smaller geomorphological and structural features and (b) smaller geophysical anomalies.

3.7.3.6 A high can be given a formal or an informal name in accordance with the "general rules for defining and naming geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). In the compound name, the proper name (Section 2.2.2) is placed between the words "the ... High" (formal). The basis for defining a high can be indicated by adding such terms as "gravimetric" or "magnetic", or, if it is known to be a structural or geomorphological high this can be shown by adding, for example, "structural".

3.7.3.7.a A high may be part of a larger geomorphological, structural and/or geophysical feature. A high has a status among positive features corresponding to that held by the depression or low among negative features. A *structural* high need not be, and need never have been, a landform.

3.7.3.7.b A *massif* (massiv) is a geomorphological and/or structural high of regional size, and consists of ancient, usually crystalline rocks. Beyond the massif these rocks form the basement for younger sequences, e.g. the Bohemian Massif and the London Massif. "Massif" is also used in the sense of *mountain massif* to characterize extensive, prominent areas of upland.

3.7.3.8 *Examples*: From the continental shelf off Norway, the Frøya High (Frøyhøyden) (Hinz 1972) and Mid North Sea High (Midtnordsjøhøyden) (Rhys 1974) are examples of structural highs.

3.7.3.9 *Key reference*: Bates & Jackson (1980).

3.7.4 Ridge (rygg)

3.7.4.1 A ridge is a long, narrow, positive geomorphological and/or structural feature delimited from the surrounding terrain by steep sides which may be defined by faults (Figs. 10, 11).

3.7.4.2 Every ridge is a high.

3.7.4.3 No limitations are placed on the dimensions of a ridge.

3.7.4.4 The structure is mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.4.5 A ridge can form an isolated, independent feature, but may also be part of a larger geomorphological and/or structural feature. It will often be possible to divide a ridge into smaller form elements.

3.7.4.6 A ridge can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). In the compound name, the proper name (Section 2.2.2) is placed between the words "the ... Ridge" (formal). If the ridge is known to be a geomorphological ridge, the nature of this may be indicated by a descriptive word, such as "volcanic ridge", "mid-oceanic ridge", etc. (see Section 3.7.4.7).

3.7.4.7.a A ridge that is known to be a *structural ridge* (strukturell rygg), but which is not delimited by faults, may be an anticline, antiform or arch.

3.7.4.7.b An *ice-marginal ridge* (israndrygg) is a general term in Quaternary geomorphology for a ridge formed along the margin of a glacier, irrespective of the inner construction and composition of the ridge. Ice-marginal ridges include ridge-shaped ice-contact deltas, moraine ridges and ridges of mixed origin. ("Ra" in Østfold and Vestfold counties is the local name for the main ice-marginal ridge of Younger Dryas age there.)

3.7.4.7.c A *moraine ridge* (morenerygg) is, in Quaternary geomorphology, any ridge-shaped deposit consisting largely of the superficial deposit, moraine. Such ridges may be deposited as terminal moraines and lateral moraines on land and in water, as crevasse fillings and by the pressing together of morainic material beneath glaciers.

3.7.4.7.d *Esker* (esker) is a morphological and/or genetical term for a ridge-shaped deposit formed in a meltwater channel in a tunnel in or at the base of a glacier, or in a crevasse in a glacier.

3.7.4.7.e A *beach ridge* (voll, strandvoll) is a low, often long, narrow ridge consisting of sand, gravel or shingle heaped up by waves along a shore. Beach ridges often mark former positions of relative sea level (strandlines).

3.7.4.7.f Form elements b-e can be given formal or informal names. Some examples of such features may have traditional, old-established proper names. Form elements b-e can provide a basis for morphostratigraphical classification (see Section 3.10).

3.7.4.8 *Example*: The Senja Ridge (Sundvor 1971) is one of several structural ridges on the Norwegian continental shelf.

3.7.4.9 *Key references*: Gjessing (1978), Bates & Jackson (1980).

3.7.5 Spur (Utstikker)

3.7.5.1 A *spur* is a positive geomorphological and/or structural form element projecting from a high. Spurs are wedge-shaped in planar or map sections, or are shaped like a spur (Figs. 9, 10).

3.7.5.2 Every spur is a high and a platform.

3.7.5.3 A spur may be regional in size, but is always smaller than the form element to which it is attached.

3.7.5.4 Spurs are mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.5.5 Spurs may often be divided into smaller geomorphological and/or structural features.

3.7.5.6 A spur can be named formally or informally in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). In the compound name, the proper name (Section 2.2.2) is placed between the words "the ... Spur" (formal).

3.7.5.7 Spurs include such geomorphological form elements as a *point* or *promontory* (nes), *nose* (nese), *spit* (tange, odde), *hook* (krumodde) and *sandbar* or *longshore bar* (revle) (Klemsdal 1979).

3.7.5.8 *Example*: The Tampen Spur (Tampenutstikkeren) (Rønnevik et al. 1975a).

3.7.5.9 *Key reference*: Bates & Jackson (1980).

3.7.6 Fault block (Forkastningsblokk)

3.7.6.1 A *fault block* is a block of the Earth's crust formed by fault movements and which has been displaced as a single unit. It may be entirely or partially bounded by faults and can have any shape whatsoever on a map (Figs. 9, 10).

3.7.6.2 Fault block is the general designation for fault-bounded blocks of the Earth's crust, irrespective of shape.

3.7.6.3 No limitations are placed on the dimensions of a fault block.

3.7.6.4 Fault blocks are mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.6.5 An elevated fault block can give rise to a high or structural high, and a depressed fault block can form a depression or structural depression. Large fault blocks may be divided up into smaller, subsidiary ones.

3.7.6.6 A fault block can be formally or informally named in accordance with the "general rules for naming and defining geological units"

(Chap. 2) and the rules for naming geological form units (Section 3.7.1). In the compound name, the proper name (Section 2.2.2) is placed between the words "the ... Fault Block" (formal). If there is no danger of misunderstanding the abbreviated form "Block" can be used in the compound name.

3.7.6.7 The term "fault block" is to be preferred to "horst" when an elevated fault block does *not* have a pronounced long, narrow shape and is *not* bounded by two major faults along its flanks. Borderline cases will occur.

3.7.6.8 *Examples*: The continental shelf contains many examples of fault blocks of various geometrical shapes. Permian fault tectonics in the Oslo Region resulted in fault blocks of various shapes.

3.7.6.9 *Key reference*: Bates & Jackson (1980).

3.7.7 Horst (Horst)

3.7.7.1 A horst is an elongate, relatively uplifted, fault block bounded by parallel or nearly parallel faults along its flanks. It is a structural form element which need not necessarily be, or have existed as, a landform (Figs. 9, 10).

3.7.7.2 Horst is a genetical term for a positive structural form element. Every horst is a structural high.

3.7.7.3 No limitations are placed on the dimensions of a horst.

3.7.7.4 Horsts are mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.7.5 A horst may be an isolated, independent form element, but may also constitute part of a larger geomorphological and/or structural feature. Horsts may frequently be divided into smaller form elements.

3.7.7.6 A horst can be formally or informally named in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). In formal compound names, a proper name (Section 2.2.2) is placed between the words "the ... Horst".

3.7.7.7 The term horst is to be preferred to ridge when it is established that the structural feature is bounded by faults along its flanks.

3.7.7.8 *Examples*: The Halibut Horst (Kent 1975) is a buried horst in the North Sea. Solbergåsen in Hedmark county (Skjeseth 1963) is a horst of basement rocks brought to the surface by erosion, separated by parallel faults from Cambro-Silurian rocks. Nesodden in Oslofjord forms a long, narrow, triangular fault block of basement, elevated in relation to surrounding rocks. The Nesodden Block can be looked upon as an eroded horst whose flanking faults are not completely parallel.

3.7.7.9 *Key reference:* Bates & Jackson (1980).

3.7.8 Dome (Dom)

3.7.8.1 A *dome* is a positive geomorphological and/or structural form element which is defined by having a regularly curved surface. In horizontal section a dome has an approximately circular or elliptical outline. The structure is usually not bounded by faults (Figs. 9, 10).

3.7.8.2 Every dome can be classified as a high.

3.7.8.3 No limitations are placed on the dimensions of a dome.

3.7.8.4 Domes are mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.8.5 Domes may often be divided into smaller geomorphological and/or structural elements. If the structure is more long and narrow, rather than circular, in outline, the term *arch* is appropriate (Section 3.7.9.7.c).

3.7.8.6 A dome can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). In formal compound names, a proper name (Section 2.2.2) is placed between the words "the ... Dome". If a dome is recognized as being a structural or geomorphological dome this can be indicated by, for example, "structural dome", "salt dome" or "volcanic dome".

3.7.8.7.a A structural dome need not be, or have been, a landform.

3.7.8.7.b A *diapir* is a dome or an anticlinal fold in which the arching process has led to the overlying rocks being pierced by plastic material squeezed from the core of the diapir.

3.7.8.8 *Example*: The Gjersøen dome is a structural dome in the Precambrian basement east of Oslo (Zetterstrøm 1974).

3.7.8.9 *Key reference*: Bates & Jackson (1980).

3.7.9 Anticline (Antiklinal)

3.7.9.1 An anticline is a fold, usually convex upwards, whose core contains the stratigraphically oldest rocks. It is a structural form element which need not be, or have been, a landform.

3.7.9.2 Anticline could be a genetical term for a positive structural feature.

3.7.9.3 No limitations are placed on the dimensions of an anticline (see Section 3.7.9.7.c).

3.7.9.4 Anticlines are mappable with the help of geological and/or geophysical methods.

3.7.9.5 An anticline can include several smaller structural elements.

3.7.9.6 An anticline can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). In the compound name, a proper name (Section 2.2.2) is placed between the words "the ... Anticline" (formal).

3.7.9.7.a An *antiform* (antiform) is a fold which is convex upwards, and in which the beds are inverted or their relative age is unknown.

3.7.9.7.b An *anticlinorium* (antiklinorium) is a positive structural form element of regional size, made up of several smaller folds, and whose core contains the stratigraphically oldest rocks.

3.7.9.7.c An *arch* (hvelv) is a broad, open antiform of regional size (see arc, Section 3.8.2.7).

3.7.9.7.d Antiforms, anticlinoria and arches can be given formal or informal names.

3.7.9.8 *Examples*: The Salangen Antiform (Gustavson 1972) is a Caledonian "cross-fold". Several of the windows in the Caledonian nappe region are formed above antiformal structures of arch character, e.g. the Komagfjord window, the Børgefjellet window, the Tømmeråsen window (called "the Tømmerås anticline" by Peacey (1964)) and the Atnsjøen window (Sigmond et al. 1984). The Østensjø anticlinorium is a basement structure (Graversen 1984).

3.7.9.9 *Key reference*: Bates & Jackson (1980).

3.7.10 Plateau (Platå)

3.7.10.1 A *plateau* is a positive geomorphological and/or structural form element which consists of an extensive area dominated by a surface of low relief. The levelled surface of the plateau is significantly higher than contemporaneous surrounding areas. A plateau can be formed by tectonic or volcanic processes and/or by erosion (Figs. 9, 10).

3.7.10.2 Every plateau is a high.

3.7.10.3 A plateau has a regional extent.

3.7.10.4 The structure is mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.10.5 A plateau may include several geomorphological and/or structural elements, such as upstanding highs, deep ravines and fault-bounded structural elements. These features are subordinate in area to the even surface of the plateau.

3.7.10.6 A plateau can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). A proper name (Section 2.2.2) is placed between the words "the ... Plateau (formal) in the compound name.

3.7.10.7 If the plateau surface is below sea level the term *submarine plateau* (undersjøisk platå) is used. *Table mountain* (bordfjell), *mesa* and *guyot* are highs with plateau summits (Bates & Jackson 1980).

3.7.10.8 Examples: The Vøring plateau was originally defined by Nansen (1904). Based on the Tertiary palaeorelief, the Vøring plateau is bounded to the southwest by the continental slope, to the northwest by the Lofoten Basin and to the east by the Vøring Basin. On the basis of the present topography of the sea floor, the Vøring plateau is part of a platform. The "Krokskogen plateau" and the "Hardangervidda plateau" are terms that are correctly used for plateau-shaped highs.

3.7.10.9 *Key reference*: Bates & Jackson (1980).

3.7.11 Platform (Plattform)

3.7.11.1 A *platform* is a geomorphological and/or structural form element which consists of a flat, tectonically relatively stable area. The even surface of the platform is formed by erosion and/or deposition. A platform is delimited on one or more sides by contemporaneous, lower-lying areas (Figs. 9, 10).

3.7.11.2 A platform is a form element which, as regards height, is located between a high and a depression (Fig. 8).

3.7.11.3 A platform is a regional-sized feature; subtypes may be local in extent (Section 3.7.11.7).

3.7.11.4 A platform is mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.11.5 A platform may often be divided into several geomorphological and/or structural form elements.

3.7.11.6 A platform can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). A proper name (Section 2.2.2) is placed between the words "the ... Platform" (formal) in the compound name.

3.7.11.7.a Platform morphology includes all types of terrace. The term *terrace* (terrasse) comprises a long, narrow *terrace surface* which usually slopes gently downwards towards an outer edge where it is bounded by a *terrace brink* or *terrace edge* and a steeper *terrace slope* towards a depression. On the inner side, the terrace surface is bounded by a corresponding steeper slope towards a high. "Terrace" has been used for both the terrace surface itself and the terrace slope, and should also include the brink or edge between them (see escarpment, Section 3.7.12). "Platform slope" and "platform brink" or "edge" are used in a corresponding manner to "terrace slope" and "terrace brink" (Figs. 9, 10).

3.7.11.7.b A *marine terrace* (marin terrasse) is a terrace built up towards the current sea level by deposition of superficial deposits, and/or cut by wave erosion in bedrock or superficial deposits.

3.7.11.7.c A *raised beach terrace* (strandterrasse) is a narrow terrace representing a former marine or lacustrine shore zone.

3.7.11.7.d A *kame terrace, ice-contact terrace* or *valley-side terrace* (kameterrasse, iskontaktterrasse, dalsideterrasse) largely consists of water-transported material piled up along the side of a valley glacier. The terrace slope may have originated as an ice-support contact, an erosion surface, or as a combination of both mechanisms.

3.7.11.7.e A *shoreline* is the line of intersection between land and sea, or between land and a lake. Levels of former shorelines (*strandlines*, strandlinjer)) can be defined by a raised beach terrace, a raised beach ridge, an erosion notch in bedrock or superficial deposits (a shore notch) and a delta surface. Former shoreline levels may also be defined litho- and biostratigraphically.

3.7.11.7.f Terraces and shoreline levels can be given formal or informal names, and can provide a basis for morphostratigraphical classifications (Section 3.10, Fig. 26).

3.7.11.8 *Example*: The Trøndelag Platform (Gabrielsen et al. 1984) is one of several structural platforms on the Norwegian continental shelf.

3.7.11.9 *Key reference*: Bates & Jackson (1980).

3.7.12 Escarpment (skrent)

3.7.12.1 An *escarpment* is a long, more or less continuous, steep slope facing in *one* main direction. It usually separates two more gently sloping surface segments and is produced by faulting or erosion, or by both agencies in combination. An escarpment may be a present-day or former landform, or a structural form element (Figs. 9, 10).

3.7.12.2 An escarpment is a form element which, as regards height, is located between a high and a depression (Fig. 8).

3.7.12.3 No limitations are placed on the extent of an escarpment.

3.7.12.4 An escarpment is mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.12.5 An escarpment of regional extent will be divisible into segments which may have different strikes and dips.

3.7.12.6 An escarpment can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). An escarpment can be given a geographical name (or an alternative name on the continental shelf) that can be identical to the proper name of the fault that it follows, or the platform or plateau that it delimits. The proper name (Section 2.2.2) is placed between the words "the ... Escarpment" (formal) in the compound name.

3.7.12.7 An escarpment can become geomorphologically expressed along a fault, be a steep slope bounding a plateau or platform, or be a terrace slope. An escarpment can be a "rock escarpment", or a "superficial deposit escarpment" where the rock surface is covered by superficial deposits. An escarpment can also be a structural feature that is provable seismically.

3.7.12.8 *Example*: Gabrielsen et al. (1984) defined the Vøring Plateau Escarpment (Vøringplatåets brattkant). According to this Code, this should be called the Vøring Escarpment (Vøringskrenten). This is a structural form element.

3.7.12.9 *Key references*: Gjessing (1978), Bates & Jackson (1980).

3.7.13 Depression, Low (Senkning, Søkk)

3.7.13.1 A *depression* is a present-day or former, negative landform and/or a structural feature of non-specified origin and shape. A *low* is (a) a negative structural feature of non-specified origin and shape, or (b) a negative geophysical anomaly (Figs. 9, 10).

3.7.13.2 Depression is a general term for a low-lying geological or geomorphological feature which is usually entirely surrounded by higher ground. Low is a corresponding general term used in a structural context and to characterize a negative geophysical anomaly. Elongate depressions or lows may be open at one or both ends.

3.7.13.3 No limitations are placed on the dimensions of depressions or lows.

3.7.13.4 The structures are mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.13.5 Depressions and lows will often be divisible into smaller geomorphological and structural features, or smaller geophysical anomalies.

3.7.13.6 Depressions and lows may be given formal or informal names in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). A proper name (Section 2.2.2) is placed between the words "the ... Depression" or "the ... Low" (formal) in the compound name. The type of data used as the basis for the designation can be indicated by inserting an adjective such as "gravimetric" or "magnetic" before "low". If a depression or low is known to have a structural origin, this can be conveyed by writing "structural depression" or "structural low".

3.7.13.7.a Depressions or lows may be parts of larger geomorphological, structural or geophysical features. They enjoy a corresponding status among negative features to that held by highs among positive ones. A *structural* depression or low need not be, or have been, expressed geomorphologically.

3.7.13.7.b The term *caldera* (kaldera) is used for a circular or oval, volcanic depression whose diameter is substantially larger than its depth.

3.7.13.8 *Examples*: The general term "depression" can be used for all large and small negative landforms and large ocean basins. Examples of named continental depressions are the Qattar Depression in Egypt and the Turfan Depression in Sinkiang in western China.

3.7.13.9 *Key references*: Gjessing (1978), Bates & Jackson (1980).

3.7.14 Basin (Basseng)

3.7.14.1 A *basin* is a present-day or former landform and/or structural form element. Basins can have any shape whatsoever in horizontal section. A basin is often bounded by faults. It often contains sedimentary and/or volcanic strata (Figs. 9, 10).

3.7.14.2 Any basin can also be classified as a depression.

3.7.14.3 No limitations are placed on the dimensions of a basin.

3.7.14.4 A basin is mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.14.5 A basin will often be divisible into smaller geomorphological and/or structural elements.

3.7.14.6 A basin can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). The proper name (Section 2.2.2) is placed between the words "the ... Basin" (formal) in the compound name.

3.7.14.7.a A structural basin need not be, or have been, a landform. *Sub-basins* (underbassenger) are small basins which, in structural terms, form part of a larger, main basin. *Palaeobasins* (paleobassenger) are former basins that are no longer geologically active, either tectonically or sedimentologically.

3.7.14.7.b *Rooted palaeobasins* (rotfaste paleobassenger) are former basins situated where they originally formed, and are recognized by the preservation of their primary shape, structural framework and a basinal stratigraphical sequence. Rooted palaeobasins are given formal or informal names. A specific sedimentary basin related to a certain unit within a stratigraphical succession (a member, formation or group) can be named, preferably informally, after the relevant lithostratigraphical unit. Structural basins on the continental shelf are rooted palaeobasins.

3.7.14.7.c1 *Rootless palaeobasins* (rotløse paleobassenger) are former basins which can only be recognized because a basinal stratigraphical succession is preserved. The original sedimentary surfaces of the basin may be entirely or partially destroyed by tectonic deformation. Rootless palaeobasins exist as transported sequences in thrust nappes.

Rootless palaeobasins are to be named after the lithostratigraphical unit defining the basin. The proper name used for that unit will be the only relevant geographical name that can be naturally associated with the former basin.

3.7.14.7.c2 Rootless palaeobasins which have previously had a very large regional distribution, such as an enclosed ocean or ocean arm, should be given names that are *not* derived from any present-day land or sea area, or from any existing, named structural element. Such names may have a mythological origin (e.g. Tethys Ocean, Iapetus Ocean).

3.7.14.8 *Examples*: The Tromsø Basin (Rønnevik et al. 1975b) is a rooted structural basin on the continental shelf. The Valdres Basin, the Hedmark Basin and the Engerdal Basin are rootless, Late Precambrian basins (Kumpulainen & Nystuen 1985). In Finnmark, Siedlecka (1985) has defined the Late Precambrian Barents Sea Basin, which is also a rootless palaeobasin. The Kråkenes Basin is an example of a small Quaternary basin of sedimentation (Larsen & Mangerud 1981).

The Zechstein Basin is named after the lithostratigraphical unit, Zechstein, which defines the distribution and history of the basin (Taylor 1984).

3.7.14.9 *Key reference*: Bates & Jackson (1980).

3.7.15 Trough (Trau)

3.7.15.1 A *trough* is a long, narrow, negative geomorphological and/or structural form element that is delimited by steep flanks relative to its surroundings. Its flanks may be defined by faults (Figs. 9, 10).

3.7.15.2 Every trough is a basin and a depression.

3.7.15.3 Troughs are regional in size.

3.7.15.4 The structure is mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.15.5 A trough may occur as an isolated, independent form element, but can also be part of a larger geomorphological and/or structural feature. A trough will often be divisible into smaller form elements.

3.7.15.6 A trough can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). The proper name (Section 2.2.2) is placed between the words "the ... Trough" in formal names.

3.7.15.7.a A trough that can be shown to be fault-bounded, is a *graben* or *rift* (Section 3.7.16).

3.7.15.7.b A *trench* (grøft) is also a long, narrow, negative geomorphological and/or structural form element, but is bounded by steeper flanks relative to its surroundings than a trough. The term trench is especially used for elongate, regional, sea-floor depressions in plate tectonic contexts ("oceanic trench", dyphavsgrøft). These can be given formal or informal names.

3.7.15.7.c The term *channel* (renne) is used in a geomorphological context for an elongate, narrow depression, such as a marginal meltwater channel (spylerenne), in Quaternary geology. In marine geology, a channel is a long, narrow depression on the sea floor which may have a regional extent; it can be given an informal or a formal name. A regional, deep submarine channel should be called a trench, *not* a channel.

3.7.15.7.d *Channel* (kanal), used in a coastal geomorphological context, characterizes (1) a narrow strip of sea or lake separating two landmasses and connecting two large bodies of water, and (2) the deeper part of a body of water through which the main current flows, or that is most suitable for shipping – usually called "renne" in Norwegian. Channels are generally given proper names.

3.7.15.7.e A *canyon* (gjel, juv) is a deep, steep-sided valley formed by river or submarine erosion (submarine canyon, undersjøisk gjel). A *gorge* resembles a canyon, but is generally smaller. Prominent canyons and gorges often have local proper names.

3.7.15.8 *Examples*: The Bamble Trough (Bambletrauet) is a structural trough (Rønnevik et al. 1975b). Examples of plate tectonic ocean trenches are the Mariane Trench (Marianegrøfta), Japan Trench (Japangrøfta) and Peru–Chile Trench (Peru–Chile-grøfta). The Norwegian Trench (Norskerenna) is an example of a submarine channel, whilst Jutulhogget in east central Norway and Savco, near Alta, in northern Norway are examples of canyons (gjel).

3.7.15.9 *Key reference*: Bates & Jackson (1980).

3.7.16 Graben (Graben)

3.7.16.1 A *graben* is an elongate, negative structural form element bounded by parallel or nearly parallel faults along one or both flanks. It need not be, or have been, a landform.

3.7.16.2 Graben is a genetical term for a negative structural form element.

3.7.16.3 No limitations are placed on the dimensions of a graben.

3.7.16.4 Grabens are mappable with the help of geomorphological, geological and/or geophysical methods.

3.7.16.5 A graben may occur as an isolated, independent form element, but can also be part of a larger geomorphological and/or structural feature. A graben will often be divisible into smaller form elements.

3.7.16.6 A graben can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form elements (Section 3.7.1). The proper name (Section 2.2.2) is placed between the words "the ... Graben" (formal) in the compound name.

3.7.16.7 The following form elements are also covered by the general term "graben":

3.7.16.7.a *Rift* (rift), which is a long, narrow depression bounded along its flanks by normal faults. It is a graben of regional extent, and marks a zone where the lithosphere has been completely or partially ruptured during extension.

3.7.16.7.b *Aulacogen* (aulakogen), which is an elongate, tectonic depression bounded by convergent normal faults. It is a graben of regional extent on a continent, and opens towards the sea.

3.7.16.7.c *Pull-apart basin* (skjærbasseng), which is a rhomb-shaped graben formed between two strike-slip faults.

3.7.16.7.d *Rift valley* (riftdal), which is a negative landform (depression) developed along a rift.

3.7.16.7.e *Half graben* (halvgraben), which is a graben bounded by one or more parallel, or nearly parallel, faults along the one long side and by a flexure along the other.

3.7.16.7.f Rifts, aulacogens, pull-apart basins, rift valleys and half grabens can be given formal or informal names.

3.7.16.8 *Examples*: The Viking Graben (Vikinggrabenen) and Central Graben (Sentralgrabenen) are two prominent graben structures in the North Sea (Ziegler 1982). The Oslo Graben is a palaeograben which today largely stands out as a series of highs because of erosion down to the massive, Permian plutons inside the graben structure.

3.7.16.9 *Key reference*: Bates & Jackson (1980).

3.7.17 Syncline (Synklinal)

3.7.17.1 A *syncline* is a fold which is usually concave upwards, and which has the stratigraphically youngest beds in its core. It is a structural form element that need not be, or have been, a landform.

3.7.17.2 Syncline could be a genetical term for a negative structural form element.

3.7.17.3 No limitations are placed on the dimensions of a syncline.

3.7.17.4 A syncline is mappable with the help of geological and/or geophysical methods.

3.7.17.5 A syncline can include several smaller structural elements.

3.7.17.6 A syncline can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the rules for naming geological form units (Section 3.7.1). The proper name (Section 2.2.2) is placed between the words "the ... Syncline" (formal) in the compound name.

3.7.17.7.a A *synform* (synform) is a fold which is concave upwards, and in which the beds are inverted or their relative age is unknown.

3.7.17.7.b A *synclinorium* (synklinorium) is a negative, structural form element of regional extent composed of several smaller folds, and in which the stratigraphically youngest beds occur in the core.

3.7.17.7.c Synforms and synclinoria can be given formal and informal names.

3.7.17.8 *Examples*: The Østmarka Syncline (Østmarksynklinalen), defined by Graversen (1984), is found in the basement in South Norway. Foslie (1949) named a prominent fold in the Caledonian nappes of Ofoten, North Norway, Håfjellmulden (the Håfjell syncline), but it has now been redefined (Gustavson 1972) as the Ofoten Synform (Ofotsynformen).

3.7.17.9 *Key reference*: Bates & Jackson (1980).

3.8 Linear structural units

3.8.1 General properties and rules

Linear structural units include all large and small structures which have properties resembling a line. It is not relevant to give small *lineations* in a rock (e.g. parallel-oriented mineral grains, slickensides and fold axes) a proper name, and these will not be dealt with here. Linear structural units also include major, straight or curved structures which stand out because of special features in the bedrock and landscape, and which can be clearly seen on satellite photographs, aerial photographs or maps. Such linear elements may originate from surface traces of various planar- or linear-shaped structures and crustal features (Figs. 14, 15). When they are recorded, their origin may often be unknown, uncertain, only partially clarified, or mixed. These types of structure are recorded by one or more remote sensing (fjernanalyse) methods and are grouped under the term "*lineaments*" (lineamenter). Increasing use of remote-sensing techniques in recent years has created a need for a uniform terminology for lineaments. The units in this category are lineaments and lineament zones.

Nomenclature

Names are applied in accordance with the "general rules for naming and defining geological units" (Chap. 2). It is recommended that only the most prominent lineaments and lineament zones are defined formally and given formal proper names. The proper name component of the formal name should consist of either one geographical name or two geographical names joined by a dash. These two names should be chosen from places situated close to the extremities of the structure (see Section 2.2.3). On the continental shelf, other names than geographical ones may be used (Section 2.2.4). The lineament structure can be redefined when its mode of formation has been clarified (Section 2.5.1).

3.8.2 Lineament (Lineament)

3.8.2.1 A *lineament* is a linear or curvilinear feature that is directly visible on the Earth's surface, or stands out on either topographical or geophysical maps, or on satellite or aerial photographs. Lineaments are assumed to reflect a geological inhomogeneity in the bedrock, such as a fracture, rock boundary, fold, linear rock body or ore body (Figs. 14, 15). Lines of intersection between the surface and foliations are not looked upon as lineaments.

3.8.2.2 Lineament is the fundamental term for a linear structure of unknown, uncertain, partly known or mixed geological origin.

3.8.2.3 No limitations are placed on the dimensions of a lineament in the field, but on the scale on which it is relevant to show it a lineament is depicted as a *line*.

3.8.2.4 The structure is mappable at the surface with the help of geomorphological, geological or

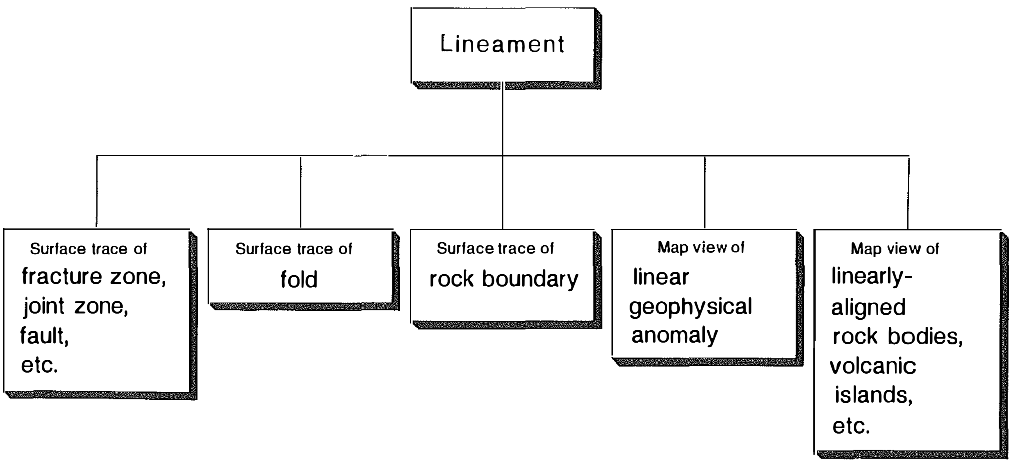


Fig. 14 Linear structural units. Lineaments are topographical features reflecting surface traces of various crustal structures.

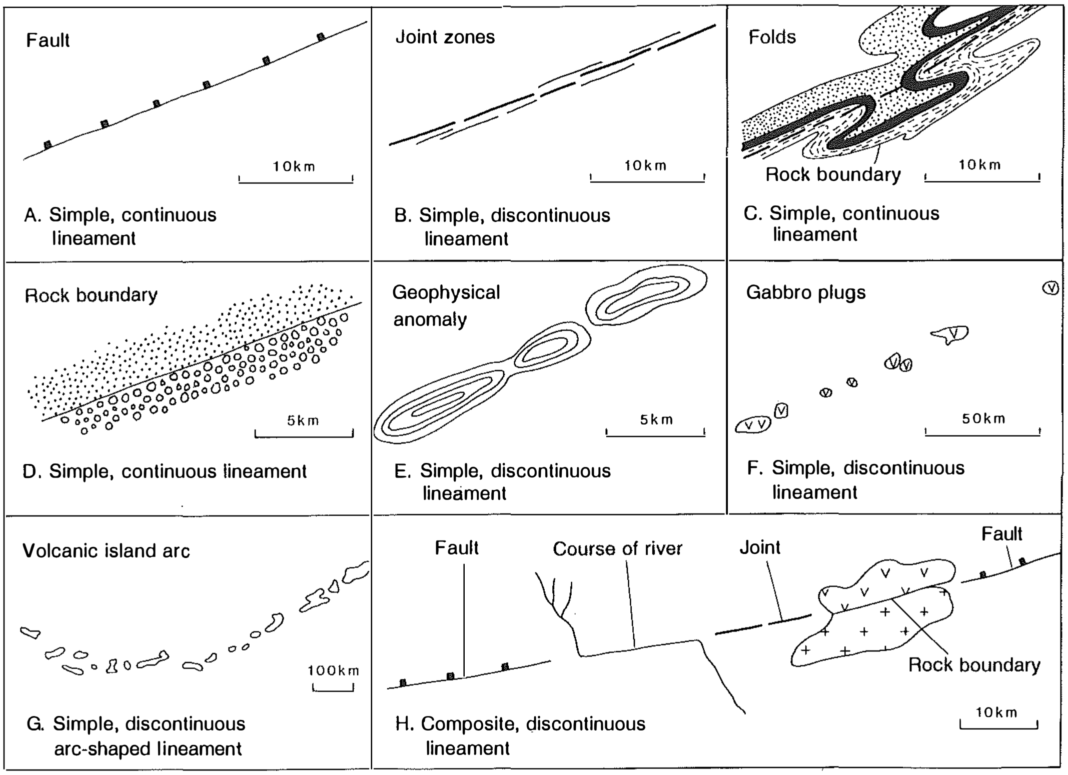


Fig. 15 Lineaments of various types and origins viewed vertically.

geophysical methods. A lineament can be defined on the basis of one or more types of remote-sensing data, such as satellite or aerial photographs, gravimetric, magnetic and seismic measurements, etc.

3.8.2.5 A lineament often consists of two or more parallel or subparallel, straight or gently curved linear segments. These segments may have different origins and extents, and may form parts of *continuous* or *discontinuous lineaments* (Fig. 15). Discontinuous lineaments consist of separate linear segments having a common orientation and located close to each other. *Simple lineaments* (enkle lineamenter) are formed by one type of linear feature, whereas *composite lineaments* (sammensatte lineamenter) consist of more than one linear feature in the bedrock (Fig. 15). A lineament that is defined on the basis of small-scale remote-sensing data (e.g. a satellite photograph) will therefore usually be resolvable into several smaller simple lineaments to emerge as a lineament zone when the structure is analyzed on a larger scale.

3.8.2.6 Lineaments are given informal and formal names in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.8.1. The data providing the basis for recognition of the lineament can be indicated by a descriptive term, such as "photolineament" and "gravimetric lineament". A lineament can be redefined when its geological origin has been shown to be, for example, the surface trace of a fracture zone, joint zone, fault, fault zone, fault system or fault complex. When such redefinition of a formal lineament takes place the original geographical name can be retained (Section 2.5.1).

3.8.2.7.a An *arc* (bue) is a curvilinear feature of structural origin (Fig. 15). An arc must not be confused with an arch (hvelv) which is a broad, open antiform of regional dimension (Section 3. 7.9.7.c). Because of the arc-shape of many rows of volcanic islands, island arcs (øybuer), the term "arc" has also gradually acquired a significance in a general plate tectonic context as the long, uplifted magmatic or structural central zone of a mobile belt, even if this zone is almost straight.

3.8.2.7.b The term linear (lineær) is *not* to be used as a synonym for lineament. It should only be used as an adjective, such as in "linear structure" (lineær struktur) and corresponding terms (O'Leary et al. 1976).

3.8.2.8 *Examples*: On the basis of the 1:1 million scale topographical map of Norway, Kjerulf (1876, 1879) defined many linear structures which, in his cartographical presentation, have the character of lineaments. The term lineaments (lineamenter) was used by Hobbs (1904, 1911) for Kjerulf's (1876, 1879) linear structures. Gabrielsen & Ramberg (1979) found that these linear structures were zones and called them "intensity zones"; these features are lineament zones according to this Code. On Varangerhalvøya, the Trollfjord–Komagelv fault zone, originally named and interpreted as a thrust fault by Siedlecka & Siedlecki (1967) is definable as a lineament on NOAA and Landsat satellite photographs (Gabrielsen 1984). The Bergen Arcs, or the inner and outer Bergen Arcs (Kolderup & Kolderup 1940), are examples of curvilinear features having the character of lineament zones. Island arcs are examples of large, regional arc structures (Fig. 15).

3.8.2.9 *Key references*: Hobbs (1904), El-Etr (1976), Hobbs et al. (1976), O'Leary et al. (1976), Sabins Jr. (1978).

3.8.3 Lineament Zone (Lineamentsone)

3.8.3.1 A *lineament zone* consists of several, geometrically closely associated lineaments occurring within a long, narrow geographical area. The lineaments in the zone may be genetically associated with one another, but this is not a prerequisite.

3.8.3.2 A lineament zone is a linear unit ranking next above a lineament.

3.8.3.3 The breadth of a lineament zone is defined by the outermost lineaments in the zone. No other limitations are placed on the extent of a lineament zone.

3.8.3.4 The zone is mappable with the help of geomorphological, geological and/or geophysical methods. The degree of detail in the cartographical presentation of a lineament zone will depend upon the map scale and the information available.

3.8.3.5 A lineament zone can consist of several segments of different origin or geometry. The segments may form part of a continuous or discontinuous lineament zone (Fig. 15).

3.8.3.6 Lineament zones are given informal or formal names in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.8.1. The information that enables the lineament zone to be recognized can be indicated by a descriptive term such as "photolineament zone", and "gravimetric lineament zone". A lineament zone can be redefined when the geological origin of the structure is shown to be, for example, surface traces of a fracture zone, joint zone or fault zone. When a formal lineament zone is redefined, the proper name originally given to the zone can be retained (Section 2.5.1).

3.8.3.7 Lineament zone corresponds to features which El-Etr (1976) called "linear set" and "linear master set", and should be used in preference to those terms.

3.8.3.8 *Examples*: Hobbs (1904, 1911) referred to Kjerulf's (1876, 1879) linear structural elements in South Norway as lineaments, e.g. "Christiania lineament". Gabrielsen & Ramberg (1979) called this "the Oslo–Trondheim intensity zone", but here it is renamed the Oslo–Trondheim lineament zone. Other examples based on Gabrielsen & Ramberg (1979) are the Møre–Trøndelag lineament zone and the Agder lineament zone.

3.8.3.9 *Key reference*: Hobbs (1904) described lineament zones, but did not use the term himself.

3.9 Planar structural units

3.9.1 General properties and rules

Planar structural units include many large- and small-scale structures, such as cleavages, foliations, axial planes, joints and faults. This Code only deals with those structures which are sufficiently large and prominent to be mappable at ordinarily used map scales, and which can be recorded directly in the field or with the aid of remote sensing. They are surfaces formed by fracturing (Fig. 16), i.e. *fracture zones, joint zones, faults, fault zones, fault complexes, fault systems* and *thrusts*. Subtypes, variants and related units are included in several of these unit divisions. The mutual relationship between units with the rank of zone, set, system and complex is shown in figure 17. Unconformity surfaces are dealt with separately in Section 3.7. The units dealt with in the present section can be given formal names. The proper name component can consist of one or two geographical names (or alternative names on the continental shelf, Section 2.2.4). If two geographical names are used these should be names of places near the extremities of the structure. These names should be linked with a dash (see Chapter 2 and Section 2.2.3). When thrusts are being named (Section 3.9.9) these are to be given the same geographical name as the proper name of the nappe or thrust sheet of which they form the floor or sole.

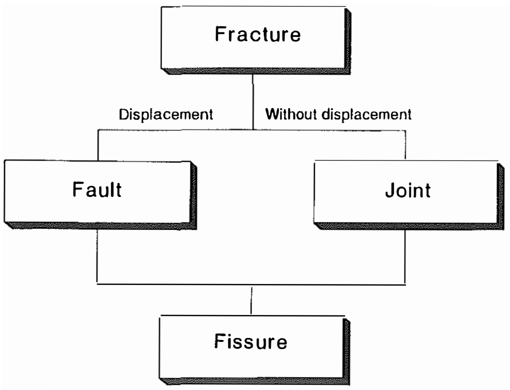


Fig. 16 Relationship between the terms fracture, fault, joint and fissure.

3.9.2 Fracture Zone (Bruddsone)

3.9.2.1 A *fracture zone* is a composite structure consisting of several neighbouring fracture surfaces (joints and/or faults). These may be genetically related to one another, but this is not a prerequisite (Fig. 17).

3.9.2.2 Fracture zone ranks next above fracture (fracture surface).

3.9.2.3 A fracture zone crops out in a long, narrow geographical area. Its breadth is defined by the outermost fractures in the zone. No other limitations are placed on the extent of a fracture zone.

3.9.2.4 A fracture zone is mappable at the surface and/or traceable in the subsurface with the help of geomorphological, geological or geophysical methods. The degree of detail in the cartographical presentation of a fracture zone will depend on the map scale and the knowledge available.

3.9.2.5 In many places a fracture zone will be characterized by irregular landscape features. It may be marked by long, narrow ridges or depressions, depending upon the type of deformation within the fracture zone and the competency of adjacent rocks.

3.9.2.6 A fracture zone can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.9.1. The proper name (Section 2.2.2) is placed between the words "the ... Fracture Zone" (formal) in the compound name.

3.9.2.7.a Fracture zones can occur within continental and ocean-floor crust, as well as between lithospheric plates of identical or different composition and origin. Fracture zones can form geomorphological features on land and on the sea floor. In a plate tectonic context the term fracture zone (bruddsone) is used about the extension of a transform fault. When the term is used in this context the descriptive term "oceanic" can be used in the compound name.

3.9.2.7.b *Fracture* (brudd) is a general term for all kinds of fracturing caused by mechanical stresses in the bedrock, irrespective of whether dislocation has taken place along the fracture. Fractures include joints and cracks (sprekker), and faults (forkastninger) (Fig. 16).

3.9.2.7.c A *fracture system* (bruddsystem) is a group of closely spaced fractures that are parallel to, or intersect each other, and that are assumed to have formed during the same deformational episode. Fracture systems should preferably only be given informal names (Fig. 17).

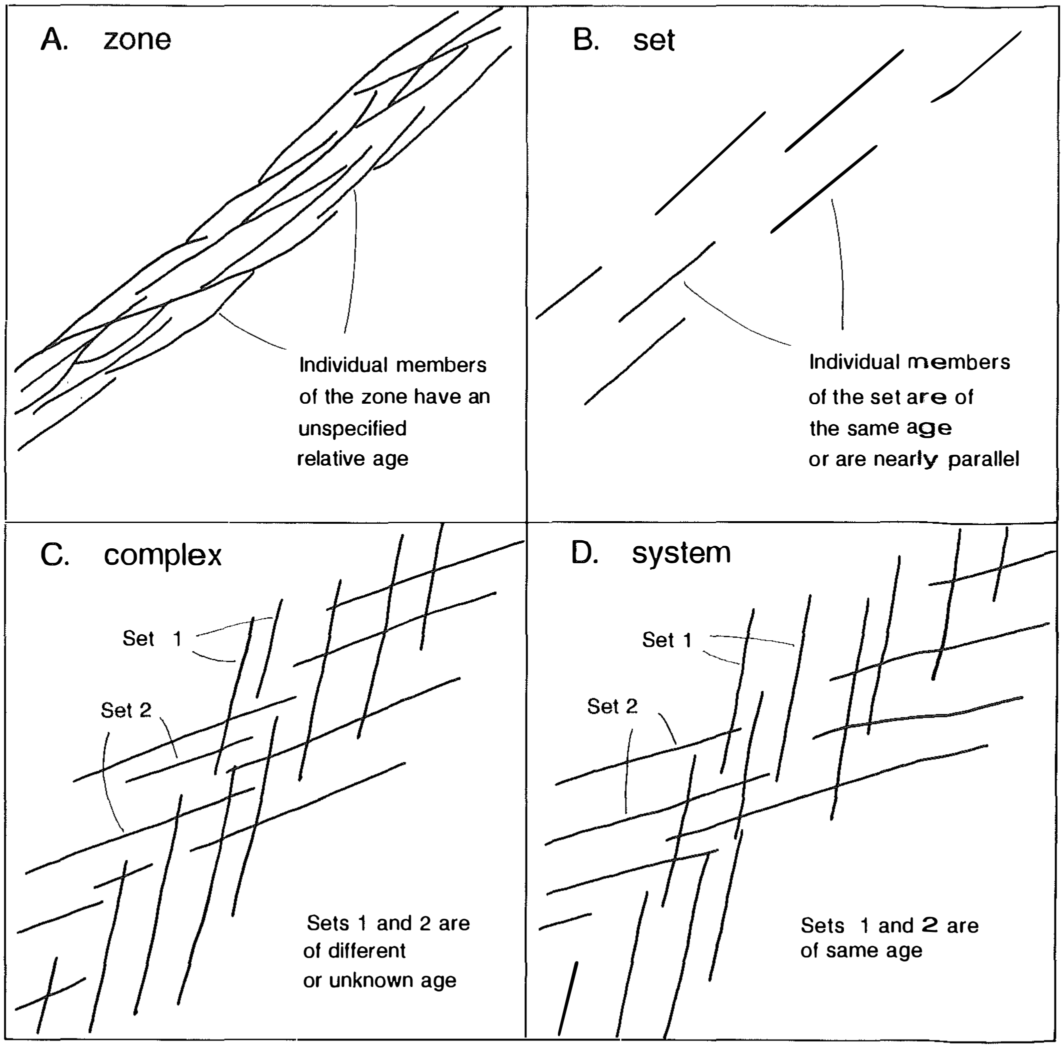


Fig. 17 Mutual relationship between the terms zone, set, complex and system as used in connection with fractures, joints and faults.

3.9.2.8 *Examples*: The Mjøsa–Vänern Fracture Zone (Oftedahl 1980) is a broad, geologically composite fracture zone in continental crust. The Jan Mayen Fracture Zone (Johnson & Heezen 1967) is one of several oceanic fracture zones which have originated by ocean-floor spreading in the Norwegian Sea. These are all characterized by being prominent, irregular, submarine form elements (Grønlie & Talwani 1977, Talwani & Eldholm 1977).

3.9.2.9 *Key references*: Anderson (1951), Price (1968), Bates & Jackson (1980).

3.9.3 Joint Zone (Sprekksone)

3.9.3.1 A *joint zone* is a structural unit composed of several adjacent joints. These may be genetically related to one another, but this is not a prerequisite (Fig. 17).

3.9.3.2 Joint zone ranks next above joint.

3.9.3.3 A joint zone crops out within a long, narrow geographical area. The breadth of the zone is defined by the outermost joints in the zone. No other limitations are placed on the extent of the zone.

3.9.3.4 The structure is mappable at the surface and/or traceable in the subsurface with the help of geomorphological, geological or geophysical methods. The degree of detail in the cartographical presentation of a joint zone will depend upon the map scale and the knowledge available.

3.9.3.5 A joint zone will often be characterized by irregular landscape features, and frequently coincides with valleys and depressions.

3.9.3.6 A joint zone is given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.9.1. The proper name (Section 2.2.2) is placed between the words "the ... Joint Zone" (formal) in the compound name.

3.9.3.7.a A *joint* (sprekk, sprekkflate) is a fracture surface in the rock along which no displacement has taken place. Joints are usually smooth and planar.

3.9.3.7.b A *joint set* (sprekksett) is a group of more or less parallel, closely spaced joints assumed to have been formed during the same deformational event (Fig. 17).

3.9.3.7.c A *joint system* (sprekksystem) is composed of two or more intersecting joint sets assumed to have been formed during the same deformational event (Fig. 17).

3.9.3.7.d A *joint complex* (sprekk-kompleks) is composed of two or more intersecting joint sets formed during different deformational events, or having unknown age relationships (Fig. 17).

3.9.3.7.e A *fissure* (spalte) is an open joint or crack, or one which clearly has been open but which has subsequently become filled with mineral growth (e.g. quartz-filled feather joints).

3.9.3.7.f A *fissure system* (spaltesystem) comprises several parallel, closely spaced fissures assumed to be of the same age (Fig. 17).

3.9.3.7.g Structural features b-f should preferably be given informal names (Section 2.3).

3.9.3.8 *Examples*: There are no examples of named joint structures in Norway. The formation of certain joints and their influence on the pattern of fjords in western Norway has been much discussed (e.g. O. Holtedahl 1956, H. Holtedahl 1967, Nilsen 1973, Roberts 1973).

3.9.3.9 *Key references*: Hobbs (1911), Anderson (1951), Price (1968).

3.9.4 Fault (Forkastning)

3.9.4.1 A *fault* is a fracture separating two bodies of rock which have moved relative to one another. When the dip of the fault surface is less than 90°, the wall rock above the surface is termed the hanging wall (hengen) and that below it the footwall (liggen) (Fig. 18).

3.9.4.2 Fault is the fundamental term for a fracture surface in the crust on which displacement has occurred.

3.9.4.3 No limitations are placed on the dimensions of a fault as regards its geographical extent or displacement. The displacement need not necessarily be capable of demonstration on the map scale on which the fault is portrayed.

3.9.4.4 The structure is mappable with the help of geomorphological, geological and/or geophysical methods. On a map, a fault will normally be depicted as a line, but when large-scale mapping takes place many faults will be subdivisible into subsidiary faults and fault segments.

3.9.4.5 A fault may consist of (a) *one* boundary surface between two rock bodies which have been displaced relative to each other, or (b) a zone of bedrock between two fault blocks, which is characterized by a branching pattern of surfaces on which displacement has taken place. A zone of this nature will have a different structural character from the bedrock in the two fault blocks, and may consist of cataclastic (e.g. fault breccia) or mylonitic rocks. A fault may also (c) be developed partly like (a) and partly like (b).

3.9.4.6 A fault is given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.9.1. The proper name (Section 2.2.2) is placed between the words "the ... Fault" (formal) in the compound name.

3.9.4.7 There are many types of faults. Faults may be classified according to (1) the relative displacement between the two adjacent bodies of rock and the slope of the fault surface, and (2) the geometrical relationship between the fault surface and the bedrock through which the fault passes (Dennis 1972). The descriptive part of the fault name will generally be related to the first classification method. Such faults comprise the following main types (Fig. 18):

3.9.4.7.a A normal fault, gravity fault, dip-slip fault or *normal slip fault* (normalforkastning) is one in which the hanging wall seems to have moved downwards relative to the footwall, chiefly along the dip of the fault surface. The dip of the fault surface is usually 45-90°. A distinction can be made between high-angle (more than 45°) and low-angle (less than 45°) normal faults.

Listric normal faults (listriske normalforkastninger) show decreasing dip towards depth (Fig. 18). They may be related to a *sole fault* (såleforkastning) or a *floor fault* (golvforkastning) formed by detachment (avglidning) of the hanging wall in relation to the footwall along a flat-lying fracture surface (Fig. 18). The hanging wall of a flat-lying fault of this kind may, in a basin formed by extension, consist of tilted, wedge-shaped blocks bounded laterally by listric normal faults (Bally et al. 1981, Wernicke & Burchfiel 1982, Gibbs 1984). Sole and floor faults are non-genetical designations for nearly flat-lying faults, and are also used for thrust faults (cf. Sections 3.9.9.7.a and 3.9.9.7.b).

3.9.4.7.b *A reverse fault* (reversforkastning) is one in which the hanging wall seems to have moved upwards relative to the footwall, chiefly along the dip of the fault surface. The dip of the fault surface is generally 45-90° (Fig. 19). When the angle of the fault surface decreases to less than 45°, a reverse fault becomes a thrust fault (Section 3.9.9).

3.9.4.7.c A *strike-slip fault, lateral fault, wrench fault* or *transcurrent fault* (sidelengsforkastning) is a fault where the relative displacement has chiefly taken place parallel to the strike direction of the fault surface. The fault surface usually has a steep dip. Vertical or nearly vertical strike-slip faults (transcurrent or wrench faults) may branch like a fan upwards or downwards in *flower structures* (blomsterstrukturer) (Harding 1985). There are two main varieties of strike-slip fault, c1 and c2 (Fig. 20).

3.9.4.7.c1 A *dextral fault, right-slip fault*, or *right-lateral fault* (høyrelengsforkastning, høyrehåndsforkastning, høyreglippforkastning) is one on which the displacement seems to have taken place towards the right.

3.9.4.7.c2 A *sinistral fault, left-slip fault*, or *left-lateral fault* (venstrelengsforkastning, venstrehåndsforkastning, venstreglippforkastning) is one on which the displacement seems to have taken place towards the left.

3.9.4.7.c3 An *oblique-slip fault* (skråforkastning) is one on which the displacement between the hanging wall and the footwall contains both a lateral component and one along the dip of the fault surface. Such faults can be normal oblique-slip faults and reverse oblique-slip faults of sinistral or dextral type.

3.9.4.7.c4 A *transform fault* (transformforkastning) is a variety of transcurrent fault found in a plate tectonic context (Wilson 1965). A transform fault connects two segments of a mid-oceanic ridge and therefore separates two lithospheric plates having opposite displacement directions. Away from the actively spreading ridge a transform fault can pass into an oceanic fracture zone (oseanisk bruddsone).

3.9.4.7.d *Thrust* or *thrust fault* (skyveforkastning) – see Section 3.9.9.

3.9.4.7.e All the terms mentioned under a-d can be used as descriptive terms in formal and informal names of faults.

3.9.4.8 *Examples*: The Oslo district has many examples of normal faults that have been recognized for a long time, e.g. the Nesodden Fault and the Ekeberg Fault (Holtedahl & Dons 1952). The Rendalen Fault and the Engerdalen Fault (Schiøtz 1902) are examples of regional

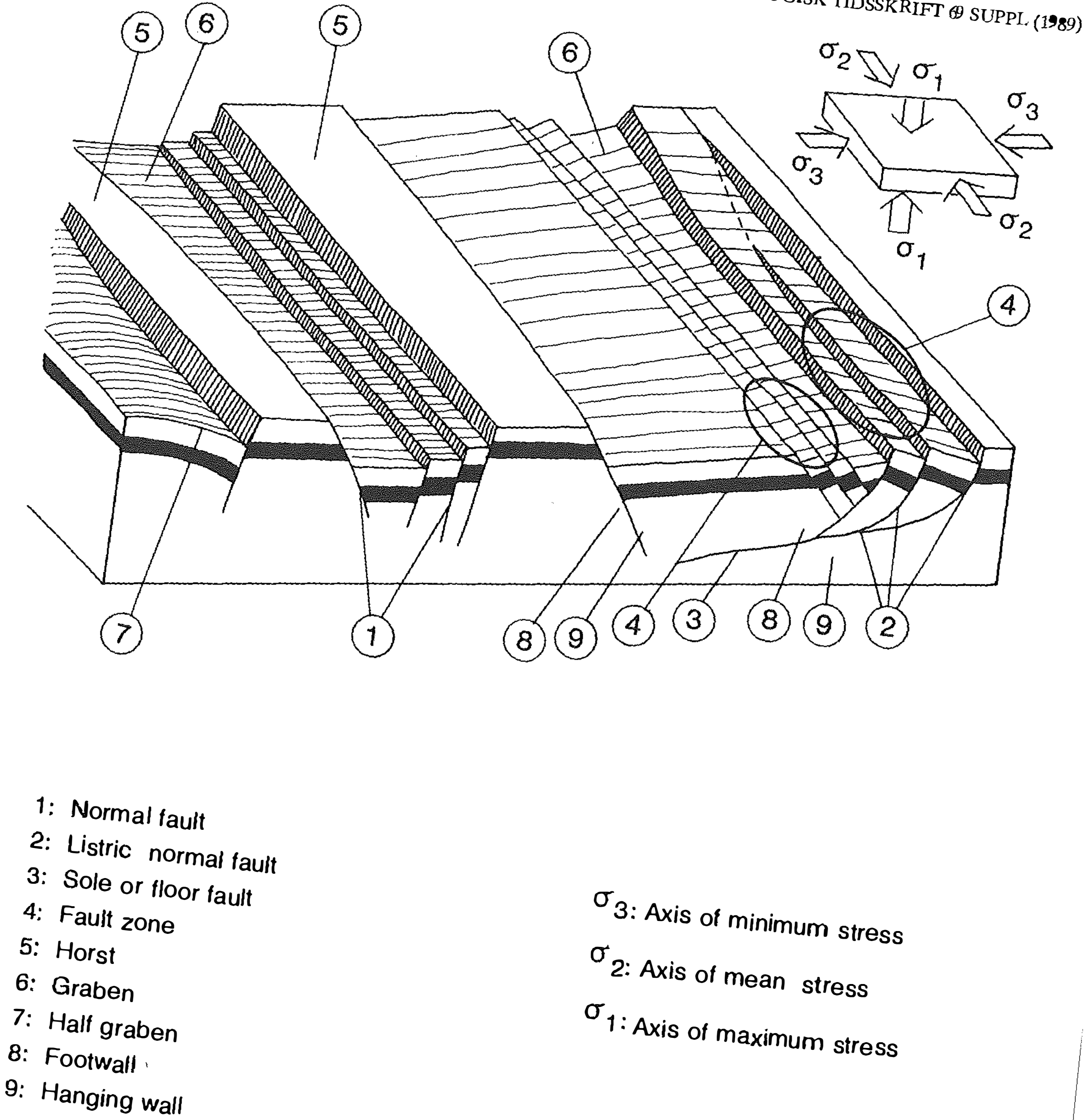


Fig. 18 Normal faults, fault zones, and horst and graben blocks formed in an extensional regime.

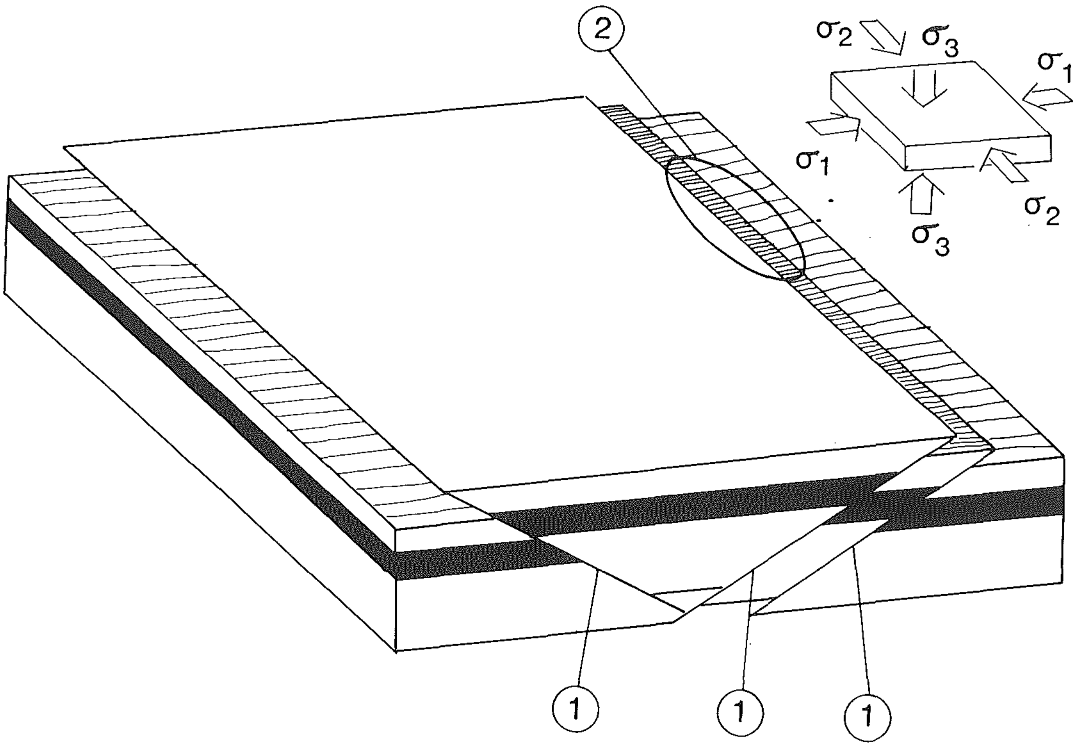


Fig. 19 Reverse faults and fault set.

normal faults which can be divided into several subfaults and fault segments.

3.9.4.9 *Key references*: Anderson (1951), Price (1965), Dennis (1972), Hobbs, Means & Williams (1976), Bates & Jackson (1980), Davis (1984).

3.9.5 Fault Zone (Forkastningssone)

3.9.5.1 A *fault zone* is a structural unit consisting of many closely spaced faults. Neighbouring areas are distinguished from the zone by having a considerably lower frequency of faults. In many cases, individual faults in the fault zone will have been formed in close association with each other, but this is not a prerequisite (Fig. 17).

3.9.5.2 Fault zone ranks next above fault.

3.9.5.3 The outcrop of a fault zone will normally be confined to a long, narrow geographical area. The breadth of a fault zone is defined by the

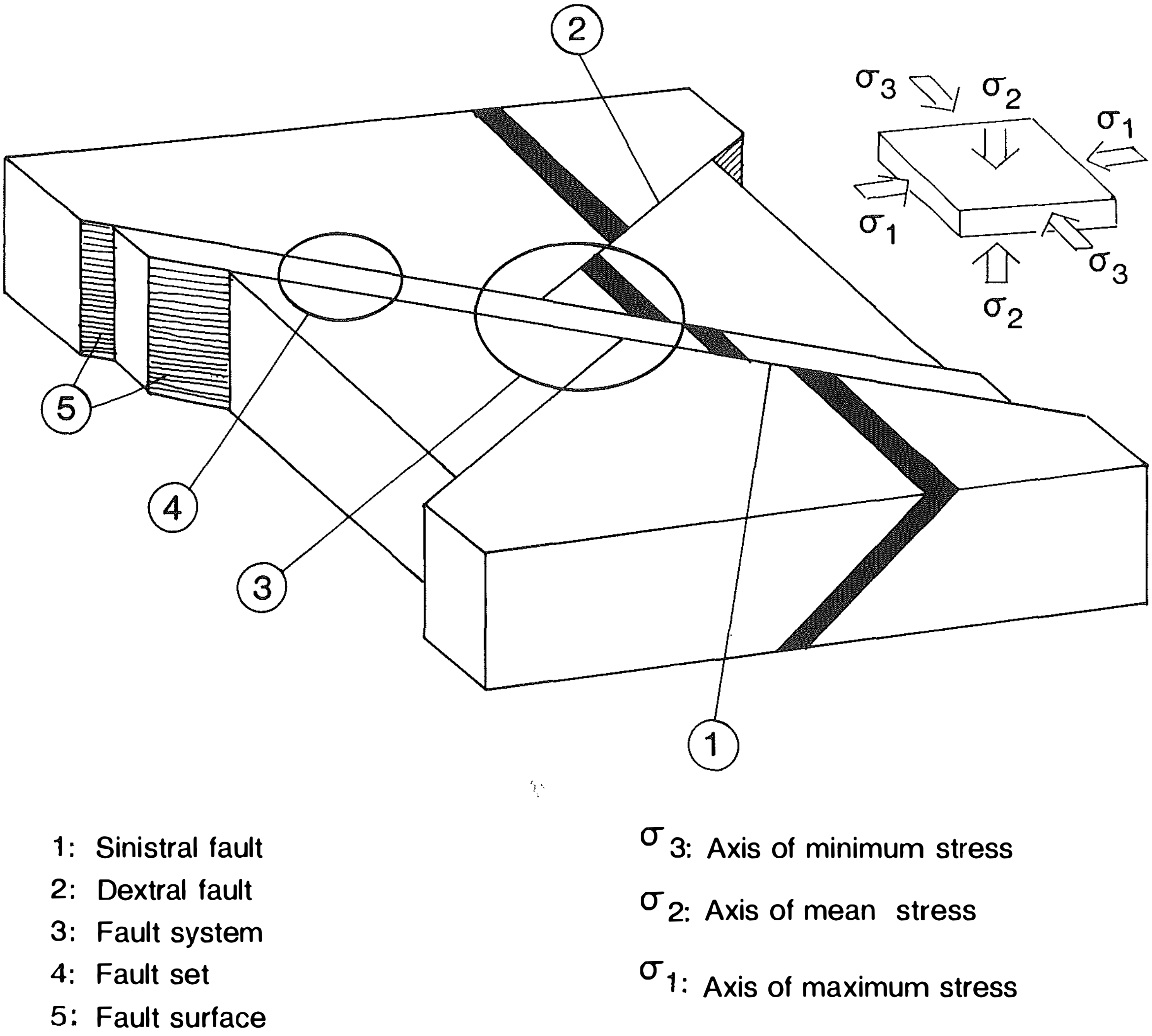


Fig. 20 Strike-slip faults, fault system and fault set.

outermost faults in the zone. No other limitations are placed on its dimensions.

3.9.5.4 The structure is mappable with the help of geomorphological, geological and/or geophysical methods. The expression of a fault zone on a map will depend upon the scale of the map.

3.9.5.5 Individual faults in a fault zone may be characterized by having identical or different structural character (see Section 3.9.4.5).

3.9.5.6 A fault zone is given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.9.1. The proper name (Section 2.2.2) is placed between the words "the ... Fault Zone" (formal) in the compound name.

3.9.5.7 A fault zone may be a fault set in which the individual faults are closely spaced. Fault zones may also define fault systems and fault complexes. Individual faults in fault zones are often *en echelon* oriented.

3.9.5.8 *Example*: The Møre–Trøndelag Fault Zone (Møre–Trøndelags-forkastningssonen) (Gabrielsen et al. 1984).

3.9.5.9 *Key reference*: Bates & Jackson (1980).

3.9.6 Fault set (Forkastningssett)

3.9.6.1 A *fault set* is a group of closely spaced, parallel or subparallel faults which can be thought to have formed during the same deformational event (Fig. 17).

3.9.6.2 Fault set, like fault zone, fault system and fault complex, ranks next above fault.

3.9.6.3 The breadth of a fault set is defined by the distance between the outermost of the parallel or subparallel faults which are assumed to be of the same age. No other limitations are placed on the extent of a fault set beyond those which are related to individual faults in the set.

3.9.6.4 The structure is mappable with the help of geomorphological, geological and/or geophysical methods.

3.9.6.5 Individual faults in a fault set may be characterized by having identical or different structural character (see Section 3.9.4.5).

3.9.6.6 A fault set is preferably given an informal name or designation (Section 2.3).

3.9.6.7 A fault set consists of faults formed when the stress field had a certain orientation, and will therefore be made up of a single type of fault – normal, reverse or lateral.

3.9.6.8 *Examples*: On Hardangervidda there is a fault set comprised of normal faults which are nearly parallel, strike NE-SW and are of post-Caledonian age (Naterstad et al. 1973, Jorde 1977). Olesen (1985) has described a fault set at Masi in Finnmark consisting of parallel normal faults which are of Late Pleistocene to Holocene age.

3.9.6.9 *Key reference*: Bates & Jackson (1980).

3.9.7 Fault Complex (Forkastningskompleks)

3.9.7.1 A *fault complex* comprises two or more intersecting or geometrically associated faults or fault sets of different ages or having unknown relative ages. It generally consists of individual faults formed during two or more deformational events (Fig. 17).

3.9.7.2 Fault complex, like fault zone, fault set and fault system ranks next above fault.

3.9.7.3 No limitations are placed on the extent of a fault complex beyond those which are related to the individual component faults.

3.9.7.4 The structure is mappable with the help of geomorphological, geological and/or geophysical methods.

3.9.7.5 A fault complex generally consists of faults having different structural character (see Section 3.9.4.5).

3.9.7.6 A fault complex should preferably be formally defined and named, this being done in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.9.1. The proper name (Section 2.2.2) is placed between the words "the ... Fault Complex" in the compound name.

3.9.7.7 Individual faults in a fault complex may be formed under different physical conditions and when stress fields have different orientations. A fault complex may therefore contain normal, lateral and reverse faults, and also faults having structural elements from all these three main types. Repeated fault movements along older fracture zones may give rise to a fault complex.

3.9.7.8 *Examples*: Gabrielsen & Robinson (1984) defined the Kristiansund–Bodø Fault Complex on the continental shelf off central Norway. The Ringvassøy–Loppa Fault Complex (Gabrielsen et al. 1984) is located on the continental shelf off Troms and Finnmark. The Trollfjord–Komagelv fault zone is also an example of a complex since the "zone" contains fault segments of different age (Gabrielsen 1984).

3.9.7.9 *Key reference*: Bates & Jackson (1980), but with the modification that a fault complex does not include fault sets of the same age (see fault system, below).

3.9.8 Fault System (Forkastningssystem)

3.9.8.1 A *fault system* consists of two or more intersecting or geometrically associated faults or fault sets assumed to have been formed during the same faulting episode (Fig. 17).

3.9.8.2 Fault system, like fault zone and fault complex, ranks next above fault.

3.9.8.3 No limitations are placed on the extent of a fault system beyond those applying to the individual faults in the system.

3.9.8.4 The structure is mappable with the help of geomorphological, geological and/or geophysical methods.

3.9.8.5 The individual faults in the fault system may have identical or different structural character (see Section 3.9.4.5).

3.9.8.6 A fault system should preferably be defined formally and is named in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.9.1. The proper name (Section 2.2.2) is placed between the words "the ... Fault System" in the compound name.

3.9.8.7 Fault systems are usually dominated by faults of one main type, normal, lateral or reverse faults. However, local variations in orientation of the principal stress axes may occur giving rise to genetically associated faults of two or all three main types within a single fault system. The locations of fault systems can be predetermined by older zones of crustal weakness. Fault systems can therefore be underlain by or associated with faults that were active during an earlier deformational episode.

3.9.8.8 *Examples*: No formally named fault systems are known from Norway or Norwegian territories. Several genetically associated fault sets on the continental shelf are likely to be fault systems according to the present definition. Faults that can most readily be defined as belonging to a single fault system are those formed in the roof rocks of rising magmatic bodies, salt domes and diapirs.

3.9.8.9 *Key reference*: Fault system has previously been used synonymously with fault set (Bates & Jackson 1980).

3.9.9 Thrust Fault, Thrust (Skyveforkastning)

3.9.9.1 A *thrust fault* or *thrust* is a fracture surface, or set of fracture surfaces, separating two rock bodies one of which, the *hanging wall* (hengen) has been displaced upwards across the *footwall* (liggen). Thrusts have originally been nearly horizontal or low-angle (less than 45°). Along a thrust, older rocks may be displaced across younger, or younger across older. Thrusts are formed by compression and imply horizontal shortening of the part of the crust that is deformed by the thrust (Fig. 21).

3.9.9.2 Thrusts often occur together in a branching *thrust system* (skyveforkastningssystem) in which the individual thrusts have different rank or order, with major thrusts (hovedskyveforkastninger) and subordinate or minor thrusts (underordnete or mindre forkastninger) (Figs. 22, 27).

3.9.9.3 No limitations are placed on the dimensions of thrusts, either geographically or as regards displacement.

3.9.9.4 The structure is mappable with the help of geomorphological, geological and/or geophysical methods.

3.9.9.5 A thrust is generally distinguished by a zone of bedrock which differs structurally from neighbouring bedrock. Such a zone may consist of cataclastic or mylonitic rocks. When the thrust consists of a set of fracture surfaces, these will often delimit lens-shaped bodies of rock in the movement zone.

3.9.9.6 A thrust can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2). A thrust which forms the floor thrust of a specific nappe or thrust sheet should be given the same geographical name as the nappe or sheet. When choosing the geographical name for a thrust, care should be taken to ensure that this name is also suitable for the tectonostratigraphical unit which overlies the thrust. If there is no danger of misunderstanding, the word fault alone can be used in the name of a thrust fault.

3.9.9.7 Modern literature dealing with thrusts (Elliott & Johnson 1980, Boyer & Elliott 1982, Butler 1982) employs several terms which have not yet been given Norwegian names. Thrust faults in many nappes, sheets, nappe complexes and nappe systems form a highly branching, often staircase (trappeformet) thrust system (skyveforkastningssystem). The different types of thrust system, or parts of thrust systems, are classified in relation to the tectonostratigraphical bodies of rock which they delimit, or in relation to the mutual geometrical relationships between the thrusts.

3.9.9.7.a A *sole thrust* (såleforkastning) is a thrust separating a nappe or major thrust sheet from underlying rock units. The term is often used for the lowermost regional thrust in a sequence of nappes (Figs. 22, 27). It is also used for a nearly flat-lying fault formed by extension (cf. Section 3.9.4.7.a).

3.9.9.7.b A *floor thrust* (golvforkastning) is a thrust marking the base of a nappe, thrust sheet or small thrust sheet (Figs. 22, 27). The term is also used for a nearly flat-lying fault formed by extension (cf. Section 3.9.4.7.a).

3.9.9.7.c A *roof thrust* (takforkastning) is a thrust at the top of a nappe, thrust sheet or small thrust sheet (Figs. 22, 27).

3.9.9.7.d A *leading thrust* (ledeforkastning) is a thrust forming the base and frontal edge of a small thrust sheet, thrust sheet, nappe, nappe complex or nappe system (Figs. 22, 27).

3.9.9.7.e A *trailing thrust* (slepeforkastning) is a thrust forming the upper and rear edge of a small thrust sheet, thrust sheet, nappe, nappe complex or nappe system (Figs. 22, 27).

3.9.9.7.f A *flat* (flateforkastning) is a thrust which was originally horizontal when the thrust was formed. A flat which is formed in an undeformed stratigraphical sequence will be parallel to bedding (Butler 1982) (Figs. 22, 27).

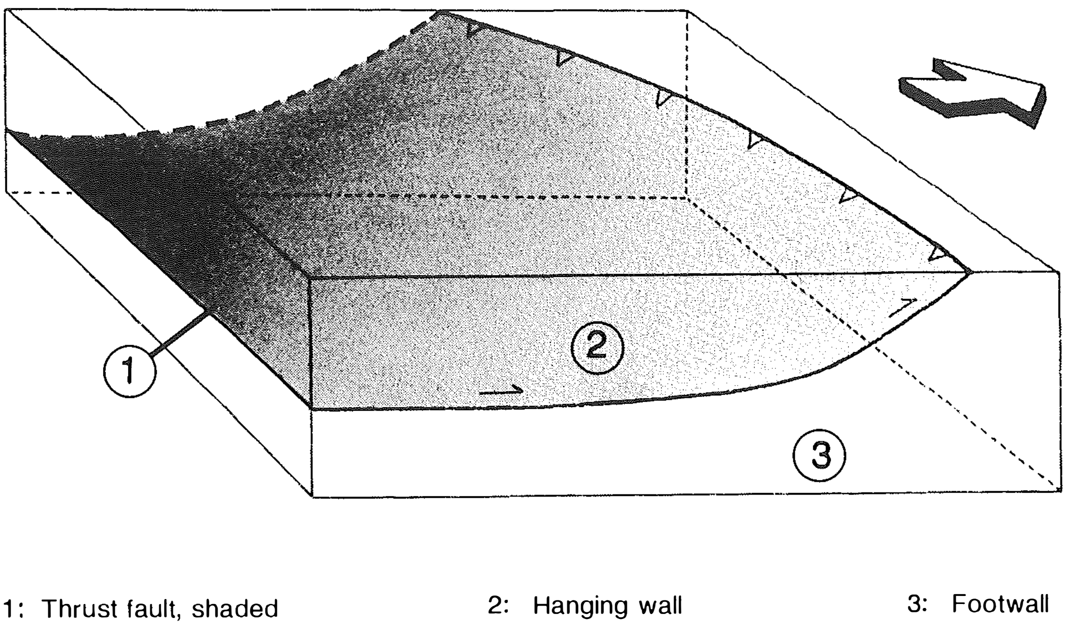


Fig. 21 Thrust fault. The block above the thrust surface, the hanging wall, has moved upwards in the direction of the arrow in relation to the block beneath, the footwall.

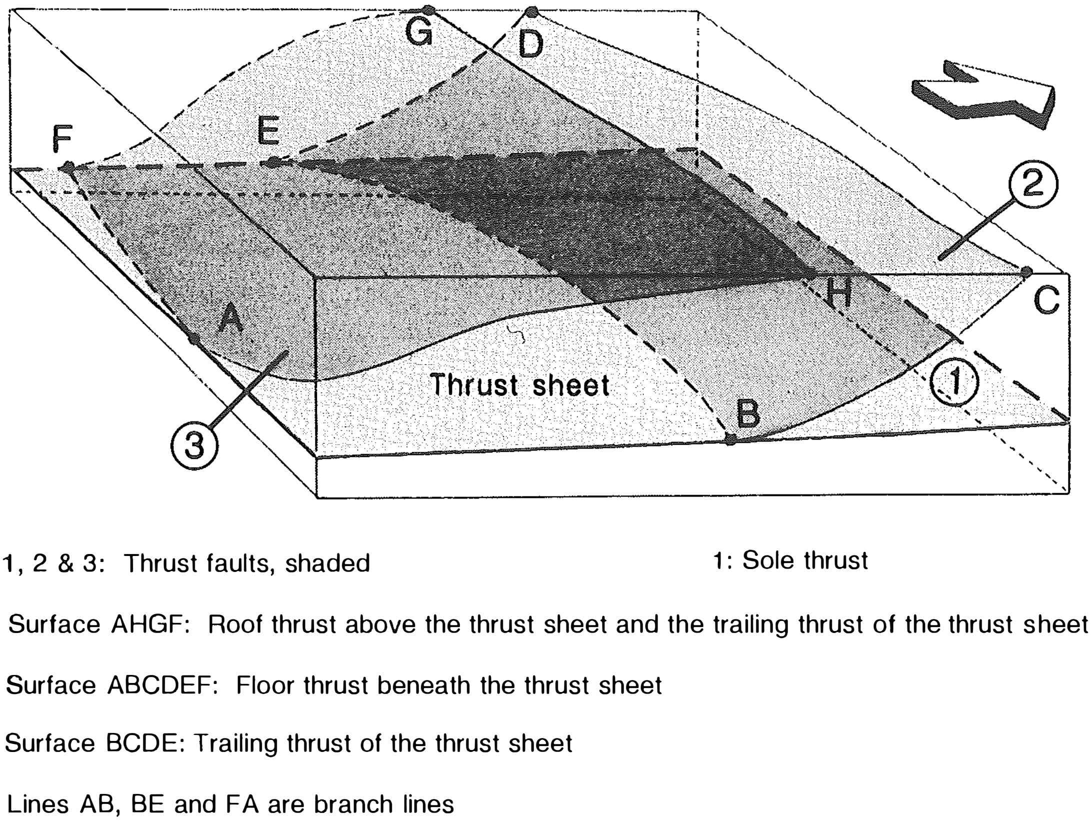


Fig. 22 Thrust faults. Thrust fault 1 is a sole thrust, whilst 2 and 3 are subordinate faults delimiting a thrust sheet as floor and roof thrusts, and leading and trailing thrusts. Displacement along the thrusts is in the direction shown by the arrow.

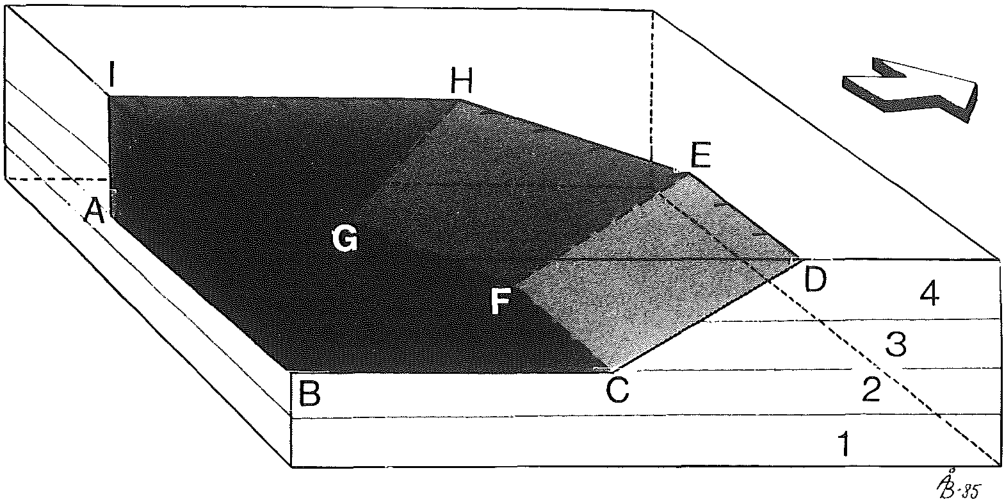
3.9.9.7.g A *ramp* (rampeforkastning or rampe) is a portion of a thrust which cuts stratigraphically upwards through the thrust-transported sequence in the direction of the foreland. Ramps consist of a *front ramp* (frontrampe), a *lateral ramp* (siderampe) and a *diagonal* or *oblique ramp* (diagonalrampe, skrårampe). These terms are used with reference to the direction of tectonic transport (Figs. 23, 27).

3.9.9.7.h A *splay thrust* (splittforkastning) is a subordinate thrust fault branching off a major thrust along a branch line or branching line. Splay thrusts can be further subdivided according to their geometrical relationship to the major thrust (Boyer & Elliott 1982) (Figs. 24, 27).

3.9.9.7.i Thrusts of the types mentioned in a-h can be given informal or formal names. Apart from particularly prominent thrusts, names should preferably be informal.

3.9.9.8 *Examples*: In the Caledonian mountain chain of Scandinavia there are many well-known examples of thrusts of different rank and order. They form floor thrusts beneath nappe units and various types of more subordinate thrusts within the nappe sequences. In Norway, it has not been common to name the thrusts themselves. From the Valdres area, Hossack et al. (1985) have named the thrusts beneath the previously defined Valdres and Synnfjell Nappes, the Valdres and Synnfjell thrusts, respectively (Valdresskyveforkastningen and Synnfjellskyveforkastningen).

3.9.9.9 *Key references*: McClay (1981), Boyer & Elliott (1982), Butler (1982).



Thrust faults, shaded

Surface ABCFG: Flat

Surface CDEF: Front ramp

1-4: Stratigraphical units

Surface EFGH: Diagonal ramp

Surface HGAI: Lateral ramp

Fig. 23 Thrust faults. A composite thrust fault surface (shaded) is divided into the following segments: flat, front ramp, diagonal ramp and lateral ramp. The ramp faults cut stratigraphically upwards in the displacement direction of the hanging wall, in the direction shown by the arrow.

3.10 Morphostratigraphy

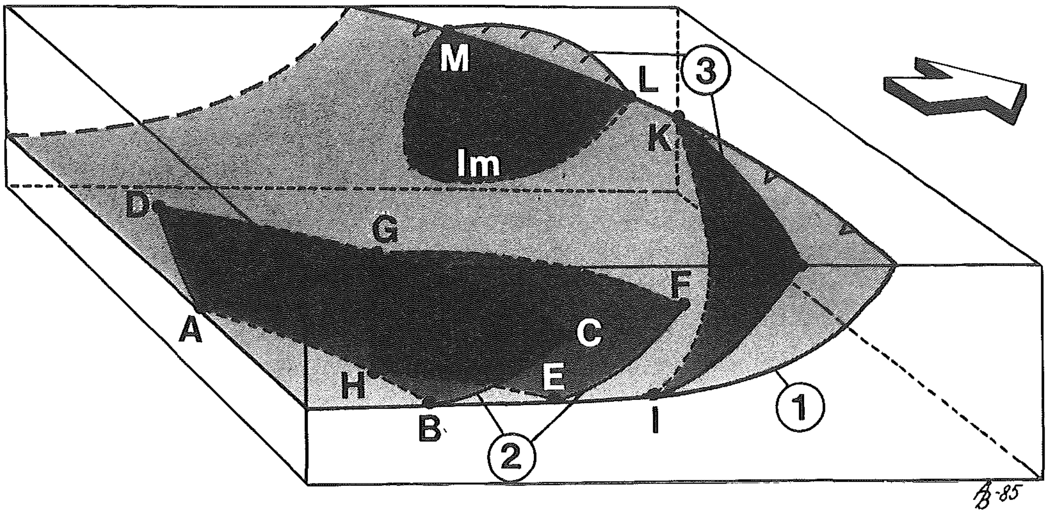
3.10.1 General properties and rules

3.10.1.1 *Morphostratigraphy* – Morphostratigraphy has to do with stratigraphical classification of geomorphological elements (landforms). The principles of stratigraphy (Section 1.2) are applied to landforms which are placed in a chronological order from older to younger. In Northern Europe, morphostratigraphy has traditions going back to studies of Quaternary ice-contact deposits and shoreline levels in the middle of the last century.

The use of landforms as morphostratigraphical units has been subject to some discussion. Frye & Willman (1962) suggested that such units should be used. Mangerud et al. (1974) argued for their continued use in Northern Europe and, in particular, stressed how practical they were when studies were being undertaken on the retreat of the continental ice-sheets and the history of isostatic recovery. According to American practice (e.g. Frye & Willman 1962), morphostratigraphical units embrace both the shape of the form element and the sediments in it, whereas the Nordic tradition (e.g. Mangerud et al. 1974) allows them to be defined by their abstract shape alone.

Morphostratigraphy is not dealt with by either ISSC (1976) or NACSN (1983). The latter Code does, however, introduce an *allostratigraphic* classification system. An allostratigraphical unit is defined partly on the basis of its material content, partly on its surface shape and its morphological boundary relationships to adjacent units. As pointed out above, there is no tradition in Norway or other Nordic countries for classifying superficial deposits and geomorphological features in this manner. It is also the opinion of NSK that using a combination of lithological and morphological features as identification criteria is an unfortunate practice. Hence, NSK does not recommend the use of the allostratigraphical classification system. Instead, a morphostratigraphical classification system is advocated, perhaps, if necessary, combined with a lithostratigraphical or biostratigraphical one.

No systematical classification system for mor-



1, 2 and 3: Thrust faults, shaded

1: Floor and leading thrust beneath nappe or thrust sheet

2: Splay thrusts ending as blind faults or blind thrusts

along tip lines DC and GF

3: Splay thrusts outcropping at the surface

Lines AB, HE, IK and MImL are branch lines

Fig. 24 Thrust faults. 1 is a floor and leading thrust beneath a nappe or thrust sheet. Splay thrusts 2 and 3 branch from the floor thrust upwards into its hanging wall.

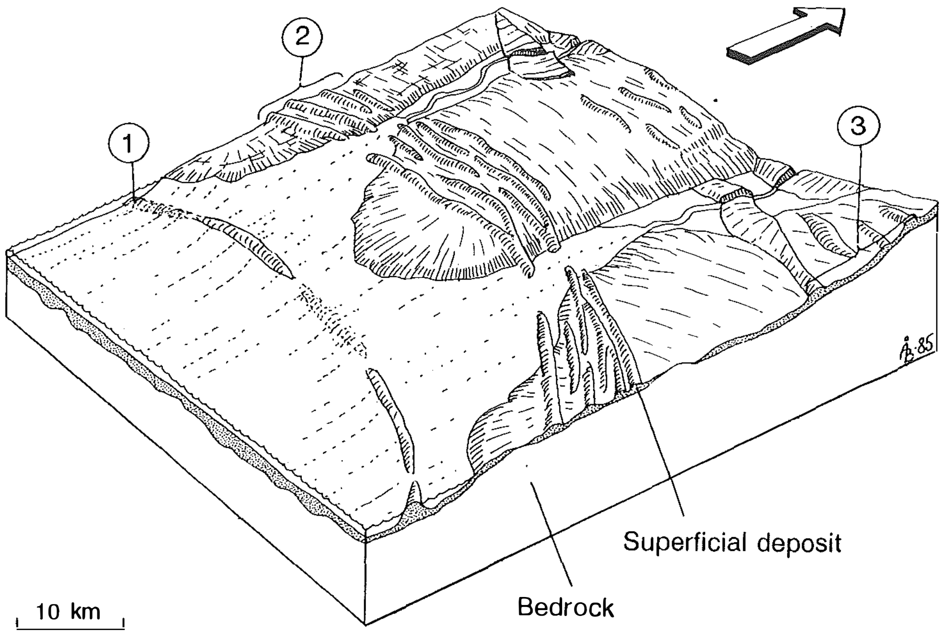
phostratigraphy, or guidelines for naming morphostratigraphical units, have so far been available. Moreover, morphostratigraphy and chronostratigraphy have sometimes been confused (see Section 3.10.2.8). The morphostratigraphical classification system proposed in this Code uses unit terms similar to those used for lithodemic units (Section 3.3). This is done because (1) neither morphostratigraphical nor lithodemic units comply properly with the Law of Superposition (Section 1.2), (2) units in both categories may have a composite mode of formation and need not be laterally continuous, and (3) the unit terms are genetically neutral.

3.10.1.2 *Definition* – A morphostratigraphical unit is a landform, or group of landforms, whose boundaries can be delimited, and which constitutes one of several corresponding units that together demonstrate a geological process in time and space. The landforms may result from deposition or erosion, or a combination of both processes. The morphostratigraphical unit is defined independently of material content and the period in time when the landform or landforms constituting it were formed. Figures 25 and 26 show idealized examples.

The individual landform in a morphostratigraphical unit can be defined and named in accordance with the rules given in Section 3.7.1. The material content can be defined as in lithostratigraphical (Section 3.2), lithodemic (Section 3.3) or biostratigraphical units (Section 3.5). The time-span which the morphostratigraphical units represent can be defined geochronometrically (Section 4.4) or diachronously (Section 4.7). It is important to keep these different categories separate when working with morphostratigraphical classification.

3.10.1.3 *Nomenclature* – Morphostratigraphical units are named according to the "general rules for naming and defining geological units" (Chap. 2). Formal names are composed of a proper name and the morphostratigraphical unit term, perhaps separated by a term describing the character of the unit (e.g. ice-contact ridge, terrace, beach ridge) (see also Section 3.10.2.6). The proper name is a geographical name for the type locality or type area; old-established proper names may also be used. A morphostratigraphical unit that is derived from a previously erected geological form unit may be given the name of that unit if misunderstanding cannot arise.

3.10.1.4 *Units and hierarchy* – Morphostratigraphical units which are integral parts of a hierarchical classification system are, in decreasing order of rank, *morphosupersuite, morphosuite* and *morphodeme. Morphocomplex* is a unit without rank in the hierarchy. The morphodeme is the fundamental unit. These terms are introduced and defined for the first time in this Code.



1: Ice-marginal ridge, defined as an ice-marginal morphodeme

2: Several associated ice-marginal ridges, defined as an ice-marginal morphosuite

3: Several associated ice-marginal ridges and ice-marginal deltas, defined as an ice-marginal morphosuite

Fig. 25 Morphostratigraphical units. The history of retreat of a glacier snout is shown in the arm of a fjord by a succession of ensuing ice-marginal deposits. Each of these can be termed an ice-marginal morphodeme. Several neighbouring ice-marginal morphodemes can be defined as ice-marginal morphosuites. The arrow indicates the dominant direction of glacier retreat.

3.10.2 Morphodeme (Morfodem)

3.10.2.1 The *morphodeme* is a landform produced by deposition and/or erosion, and forms an integral part of a lateral assemblage of corresponding units which together demonstrate a geological process.

3.10.2.2 Morphodeme is the fundamental unit for morphostratigraphical classification and nomenclature.

3.10.2.3 There are no limitations on the dimensions of a morphodeme.

3.10.2.4 A morphodeme should be mappable on the surface using geomorphological methods.

3.10.2.5 A morphodeme is a landform which is identified exclusively on the basis of its distinctive shape. A morphodeme can be formed during a simple geological event, or during an event consisting of several separate episodes. The period of time represented by a morphodeme therefore often varies in length along the extent of the morphodeme (see Sections 3.10.2.7 and 4.7.3-4.7.5).

A morphodeme may be an ice-marginal deposit that can be traced laterally as a morphostratigraphical unit (Fig. 25). Such an ice-marginal unit may consist of segments having different modes of formation, composition and age. A morphodeme may also be a marine terrace, kame terrace, beach ridge or some other landform that can be traced laterally as a morphostratigraphical unit (Fig. 26).

3.10.2.6 A morphodeme can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and according to the provisions in Section 3.10.1.3. The proper name (Section 2.2.2) is placed between the words "the ... Morphodeme" in formal names, perhaps with a descriptive term such as "ice-marginal", "terrace", "beach ridge", in front of "morphodeme". If misunderstanding about the meaning cannot arise, the unit term "morphodeme" can be omitted from the name once the unit has been formally defined (see Section 3.10.2.8).

3.10.2.7 A morphodeme may consist of one or more formally or informally defined geomorphological elements (Section 3.7). The total time interval of the morphodeme may be a *phase, span* or *cline* (see Sections 4.7.3-4.7.5).

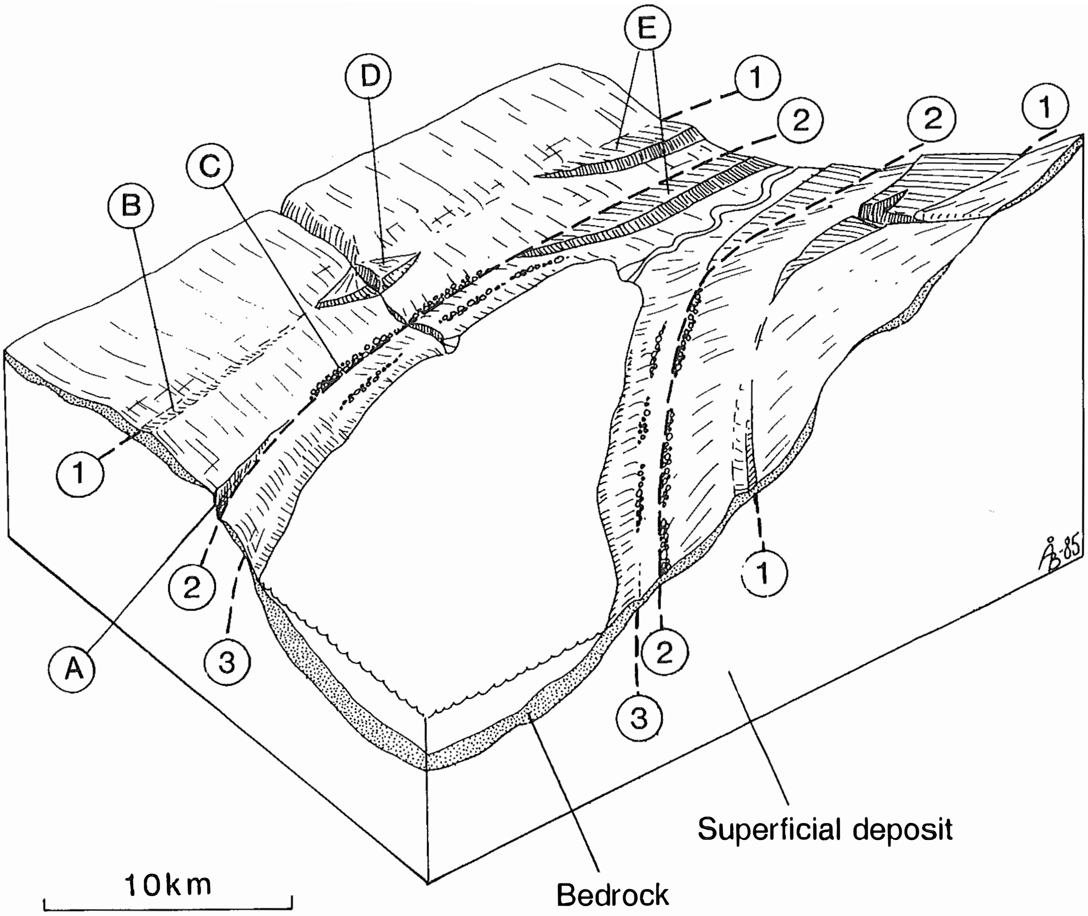
3.10.2.8 *Examples*: Long-established examples of morphological units in Norway are Pleistocene–Holocene ice-marginal deposits and beach terraces. Morphostratigraphical ice-marginal deposits have been called "linjer" ("lines") or "trinn" ("stages") (e.g. "Ra-trinnet", "Ski-trinnet", "Aker-trinnet" (Holtedahl 1953). The term "trinn" was used by Kjerulf (1879) as a term for marine terrace surfaces. Holtedahl (1924, p. 11) also originally used "trinn" in a purely *morphological* sense about ice-marginal deposits. By degrees, the word "trinn", used for ice-marginal deposits, obtained a time connotation (Norsk Riksmålsordbok, p. 2946) and was translated into English as "stage" or "substage" (Holtedahl 1960). In line with this meaning of "trinn", the word "stadium" (plural "stadier") became used as a kind of morphostratigraphical term (Anundsen & Simonsen 1967). Mangerud (1973) proposed that "trinn" should be used as a morphological term, and this has been largely practised since that time. *In this Code, "trinn" is defined as a diachronous unit (Section 4.7.4)*, and it is proposed that the word "span" should be used as the equivalent English term. The English terms "stage" and "substage" (along with the associated Norwegian word "stadium") denote, and should only be used for, chronostratigraphical units (Section 4.2.6).

The prominent ice-marginal ridge called the Ra ("Raet") in Østfold and Vestfold, in South Norway, is an important morphostratigraphical unit (Andersen 1960). It should have the rank of a morphodeme, the Ra Morphodeme ("Ramorfodemen") or "the Ra Ice-Marginal Ridge" or simply "the Ra Ridge". (Portions of the Ra may have been given geomorphological proper names. The term "ra" has traditionally been used as a common name for several major and minor ice-marginal ridges elsewhere in the Oslofjord region.)

3.10.2.9 *Key reference*: this Code.

3.10.3 Morphosuite (Morfosuite)

3.10.3.1 A *morphosuite* is a morphostratigraphical unit consisting of two or more morphodemes, or a corresponding number of informal morpho-



Types of morphodemes

A: Notch in bedrock

B: Notch in superficial deposit

C: Beach ridge

D: Delta terrace

E: Marine terrace

1, 2 and 3 are shoreline levels of decreasing age, and can be defined as three shoreline morphocomplexes

Fig. 26 Morphostratigraphical units. Postglacial isostatic recovery is shown in the arm of a fjord by various types of morphodemes, A-E. 1, 2 and 3 can be designated as shoreline morphocomplexes. 1 is defined by a shore notch in superficial deposits, including a delta terrace and a marine terrace, 2 by a shore notch in bedrock, beach ridges and a marine terrace, and 3 by beach ridges and a shore notch in superficial deposits.

demic units. The individual units constituting a morphosuite must belong to the same class.

3.10.3.2 Morphosuite is a formal morphodemic unit ranking next above morphodeme. Two or more morphosuites of the same or different class(es) can be defined as a *morphosupersuite*.

3.10.3.3 A morphosuite usually has a regional extent, or may consist of a few separate units which together have a regional extent.

3.10.3.4 A morphosuite is mappable using geomorphological methods.

3.10.3.5 A morphosuite consists of formal morphodemes and/or informal and unnamed morphodemic units belonging to the same class of landforms. Such classes may be ice-marginal deposits, marine terrace surfaces, beach ridges, kame terraces or similar features (Figs. 25, 26). The individual units in a morphosuite occur relatively close to each other in a group, but need not be found throughout the distribution area of the morphosuite.

3.10.3.6 A morphosuite is only given a formal name, this being constructed in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.10.1.3. The name should consist of a geographical name between the words "the ... Morphosuite". An additional descriptive term can be placed in front of morphosuite, e.g. Ice-Marginal Ridge, Terrace, Beach Ridge.

3.10.3.7 A morphosuite may change character regionally to such a degree that in an area beyond its type area it will be most appropriate to call the unit a morphodeme. The proper name component of the originally-defined morphosuite can be retained even though the rank is changed to morphodeme (Section 2.5.1).

3.10.3.8 *Examples*: No morphosuites have so far been defined in Norway. A possible morphosuite might be several adjacent ice-marginal deposits. In the Ås-Ski area east of Oslofjord there is a group of several large and small ice-marginal ridges (Sørensen 1983) which could form part of an ice-marginal morphosuite.

3.10.3.9 *Key reference*: this Code.

3.10.4 Morphocomplex (Morfokompleks)

3.10.4.1 A *morphocomplex* is a morphodemic unit consisting of a mixture or assemblage of landforms belonging to two or more classes.

3.10.4.2 Morphocomplex is without rank in the morphodemic classification system.

3.10.4.3 No limitations are placed on the dimensions of a morphocomplex, but it most often has a regional extent.

3.10.4.4 A morphocomplex is mappable using geomorphological methods.

3.10.4.5 The individual morphostratigraphical units constituting a morphocomplex may be formally or informally defined units of different origin. A morphocomplex consisting of terrace morphodemes, beach ridge morphodemes and shore notch morphodemes may, for example, be erected to define a shoreline level (see Section 3.7.11.7.e and Fig. 26).

3.10.4.6 A morphocomplex is given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.10.1.3. Names composed of a geographical name and the words "the ... Morphocomplex" should preferably only be used for formally defined morphocomplexes.

3.10.4.7 The term morphocomplex must not be used for assemblages of morphostratigraphical units belonging to the same class (e.g. ice-marginal deposit, marine terrace, beach ridge), even if the individual landforms have a composite (i.e. "complex") lithology and mode of origin. Such assemblages are either morphosuites or morphosupersuites.

3.10.4.8 *Example*: No morphocomplexes have so far been defined in Norway.

3.10.4.9 *Key reference*: this Code.

3.11 Tectonostratigraphical units

3.11.1 General properties and rules

3.11.1.1 *Tectonostratigraphy* – Tectonostratigraphy is concerned with the stratigraphical division of bodies of rock which are piled on top of each other and separated by thrusts (Section 3.9.9). A tectonostratigraphical unit is therefore a body of rock which has been displaced along a thrust fault (floor thrust), and may be delimited uppermost by a roof thrust or the erosion surface (Fig. 27). Tectonostratigraphical classification therefore differs fundamentally from lithostratigraphical and lithodemic classifications. A tectonostratigraphical unit may consist of one or more lithostratigraphical and/or lithodemic units.

3.11.1.2 *Nomenclature* – Tectonostratigraphical units are given names in accordance with the "general rules for naming and defining geological units" (Chap. 2). Formal names are composed of a geographical name (or an alternative name in the case of the continental shelf) and the tectonostratigraphical unit term. A tectonostratigraphical unit which is defined first after its floor thrust has been given a formal name is to have the same proper name as the floor thrust, and vice versa, a floor thrust is to be given the same proper name as the nappe of which it forms the base.

Many nappes in the Scandinavian mountain chain have old-established names derived from a type area. It should be possible to erect reference sections for the bounding thrusts of such nappes. When erection of a new tectonostratigraphical unit is desirable this should preferably be defined on the basis of a type section, with the possible addition of one or more reference sections, to cover the bounding thrusts. It is particularly important that the floor thrust is included (see Sections 2.4.5 and 3.9.9, and figure 22).

3.11.1.3 *Units and hierarchy* – The tectonostratigraphical units forming a hierarchical classification system are, in decreasing order of rank, *nappe system* and *nappe complex, nappe, thrust sheet* and *small thrust sheet.* Thrust sheet (flak or skyveflak) may also be used as a general unit term without rank. Nappe is the fundamental unit. Nappe complex and nappe system have equal rank, but are distinguished from each other on the basis of the relative age differences of movements on the internal thrust faults.

3.11.2 Nappe (Dekke, Skyvedekke)

3.11.2.1 A *nappe* is a sheet-, slice-, wedge-, or lens-shaped body of rock that has been displaced a large distance along a thrust fault (skyveforkastning). The thrust fault at the sole of the nappe is approximately horizontal or low-angled, or it may be assumed to have been so prior to subsequent deformation. A nappe consists of one or more nappe sheets or thrust sheets (dekkeflak, skyveflak) which are assumed to have undergone displacement together (piggyback displacement) on the floor thrust of the nappe. The rocks in a nappe may differ from the autochthonous (stedegne) rocks in the geological region in which the nappe occurs with respect to the following properties: stratigraphy, composition, sedimentary facies, degree of metamorphism and deformation.

3.11.2.2 Nappe is the fundamental formal unit for tectonostratigraphical classification and nomenclature.

3.11.2.3 No limitations are placed on the size of a nappe. A nappe may, because of erosion, be divided up into several detached nappe remnants or *klippen* (dekkerester, klipper) and may envelop one or more *windows* (vinduer). The tectonostratigraphical units underlying the nappe are exposed in the window.

3.11.2.4 A nappe is mappable at the surface or traceable in the subsurface with the help of geological and/or geophysical methods.

3.11.2.5.a A nappe may consist of one or more rock types having a common or different origin, age, and degree of metamorphism and deformation. It is therefore possible to distinguish lithostratigraphical, lithodemic and biostratigraphical units within the nappe. The rocks in a nappe usually derive from one or a few plate tectonic environments in an orogen (terranes), e.g. a foreland basin on continental crust, a volcanic island arc, a deep ocean trench, or ocean-floor crust (Section 3.11.7).

3.11.2.5.b A nappe is delimited from underlying older or younger rocks by a thrust fault which is its *floor thrust* (golvforkastning). A nappe may in addition be bounded by later depositional surfaces, other tectonic surfaces (e.g. a roof thrust which may be a floor thrust to an overlying nappe), intrusive contacts and the erosion surface (Fig. 27).

3.11.2.5.c A nappe may be tectonically undivided or consist of *imbricate fans* and *duplexes*, and of large fold structures in which significant portions of the stratal sequence in the nappe may be preserved in an overturned state, as in *fold nappes* (foldedekker) (Fig. 27).

3.11.2.6 Nappes can be given formal or informal names, this being done in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.11.1.2. Nappes should preferably be defined formally. The type section or type locality of a nappe is situated within the area in which the thrust sheets forming the nappe are located. The first part of the nappe name must be the same geographical name as that of the floor thrust of the nappe, if that is given a name. A nappe must *not* be given the same geographical name as named lithological units in the nappe. The name of the nappe can be used formally or informally, also in those cases when the nappe unit is defined as a thrust sheet (skyveflak). The proper name (Section 2.2.2) is placed between the words "the ... Nappe" in formal names.

3.11.2.7.a The rocks in a nappe can be said to be *allochthonous* (alloktone, flyttet) if they differ significantly from the *autochthonous* (stedegne, autoktone) rocks of the foreland succession and its basement (underlag) in composition, stratigraphy, sedimentary facies, and degree of metamorphism and deformation, giving grounds for assuming that the nappe rocks have been transported over regional distances. Autochthonous rocks proper are only those rocks which have remained static in their relation to the continental crustal basement of the foreland. That part of the succession is said to be *pinned* (naglet), i.e. pinned to the basement.

3.11.2.7.b The rocks in a nappe can be said to be *parautochthonous* (nærstedegne, parautoktone) if the sedimentary succession in the nappe is readily correlatable with the stratigraphy and sedimentary facies in the autochthonous sequence, giving grounds for assuming a more moderate transport of the nappe.

3.11.2.7.c The term nappe is non-genetical and therefore says nothing about the mechanisms leading to the transport of the nappe rocks.

3.11.2.7.d In modern Anglo-American nomenclature relating to "thrust systems" (Elliott & Johnson 1980, Boyer & Elliott 1982, Butler 1982) the term "dominant thrust sheet" or perhaps "major thrust sheet" will correspond to "dekke". These may consist of "minor thrust sheets", but frequently the term "thrust sheet" is used for tectonostratigraphical units ranging in size from small thrust sheets to large nappe units.

3.11.2.8 *Examples*: Many nappes have been named in the Caledonian mountain chain of Scandinavia. Examples and references are found in Gee & Sturt (1985).

3.11.2.9 *Key references*: Tollmann (1968), McClay (1981), Boyer & Elliott (1982).

3.11.3 Thrust sheet (Flak, Skyveflak)

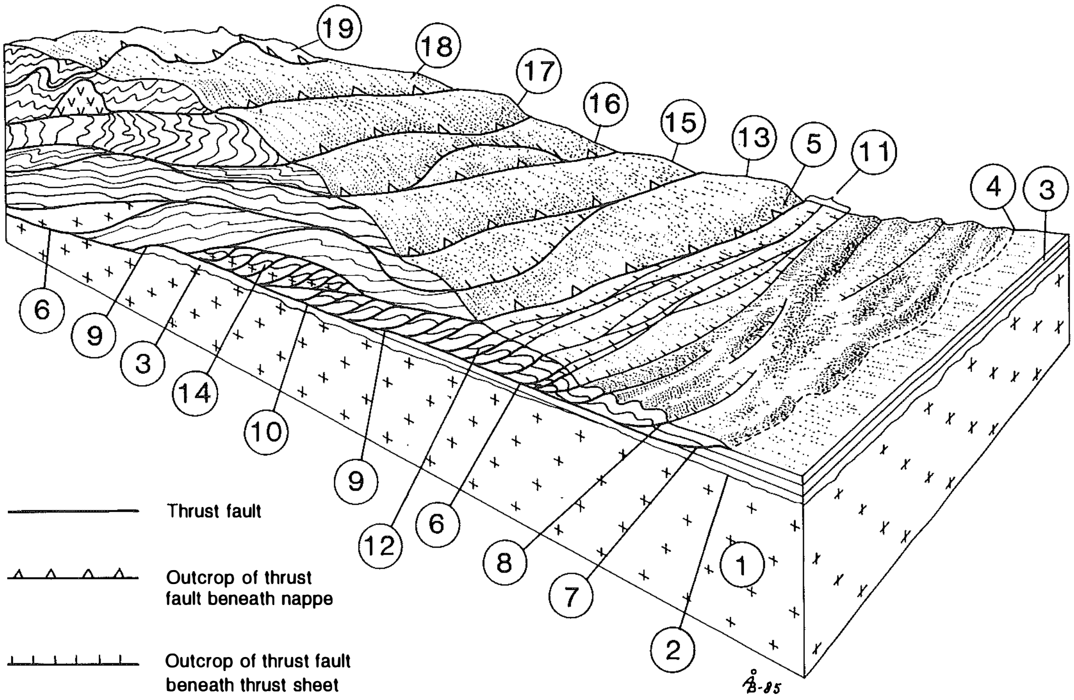
3.11.3.1 A *thrust sheet* is a sheet-, slice-, wedge- or lens-shaped body of rock that has been displaced upwards along a thrust fault (skyveforkastning). The thrust fault may be approximately horizontal, low-angled or listric (concave upwards), or it should be conceivable that it had one of those attitudes prior to subsequent deformation.

3.11.3.2 Thrust sheet ranks next after nappe in areas where a nappe has been defined as a formal tectonostratigraphical unit. A thrust sheet that forms part of a nappe unit may be called a *nappe sheet* (dekkeflak). Thrust sheet can also be used as a non-ranking tectonostratigraphical term (see Section 3.11.3.7).

3.11.3.3 No limitations are placed on the dimensions or length of transport of a thrust sheet. Like a nappe, a sheet may be eroded and divided up into *klippen*, and it may surround one or more *windows*.

3.11.3.4 A thrust sheet is mappable at the surface or traceable in the subsurface with the help of geological and/or geophysical methods.

3.11.3.5.a A thrust sheet can consist of one or more rock types having a common or different origin and degree of metamorphism and deformation. It is therefore possible to distinguish lithostratigraphical, lithodemic and biostratigraphical units in a thrust sheet.



1: Ancient autochthonous basement
2: Nonconformity surface, peneplain
3: Autochthonous, pinned foreland succession
4: Thrust front
5: Nappe front, present erosion limit for nappes
6: Regional sole thrust
7: Front ramp, front of the sole thrust
8: Splay thrust
9: Ramps, parts of the sole thrust
10: Flat, part of the sole thrust
11: Exposed portion of an imbricate thrust sheet
12: Imbricate nappe developed as a duplex bounded by floor and roof thrusts
13: Nappe with subordinate thrust sheet
14: Duplex with simple small thrust sheets in which the basement (1) and the oldest component of the foreland succession (3) are preserved
13-19: Nappes which are long-transported relative to underlying tectonostratigraphical units

13, 15 and 16: Nappes having a common history of thrusting

17, 18 and 19: Nappes containing strongly metamorphic rocks and having an uncertain and in part unknown history of thrusting

Fig. 27 Diagram showing a simplified section from the foreland of a mountain chain to the right in to the nappe region to the left. Features 1-19 illustrate a tectonostratigraphical pile from the ancient autochthonous basement lowermost to the long-transported nappes uppermost.

3.11.3.5.b A thrust sheet is delimited from the underlying older or younger rocks by a thrust fault which is the *leading thrust* (ledeforkastning) or *floor thrust* (golvforkastning) of the thrust sheet. It may also be delimited from an overlying thrust sheet by a thrust fault which is its *trailing thrust* (slepeforkastning) or *roof thrust* (takforkastning). The thrust sheet may, in addition, be delimited by other tectonic surfaces, later depositional surfaces, intrusive contacts and the erosion surface (Figs. 22, 24, 27).

3.11.3.5.c A thrust sheet may be tectonically undivided, have a feather-like imbricate structure (imbricate fan) or duplex geometry (Fig. 28).

3.11.3.6 Thrust sheets can be given formal or informal names in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.11.1.2. If the term "thrust sheet" (flak, skyveflak, dekkeflak) is used for a tectonostratigraphical unit that has already been defined as a nappe, the geographical name of the nappe must also be used together with the term thrust sheet in the formal version of the name. A thrust sheet that has been defined and given a formal name can have its status changed to nappe if investigations show this to be desirable. If the floor thrust beneath the thrust sheet is given a name, the sheet must have the same name, formally or informally, as the thrust. (If the floor thrust beneath the thrust sheet is the floor thrust of a nappe of which the thrust sheet forms an integral part, the nappe and the floor thrust should have the same geographical name (see Sections 3.11.1.2 and 3.11.2.6).) A thrust sheet must *not* be given a formal or an informal name containing the same geographical name as one of the lithological units in the nappe or thrust sheet. The proper name (Section 2.2.2) is placed between the words "the ... Thrust Sheet" (formal) in the compound name.

3.11.3.7 In modern Anglo-American nomenclature relating to thrust systems (Boyer & Elliott 1982) the term thrust sheet is used broadly for all displaced bodies of rock that are bounded by one or more thrust faults, irrespective of the size of the unit. Subject to terms specified in this Code (see Sections 3.11.1.2, 3.11.2.7 and 3.11.3.2), a corresponding use of thrust sheet is permitted.

3.11.3.8 *Example*: An example of a named thrust sheet is the Mistra Thrust Sheet (Mistraflaket) (Holmsen & Oftedahl 1956).

3.11.3.9 *Key references*: McClay (1981), Boyer & Elliott (1982).

3.11.4 Small (minor) thrust sheet (Skjell)

3.11.4.1 A *small (minor) thrust sheet* is a thrust sheet that is (a) bounded on all sides by thrust faults, or (b) bounded by thrust faults and the erosion surface. A small thrust sheet is wedge- or lens-shaped and is not divided into smaller tectonostratigraphical units. The thrust faults beneath and above the small thrust sheet, floor and roof thrusts respectively, have or can be assumed to have had, listric or sigmoidal (S-shaped) geometry.

3.11.4.2 Small thrust sheet holds the lowest rank among tectonostratigraphical units, and in the form of imbricate fans and duplexes it can be an integral part of larger thrust sheets and nappes (Fig. 28).

3.11.4.3 No lower limit is placed on the size of a small thrust sheet. The dimensions will otherwise be limited by the size of the thrust sheet or nappe of which the small thrust sheet forms a part.

3.11.4.4 A small thrust sheet is mappable on the surface or traceable in the subsurface with the help of geological and/or geophysical methods; small ones are not necessarily mappable on the scale of available base maps.

3.11.4.5 A small thrust sheet may consist of one or more rock types having a common or different origin, age and degree of metamorphism and deformation. It is therefore possible to distinguish lithostratigraphical, lithodemic and biostratigraphical units in a small thrust sheet.

3.11.4.6 Small thrust sheets can be given formal or informal names in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.11.1.2, but should preferably be named informally.

3.11.4.7 Small thrust sheets are the smallest tectonic units in imbricate fans and duplexes (Fig. 28).

3.11.4.7.a An *imbricate fan* (Boyer & Elliott 1982) (skjelldelt flak) consists of small thrust sheets piled one on top of the other and having an imbricate, feather-shaped geometry when viewed in vertical section transverse to the thrust sheet structure. Each small thrust sheet is bounded by a leading thrust (ledeforkastning) and a trailing thrust (slepeforkastning) which have listric geometry and meet the floor thrust (golvforkastning) of the sheet along branching (or branch) lines (forgreiningslinjer). The imbricate fan is bounded uppermost by either the erosion surface or a succession of strata in which the thrust faults separating the small thrust sheets die out as blind thrusts (blindforkastninger) along tip lines (tupplinjer) beneath the present erosion surface (Figs. 22, 24, 28).

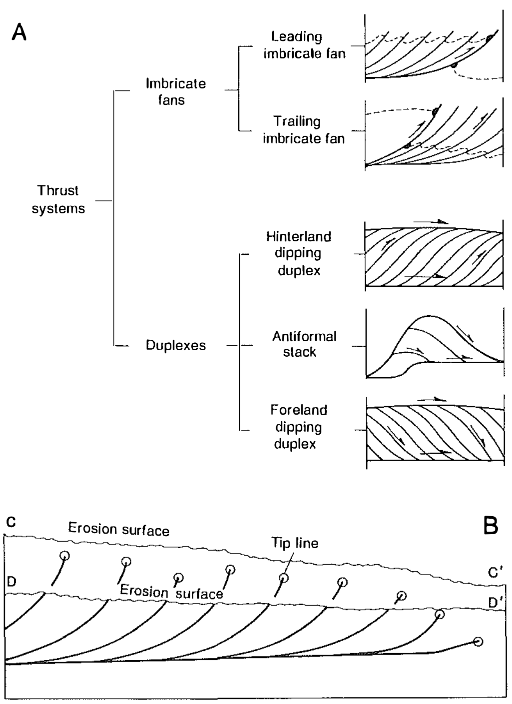


Fig. 28 A. Various types of imbricate fans (and nappes). B. Vertical section transverse to the displacement direction, towards right, through an imbricate fan at two *synorogenic* erosion levels. In the upper section the individual splay thrusts have not reached synorogenic surface CC', and end along tip lines resulting in a *blind* imbricate fan. In the lower section the splay thrusts have reached synorogenic surface DD', resulting in an *emergent* imbricate fan. The sole thrust is a blind thrust. After Boyer & Elliott (1982).

3.11.4.7.b *Duplexes* (duplekser) (Boyer & Elliott 1982) are thrust sheets comprised of sigmoidal (S-shaped), smaller thrust sheets called horses (skjell), piled one on top of the other in an imbricate pattern, and bounded at the base by a floor thrust (golvforkastning) and at the top by a roof thrust (takforkastning). The thrust faults separating the individual horses pass asymptotically into the floor and roof thrusts of the sheet to which they belong. An *antiformal stack* (antiformstakk) is a duplex in which each higher horse is folded around the underlying ones (Fig. 28).

3.11.4.7.c *Lenses, megalenses, boudins* and *megaboudins* (linser, megalinser) are small thrust sheets or thrust sheets bounded by thrust faults and located in broad movement zones between or within nappes (Fig. 27).

3.11.4.7.d Imbricate fans, duplexes, lenses and megalenses should preferably be given informal names. They should *not* be given the same name as the major tectonostratigraphical unit of which they form subordinate parts.

3.11.4.8 *Examples*: Small thrust sheets have been described from the Osen Nappe along the northern part of Mjøsa where they occur in imbricate fans (Skjeseth 1963, Bjørlykke 1979). Duplexes have been described from the Osen and Synnfjell Nappes in the Valdres district, being called, respectively, the Aurdal duplex and the Synnfjell duplex (Hossack et al. 1985). The Turtbakktjørna lens in Trøndelag (Kautsky 1978) and the Brakfjellet lens in Nordland (Ramberg 1981) are examples of megalenses that are assumed to have been formed by tectonic pinch and swell (uttynning og fortykning) of nappe units.

3.11.4.9 *Key references*: McClay (1981), Elliott & Johnson (1980), Boyer & Elliott (1982), Butler (1982).

3.11.5 Nappe Complex (Dekkekompleks)

3.11.5.1 A *nappe complex* is defined as comprising two or more nappes that are geometrically closely related to one another. The movements along the floor thrusts of the individual nappes originally took place during different deformational phases or orogenies, or are of unknown or uncertain relative ages (Fig. 27).

3.11.5.2 Nappe complex is a tectonostratigraphical unit ranking next above nappe.

3.11.5.3 A nappe complex has a regional extent, but all the individual nappes in a complex need not be present wherever it is found. In areas where the nappe complex thins, it may be represented by only one of its component nappes.

3.11.5.4 A nappe complex is mappable on the surface and traceable in the subsurface with the help of geological and/or geophysical methods.

3.11.5.5 A nappe complex usually contains several individual nappes and thrust sheets that can be distinguished from one another by their content of lithostratigraphical, lithodemic and biostratigraphical units. The nappes may be characterized by earlier and different degrees and types of deformation and metamorphism, but may have experienced one or more later and common metamorphic and deformational event(s).

3.11.5.6 A nappe complex can be given a formal or an informal name in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.11.1.2. It must *not* be given the same geographical name as a component nappe, or as any of the lithological units in it. In areas where the nappe complex becomes thin its name is retained even though the complex is only represented by a single nappe. The proper name (Section 2.2.2) is combined with the words "the ... Nappe Complex" in formal names. In informal contexts the geographical name of the nappe complex can be used together with the term "the nappes" (e.g. "the Nordland nappes" – "Nordlandsdekkene"). Informal names of this kind which are in use may, if desired, be redefined to formal names of nappe complexes.

3.11.5.7 A nappe complex can be redefined as a nappe system when it can be shown that movement along all the thrust faults is of the same age or belongs to the same deformational event (see Section 4.8).

3.11.5.8 *Examples*: The Kalak Nappe Complex (Roberts 1974) was originally called the Kalak Nappe by Føyn (1967), but was subsequently termed a complex due to its structural complexity and complicated geological history (e.g. Sturt et al. 1975). The Trondheim Nappe as it was defined by Wolff (1979) will, according to this Code, be a nappe complex having the Gula and Støren Nappes as individual nappes.

3.11.5.9 *Key reference*: this Code.

3.11.6 Nappe System (Dekkesystem)

3.11.6.1 A *nappe system* is defined as two or more nappes that are geometrically closely related to one another. The movements along the floor thrusts of the individual nappes took place during the same deformational event (see Section 4.8).

3.11.6.2 Nappe system is a tectonostratigraphical unit ranking next above nappe and equivalent in rank to nappe complex.

3.11.6.3 A nappe system has a regional extent, but all the individual nappes in the system need not be present wherever it is found. In areas where the nappe system thins, only one or a few of its component nappes may be present.

3.11.6.4 A nappe system is mappable on the surface and traceable in the subsurface with the help of geological and/or geophysical methods.

3.11.6.5 A nappe system usually contains several individual nappes and thrust sheets that can be distinguished from one another by their content of lithostratigraphical, lithodemic and biostratigraphical units.

3.11.6.6 Nappe systems can be given formal or informal names in accordance with the "general rules for naming and defining geological units" (Chap. 2) and the provisions of Section 3.11.1.2. They are *not* to be given the same geographical name as any of the nappes in the system, or as any of the lithological units. In areas where the nappe system thins, its name is retained even if it only survives as a single nappe. In informal contexts the geographical name of the nappe system can be used together with the term "the nappes". Informal names of this kind which are in use can, if desired, and following appropriate documentation, have their rank changed to nappe system. The proper name (Section 2.2.2) is combined with the words "the ... Nappe System" in formal names.

3.11.6.7.a The term nappe system must only be used when it is established that the movements along all the thrust faults are of the same age or belong to the same deformational event. If this is *not* documented, the term nappe complex is to be used (Fig. 27).

3.11.6.7.b The term nappe system (dekkesystem) must not be confused with the term thrust system which refers to thrusts that are geometrically and genetically related (Boyer & Elliott 1982).

3.11.6.8 *Examples*: Many related nappes and thrust sheets in the lower allochthon (Gee & Sturt 1985) of the Caledonian mountain chain of Scandinavia are assumed to have been displaced during the same deformational phase. Such nappe piles may comprise nappe systems.

3.11.6.9 *Key reference*: this Code.

3.11.7 Tectonostratigraphical terrane (Tektonostratigrafisk terreng)

Tectonostratigraphical terrane, tectonic terrane or *terrane* are terms used in plate tectonic contexts. They characterize a block or portion of the Earth's crust entirely bounded by faults. A terrane is distinguished from adjacent portions of crust by having a distinctly different geological history.

The bedrock composition in a tectonostratigraphical terrane may be homogeneous, or complex and varied. The terms "suspect terrane" and "exotic terrane" are used to emphasize that the geological origin and composition of such a block of crust seem to be foreign relative to the surroundings.

Tectonostratigraphical terranes are formed by plate tectonic processes. Plate tectonic movements also accrete terranes during orogenies along the edges of older, tectonically stable cratons.

Terranes may be (a) large and small continental masses bounded by suture zones (collision boundaries) and newly-formed ocean-floor crust, (b) segments bounded by steep, regional, transform faults, (c) nappes bounded by thrust faults, or (d) portions of crust having complicated and structurally composite fault surfaces.

A tectonostratigraphical terrane is defined on the basis of its characteristic geological structure and evolutionary history, age, fauna and flora, palaeomagnetic history and bounding faults.

Tectonostratigraphical terranes can be distinguished informally using their assumed plate tectonic origin, e.g. "Mid-Ordovician island-arc terrane", "ophiolite terrane", "rift-basin terrane", "fore-arc basin terrane". Such terms can be used together with a geographical name from a type section or type area (see Section 2.4.5).

If a tectonostratigraphical terrane coincides with a previously defined and named nappe, nappe complex or nappe system, the geographical name in the proper name of that unit should be used in the proper name of the terrane in formal nomenclature (cf. rootless palaeobasins, Section 3.7.14.7.c1). If the terrane has a different delimitation from previously defined tectonostratigraphical units it should be defined and named in accordance with the rules in Chap. 2.

Examples: India is a huge tectonostratigraphical terrane. The mountain chain along the North American Pacific coast consists of many long, narrow terranes. The Caledonian mountain chain in Norway contains tectonostratigraphical terranes which largely coincide with nappe units.

Key reference: Howell (1985).

3.12 Seismostratigraphy (Seismisk stratigrafi)

Seismostratigraphy is the study of stratigraphy and depositional facies as they can be interpreted using seismic data.

Seismic reflectors form where significant, rapid changes of acoustic impedance (density x sound velocity) take place in the bedrock. Seismic reflectors will therefore chiefly be linked to bedding planes and unconformity surfaces.

Seismostratigraphy relies upon the assumption that persistent primary seismic reflectors are time-stratigraphical horizons rather than lithological boundaries. A seismic section is therefore assumed to give a chronostratigraphical representation of the succession, not a lithological one.

Seismostratigraphy comprises seismic sequence analysis, seismic facies analysis and analysis of changes in relative sea level. In the seismic section (seismisk snitt), various seismic successions or sequences are identified. Each sequence is characterized by a succession of conformable seismic reflectors. The sequences are bounded at the base and top by seismic unconformity surfaces or correlatable conformity surfaces. A unit of this nature is looked upon as a chronostratigraphical sequence.

Seismic facies analysis comprises analysis of the acoustical properties and patterns of the seismic reflectors to thereby enable the lithology to be predicted. The sequence analysis forms the basis for the construction of chronostratigraphical diagrams and diagrams depicting sea level changes. These may be correlated locally with wells and regionally with a global diagram for sea level changes, to establish the age of the sequence boundaries.

Seismic data are remote-sensing recordings of certain physical properties in the bedrock. Subdivision into seismic sequences and prediction of lithology involve a great deal of interpretation. Seismic sequences will therefore not be true geological units and will be unable to fulfil the demands set for defining such features (cf. Section 2.4). NSK, therefore, does not consider it necessary to propose special rules for defining and naming units on the basis of analyses of seismostratigraphy.

4 Geological units defined on the basis of time or age

4.1 General

Geological units that are defined on the basis of time or age relationships are (a) bodies of rock or superficial deposits formed during a certain period of time, and (b) time units (Fig. 29). The first category consists of *chronostratigraphical* (Section 4.2) and *polarity-chronostratigraphical* units (Section 4.5), whilst time units comprise *geochronological* (Section 4.3), *geochronometrical* (Section 4.4), *polarity-chronological* (Section 4.6), *diachronous* (Section 4.7) and *deformational-diachronous* units (Sections 4.8), (see Table 1).

Chronostratigraphical units are usually defined on the basis of selected biostratigraphical type sections, and named after these (Section 3.5), whereas polarity-chronostratigraphical units are erected with the polarity zone (Section 3.4.2) as the physical reference basis. Geochronological units have old-established names (e.g. Palaeozoic, Mesozoic, Tertiary, Quaternary), or are defined and named after chronostratigraphical material units. Geochronometrical units are time units that are defined by time boundaries denoted as a specific number of years before present, independent of physical type or reference sections. Polarity-chronological units are intervals of time defined on the basis of material polarity-chronostratigraphical units. All these units, no matter whether they are material units, time units defined on the basis of a reference succession or units defined purely chronometrically without any material reference unit, have *synchronous* lower and upper boundaries. This means that each individual boundary is defined as having the same age throughout the world. The individual unit between two such synchronous boundaries is *isochronous*. Hence, the period separated by the two boundary surfaces is of equal duration worldwide.

A *diachronous* unit is a time unit that is bounded by non-synchronous lower and upper boundaries. Such a period may be represented by the unequal lengths of time required for deposition of a lithostratigraphical or biostratigraphical unit. Deformational-diachronous units are similarly the unequal lengths of time taken up by deformational events. These again may be defined on the basis of unconformities (Section 3.7.2).

Names of time units and material units that are defined by time and age are to be looked upon as abstract terms or general designations. As these are *collective names*, initial letters are not capitalized in Norwegian unless other rules take supremacy. When the term is used in English, the initial letter is capitalized. Names such as Precambrian, Silurian, Jurassic, Oligocene and Holocene are therefore written in lower case in Norwegian (i.e. prekambrium, silur, jura, oligocen and holocen).

The descriptions and designations of the various units dealt with in this chapter are arranged in slightly different ways depending upon the distinctive characteristics of the units and the importance placed on them by NSK in this national Code.

4.2 Chronostratigraphical units

4.2.1 General properties and rules

4.2.1.1 *Chronostratigraphy* is concerned with clarifying the relative or absolute age of stratified bodies of rock or superficial deposits. The aims of chronostratigraphical classification are (a) to provide a framework for temporal correlation, (b) to place rocks and superficial deposits in a systematic age sequence in relation to Earth history, and (c) to construct a Standard Global Chronostratigraphical Scale.

4.2.1.2 *Definition* – A chronostratigraphical unit is a stratified body of rock or superficial deposits formed during a specific interval of time. Both lower and upper boundaries are distinct synchronous surfaces. The unit constitutes the material reference for all rocks and superficial deposits formed during the same period of time. A chronostratigraphical unit can be defined on the basis of a biostratigraphical or lithostratigraphical unit.

4.2.1.3 *Type section and boundaries* – A chronostratigraphical unit should be erected with reference to a type section that includes the entire unit (*unit stratotype*, see Section 2.4.5). In such a section, the whole unit should preferably be completely exposed, without any stratigraphical or tectonic break, and containing a continuous fossil record. Because such ideal sections are rarely found, a chronostratigraphical unit can be

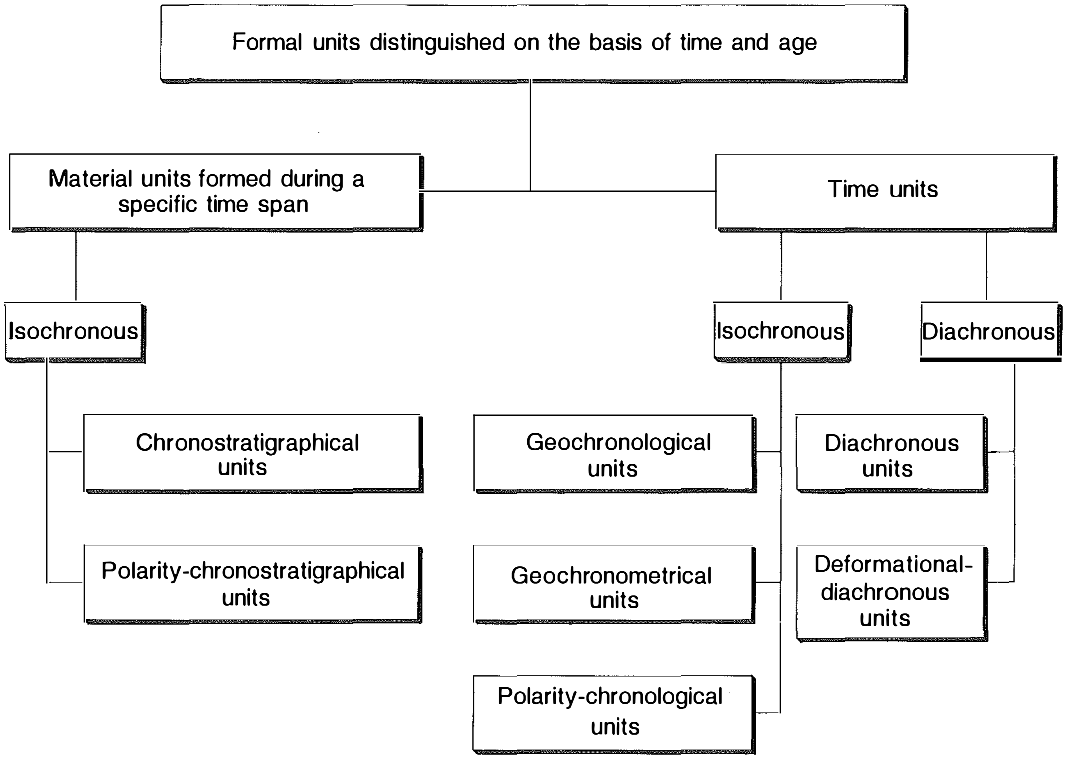


Fig. 29 Categories of formal units defined on the basis of time or age.

defined by its *lower boundary* in a type section for this feature (a *basal boundary stratotype* - typesnitt for undre grense). The upper boundary of a chronostratigraphical unit should not be defined before the lower boundary for the next younger chronostratigraphical unit has been determined. This will avoid overlaps or gaps in the total chronostratigraphical succession.

When erecting or revising chronostratigraphical units the "general rules for naming and defining geological units" (Chap. 2) are to be followed. Revision or redefinition of a unit of system or higher rank can only be carried out by international agreement in the IUGS Commission on Stratigraphy.

4.2.1.4 *Correlation* – Chronostratigraphical correlations are chiefly based on palaeontological techniques. Other, preferably supplementary, correlation methods are the use of remanent magnetism, relative-age criteria and indirect criteria such as climatic changes, changes in eustatic sea level, degree of weathering, and relations to unconformities (Section 3.7.2). It should be emphasized that despite the use of methods such as these, which have limited precision for chronostratigraphical correlations, the boundaries of chronostratigraphical units are to be looked upon as synchronous and in their individuality independent of fossils, lithology, magnetism and other physical properties in the reference succession.

4.2.1.5 *Naming* – When chronostratigraphical units are being named the "general rules for naming and defining geological units" (Chap. 2) are to be followed. Names of chronostratigraphical units are collective and are therefore written with lower-case initials in *Norwegian* (Section 4.1). In *English*, each component of compound names is written as a separate word and is capitalized in formal names except when names are based on trivial taxonomical terms (Section 4.1). Except for chronozones (Section 4.2.7.2), names proposed for new chronostratigraphical units should not duplicate those already used for other geological units.

Adjectives such as Lower (undre), Middle (midtre) and Upper (øvre) may be used for formal and informal chronostratigraphical units. Note that the adjectives Early (tidlig) and Late (sen) should only be used for time units (see Section 4.3.1).

4.2.1.6 *Rank and hierarchy* – The hierarchy of chronostratigraphical units, in decreasing order of rank, is *eonothem, erathem, system, series* and *stage* (Table 2).

System is the fundamental chronostratigraphical unit. This and units of higher rank have worldwide validity. Systems, erathems and eonothems are always divided into units of next lower rank.

The *chronozone* is a non-hierarchical, usually lower rank, formal or informal chronostratigraphical unit. The corresponding time division is the *chron*.

More than one defined stage or chronozone need not together form the next higher ranking unit. Nor need stages and chronozones be defined so that they together form a continuous succession.

The position of the individual unit within the hierarchy is decided by the time interval represented by the unit, not by the thickness or areal extent of the biostratigraphical or lithostratigraphical unit forming the reference basis.

4.2.2 Eonothem (Eonotem)

4.2.2.1 The *eonothem* is the highest-ranking chronostratigraphical unit. The Phanerozoic Eonothem (fanerozoikum) is comprised of three erathems, the Palaeozoic, Mesozoic and Cenozoic Erathems (paleozoikum, mesozoikum, kenozoikum). Older rocks have generally been assigned to the Precambrian Eonothem, but the IUGS Subcommission on Precambrian Stratigraphy has recently proposed the erection of two eonothems for the Precambrian, the Archaean (arkeikum) and Proterozoic (proterozoikum). The division of time corresponding to an eonothem is an *eon*, and this is given the same name as the corresponding eonothem.

4.2.3 Erathem (Eratem)

4.2.3.1 The *erathem* is the formal chronostratigraphical unit ranking next below an eonothem. It consists of several adjacent systems. The names of the three Phanerozoic erathems are based on early views about stages in the development of life on Earth: Palaeozoic (old), Mesozoic (intermediate) and Cenozoic (recent) life. Several names have been proposed for Precambrian erathems, but none are officially recommended; they are still being considered by the IUGS Subcommission on Precambrian Stratigraphy. The division of time corresponding to an erathem is an *era* (æra).

4.2.4 System (System)

4.2.4.1 *System* is the fundamental chronostratigraphical unit. It ranks next below an erathem, and is applicable and valid worldwide. The Phanerozoic systems are the Cambrian (kambrium), Ordovician (ordovicium), Silurian (silur), Devonian (devon), Carboniferous (karbon), Permian (perm), Triassic (trias), Jurassic (jura), Cretaceous (kritt), Tertiary (tertiær) and Quaternary (kvartær). The division of time corresponding to a system is a *period* (periode).

4.2.4.2 *Subsystem (undersystem) and supersystem (oversystem)* – Every system so far approved originated in European geology. Elsewhere in the world, some of these systems have been divided or combined. These new units have also been referred to as systems, but it is better to use subsystem (e.g. the Mississippian Subsystem of the Carboniferous System) or supersystem (e.g. the Karroo Supersystem) in such cases (NACSN 1983).

4.2.5 Series (Serie)

4.2.5.1 *Series* is the formal chronostratigraphical unit ranking next below the system. Series always form the major divisions of a system. A series is the most important chronostratigraphical correlation unit within a geological province, between provinces and between continents. Series are being defined and used to an increasing extent for worldwide correlations, but well-defined provincial series can still be used. The division of time corresponding to a series is an *epoch* (epoke).

4.2.5.2 *Names of series* – A series is given a formal name which may be a geographical name from the type area, combined with the words "the ... Series", written in separate words in English but in one word ("....serien") in Norwegian. When misunderstanding cannot arise, the geographical name can be used alone. The Silurian System, for example, is divided into the following series, the Llandovery (llandovery), Wenlock (wenlock), Ludlow (ludlow) and Pridoli (pridoli) Series. Formal names of series may also consist of the system name preceded by Lower (undre), Middle (midtre), and Upper (øvre).

In *British English* it has now become standard to use geographical names for series without the endings "-ian" or "-an" (Holland et al. 1978). In *American English*, however, these adjectival endings are also recommended to be used in series names (NACSN 1983).

4.2.5.3 *Misuse and informal use of the term "Series"* – The term "Series" has previously been employed formally as a lithostratigraphical designation (e.g. "Ringeriksserien" – the Ringerike Series), as a designation for groups of magmatic rocks, or with an approximate biostratigraphical meaning (e.g. "Pentamerusserien" – the Pentamerus Series). "Series" must *not* be used in such connections. Such terms must be changed to a suitable lithostratigraphical, lithodemic or biostratigraphical term carrying formal rank, or be abandoned.

"Series" can only be used *formally* in a chronostratigraphical sense. It may be used for *clearly informal designations* in other categories of geological units, except biostratigraphical units and those defined on the basis of time or age (e.g. nappe series, ice-marginal series, schist series).

4.2.6 Stage (Etasje)

4.2.6.1 *Stage* is the formal chronostratigraphical unit ranking next below series. It is usually valid over a more limited area than a series, and has so far been found most useful for regional classification and correlation. The aim should be to define stages in such a way that they have a potential for use in worldwide correlation. The division of time corresponding to a stage is *age* (alder).

4.2.6.2 *Substage* (underetasje) – A stage may be subdivided, completely or partially, into substages. The corresponding division of time is a *subage* (underalder).

4.2.6.3 *Names of stages* – Like series, stages are given formal names which consist of a geographical name from a type area combined with the words "the ... Stage" (written in one word in Norwegian – "....etasjen"). When misunderstanding cannot arise, the geographical name can be used alone. In British and American English the geographical name is used with the adjectival ending "-ian" or "-an". These endings are not to be used in texts written in Norwegian. Examples of stages are the Sheinwood Stage or simply Sheinwoodian (sheinwoodetasjen or sheinwood) and the Homerian (homeretasjen), which are European divisions of the Wenlock in the Silurian System. The traditional alphanumerical "stages" in the Cambro-Silurian succession of the Oslo Region are informal stratigraphical terms of mixed litho- and biostratigraphical character.

4.2.7 Chronozone (Kronosone)

4.2.7.1 *Chronozone* is a non-hierarchical, formal or informal chronostratigraphical unit (Table 2), which nevertheless usually has a low rank. A chronozone is defined on the basis of a biostratigraphical, lithostratigraphical or magnetostratigraphical unit. The basis for the definition should be made apparent when the chronozone is designated (e.g. "biochronozone", "lithochronozone" or "polarity-chronozone") (Section 4.5.2). The boundaries of a chronozone can be defined independently of those of ranked units in the reference succession.

Chronostratigraphical units		Geochronological units	
Eonothem	(eonotem)	Eon	(eon)
Erathem	(eratem)	Era	(æra)
System	*(system)*	*Period*	*(periode)*
Series	(serie)	Epoch	(epoke)
Stage	(etasje)	Age	(alder)

Table 2 Formal hierarchical chronostratigraphical and corresponding geochronological units (Norwegian terms in brackets).

Informal biochronozones and lithochronozones based on key horizons or marker beds often have great practical importance when investigations and interpretations of local sedimentary basins are being carried out.

The division of time corresponding to a chronozone is a *chron* (kron).

4.2.7.2 *Names of chronozones* – Formal and informal names given to chronozones are constructed according to the physical definition of the chronozone. A chronozone that is defined on the basis of a biozone carries the biological name of the biozone, e.g. "*Exus albus* chronozone" ("*Exus albus* kronosone"). Corresponding examples for lithochronozones and polarity chronozones are "Woodbend Lithochronozone" ("woodbend litokronosone") and "Gilbert Reversed-Polarity Chronozone" ("gilbert reverspolaritetskronosone"), respectively.

4.3 Geochronological units

4.3.1 General properties and rules

A geochronological unit is a *division of time* that is traditionally distinguished on the basis of a rock succession and the chronostratigraphical unit that can be deduced from it. A geochronological unit is isochronous, and its beginning and end correspond to the synchronous base and top of the physical reference unit.

The hierarchy of geochronological units, in decreasing order of rank, is *eon, era, period, epoch* and *age*. These are shown in Table 2 alongside the corresponding chronostratigraphical units. A *chron* is the non-hierarchical geochronological unit corresponding to the chronozone. The sum of several *ages* need not correspond to an epoch or form a continuum.

Names of periods and units of lower rank are identical with those of the corresponding chronostratigraphical units. They are also written in the same way, with a lower-case initial in Norwegian, and capitals in English when used formally. The relevant geochronological unit term replaces the chronostratigraphical term in the formal name. To distinguish chronostratigraphical and geochronological units which have the same proper name, the rank designation should be added (e.g. Jurassic System/Jurassic Period, Dogger Series/Dogger Epoch and Bathonian Stage/Bathonian Age).

In formal and informal geochronological units the terms Early (tidlig), Middle (mellom) and Late (sen) are to be used; these correspond to Lower, Middle and Upper in formal chronostratigraphical units (Section 4.2.1.5).

Key reference: NACSN (1983).

4.4 Geochronometrical units

4.4.1 General properties and rules

A geochronometrical unit is a geological time unit established and defined by direct division of time expressed by a specific number of years. Unlike geochronological units, geochronometrical units are *not* based on the physical boundaries of specific chronostratigraphical units. The boundaries can be convenient, arbitrarily chosen ages in years (such as, for example, some of the proposed divisions of the Precambrian). A geochronometrical boundary may also be decided upon on the basis of many radiometric age determinations within a succession in which changes in lithology, fossil content, climatic indicators, etc. have been recorded, making it natural to distinguish between two contiguous time units.

The same names, rank terms and hierarchy are used for geochronometrical units as for geochronological units (Table 2, Section 4.3).

Geochronometrical units can often be linked to chronostratigraphical units that fully or partially correspond in time to the chronometrical unit. A basal boundary stratotype (typesnitt for undergrensen) should, nevertheless, not be defined in a succession of this sort. If this is done, the time unit must be redefined as a geochronological unit. Determination of a relevant time boundary in other successions must then take place by chronostratigraphical correlation (Section 4.2.1.4) to the erected boundary stratotype.

Geochronometrical definition of a time boundary has the advantage of not being dependent upon whether the succession contains fossils that can be correlated with fossils in a chronostratigraphical type section. Geochronometrical time boundaries should not be defined more closely than they can practicably be determined in a succession, given the ability for time resolution that numerical age determination methods have at any given time.

Example: As part of the process of defining the Pleistocene-Holocene boundary, the Holocene Commission, during the INQUA Congress in Paris in 1969, decided that the boundary should be placed at 10 000 ^{14}C years before present (Olausson 1982). ^{14}C determinations are to be calculated using the Libby half-life (5568 years) with 1950 as the reference year for the present. When defined in this way, the Quaternary series, Pleistocene and Holocene, are geochronometrically defined and are therefore not dependent on a type section. The Holocene has now been geochronometrically subdivided, too.

Key reference: NACSN (1983).

4.5 Polarity-chronostratigraphical units

4.5.1 General properties and rules

Polarity chronostratigraphy is concerned with chronostratigraphical classification of rocks and superficial deposits on the basis of their remanent-magnetic polarity properties (see Section 3.4).

A polarity-chronostratigraphical unit is a body of rock or superficial deposits that crystallized or was deposited during a certain interval of time characterized by a specific primary magnetic polarity. The magnetic polarity during this period must be identifiable in the lithological reference units. A reference unit of this sort will be a polarity zone in the magnetostratigraphical classification system (Section 3.4.2).

A polarity-chronostratigraphical unit is termed a *polarity chronozone*.

4.5.2 Polarity chronozone (polaritets-kronosone)

4.5.2.1 *Polarity chronozone* is the fundamental polarity-chronostratigraphical unit. It consists of rocks and superficial deposits having a specific *primary* polarity that is valid globally. Polarity chronozones are erected following extensive documentation of the magnetopolar properties, lithostratigraphy, biostratigraphy, chronostratigraphy, correlation and age relationship of a unit (see Section 2.4).

A polarity chronozone can be divided into two or more *polarity subchronozones* (polaritets-underkronosoner). Two or more polarity chronozones can be grouped in a higher-ranking unit called a *polarity superchronozone* (polaritetsoverkronosone) (Table 1).

4.5.2.2 *Naming of polarity chronozones* – A polarity chronozone is named in accordance with the "general rules for naming and defining geological units" (Chap. 2). The complete formal name has three component parts. The first is a proper name, which is a geographical name from a type locality or type area. It is followed by a term denoting the type of polarity, *normal* (normal), *reversed* (revers), or *mixed* (blandet), and finally by the word "chronozone". The initial letters of all these words are capitalized in English, but written in lower case in Norwegian (see Section 4.1).

If the same geographical name is used for both a polarity zone and a polarity chronozone, the difference is marked in English by adding the adjectival ending "-an" or "-ian" to the geographical name of the polarity chronozone. Frequently used names which do not have a geographical origin can still be employed. Examples of this are "Brunhes" ("brunhes"), "Matuyama" ("matuyama"), "Gauss" ("gauss") and "Gilbert" ("gilbert"). The proper name can be used alone provided misunderstandings cannot arise.

Key reference: NACSN (1983).

4.6 Polarity-chronological units

4.6.1 General properties and rules

A polarity-chronological unit is a division of geological time that denotes the time interval represented by a polarity-chronostratigraphical unit (Section 4.5).

The *polarity chron* (polaritetskronen) is the fundamental polarity-chronological unit. It designates the time span of a polarity chronozone. The hierarchy of polarity-chronological units, in decreasing order of rank, is *polarity superchron* (polaritetsoverkron), *polarity chron* and *polarity subchron* (polaritetsunderkron) (Table 1).

Formal names of polarity-chronological units are identical with those of corresponding polarity-chronostratigraphical units, except that chron, superchron and subchron replace chronozone, superchronozone and subchronozone, respectively.

Key reference: NACSN (1983).

4.7 Diachronous units

4.7.1 General properties and rules

4.7.1.1 *Definition and use* – A diachronous geological time unit comprises the unequal spans of time represented by the deposition of a lithostratigraphical, biostratigraphical, pedostratigraphical or morphostratigraphical unit, or an assemblage of two or more units within one of these categories. A diachronous time unit represents the time span of a geological *event* (hendelse). In a geological sense an event is therefore a period of time characterized by certain geological processes (e.g. sedimentation, volcanism, folding, glacier advance, etc.) within a specified area.

Diachronous classification of geological time units provides a basis for (a) comparing the spans of time represented by stratigraphical units with non-synchronous boundaries at different localities; (b) determining the beginning and end of deposition of a stratigraphical unit at different localities; (c) assessing how quickly a unit was deposited over a given area; (d) determining and comparing the speed of deposition of a unit at different localities; and (e) comparing various temporal and spatial relationships in diachronous stratigraphical units.

A diachronous time unit is only valid within the area in which the physical reference unit occurs, or in which a stratigraphical unit can be found that is correlatable with the reference unit.

The relationship between diachronous, chronostratigraphical and geochronological units is shown in figure 30.

4.7.1.2 *Boundaries and erection of formal units* – The boundaries of a diachronous unit are the times recorded by the beginning and end of deposition of the reference unit at a given place (Figs. 30, 31). These times may be determined using chronostratigraphical methods or numerical age determinations. One or both of the boundaries are time-transgressive. They are defined by a number of reference sections that enable the age of the boundary to be determined (Fig. 31).

Formal diachronous units are erected in accordance with the "general rules for naming and defining geological units" (Chap. 2). In addition to the requirements stated in Section 2.4.6, several reference sections must be specifically identified and described to document the temporal and spatial variations.

Formal diachronous units should only be defined and named if this serves a useful purpose. Informal designations can be used to refer to diachronous intervals encompassing the deposition of a stratigraphical unit.

4.7.1.3 *Units, rank and hierarchy* – The *diachron* (diakronen) is the fundamental, non-hierarchical, formal diachronous unit. If a hierarchy of formal diachronous units is needed, the following terms are recommended, in decreasing order of rank, *Episode* (episode), *Phase* (fase), *Span* (trinn) and *Cline* (skifte) (Fig. 31).

A diachronous unit is given rank in the hierarchical classification system according to its relative duration and importance (Fig. 31). Diachronous units may therefore vary greatly in duration – even units having the same rank. One and the same diachronous unit may also have the same duration at different localities, even though it started and ended at different points in time at the individual localities.

4.7.1.4 *Naming* – Diachronous units are given formal and informal names in accordance with the "general rules for naming and defining geological units" (Chap. 2). The proper name (Section 2.2.2) is a geographical name (or an alternative name in the case of the continental shelf). If the diachronous unit covers the period spanning the deposition of a single stratigraphical unit, the proper name of this depositional unit can also be used as the proper name of the derived diachronous unit. If the diachronous unit encompasses several formal stratigraphical units, the proper name of the diachron must not repeat any of the proper names of the reference units covered by the diachron. In such a case, the superior diachronous unit is given a new proper name.

In English, the proper name is combined with the word "Diachron", or the relevant rank designation, using capitals for the initial letters in formal names. In Norwegian, the term is written in one word without a capital letter (see Section 4.1). To refer to diachrons informally, the designations "event" ("hendelse" or "begivenhet") and "time" ("tid") may be used. The formal terms "episode", "phase", "span" and "cline" may also be used informally, but are never then combined with a formal proper name. An informal designation of a diachronous period of time might, for example, be "Rjukan time" (rjukantid). This means the variable period of time during which the Rjukan Group formed.

4.7.2 Episode (Episode)

4.7.2.1 *Episode* is the diachronous unit of highest formal rank. Størmer (1966) proposed "episode" as the formal geochronological unit corresponding to the chronostratigraphical chrono-

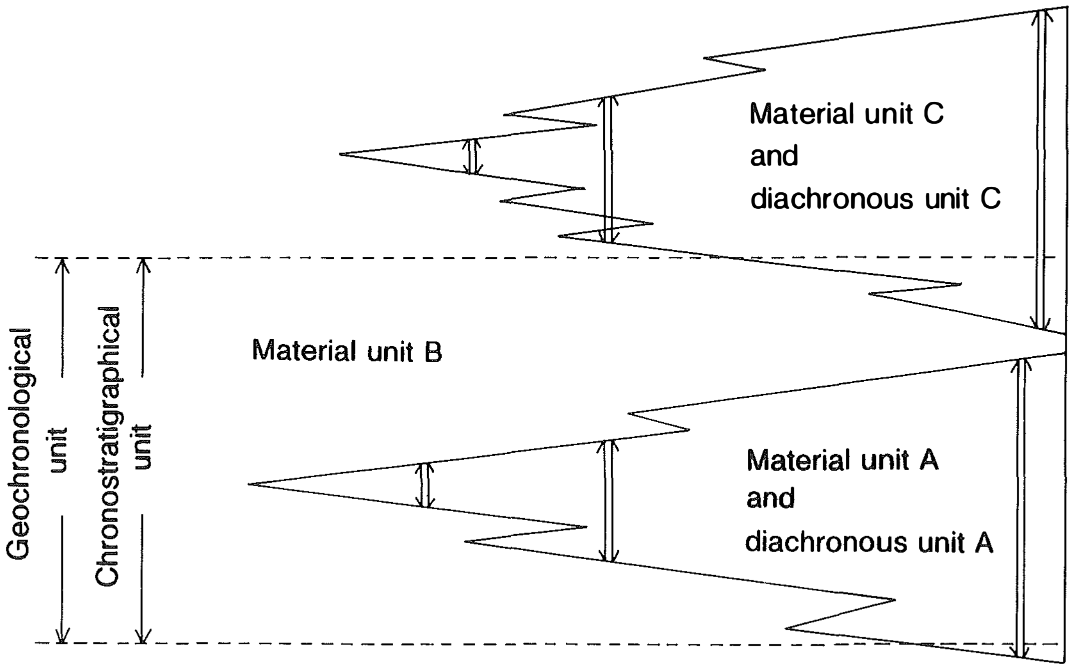


Fig. 30 Diachronous units and their relationship with their material reference units, and with geochronological and chronostratigraphical classifications. Unbroken lines are time boundaries for diachronous units, and broken lines are synchronous time boundaries. Vertical arrows indicate duration. After NACSN (1983).

zone. This isochronous unit of time is now called a chron (Section 4.2.7). Episode should only be used formally for diachronous periods represented by depositional units of high stratigraphical rank, e.g. group or supergroup, morphosuite or morphosupersuite. Episode can, for example, be used to denote the period covering depositions related to a single ice age. When "episode" is used in informal contexts, it is recommended that the word be ascribed a meaning corresponding to that which applies in formal usage.

4.7.3 Phase (Fase)

4.7.3.1 *Phase* is the diachronous unit that has formal rank next below episode and next above span. When phase is used formally, it must refer to one of several similar, prominent events that together constitute a major event with the rank of episode (Fig. 31). Phases in an ice-age episode may, for example, be represented by two or more "stadial" moraine formations and intermediate "interstadial" water-deposited sediments. When used informally, the word "phase" should retain a corresponding meaning of relative time.

4.7.4 Span (Trinn)

4.7.4.1 *Span* is the diachronous unit that has formal rank next below phase and next above cline. A span will generally be the lowest diachronous unit that it is practical to distinguish in a reference succession. A span may, for example, be the time during which a single lava flow, ice-marginal ridge (e.g. Ra Span) or conglomerate fan formed. A span may be defined without it needing to form part of a formal phase. When used informally, the word "span" should retain a corresponding meaning of relative time.

The Norwegian word "trinn" has previously also been used as a geomorphological term for marine terrace surfaces and for ice-marginal deposits. This usage of "trinn" is not recommended in Norwegian (see Section 3.10.2.8).

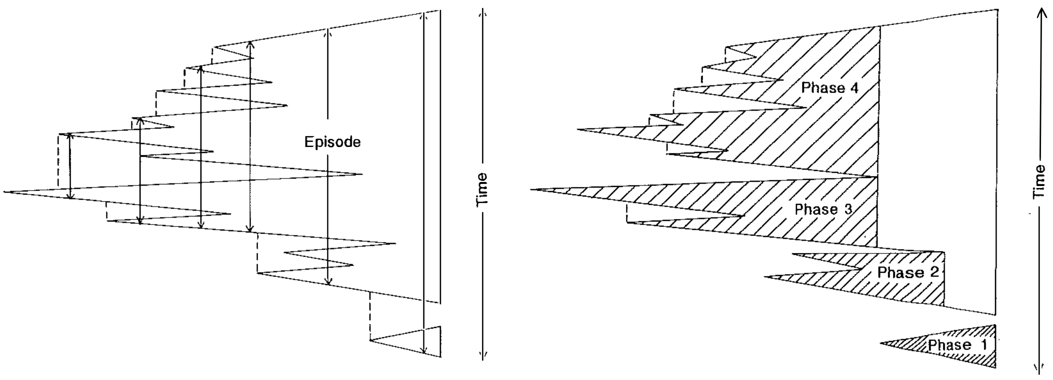


Fig. 31 Diachronous units. Relationship between episode and phase. An *episode* can be divided into two or more *phases*. A phase can be further divided into *spans*, and spans into *clines*. (This could, for example, be done in phase 4.) Unbroken lines are time boundaries, and vertical arrows indicate duration at various localities along the material reference unit for the diachronous time unit. After NACSN (1983).

4.7.5 Cline (Skifte)

4.7.5.1 *Cline* is the lowest-ranking formal diachronous unit. It designates a brief geological event, but one which nonetheless is reflected in a stratal succession as an important lithological or biological change. A cline may, for example, be the period of time covered by a single retreat with a new advance of an ice-front marked by an ice-marginal deposit, a flood, a storm, or a slide. When used informally, the word "cline" should retain a corresponding meaning of relative time.

4.7.6 Climatostratigraphy and diachronous units

In Quaternary stratigraphy it has been common practice to define stratigraphical units and derived time units on the basis of palaeoclimatical criteria. Classification systems constructed on this basis have been proposed by Mangerud (1973) and Mangerud et al. (1974). The recommendations made by NSK in this Code concerning the use of climatostratigraphy are to be looked upon as an updated extension of these classification systems.

"A *climatostratigraphical unit* is a stratigraphical unit with the boundaries defined by geological indications of climatic changes" (Mangerud et al. 1974, p. 113). The palaeoclimatical criteria are interpreted on the basis of lithological and biostratigraphical data and isotope analyses. The boundaries of a climatostratigraphical unit are placed at marked steps in the palaeoclimatical data basis.

Climatostratigraphical units have formed the physical reference basis for "chronostratigraphical" and "geochronological" units in Quaternary stratigraphy. The use of chronostratigraphical and geochronological terminology presupposes that the units in question are isochronous (cf. Section 4.1). Climatic changes, *as they can be traced in a stratal succession*, will usually not be synchronous except over fairly limited areas. An ice age, for example, can begin and end at different times in different parts of the world. It is therefore possible for the sediments, or fossil fauna or flora, selected as criteria for an ice age in a stratal succession, to differ in age in different areas. The immigration of a temperature-indicative flora or fauna into an area may also be delayed relative to the climatic change itself. Those time units which can be derived from physical, climatostratigraphical reference units are therefore diachronous in character.

Climatostratigraphical time units can be termed (a) *informal climatic events*, e.g. "glacials" (glasialer), "interglacials" (interglasialer), "stadials" (stadialer), "interstadials" (interstadialer), "cryomers" (kryomerer), "thermomers" (termomerer), etc.; (b) *formal diachronous units*; (c) *formal geochronometrical units*. In (b) and (c) the degree to which time is divided must be adjusted to how well it can be resolved by numerical age determination methods. Geochronometrical classification implies that *the time boundary in question is defined as being syn-*

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6. Index

Terms printed in *italics* are the Norwegian equivalent of the immediately succeeding term(s).
* denotes that the term has identical spelling in English and Norwegian.

Appendix 1

Regulations for the Norwegian Committee on Stratigraphy

Approved by the Norwegian Council of Geology (Norsk geologiråd) on May 5, 1982; revised on March 17, 1989.

Status

The Norwegian Committee on Stratigraphy is responsible to the Norwegian Council of Geology (NGR). Decisions taken by the Norwegian Committee on Stratigraphy can be put before NGR for their ruling.

Mandate

The Norwegian Committee on Stratigraphy is authorized to:

1. Draw up a Code for Norwegian stratigraphical terminology.
2. Approve Norwegian stratigraphical terms.
3. Establish and maintain a computer-based register of valid and invalid stratigraphical units on the Norwegian mainland, Svalbard, Jan Mayen and Norwegian claims, and on the adjoining continental shelves.
4. Draw up and maintain up-to-date a stratigraphical glossary for the areas mentioned in point 3.
   This glossary is to contain lists of:
   a) all types of stratigraphical units,
   b) tables showing comparable stratigraphical units, both within Norway and in relevant foreign areas.
5. Maintain a continual control over, and provide advice on, the introduction of new stratigraphical units.

Composition

The Norwegian Committee on Stratigraphy consists of 13 members including a permanent member from the Norwegian Language Council. The members themselves elect the chairman. The secretariat for the committee, and the computer-based register, are to be located at the Geological Survey of Norway (NGU). The following institutions will be requested to propose 2 persons each as candidates for membership of the Norwegian Committee on Stratigraphy:

Geological Survey of Norway (NGU)
Agricultural University of Norway (NLH)
Norwegian Polar Research Institute (NP)
Norwegian Petroleum Directorate (OD)
University of Bergen (UB)
University of Oslo (UiO)
University of Tromsø (UiT)
University of Trondheim (UiTr)
Norsk Hydro
Saga Petroleum a.s.
Statoil

The Norwegian Council of Geology may propose candidates for the Norwegian Committee on Stratigraphy who are not on the list proposed by these institutions and companies. The Norwegian Council of Geology appoints members from among the nominated candidates to serve for 2 consecutive years, with the possibility for reappointment. Not more than half the committee members should be changed at any one time. The members should be chosen so that their combined knowledge of stratigraphy (Precambrian to Recent) within the areas mentioned in point 3 of the mandate is as good as possible. The Geological Survey of Norway, the Norwegian Petroleum Directorate and the Norwegian Polar Research Institute are always to be represented on the Norwegian Committee on Stratigraphy with at least one member each.

Manner of working

The Norwegian Committee on Stratigraphy should hold at least two meetings yearly. The travelling expenses are met by the participating institutions. The Norwegian Committee on Stratigraphy itself decides its working methods in such a way as to ensure that the tasks mentioned in the mandate are dealt with in the best possible manner. The Norwegian Committee on Stratigraphy must present an annual report to the Norwegian Council of Geology on its activities and future plans, and at least once each year make known new, approved stratigraphical terms.

Appendix 2a

Norwegian Committee on Stratigraphy

REGISTRATION FORM FOR GEOLOGICAL UNITS IN NORWAY

1. Name, rank & category of unit, formal (F) or informal (I) status

2. New unit ☐ Previously defined unit ☐ Revision of name/rank/status of unit ☐

3. Former name/rank/status

4. References
   a) First use of name
   b) Current definition
   c) Type description

5. Geographical location
   a) General region
   b) 1:250 000
      Field on continental shelf
   c) 1:50 000
      Block no.
   d) Type locality/profile
      Drill hole no.

6. Regional context
   a) Geological region
   b) Tectonic unit
   c) No. on Bedrock Map of Norway

7. Geological description

8. a) Age
   b) Type of age
   c) Dating method
   d) Reference

9. a) Name of overlying unit
   b) Name of underlying unit

10. Name of superior unit

11. a) Correlations
    b) References

12. Is the name used in another geological context?
    Which?

13. Other information

14. Place ______________________ Date ______________
    Name ______________________
    Address ______________________

To be filled in by NSK

NSK no. Received
Approved by NSK
Formal spelling in Norwegian
Formal spelling in English
Dealt with by
Other information

Appendix 2b

Norwegian Committee on Stratigraphy

Instructions for filling-in the registration form

1. All named geological units, formal (F) and informal (I), are to be registered. (For definition of formal and informal units, see "Regler og råd for navnsetting av geologiske enheter i Norge" by NSK, *Norsk Geologisk Tidsskrift 66, (Suppl. 1) pp. 1-96*, and/or "Rules and recommendations for naming geological units in Norway" by NSK, *Norsk Geologisk Tidsskrift, Vol. 69 Suppl) pp. 1-111.)* In the case of already established units the original spelling of the name is used. Any new, official spelling of the geographical name in question is to be put in brackets. Geographical names used for newly proposed units should be on an official Norwegian map. The category, rank and status (formal and informal) of a unit are determined according to the guidelines in the Code. Any doubts concerning status are decided by NSK.

Key for unit categories:

Biostratigraphical units	B
Deformational-diachronous units	Dd
Diachronous units	D
Geological form units	Gf
Climatostratigraphical units (see also diachronous units)	Kl
Chronostratigraphical units	Kr
Lithodemic units	Ld
Lithostratigraphical units	L
Morphostratigraphical units	M
Planar structural units	Sgf
Linear structural units	Sgl
Tectonostratigraphical units	Ts
Others (see the Code)	A

Examples of ways of filling-in the form: Barents Sea Group, L.F., Bjørnøy Basin, Gf,F., Kalak Nappe Complex Ts, F., Ekne discontinuity, Dd,I., Jørstad moraine, L, I.

2. Put X.

3. When revising the name and/or rank of a unit, the old name and rank is written here.

4. References that are as complete as possible are given here. If there is insufficient space, the title of the publication can be omitted. a) Reference for the first time the name is used for this unit in the literature. b) Reference for the current definition of the unit if that is not in (a). c) Reference for the description of the unit if that is not in a) or b).

5. a) The main geographical region is given according to the following key:

Norwegian mainland	N	Continental shelf	K
Svalbard	Sv	Antarctic/Bouvetøya	A
Jan Mayen	JM	Sweden	S
Finland	SF	Soviet Union	SU
Denmark	DK	Rest of Europe	E
Great Britain	GB		

b) The name of the map-sheet is used for the 1:250 000 series; field names are used for the continental shelf.

c) Use the number of the 1:50 000 map-sheet containing the unit. Other official maps may also be used; state which here.

d) To refer to the type locality or type section, use the UTM grid reference scheme or Greenwich degrees. In the case of the continental shelf use degrees as well as bore-hole number.

6. a) The name or designation of the geological region containing the unit, e.g. Bergen Arcs, Trondheim Region, southeast Norwegian basement area, etc., is put here.

b) If relevant, information should be given here concerning in which major tectonostratigraphical unit the unit in question is located.

7. For the geological description it is recommended that those guidelines given in the Code, that are relevant for the unit in question, are followed. In the case of lithological units, the name of the rock type is put first, followed by the description of features, including lithology, fossil content, deformation, metamorphism, etc., which characterize the unit. Boundary relationships to neighbouring units are to be described. If there is insufficient space, use a separate sheet.

8. a) When referring to geological periods use the following abbreviations:

Quaternary	Q	Palaeozoic	Pz	Precambrian	PK
Cenozoic	Cz	Proterozoic	Pt		
Mesozoic	Mz	Archaean	Ar		

For other geochronological time units and abbreviations see the Statoil geological time scale (Appendix 3 in "Regler og Råd for navnsetting av geologisk enheter i Norge" by NSK, *Norsk Geologisk Tidsskrift 66, (Suppl. 1) pp. 1-96, 1986* or other published time scales.

More precise ages are written in full, e.g. 400 ± 20 my. Give the assumed age if an age determination is not available; write, for example, "assumed Devonian".

b) State whether the age represents the time the unit was originally formed (by deposition, intrusion, movement, deformation, etc.) or later metamorphism, tectonic movements or other disturbances of the original properties of the unit.

c) State whether the age determination derives from indirect techniques, the aid of fossils or radiometric methods. In the last-mentioned case, the actual method should be stated, e.g. Rb/Sr whole-rock.

9. The names of adjoining units, underlying, overlying, or adjacent to, preferably of the same rank as the unit described, are listed here.

10. If the unit forms part of a hierarchical classification system, the name of the unit that has the next higher rank and contains the unit in question, is given here. (This may, for example, be a group, if the unit is described as a formation; see the Code.)

11. The name(s) of other unit(s) with which the unit described has been correlated, is (are) given here, along with appropriate reference(s). If necessary, use a separate sheet.

12. It is important to state whether the geographical name used as a proper name for the unit described has also been used for other geological units. (This is usually an undesirable practice; see the Code.)

13. "Other information" may be additional information that is of interest and importance for defining and describing the unit.