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Guide for geological nomenclature in Sweden

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Guide for geological nomenclature in Sweden

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ABSTRACT
This guide provides recommendations on how to introduce formal names for geological units, specifically lithostratigraphic, chronostratigraphic, biostratigraphic, lithodemic, tectonic and tectonostratigraphic units, as well as for other geological features such as deformational structures and bedrock landforms. The recommendations apply to Swedish geology but are crafted to harmonize with international practice in geological nomenclature.

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Preface

For several years, awareness has been growing within the Swedish geological community of the need to harmonize the principles used in Sweden for geological nomenclature with those used internationally, as expressed in various stratigraphic guides. According to the initial intentions, this guide would contain guidelines on how to name units of stratified rocks in Sweden. The types of stratigraphy thought applicable to Swedish geological nomenclature were lithostratigraphy, chronostratigraphy, and biostratigraphy; lithodemic and tectonostratigraphic nomenclature were also accommodated.

To this end, the Class for Geosciences (Class V) of the Royal Swedish Academy of Sciences (KVA) decided in 2007 to appoint a *Committee for Swedish Stratigraphic Nomenclature.* The task for the committee was to prepare, under the supervision of KVA, a stratigraphic guide.

The appointment of a *Committee for Swedish Stratigraphic Nomenclature* was originally suggested by Stefan Bengtson, Jan Bergström and Maurits Lindström, members of the Class for Geosciences (Class V), KVA.

A working group with Jan Bergström, David Gee, Karna Lidmar-Bergström and Maurits Lindström was appointed to present, to Class V, a list of nominees for such a committee. The following committee was then appointed: Jenny Andersson, Björn Berglund, Sten-Åke Elming, Gunnel Johansson, Risto Kumpulainen (secretary), Karna Lidmar-Bergström, Maurits Lindström (chairman), Kärstin Malmberg Persson, Arne Thorshøj Nielsen, Birger Schmitz, Håkan Sjöström, Annika Wasström and Pär Weihed. Later, Gunnel Johansson was replaced by Åsa Holmér. After Maurits Lindström passed away in 2009, KVA appointed Risto Kumpulainen as the new chairman and Karin Högdahl as the new secretary. During the process Björn Berglund retired from the committee.

Significant contributions from other than the committee members to the content of the guide were provided from the Geological Survey of Sweden (SGU) through Stefan Bergman, Benno Kathol and Michael Stephens, and from Peter Bengtson, Stefan Bengtson, David Cornell, Mark Johnson, Åke Johansson, Johan Kleman and Thomas Lundqvist. Additional comments were received from Per Ahlberg, Ulf B. Andersson, Per-Gunnar Andréasson, Stig M. Bergström, Mikael Calner, Stefan Claesson, Hemin Koyi, Sören Jensen, Katarina Persson Nilsson, and Stephen McLoughlin. External reviews of the penultimate draft were carried out by Johan Petter Nystuen, Oslo, Tõnu Meidla, Tartu, and Kari Strand, Oulu.

Nomenclatorial background

A number of stratigraphic guides have been prepared in other countries, notably (1) the International Stratigraphic Guide (Hedberg 1976; Salvador 1994; Murphy & Salvador 1999) under the auspices of the International Union of Geological Sciences, (2) the North American Stratigraphic Code supervised by the North American Commission on Stratigraphic Nomenclature (NACSN 1983, 2005), (3) the rules and recommendations for naming geological units in Norway (Nystuen 1986, 1989) under the supervision of the Norwegian Committee on Stratigraphy, (4) Guidelines and Procedures for Naming Precambrian Geological Units in Finland (Strand et al., 2010) after the initiative of the Stratigraphic Commission of Finland; (5) Bengtson (1980, 1981),

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and (6) Bengtson & Martinsson (1988) have published a set of guidelines for use in Sweden. These documents formed the primary sources for the preparation of the present guide.

The word *stratigraphic* in the guide name, as used in most guides, is replaced here with the word *geological,* enabling the application of this guide to nomenclature of geological units and features other than stratified rocks

The Swedish National Committee for Geology, appointed by KVA/Class V, has established under its sponsorship a new sub-committee, *the Swedish Committee for Geological Nomenclature* (*SCGN; Svenska geologiska namnkommittén)* to monitor the application of the recommendations of this guide. The Committee for Swedish Stratigraphic Nomenclature will be dissolved following the publication of the guide.

On behalf of the Committee for Swedish Stratigraphic Nomenclature

Risto Kumpulainen

Chairman of the committee

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1. Introduction

The geological nomenclature presented herein deals with a system of names for (1) units of rock or sediment, which are defined by visible features including composition, depositional structure, age, metamorphic grade, chronological order of events and geographic occurrence and distribution, or by magnetic or other physical properties, (2) units defined by their tectonic setting. Some advice is also given for naming other large-scale geological and certain geomorphological structures and features.

The names should be stable, understandable, consistent and as self-evident and easy to apply as possible. Stratigraphic *nomenclature* is not synonymous with stratigraphic *terminology* (see, e.g., Salvador 1994, Chapter 3), a misconception widely embraced nationally and internationally. Terminology is the set of terms used in a specific field (such as geology). Nomenclature is a system for naming specific objects or concepts. This document focuses on geological (not only stratigraphic) *nomenclature.* For *stratigraphic terminology*, the reader is referred to the Glossary of Stratigraphic Terms (in Salvador 1994, pp. 105–142). *Geological terminology* in general is treated by, e.g., TNC (1988) and Neuendorf et al. (2011).

Sweden has a long and strong tradition in stratigraphy. Linnaeus (1747) published an accurate and fairly detailed section through the classical Lower Palaeozoic succession of Kinnekulle of south-western Sweden. Angelin (1851) described characteristic Swedish fossils in stratigraphic order; the corresponding rock units were named after their fossil content. This remained common practice until the middle of the 20th century. From the early 19th century onwards, some lithostratigraphic units containing a geographic name were also established. That became the common practice during the first half the 20th century. Some early studies also gave names to various tectonic features, such as, orogens, shear zones and other structures. Recently, lithostratigraphic principles have been applied also to the Quaternary deposits in Sweden (Lagerlund & Björck 1979). A stratigraphic lexicon for Sweden was published by Magnusson (1958).

For any nomenclatorial recommendations to become useful, they should conform as closely as possible to other commonly used guides for stratigraphic and geological nomenclature and, at the same time, adhere as closely as possible to the geological nomenclature that has developed in Sweden. The border zone, where these two sets of principles meet, is the concern of all users of the present guidelines. Many Swedish names for geological units that are currently in use in Sweden are informal and lack adequate definition. The instability of the previous Swedish nomenclature is a serious problem. The recommendations suggested in this guide are intended to counteract instability, uncertainty and confusion.

Practices in nomenclatorial principles change. One example is the application of the term *series*. More than 50 years ago, it was applied to lithostratigraphy for certain Precambrian sedimentary successions of Sweden. One of these successions is the Visingsö Series (Nathorst 1879). This document and the other nomenclatorial guides mentioned above restrict the use of series to chronostratigraphy; hence, it cannot be used in lithostratigraphy. The term *series* in lithostratigraphical connotations should be replaced by either group or formation.

One of the most important underlying principles for the future is that it should be possible to validate existing names through relevant descriptions and identification of type sections (also called stratotypes), type localities or type areas (regions) that conform to the intentions of the original author(s) or common practice. The validation of existing names should be carried out as the need arises in the course of ongoing research or mapping programmes. This process should be aided by scientific experts with sufficient background to deal in depth with the geological units concerned. In some cases, it will be found that names need to be abandoned in order to avoid confusion. One such example is when a geographic name is used in more than one geological name, e.g., Offerdal Conglomerate, Offerdal Nappe, Offerdal Schist, Offerdal Group and Offerdal Synform.

The present geological guide is not intended to replace the other well-established guides, which include definitions and procedures for defining and naming various stratigraphic units. Some introductory notes concerning selected categories of geological units are given in Section 2, including topostratigraphic and tectonic units as well as geological large-scale structures and bedrock forms. The various types of stratigraphic units are all established based on their own characteristic properties and independent of each other and, hence the unit boundary of one category is almost never identical to the boundary of another category.

The International Stratigraphic Guide (Salvador 1994; Murphy & Salvador 1999) does not adequately define the nomenclature needed to classify and map the crystalline bedrock that dominates Sweden. Therefore, the present guide introduces procedures for formalizing names for igneous and metamorphic rocks as well as tectonic, structural and some other geological units and features. In general, the lithodemic classification of non-stratified rocks, developed for the North American Stratigraphic Code (NACSN 1983, 2005), is accepted here.

There is a long tradition in Sweden to identify parts of the present land surface as a re-exposed unconformity, the sub-Cambrian (sub = below) peneplain (Högbom 1910). Asymmetric horsts have been identified in relation to the sub-Cambrian peneplain (De Geer 1910). An analysis, which uses the relationships between the basement surface and its cover rocks, is extended from the identification of the sub-Cambrian peneplain to identify hilly unconformities (and their extension as hilly peneplains) in south Sweden in relation to Mesozoic cover rocks and, further, to incorporate crosscutting epigene (never covered) peneplains (plains with residual hills). The stratigraphic landscape analysis (SLA; Lidmar-Bergström et al. 2013) is based on particular large-scale denudation landscapes (plains, hilly terrain, landscapes with joint aligned valleys), sometimes identified as unconformities, and results in identification of major Phanerozoic geological structures (Appendix C).

The main categories of geological units and features that are important for scientists in Sweden are identified and defined in Section 2. General guidelines for the naming of geological units and features, together with the choice of type sections (stratotypes), type localities, type areas and regions, are provided in Sections 3–6. A more detailed treatment is limited to the four main geological units and features and their subunits are discussed in Sections 7–10.

2. Main geological units and structures

The four main geological features in Sweden for which nomenclatorial guidelines are provided here, are: (1) stratigraphic units, (2) lithodemic units, (3) tectonic units and (4) structures and bedrock forms. These features are summarized in this section and Fig. 1 and described in further detail in later sections.

2.1. Stratigraphic units

Different opinions exist concerning the meaning of the word "stratigraphy". Neuendorf et al. (2011) stated that stratigraphy is "the science of rock strata", i.e., layered rocks for which the Law of Superposition applies. However, Salvador (1994) suggests that the principles of stratigraphic nomenclature should be expanded beyond normal stratified units by writing

> all observed properties of rock bodies and their interpretation in terms of environment or mode of origin and of geological history. All classes of rocks, igneous and metamorphic as well as sedimentary, unconsolidated and consolidated, fall within the general scope of stratigraphy and stratigraphic classification.

This guide applies the definition of stratigraphy according to Neuendorf et al. (2011).

Many stratigraphic unit categories have been recognized in various earlier stratigraphic guides; several are mentioned below. Only three, i.e., *lithostratigraphic, chronostratigraphic* and *biostratigraphic units,* are addressed in more detail in Section 7. Further usage of the locally adopted *topostratigraphic unit* is discouraged here for reasons discussed in Appendix A. For certain other categories, internationally accepted recommendations are either lacking or are currently considered less relevant for our national guide; if need arises, they may be added to later versions of this guide.

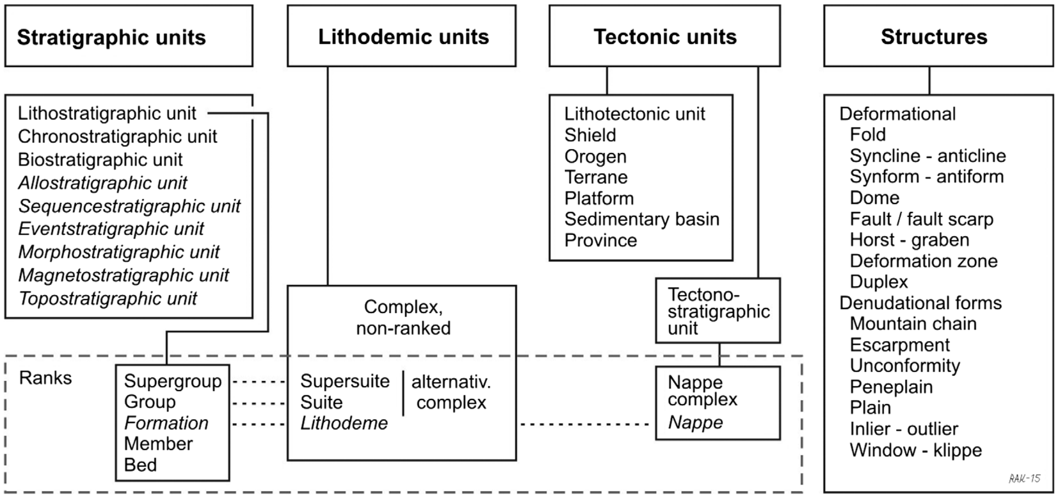

Figure 1. Summary of the geological units and other features discussed in this guide. Units written in italics are mentioned only briefly in this text.

2.1.1. Lithostratigraphic units

(lithostratigraphy, *litostratigrafi*) are used for the description and classification of layered rocks. The significant rock properties and boundary conditions of each recognized unit are described. Lithostratigraphy is a fundamental stratigraphic discipline and is basic for the geological mapping of well-preserved sedimentary and extrusive igneous successions, including unconformities. Its use depends on local geology and local traditions in geological mapping, both of which must, therefore, be given special attention in this guide. In certain cases, e.g., owing to thermal or kinetic metamorphism, a lithostratigraphic unit may lose its original characteristics and be altered to a metamorphic rock; such a unit should be classified as a lithodemic unit (see below).

2.1.2. Chronostratigraphic units

(chronostratigraphy, *kronostratigrafi*) refer to rocks distinguished by age and time relations. The units are international. The purely regional concern for naming such units may be dwindling. If a need arises for establishing regional stages, substages or chronozones in Swedish geology, strict adherence to the international guides is recommended.

2.1.3. Biostratigraphic units

(biostratigraphy, *biostratigrafi*) refer to bodies of layered rocks or sediments distinguished by their fossil content or bioecological criteria; they are *fundamentally* independent of lithostratigraphy. Biostratigraphy and chronostratigraphy are frequently used in a practically synonymous sense, although they are quite different concepts in principle. The boundaries of many biostratigraphic units are not precisely synchronous from one locality to another.

2.1.4. Topostratigraphic units

(topostratigraphy, *topostratigrafi*) are defined by a mixture or a combination of litho and biostratigraphy. The use of topostratigraphic units is restricted to the Baltic area and it is not accepted internationally. For these reasons, topostratigraphy is not recommended for further use in Sweden (see Appendix A).

2.1.5. Allostratigraphic units

(allostratigraphy, *allostratigrafi*) organize rocks or sediments, also volcanic in origin, by a system of bounding unconformities. Allostratigraphic units are convenient for successions of sediments or sedimentary rocks that are similar and therefore difficult to distinguish lithologically from each other but contain distinct unconformities (for example, soil horizons, erosion surfaces, etc.). Allostratigraphic units are units defining the material between an overlying and underlying unconformity. No attempt is made in this current guide to recommend formalization of allostratigraphic units in Sweden.

2.1.6. Sequence stratigraphic units

(sequence stratigraphy, *sekvensstratigrafi*) deal with extensive, depositional units that may be bounded by subaerial unconformities and their correlative conformities, by transgressive surfaces or by surfaces of maximum marine flooding. A sequence stratigraphic unit documents changes in relative sea level, which may have been the result of eustasy, regional or local tectonic movements, compaction, isostasy or the combination of two or more of these factors. Sequence stratigraphic units may represent rhythmic deposition in terms of transgressive–regressive cycles. The far-reaching identification of the processes that formed the component sediments is a primary goal. An international committee, ISSC Task Group on Sequence Stratigraphy, for the formalization of sequence stratigraphic nomenclature is active, but owing to the diversity of the subject, it may yet take some time for this group to achieve its purpose. For this reason, it is premature to discuss sequence stratigraphic nomenclature here; it may be included in a future version of these guidelines. For a comprehensive summary of sequence stratigraphy, see Catuneanu et al. (2011).

2.1.7. Event stratigraphic units

(event stratigraphy, *eventstratigrafi*) reflect physical, chemical and biological events that left widespread, even worldwide traces that can be recognized in the sedimentary or extrusive igneous record. The event can be caused, for example, by a period of deviating climate or sea-level change, perhaps caused by glaciations, by volcanism or by asteroid impact. A current method to correlate events ("chemostratigraphy") is by tracing "excursions" in isotope curves (e.g., $\delta^{13}C$, $^{87}Sr/^{86}Sr$, $\delta^{18}O$ or $\delta^{34}S$) for sediments and sedimentary rocks, also of igneous origin. "Episode", "orogeny", "stadial", "interstadial", "glaciation" and "interglaciation" are examples of terms used in informal event stratigraphy.

However, many geological events are diachronous, e.g., a transgressive shoreline or an ice advance, and the material deposited in association with that event are time transgressive. The NACSN (2005) allows for the formal classification of diachronous units (including "episode" and "phase") and these have found limited use in Quaternary stratigraphy. However, as in the case of sequence stratigraphy, it is premature to discuss formal event stratigraphic nomenclature in the present guidelines.

2.1.8. Magnetostratigraphic units

(magnetostratigraphy, *magnetostratigrafi*) deal with the history of the Earth's magnetic field, notably the magnetic field reversals, and how they are recorded in the rock or sediment record. Local magnetostratigraphic units can be established according to the international rules. In a succession, rock units are characterized by a given magnetic parameter, which may be polarity. A major goal of magnetostratigraphy is to create polarity-chronologic units, global time units based on periods of reversed and normal polarity. For this goal, national magnetostratigraphic rules are not needed.

2.2. Lithodemic units

Bodies of rock whose character is not ruled by the Law of Superposition are described as lithodemic. A lithodemic unit is a three-dimensional body composed of one or more intrusive, highly deformed or highly metamorphosed rock types, distinguished and delimited on the basis of rock characteristics. Its contacts with other rock units may be sedimentary, extrusive, intrusive, and tectonic or relate to metamorphic grade (NACSN 1983, 2005).

In Sweden, some intrusive rock bodies composed commonly of one predominant rock type have been described and named based on their petrographic characteristics, e.g., Stockholm Granite, whereas the three-dimensional character has been of secondary interest. In lithodemic nomenclature, as also in lithostratigraphy, the description of the bedrock body begins with at least a general description of the form of the rock body; thereafter its content is described. The use of common principles for naming and classifying lithodemic units in Sweden would enhance the future understanding and sharing of geological data. Lithodemic units and the complementary rank terms (e.g., suite) are addressed in more detail in Section 8.

2.3. Tectonic units

According to Neuendorf et al. (2011), tectonics is the "branch of geology dealing with the broad architecture of the outer part of the Earth, that is, the regional assembling of structural or deformational features, a study of their mutual relations, origin and historical evolution". The science of tectonics generally deals with broader, regional features in the Earth's crust relative to that encountered in structural geology (see below) to which, however, it is closely related and with which it is commonly confused.

Such a broad concept forms the primary basis for the division of geological units in heterogeneous bedrock composed of igneous, metamorphic and sedimentary rocks of different ages and with different degrees and timing of deformation and metamorphism, such as that exposed in Sweden. It can be applied to all the rocks in the country.

Several types of tectonic unit, with their definitions in the international literature, are discussed in Section 9. One unit category, tectonostratigraphic unit, has its own rank terms, in a manner similar to that which concerns the stratigraphic units. This tectonic unit category is addressed in more detail in Section 9.

2.3.1. Tectonostratigraphic units

According to the Scandinavian view on the term tectonostratigraphy (*tektonostratigrafi*), it describes the structure of an orogenic belt (in contrast to a pure geographic mountain chain) as composed of flat lying, perhaps folded, tectonically displaced allochthonous sheets (nappes or nappe complexes) of rocks (see Appendix B). These tectonic units may be composed of variously metamorphosed, lithostratigraphic or lithodemic rocks of various ages. The different nappe units are separated by high-strain zones (ductile shear zone, deformation zone or belt, fault, fault zone, etc.), which may be contractional, extensional or both.

The term tectonostratigraphy has been used in the geological literature also in other connotations, reminiscent in certain aspects of lithostratigraphy, sequence stratigraphy and basin analysis of earlier days (e.g., Potter & Pettijohn 1977; Miall 1984). The development of the term tectonostratigraphy in the Scandinavian Caledonides and also its subsequent development towards other connotations, notably to sedimentary geology, are discussed in some detail in Appendix B.

2.4. Structures

According to Neuendorf et al. (2011), structural geology is "the branch of geology that deals with the form, arrangement and internal structure of the rocks, and especially with the description, representation and analysis of structures, chiefly on a moderate to small scale". However, small-scale and meso-scale structures are rarely given formal names. The practice is more common with large-scale structures including bedrock forms (Appendix C). For this reason, structures that result from rock deformation and denudation, i.e., weathering and erosion of rocks, need to be accommodated in presentations of geological nomenclature. These include several categories of structural features. Proper naming is highly relevant, for example, in the definition of the high-strain zones that bound, for example, tectonostratigraphic units in the Caledonian Orogen or many lithotectonic units in the Precambrian shield area in Sweden. Many structures (e.g., dome, horst, fault scarp) can be identified by related sedimentary strata and by stratigraphic landscape analysis (SLA, Section 1). Structures are addressed again in Section 10.

3. Formal and informal units

3.1. Formal units

The International Stratigraphic Guide (Salvador 1994) makes the following statement regarding formal units:

> The proposal of a new formal stratigraphic unit requires a statement of intent to introduce the new unit and the reasons for doing so. To be valid and useful, a new unit must be duly proposed and duly described.
>
> The proposal should include: (1) a clear and complete definition, characterization, and description of the unit so that any subsequent investigator can recognise it unequivocally, (2) the proposal of the kind, name, and rank of the unit, (3) the designation of a stratotype (type section) or type locality on which the definition and description of the unit is based, (4) the proposal should be published in a recognised scientific medium.

The quoted sentences above are to be taken as an essential part of the present guide. They apply fully and equally to the proposal of a new formal unit or the revision of a previously proposed and named unit. A proposal for revision requires in addition a statement of intent to revise the unit, the reasons for doing so, and a discussion of the history of the unit, author(s), original reference and previous treatment.

A new proposal, revision of a unit or abandonment of a unit name, may be made available through publication in a scientific journal or in the database "Geological names in Sweden" (*Geologiska namn i Sverige*), which is administered by the Geological Survey of Sweden (SGU), after approval by the Swedish Committee for Geological Nomenclature (SCGN).

3.2. Informal units

Informal units are those units that are not defined according to the procedures given in this document. Informal units may be useful and introduced in order to refer to occurrences of rock that do not belong to any formally named unit and need to be referred to under a collective informal name. Informal names do not have the protection provided by these guidelines to the formal names. In general terms, the use of informal units should be avoided and the units should be formalized wherever possible.

4. Type section, type locality, type area or region

In order to reduce confusion and to increase accuracy in geological communication it is necessary to define a type section, a type locality or a type area (or region) and establish what kind of standard sections, localities or areas (regions) they are.

4.1. Type sections, stratotypes

Type section (*typsektion*). A type section defines a unit (unit stratotype) or a boundary between two units (boundary stratotype). A unit stratotype is the representative section that exposes the most representative characteristics of a unit in as small a geographic area as possible. Ideally, it should contain both the lower and upper boundary of the unit. A unit stratotype may be composite (composite stratotype). In the case a drill core is used as a stratotype, an exposed hypostratotype (see below) should also be named, if possible. Boundary stratotypes are mainly used in chronostratigraphy. Type sections are essential in lithostratigraphy, chronostratigraphy and tectonostratigraphy.

The International Stratigraphic Guide (Salvador 1994, pp. 27–28) distinguishes the following kinds of type sections, stratotypes:

Holostratotype (*holostratotyp*). The original stratotype designated by the original author at the time of proposing a stratigraphic unit or boundary (mostly called stratotype, for short).

Parastratotype (*parastratotyp*). A supplementary stratotype used by the original author to illustrate the diversity or heterogeneity of the defined stratigraphic unit or some critical feature not evident or exposed in the holostratotype.

Lectostratotype (*lektostratotyp*). A stratotype for a previously described stratigraphic unit selected later in the absence of an adequately designated original holostratotype. Numerous lectostratotypes will be selected when previously described, informal units are validated.

Neostratotype (*neostratotyp*). A new stratotype selected to replace an older one that has been destroyed, covered, or otherwise made inaccessible. Investigators, who study a stratigraphic interval, are encouraged to select neostratotypes, if they discover that this is necessary.

Hypostratotype (*hypostratotyp*), also called reference section (*referenssektion*). A stratotype proposed either together with, or after the original designation of the holostratotype (and parastratotype) in order to extend knowledge of the unit or boundary to other geographic areas. It is always subordinate to the holostratotype.

Type locality (*typlokal*) is a single geographic area, where a type section is particularly well preserved and exposed. The description of the type locality should give information about its location and region and also provide geographic coordinates as accurately as possible.

Lithodemic units, tectonic units and structures, including denudational bedrock forms, may be defined from a type area or type region, which encompasses one or more type localities or possibly a type locality or type section. The accessibility and probability of continued preservation of the type locality should be assessed.

Similarly, in case the definitions and descriptions of geological units and features refer to a type locality, a type area or a type region, localities may be called holotype locality, paratype locality, lectotype locality, neotype locality or hypotype locality.

4.2. Political and administrative boundaries

Geological units are not affected by political and administrative boundaries. The name of a geological unit should not change in case a unit crosses such a boundary. Political boundaries include boundaries between municipalities, counties and countries. The *first* given valid name applies regardless of whether it is based on a holostratotype (holotype locality) or lectostratotype (lectotype locality); the other kinds of stratotypes/localities are mostly irrelevant under the aspect of priority.

4.3. Principle of priority

An overall principle in naming of geological units and objects is the *priority of the name*. This means that the first properly

Table 1. Names of geological units should consist of (1) a mandatory geographic name (except for chronostratigraphic and biostratigraphic units), (2) a rank term or (3) a qualifying rock or another geological term. Naming chronostratigraphic and biostratigraphic units should follow the International Stratigraphic Guide. The table provides a few examples of geological names from selected categories. Fundamental units are in Italics.

Geological units		Geographic name	Rank term	Rock or other geological term[1]: examples	Examples of geological names
Stratigraphic units	Litho-stratigraphic units	From type section, type locality, type area or region	Supergroup, group, *formation*, member, bed	Rock term, e.g., sandstone, limestone, konglomerate, shale	Jämtland Supergroup (Gee 1975) Kullsberg Limestone (Troedsson 1929) Skurup Formation (Lagerlund 1987) Malmö Member (Lagerlund 1987)
Stratigraphic units	Chrono-stratigraphic units	apply international guidelines	System, series, *stage*, chronozone		
Stratigraphic units	Bio-stratigraphic units	apply international guidelines	*Biozone*		
Lithodemic units		From type section, type locality, type area or region	Supersuite, suite, *lithodeme*, complex (e.g. volcanic com-plex, structural complex)	Rock term or descriptive term, e.g. intrusion, pluton, dyke, sill	Stockholm Granite[2] (Holmqvist 1906) Breven Dolerite Dyke[2] (Winge 1896) Tännäs Augen Gneiss[2] (Strömberg 1955)
Tectonic units		From type section, type locality, type area or region		Terms include: lithotectonic unit, shield, craton, orogen, terrane, platform, sedimentary basin, magmatic (igneous) province, rift	Sveconorwegian Orogen Fennoscandian Shield Baltoscandian Platform
Tectonic units	Tectono-stratigraphic units	From type section, type locality, type area or region	Nappe complex, *Nappe*		Offerdal Nappe[2] (Högbom 1906)
Structures		From type section, type locality, type area or region		Deformational: fold, syncline, anticline, synform, antiform, dome, fault, fault scarp, fault zone, shear zone, deforma-tion zone, duplex, horst, graben etc. Denudational: inlier, outlier, window, klippe, unconformity, escarpment, plain,peneplain etc.	Remdalen Syncline (Zachrisson 1964) Njakafjäll Duplex (Warr et al. 1996) South Swedish Dome (Lidmar-Bergström 1988) Söderås Horst (Norling & Bergström 1987) Alsen Klippe (Gee 1977) Nasafjället Window (Thelander et al. 1980) Muddus Plain (Lidmar-Bergström 1996)

[1] Rock or other geological terms suggesting genesis of the unit should not be used in any formal geological nomenclature

[2] Not formalized

defined formal name has the priority to all other later given names. Names of long traditional use will thus have preference relative to other suggested names. The principle of priority is also applied as concerns common place names. There must be very strong, well-documented reasons to discard the principle of priority.

5. Definition and characterization

To define a geological unit and its boundaries, as many relevant features as possible should be included in the description. This concerns also structures and bedrock forms. The features to be considered must differ between the principal categories of geological units, for example, type of rock and rank of the unit, type of tectonic unit, type of geological structure or bedrock form. Therefore, a comprehensive check list would be not only cumbersome but also illusory, because it will not be complete. It should be the task of those engaged in constructing databases to assemble such check lists for the cases to which they are applicable.

Names of fossil species are not to be used in lithostratigraphic, lithodemic or tectonic units, or in structural names. However, the presence of some major groups of facies-dependent macroscopic fossils can be important, such as "reef" builders, important bioclast-producing groups, e.g., echinoderms and bryozoans, or any other group including micro and nannofossils which, as physical, rock-forming particles or chemical components, may characterize the rock. In lithodemic classification, particularly in the Precambrian bedrock of Sweden, *age information is considered relevant* for the definition of lithodemic units.

6. Name

The International Stratigraphic Guide (Salvador 1994; Murphy & Salvador 1999) advises the authors to adhere to the following procedure to introduce a name for a new lithostratigraphic name, or to re-name, re-define or revoke an earlier lithostratigraphic name. The same principles should apply to all other geological names. The name should begin with (a) the geographic name of the type section, type locality or type area or region, followed by (b) a rank term (see Table 1), or (c) a rock term or another descriptive geological term. Following international practise, the use of a rank term is encouraged for lithostratigraphic units before the use of a rock term. Terms suggesting the genesis of the unit should not be used, since the interpretation of the origin of the unit may change. The use of a rock term or another geological term and rank term is *not recommended*, i.e., in a hypothetical case, either the Rusvattnet Formation or Rusvattnet Sandstone should be used, not Rusvattnet Sandstone Formation.

The international rules do not recommend the use of the same geographic name for two or more different geological units. Practice has shown that exceptions may be allowed in a few cases, e.g., (1) the name Risbäck may be used in the Risbäck Group (Gee et al. 1974) and in the Risbäck Basin (Kumpulainen & Nystuen 1985), the palaeobasin in which the group was originally deposited; this praxis is in use in Norway, or (2) the name of a nappe unit may carry the same geographical name as that of its basal fault (thrust/detachment) surface. Otherwise exceptions should be rare.

The chosen geographic name should not occur commonly in different parts of Sweden, or in other countries. In the case of the absence of a suitable, geographic name for a certain unit, e.g., in remote areas, a new geographic name may be introduced, for instance, in cooperation with local residents and after the approval by the governmental authorities dealing with place-names in Sweden (*Lantmäteriet* and the Institute for Language and Folklore, *Institutet för språk och folkminnen*). For structures with regional extent, a composite geographic name has been used in some cases (e.g., Storsjön–Edsbyn Deformation Zone). The use of composite geographic names is *not recommended*.

There may be cases in which an already well-established name should be preserved even though a different locality (section) must be chosen as type. Such a case may occur, if a certain local name has become well-established by long and consistent practice but without having become duly formalized, and it is found that the name-giving locality is no longer adequate or not even accessible as a type locality. In such a case, it may create the least confusion to name a different type locality (section) but preserve the original geographic name, when the unit is defined as formal. A few well-established names with an unequivocal meaning should be validated and preserved although they do not contain a geographic name, e.g., Alum Shale Formation (*Alunskifferformationen*), but the introduction of new such names should be avoided.

The original geographic part of a geological name should be preserved although the name is spelled differently or replaced by another name on later topographic maps. In the interest of continuity, also names such as Vojtja Formation (Kulling 1933; Stephens 1977), where Vojtja is only a fragment of Vojtjajaure, from which it is derived, should be preferred, also when the most recent spelling of Vojtjajaure is Våjhtjajávrri.

In English texts, a formal stratigraphic or other geological name has the first letters of both components capitalized (Torneträsk Formation), whereas a lowercase first letter of the second component (referring to the kind of unit) indicates that the unit is informal (hypothetically Vilhelmina formation). In Swedish texts, *formal and informal* geological names have first letters capitalized (*Torneträskformationen*). First time mentioned in any later publication dealing with an earlier established informal unit, its name should be accompanied by the word *informal*.

In English texts, the geographic name should be written in full as it appears on topographic maps (Torneträsk Formation, Thelander 1982, and Gärdsjön Formation, Gee et al. 1974). In Swedish texts, the two parts of the name are normally written together as one word. The practices applied in joining two nouns into one are poorly regulated and might depend on what is considered euphonious or good Swedish in each particular case. The Gärdsjön Formation is called in Swedish *Gärdsjöformationen*, i.e., the definite form ending *n* in Gärdsjön is dropped, but the ending is kept in the Swedish name for, e.g., the Skagen Limestone (*Skagenkalksten*). Similarly, the use of a connecting -s-, such as in *Filipstadsgranit* (for Filipstad Granite), or a connecting vowel, such as in *Lundasandsten* (for Lund Sandstone) is not governed by firm rules. For the benefit of translators, the Swedish form of the name should be given in addition to the English, when a unit is formally named, which will normally be in English. Conversely, the English version of the formal name should accompany a definition published in Swedish.

The lithologically descriptive, petrographic term should be included in the lithodemic unit name. If the lithodemic unit displays a range of compositions, such as quartz monzonite and monzonite, the dominant rock type should be used, or, as a possible alternative, a descriptive form term of the lithodeme, e.g., "dyke", "sill", "intrusion", "batholith", "pluton" or "dyke swarm". The use of the lithologically descriptive term should follow international rules and recommendations for naming rock units (Le Maitre 2004; Fettes & Desmons 2007; Neuendorf et al. 2011). Compound rock terms, such as augen gneiss or sillimanite gneiss, may be used when such specific properties are prominent and considered useful, but their *general* use should be *avoided*.

It is important to note that a lithodemic unit is a three-dimensional rock body composed of one or more than one rock types. Such a unit may be given a formal lithodemic name. One of the basic principles in all geological nomenclature (see below) is that two units of same, or closely related category, cannot have the same formal name. If a hypothetical lithodemic unit composed of granite, pegmatite and crosscutting mafic dykes has the formal lithodemic name Klunkamåla Granite, then its granite component cannot have the name Klunkamåla Granite. Instead, the granite should be addressed as "granite of Klunkamåla type" (*granit av Klunkamålatyp*) and, it is not a formal lithodemic name.

6.1. Synonyms

One and the same unit can have only one formal name. If more than one name has been formally introduced for what is obviously the same unit, the oldest of these names applies, i.e., it has priority for protection. The date of publication of a formal name is the date it was published in the SGU-administered database "Geological names in Sweden". For names published before the database was established, the date of publication is the date specified in the published work unless there is evidence that this date is incorrect.

In the case that an informal name has become established, it is advisable to formalize it through the procedure required to establish a formal unit, rather than introducing a completely new name.

6.2. Homonyms

A name that is already in use for a unit cannot be used for another geological unit of any kind. *The geographic name* component is likewise restricted to one unique name and cannot be used in any other kind of geological nomenclature. Similarly, a name once used and later revoked cannot be used again for any other unit regardless of rank and kind of geological unit in which it is being or was used.

From this principle it strictly follows that, when subdivisions of lower rank are distinguished within a geological unit, neither of these subdivisions should carry the name of the higher ranking unit of which they are parts. This means that the Torneträsk Formation cannot contain a Torneträsk Member. Likewise, the combination of units into a higher ranking unit does not confer the name of either of these units to the higher ranking unit. The need to apply these principles rigorously follows from the principle dealt with in the section on the formation as a lithostratigraphic unit (see Section 7). A formation may pass laterally into a member of another formation, in which case it still retains its geographic name, or it may pass into a group that comprises two or more, differently named formations. Even in the latter case, the formation can retain its name, although its rank becomes elevated. These transmutations could not take place with retention of the name, if a group could be named after one of the component formations, or a member could have the same name as the formation within which it occurs.

The use of the words "lower", "middle" or "upper" to refer to a certain part of a lithostratigraphic or lithotectonic unit may be applied in informal sense only and preferably avoided by using the expressions "lower part", "middle part" or "upper part" of a certain unit. Similarly, the use of a hypothetical lower Lubbamölla member and an upper Lubbamölla member as two different lithological units in a formation should be considered informal.

6.3. Approval of a geological name by the SCGN

In the process of erecting a new geological name, re-naming, re-defining or revoking an existing geological name, the authors should, preferably before publication, submit reasons and a justification for the proposed action for an evaluation by the SCGN (*Svenska geologiska namnkommittén*). This should be done by filling in an application form and sending it or the whole manuscript to SCGN. The SCGN is solely concerned with the practices involved in the naming of geological units, in order to promote stability and consistency. The committee has no responsibility to evaluate the scientific basis for erecting such units. The approved names will be made available in a database containing "Geological names in Sweden". Only the approved names either previously defined or new, are considered formal, having priority and protection provided by these guidelines. All other names are considered informal or revoked. A name post in the SGU database will constitute the formal publication of a certain new name and should be cited when the unit name is used in subsequent reports or publications. The same database should subsequently contain information also of all the other names used in Swedish geology.

7. Stratigraphic units

7.1. Lithostratigraphic units

A lithostratigraphic unit (*litostratigrafisk enhet*) is a body of sediments, sedimentary or volcanic rocks or metamorphosed sedimentary or volcanic rocks, which can be delimited on the basis of its stratigraphic position and specific lithological characteristics, observable in the field (Figs. 2 and 3). The definitions of lithostratigraphic units do not depend on inferred depositional environment, geological history or the presence or absence of index fossils. Boundaries of lithostratigraphic units are independent of numeric time spans however determined, e.g., by radiometric dating of tephra layers or other event beds (Fig. 3, units P and Q).

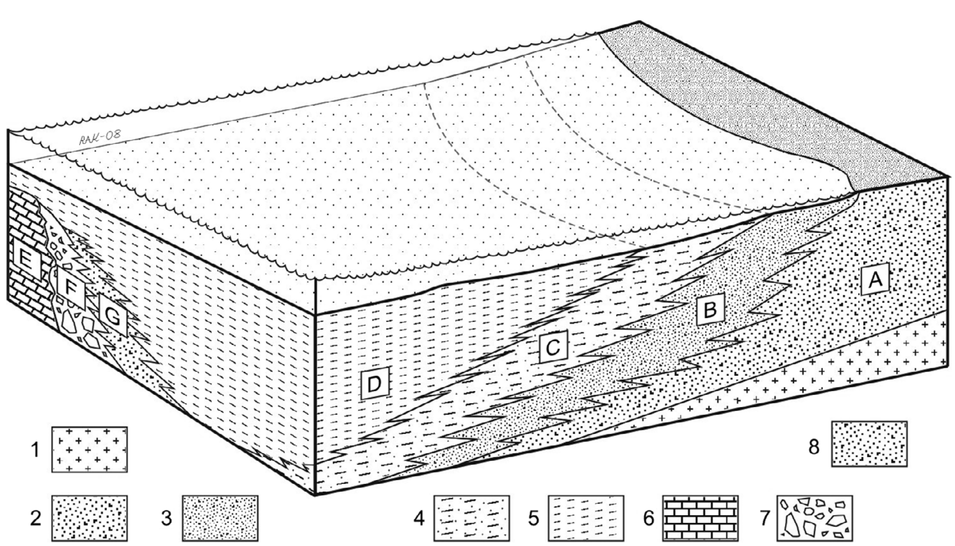

Figure 2. Lithostratigraphic units A–E rest non-conformably on a crystalline basement. Each of them display lateral facies change from one unit to another and may be defined as informal or formal formations. Formation C may be defined as a characteristic zone of facies change from unit B to unit D. The limestone formation E is a probable carbonate platform, which is limited basin wards by first a breccia (F) and then a carbonate sandstone (G). Rock symbols 1 – Crystalline basement, 2 – coarse sandstone, 3 – fine sandstone, 4 – sandy mudstone, 5 -mudstone, 6 – limestone, 7 – limestone breccia, 8 – carbonate sandstone.

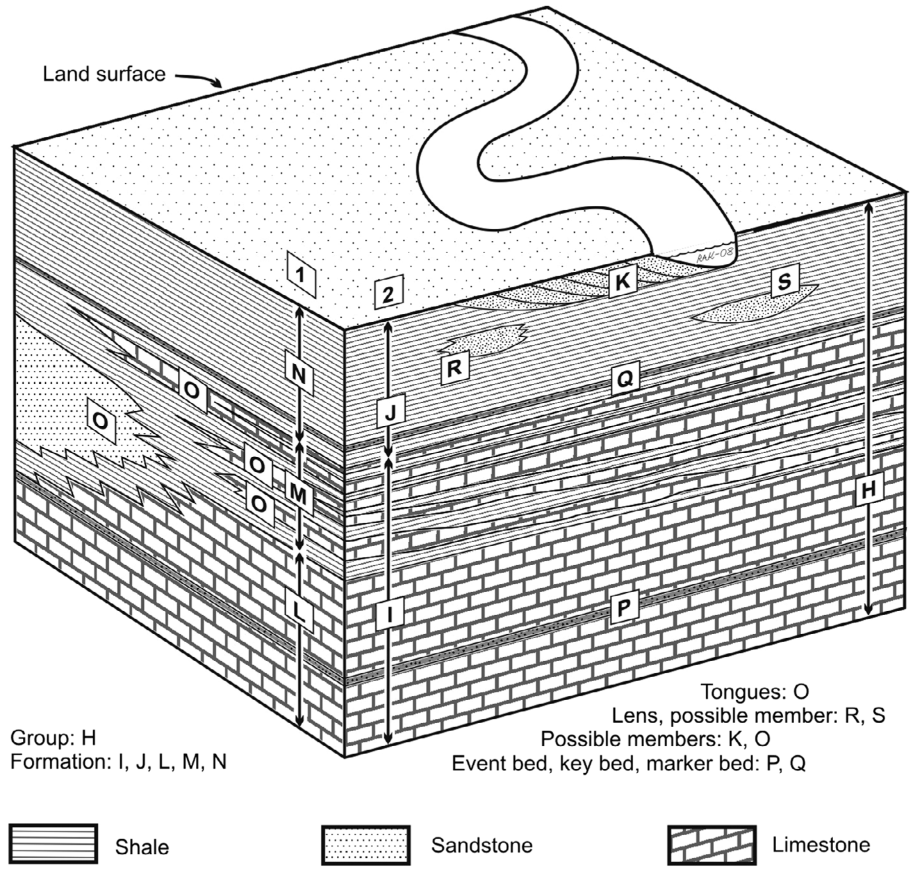

Figure 3. Lithostratigraphic units, depositional architecture of lithostratigraphic units and possible subdivision into formations and members. The diagram displays a hypothetical foreland basin with a carbonate platform on the front side and a clastic wedge (O) arriving down-hill from a likewise hypothetical approaching thrust-and-fold-belt. Sections 1 and 2 illustrate two alternative ways to subdivide the succession into formations and if aggregated they form the Group H. Two sand lenses (R and S) occur in the mudstone unit N. Event beds P and Q may or may not cut across from one facies to another.

Most lithostratigraphic boundaries are time-transgressive (Fig. 2).

Lithostratigraphic units are the basic elements in the geological mapping of layered bedrock (and non-consolidated sediment) used to describe the distribution of different rock types, identifying local and regional structural elements, and economic resources, as well as to describe the geological development of a particular succession or region. Lithostratigraphic classification is normally the first procedure in stratigraphic work in a certain area or region. A lithostratigraphic unit is three-dimensional and forms a sheet, lens, wedge, ridge, finger or tongue.

Boundaries between lithostratigraphic units may be lithologically sharp and define a discontinuity surface, or they may be gradational (Fig. 2). A sharp boundary is characterized by an abrupt change in rock type. A gradational boundary may represent a vertical or lateral facies change (Fig. 3, unit O). A zone of facies change may migrate laterally through time and form wedge-like stratigraphic units (Fig. 3, unit O). However, the observed boundaries may also be caused by intrusions (e.g., sills), structures or changes in metamorphic grade. The upper boundary is missing if the unit forms the top of the local sedimentary succession. This can be the case even at the stratotype.

Lithostratigraphic units in descending order of rank are supergroup, group, formation, member and bed.

7.1.1. Formation

A formation (*formation*) is the fundamental unit in lithostratigraphic classification (Fig. 3). It is a body of rocks or superficial deposits in a layered succession. It is characterized by its stratigraphic position in the succession and the specific lithological properties that distinguish it from other lithological units in the succession.

A formation must be mappable at the surface and/or traceable in the subsurface, and this criterion is the only limitation placed on the dimensions of a formation. Hence, its thickness may vary from metres to kilometres (Fig. 3). A formation must be possible to present on ordinarily available maps (normally in the scale of 1:50 000), such as topographic, land-use maps or other openly available maps or sections on the same scale in order to show its spatial, three-dimensional extension. A particularly thin formation may be represented on a map with a single thin line; this practice should be applied restrictively, though.

A formation may be composed of (a) one single lithology, (b) two or more interlayered lithologies or (c) an inhomogeneous unit, which is readily distinguished from other stratigraphic units in the succession by its bounding criteria (Fig. 3). A formation must be characterized by at least one property of the rock itself, observable in the field, e.g., mineral composition, structure, grain size or other textural features. Also the fossil content may be a distinctive factor, either as a characteristic physical or chemical component or because of its rock-forming properties, e.g., in a reef structure.

The age of a formation is irrelevant, except in those cases in which the ascertained ages in separate outcrops are so widely different that an original continuity of the occurrences is deemed unlikely.

Where the stratigraphic unit is not available for direct visual inspection, the definition of a formation may rely on measured properties, such as electric, magnetic, radiometric, hydraulic or seismic characteristics.

Certain properties of a formation may change laterally (Fig. 3), e.g., (a) the formation thins to a degree that it may preferably be designated a member, while keeping its original geographic name, (b) it thickens and at the same time shows some degree of internal diversification so that it may be designated a group, (c) its lithological composition changes, either moderately, in which case the name may remain the same, while the change is specified in the description, or to such extent that the formation can no longer be recognized as the same, or (d) it develops a metamorphic grade that no more permits the formation to be unequivocally recognized. In that case it is desirable to introduce a new unit name, type locality and definition. In the last case, the unit should be classified as a lithodemic unit.

A laterally discontinuous series of bodies of rock, such as reefs, volcanic deposits etc., occurring at approximately the same stratigraphic level, may be included in the same formation. An example is the Ordovician Kullsberg Limestone of the Siljan area, which consists of several discrete bodies of reef-like limestone, all of which occur within the lower part of the Upper Ordovician (Ebbestad & Högström 2007).

7.1.2. Group

A group (*grupp*) is the formal unit next in rank above a formation. A group may be composed of two or more regularly associated formations (Fig. 2), mostly with related lithological properties and diagnostically different from those in other adjacent formations or groups. Formations should be aggregated to a group only, if it simplifies general stratigraphic classification, particularly in mapping and regional stratigraphic analysis.

A succession should not be established as a group without defining the constituent formations, particularly if it is expected that the formations will be defined later. Instead, such a succession should be defined as a formation. A later subdivision of the unit into constituent formations would then change the rank of the original unit to that of a group; its original geographic name should be retained. Thickness alone is no valid reason to define a unit as a group rather than a formation. The character of the formations within the group may change from one place to another within the area of distribution of a group (Fig. 2).

7.1.3. Supergroup

An assemblage of regularly associated groups that evidently formed in a large sequential context may be united into a supergroup (*supergrupp*). A supergroup is regionally extensive and should be defined with all reasonable precision from a type area or region.

In order to be useful, a supergroup should be restricted to a certain tectonic unit, such as a platform, a foreland basin, a passive continental margin or an active continental margin.

Some interpretation is common in all geological classification but, in the case of lithostratigraphic units up to group level, the emphasis is categorically on the descriptive aspect. An interpretive aspect may play a greater role in defining a supergroup.

7.1.4. Member

A member *(led)* is a formal lithostratigraphic unit next in hierarchy below a formation; it is always part of a formation (Fig. 3). A formation may or may not be subdivided into members, or only a characteristic part of the unit may be distinguished as a member. There are no limitations concerning the extension or thickness of a member. A lens or a tongue may be defined as a member (Fig. 3).

7.1.5. Bed

A bed (*lager*) is the smallest formal unit in the hierarchy of lithostratigraphic classification (Fig. 3). It consists of a single bed with significant lithological characteristics that distinguish it from the adjacent beds. Regional, laterally persistent beds (Fig. 3, units P and Q) may be called a *key bed*, *marker bed or event bed,* and may be given a formal lithostratigraphic name. They may be sedimentary or volcanic in origin. They are particularly useful in chronostratigraphic correlation on the regional scale. An example is the Kinnekulle K-bentonite (Bergström et al. 1995)

7.2. Chronostratigraphic units

A chronostratigraphic unit *(kronostratigrafisk enhet)* comprises rocks with isochronous (time-parallel) lower and upper boundaries. A chronozone (*kronozon*) or simply "zone" (*zon*) is named after an eponymous "index fossil" and is the smallest formal unit in chronostratigraphic classification. The fundamental chronostratigraphic unit is stage *(etage)*. Two or more stages form a series *(serie)*, whereas two or more series form a system (*system*). The boundaries and names of global stages are decided by international agreement on the basis of the recognition of a Global boundary Stratotype Section and Point (GSSP). The lower boundary of a global stage defines the upper boundary of the chronostratigraphically underlying stage. The identification of the boundary in other sections is based on correlation with the GSSP using all available means.

The nationally adapted recommendations of stratigraphic nomenclature are not concerned with global systems and series. However, the demanding procedures necessary for establishing these units cannot be applied in the case of regional stages, substages and chronozones, which are the three unit ranks next below the stage. These units can, therefore, be subject to national or, better, regional consideration. Such units should be established following international practice including designation of type sections.

The principal functions of chronostratigraphy are the positioning of layered rocks and sediments in chronological order according to their time of formation and the identification of the geochronological (time) units during which the chronostratigraphic units formed. Of the units referred to here, the chronozone corresponds to the geochronological unit chron.

Substage corresponds to subage, stage to age, series to epoch and system to period, on the geological time scale. "Early" and "late" define intervals of time, "lower" and "upper" divisions of strata (see Owen 2009, Table 4). A phrase such as "During the Lower Ordovician …" is therefore incorrect, the correct wording being "During the Early Ordovician …". Similarly, "The Lower Ordovician beds of the area …" is to be preferred to "The Early Ordovician deposits of the area …", unless there is the need to emphasize the age of the deposits.

7.3. Biostratigraphic units

A biozone (*biozon*) is the fundamental unit in biostratigraphy, casually referred to as zone (*zon*). A biozone is named after one or two characteristic fossil species (rarely genera) and comprises the rocks that contain either this species or a characteristic association of species that are bounded by lowest or highest occurrences of selected species. There are different kinds of biozones depending on the kind of method used for their definition.

If the biozone has been formally named, the initial letter of the word is capitalized; Biozone or simply Zone. Since the habitats or ecological factors of organisms move about in space, biozones are diachronous to some extent, particularly when applied across wide distances.

Different successions of biozones may be based on different kinds of organisms depending on facies and biogeographic province. Furthermore, the existence of parallel sets of biozones based on different kinds of organisms generally increases the precision of biostratigraphic correlation of the sedimentary rocks. For instance, the Ordovician System is subdivided into parallel successions of biozones based on graptolites, conodonts, chitinozoans, ostracodes and trilobites.

The names of biozones change with those of the nominal species.

As complementary information to the biological data in description of biozones, Salvador (1994, p. 65) recommends:

> It is desirable, …, that the definition and description of a biostratigraphic unit and of its boundaries include the designation of one or more specific reference sections that demonstrate the occurrence of the taxon or taxa diagnostic of the unit and that permit its recognition elsewhere. The designation of one or more such reference sections serves as protection against the inadequacies of language, fossil recovery, and the uncertainties of taxonomic identification.

8. Lithodemic units

Bodies of rock whose character is not ruled by the Law of Superposition are described as lithodemic. A lithodemic unit (*litodemisk enhet*) is a body of predominantly intrusive, highly deformed or highly metamorphosed rock unit, distinguished and delimited on the basis of rock characteristics (Fig. 4). A lithodemic unit may be composed of one or more than one rock type. Its contacts with other rock units may be sedimentary, extrusive, intrusive, tectonic or metamorphic (NACSN 1983, 2005).

A lithodemic unit should be large enough to be shown on a map in an ordinary mapping scale (normally 1:50 000). The extension and distribution of a lithodemic unit should be established in the field by common mapping methods including geological, geophysical, remote sensing or other relevant methods.

Although geochronological data should not be used as a primary criterion to define a lithodemic unit, age relationships to other rock units are important. It is, therefore, recommended that firm field evidence of the relative age to adjoining geological units and possible isotopic age data should accompany the introduction, definition and naming of a formal lithodemic unit.

The contacts to the adjacent rocks may be sharp or gradational. A gradational boundary is characterized by the change of one or more parameters used to describe a lithodemic unit, e.g., composition, grain size, texture, metamorphic grade, structure such as schistosity or other secondary deformational features. It may be necessary to define an arbitrary boundary within the zone of gradual change. For practical reasons, a gradational boundary zone may constitute a separate lithodemic unit. This may be the case in, e.g., a variously, low to highly metamorphosed volcano-sedimentary succession, classified according to the principles of lithostratigraphy in one area and according to lithodemic classification in the adjoining area. Although distinct contacts between the different lithodemic units in an area may or may not be observed, lithodemic classification may be applied to an individual highly metamorphosed or deformed rock unit.

Lithodemic units in ascending order of rank are lithodeme, suite and supersuite. A lithodeme may contain informal

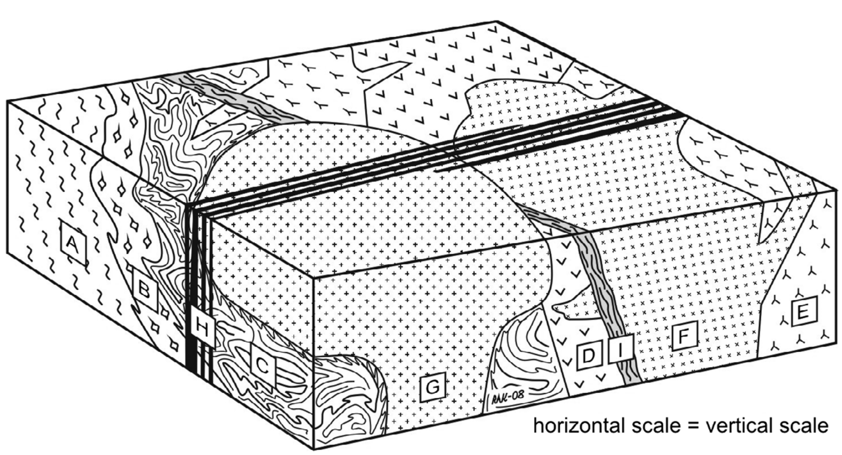

Figure 4. A hypothetical portion of crystalline crust such as that of Sweden. A – Gneissose granodiorite, B – augen gneiss, C – migmatitic lithic wackes (metatexites?), D – gabbro, E – diorite, F – tonalite, G – granite, H – dyke swarm, I – shear zone. Possible lithodemes: A, B, C, D, E, F, G, H and I. Possible igneous suite: D + E + F. Possible metamorphic suite: A + B + C. Possible dyke suite: H.

sub-lithodemes, some of which may be named phase or zone (e.g., mineralized zone, pegmatitic zone). The term complex can be used for a non-ranked lithodemic unit.

8.1. Lithodeme

A lithodeme (*litodem*) is the fundamental formal unit in lithodemic classification and corresponds to formation in lithostratigraphy. A lithodeme (Fig. 4) may consist of a single rock type or several rock types, if they form a lithologically coherent unit. The latter may apply to different co-magmatic intrusions that are lithologically different. A lithodeme may also be composed of several rocks that have become tectonically intermingled to form a lithological unit, distinct from its side rock, e.g., a diatexitic migmatite with characteristic mafic intercalations. A lithodeme may change its composition laterally and form a suite in a region outside its original type area.

A lithodemic unit may be divided into informal sub-lithodemes and classified according to their compositional characteristics. Two or more lithodemes may form a *suite*.

8.2. Suite

A suite (*svit*) consists of two or more lithodemes (Fig. 4) that are genetically associated and have a common geological history. It is not required that the individual lithodemes of a suite have identical ages (crystallization or depositional ages) but they should have similar ages and belong, for example, to the same phase of an orogeny.

The individual lithodemes in a suite must be of the same lithological class, either intrusive or metamorphic. A dolerite dyke swarm or a set of plutons may be defined as a dolerite suite or a plutonic suite, respectively. A suite is defined according to its lithodemic members and may be named after its type area, or its geographical distribution, and its lithological properties.

The type locality or type area and the possible reference localities of a suite are those of its individual component lithodemes. Two or more suites may form a *supersuite*.

8.3. Supersuite

A supersuite (*supersvit*) is composed of two or more suites that are genetically associated, i.e., belong to the same class, and have at least partly a common geological history, e.g., the same orogenic phase. A supersuite is defined according to its lithodemic members and may be named after a type area, its geographical distribution and/or its lithological properties.

8.4. Complex

Lithodemic classification includes also a complex (*komplex*). In this classification a complex is a non-ranked lithodemic unit and corresponds to suite or supersuite. A complex is used to organize and classify an assemblage of two or more genetically different rock types, i.e., igneous, metamorphic or sedimentary. Complex is used for mapping, organization and classification of rock bodies that are characterized by such a pervasive and consistent lithological heterogeneity that the single rock types are volumetrically too limited or too intimately intermingled to be mapped as discrete lithologic units. For example, a tectonic amalgamation of igneous, sedimentary and metamorphic rocks may form a structural complex. Another example is a volcanic environment where extrusive, sedimentary and the related intrusive components may occur intimately intermingled forming a volcanic complex.

A complex is named and classified according to its geological context (structural and/or volcanic etc.) and its geographic distribution.

9. Tectonic units

An understanding of the geology of the planet requires the use of terms that place stratigraphic and lithodemic units in a global or regional tectonic context. Naturally, the time dimension plays an important role, distinguishing the changing tectonic context during different phases of the planet's geological evolution within a particular region. For this reason, the breakdown into current tectonic and palaeotectonic conceptual thinking must be kept in mind.

Regional-scale terms such as shield, craton, orogen, lithotectonic unit, terrane and magmatic (igneous) province (formed inside a particular tectonic setting, e.g., continental magmatic arc), etc. are all included under the general term "tectonic unit". The same stratigraphic or lithodemic unit may exist in two different tectonic units, e.g., the Alum Shale Formation is found both within the Baltoscandian Platform and within the Caledonian Orogen.

For purposes of clarity, the definitions of the terms lithotectonic unit and terrane have been extracted from the international literature. A lithotectonic unit refers to "an assemblage of rocks that is unified on the basis of structural or deformational features, mutual relations, origin, or historical evolution, and the contained material may be igneous, sedimentary or metamorphic" (Neuendorf et al. 2011). By contrast, a terrane refers to a geological unit of regional extent that is bounded by zones of high strain (ductile shear zone, deformation zone or belt, fault, etc.) and characterized by a geological history different from that of contiguous geological units (Irwin 1972).

In general, tectonic units may be named in a straightforward manner, e.g., Fennoscandian Shield, Caledonian Orogen, Sveconorwegian Orogen and Baltoscandian Platform. The boundaries of tectonic units may be primary, i.e., depositional or intrusive, or tectonic in character. The latter are marked by a zone or belt with concentrated strain that is ductile, brittle or both ductile and brittle in character. The naming of these bounding structures is included in Section 10.

Special types of tectonic units, the tectonostratigraphic units, have their own rank terms. Both the history of the term 'tectonostratigraphic unit' in Sweden and the nature of the rank terms that steer the naming procedure are discussed in more detail below.

9.1. Tectonostratigraphic units

A tectonostratigraphic unit refers to a generally flat-lying, scale-independent, tectonic unit that is bounded by zones of high strain (ductile shear zone, deformation zone or belt, fault, fault zone, etc.). The boundaries may be thrusts or extensional

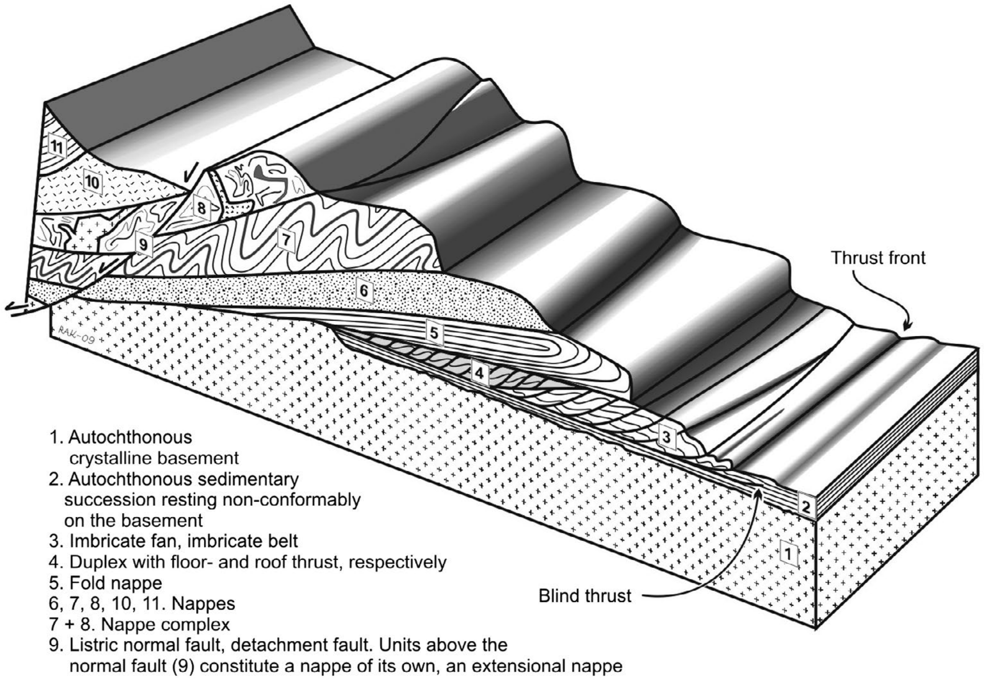

Figure 5. Terminology of a random thrust belt.

high-strain zones or both. Internally, a tectonostratigraphic unit may include lower order tectonic boundaries with a range of attitudes and shapes. Different lithostratigraphic or lithodemic units and structures may also occur between the boundary zones or boundary belts in various places. Kinematic aspects related to the bounding, high-strain zones are avoided in this guide.

9.1.1. Nappe

The tectonic term nappe (*skolla*) is derived from the French word for "table cloth" or "cover sheet" and refers to any allochthonous, sheet-like body that has been moved on a shallow-dipping high-strain zone (Twiss & Moores 1976; Dennis et al. 1979; Dennis 1987). Following Nystuen (1989), the term nappe is non-genetic with respect to the transport mechanism of the nappe rocks.

Nappe is the basic tectonostratigraphic unit and is generally considered to be equivalent to a thrust sheet in the Anglo-American (Twiss & Moores 1976) terminology. However, the term nappe includes thrust sheets, detachment sheets and fold nappes. Fold nappes consist of large-scale, isoclinal recumbent folds (*liggande veck;* Fig. 5). Detachment faults may cut across earlier fault zones and tectonic units. Some nappes have, at least locally, internal imbricate or duplex structures. The latter consist of stacked tectonic slices, horses and are not unique to nappes (Figs. 5 and 6).

The type section or type locality of a nappe should be defined as precisely as possible where its bedrock is well exposed and should preferably include the lower boundary. A nappe is named after the type section, or if it's lower boundary relations are especially clear, after its floor high-strain zone, if this has already been named. This means that a single geographic name may be used both for the name of the nappe and the high-strain zone at its base, hence being an exception to the principal rule (see Section 6, homonyms). A nappe consisting of more than one, closely related, smaller nappes can be referred to in the plural. Example: the Särv Nappes (Gee & Kumpulainen 1980; Gilotti & Kumpulainen 1986).

9.1.2. Nappe complex

A nappe complex (*skollkomplex*) consists of two or more distinct nappes that are stacked upon, and related to, one another in some significant respect, e.g., shared general environment of origin, similar metamorphism and/or deformation. The type area of a nappe complex normally has a regional extent but should have its limits defined as narrowly as possible. A nappe complex should be named after a locality or its floor high-strain zone, if this has been properly described and carries a name. An example is the Seve Nappe Complex of the Scandinavian Caledonides.

10. Structures

Common large-scale structures that are named include syncline, anticline, synform, antiform, dome and deformation zone. Deformation zone is an umbrella term including fault, shear zone, thrust, décollement and detachment. Other structures are duplex, fold, stack, horst, graben, trough, fault scarp, etc. Denudational (i.e., shaped by weathering and erosion) features such as inlier, outlier, window, klippe, unconformity and peneplain are here included among structures. Large-scale, regional structures may be given a formal or informal name. The name should be composed of a geographic name and a structural term. One exception from this rule, for the informal naming of re-exposed peneplains, is described in Appendix C.

In Sweden there is a long tradition of describing large-scale forms of the bedrock surface, in particular the top surface of the Precambrian basement rocks. In this guide, such landforms are also included among structures. Over the years a special terminology for their description has developed,

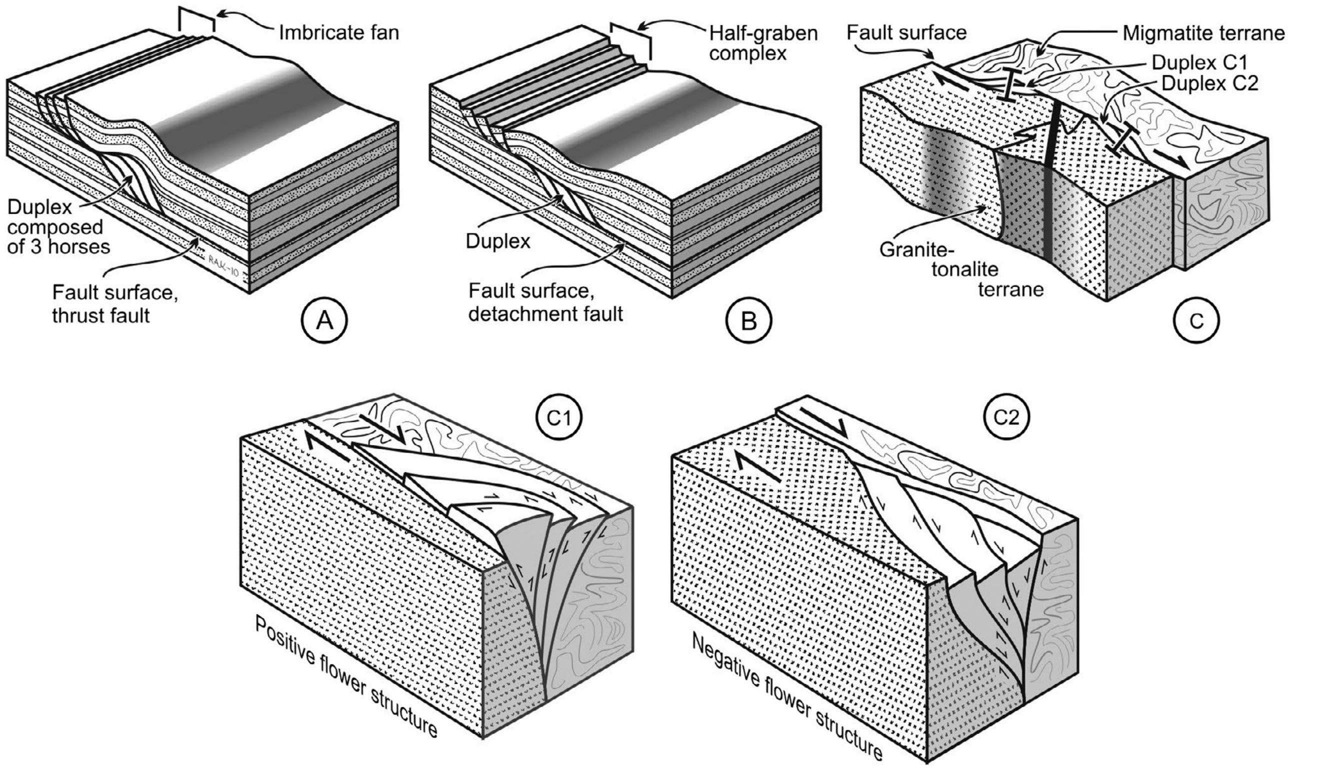

Figure 6. Duplexes form along deformation zones in various tectonic settings. They may be related to flat-lying (A and B) and steeply dipping (C) fault surfaces, respectively. Contractional and extensional duplexes are related to flat-lying fault surfaces. Positive (C1) and negative (C2) flower structures form along steeply dipping fault surfaces, strike-slip faults or strike-slip fault zones.

but the definition of these terms is still not fully established. This guide does therefore not provide strict recommendations for their use. In Appendix C, the traditional use of the term *peneplain* and several other widely used, related terms are described. In the absence of generally accepted definitions, Appendix C also provides some guidance for the informal naming of large-scale and some spatially more restricted geomorphological landforms.

Many structural terms contain an element of genesis, indicating the mode of formation at a general level. More specific genetic terms, such as a thrust and detachment, should not be used in formal geological nomenclature. Certain deformation zones have been named without a geographic term, e.g., Mylonite zone and Protogine zone. This usage is not recommended; instead, names of structures should contain a geographic name and a structural term. Meso-scale and small-scale structures should not be given a formal name.

Examples of named structures in Sweden are Remdalen Syncline (Zachrisson 1964), Skardøra Antiform (Sjöström 1983), South Swedish Dome (Lidmar-Bergström 1988), Njakafjäll Duplex (Warr et al. 1996), Söderåsen Horst (Norling & Bergström 1987), Vomb Trough (Norling & Bergström 1987), and Skagerrak–Kattegat Platform (Erlström & Sivhed 2001).

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References

Angelin, N.P., 1851: *Palaeontologia Svecica*, pp. 1–24 + 24 plates (re-edited by G. Lindström and published under the title "Palaeontologia Scandinavica". Samson & Wallin, Holmiae 1878).

Asklund, B., 1938: Hauptzüge der Tektonik und Stratigraphie der mittleren Kaledoniden in Schweden. *Sveriges geologiska undersökning C417*, 99 pp.

Bengtson, P., 1980: Orthography of geological names derived from fossil taxa. *Geologiska Föreningens i Stockholm Förhandlingar 102*, p. 222.

Bengtson, P., 1981: Formal and informal stratigraphical names. *Geologiska Föreningens i Stockholm Förhandlingar 103*, p. 32.

Bengtson, P. & Martinsson, A., 1988: Svensk stratigrafisk terminologi och nomenklatur. *In Geologisk ordlista – Glossary of Geology*, 471–477. TNC 86. Tekniska nomenklaturcentralen, Stockholm.

Bergström, S.M., Huff, W.D., Kolata, D.R. & Bauert, H., 1995: Nomenclature, stratigraphy, chemical fingerprinting, and areal distribution of some Middle Ordovician K-bentonites in Baltoscandia. *GFF 117*, 1–13.

Catuneanu, O., Galloway, W.E., Kendall, C.G.St.C., Miall, A.D., Posamentier, H.W., Strasser, A. & Tucker, M.E., 2011: Sequence Stratigraphy: Methodology and Nomenclature. *Newsletters on Stratigraphy 44*(3), 173–245.

Davis, W.M., 1899: The geographical cycle. *The Geographical Journal 14*, 481–504.

Dean, P.L. & Strong, D.F., 1977: Folded thrust faults in Notre Dame Bay, central Newfoundland. *American Journal of Science 277*, 97–108.

De Geer, S. 1910: Map of land-forms in the surroundings of the great Swedish lakes. Scale 1:500 000. With explanation. *Sveriges geologiska undersökning Ba 7*, 1–30.

Dennis, J.G., 1987: *Structural Geology, An Introduction*. W. C. Brown, Duburque, 448 pp.

Dennis, J.G., Murawski, H. & Weber, K., 1979: *International Tectonic Lexicon*. Part I. Schweizerbart, Stuttgart, 153 pp.

Ebbestad, J.O.R. & Högström, A.E.S., 2007: Locality descriptions, the Siljan District: WOGOGOB 2007. 9th meeting of the Working Group on Ordovician Geology of Baltoscandia. Field guide and Abstracts. *Sveriges geologiska undersökning, Rapporter och meddelanden 128*, 52–58.

Erlström, M. & Sivhed, U., 2001: Intra-cratonic dextral transtension and inversion of the southern Kattegat on the southwest margin of Baltica – Seismostratigraphy and structural development. *Sveriges geologiska undersökning C 832*, 1–33.

Fettes, D. & Desmons, J., 2007: *Metamorphic Rocks. A Classification and Glossary of Terms. Recommendations of the IUGS Subcommision on the Systematics of Metamorphic Rocks*. Cambridge University Press, Cambridge, 244 pp.

Gee, D.G., 1975: A geotraverse through the Scandinavian Caledonides – Östersund to Trondheim. *Sveriges geologiska undersökning C 717*, 1–66.

Gee, D.G., 1977: Nappe displacement in the Scandinavian Caledonides. *Tectonophysics 47*, 393–419.

Gee, D.G., Karis, L., Kumpulainen, R. & Thelander, T., 1974: A summary of Caledonian front stratigraphy, northern Jämtland/southern Västerbotten, central Swedish Caledonides. *Geologiska Föreningens i Stockholm Förhandlingar 96*, 389–397.

Gee, D.G. & Kumpulainen, R., 1980: An excursion through the Caledonian mountain chain in central Sweden from Östersund to Storlien. *Sveriges geologiska undersökning C 774*, 1–66.

Gee, D.G. & Zachrisson, E., 1979: The Caledonides in Sweden. *Sveriges geologiska undersökning C 769*, 1–48.

Gilotti, J.A. & Kumpulainen, R.A., 1986: Strain softening induced ductile flow in the Särv thrust sheet, Scandinavian Caledonides. *Journal of Structural Geology 8*, 441–455.

Hedberg, H.D. (ed.), 1976: *International Stratigraphic Guide – A Guide to Stratigraphic Classification, Terminology and Procedure*. John Wiley & Sons, New York, 200 pp.

Holmqvist, P.J., 1906: Studien über die Granite von Schweden. *Bulletin of the Geological Institutions of the University of Upsala 7*, 77–269.

Högbom, A.G., 1906: *Norrland: naturbeskrifning. Norrländskt handbibliotek*. Almqvist & Wiksell, Stockholm, 412 pp.

Högbom, A.G., 1910: Precambrian Geology of Sweden. *Bulletin of the Geological Institutions of the University of Upsala 10*, 1–80.

Irwin, W.P., 1972: Terranes of the western Paleozoic and Triassic belt in the southern Klamath Mountains, California. *In Geological Survey Research 1972*, C103–C111. Geological Survey Professional Paper 800-C, Washington, DC.

Jaanusson, V., 1960: The Viruan of Öland (Middle Ordovician). *Bulletin of the Geological Institutions of the University of Upsala 38*, 207–288.

Kautsky, G., 1953: Der geologische Bau des Sulitjelma-Salojauregebietes in den nordskandinavischen Kaledoniden. *Sveriges geologiska undersökning C 528*, 232 pp.

Kulling, O., 1933: Bergbyggnaden inom Björkvattnet—Virisen-området i Västerbottensfjällens centrala del. *Geologiska Föreningens i Stockholm Förhandlingar 55*, 167–422.

Kulling, O., 1939: Några anmärkningar rörande den kaledoniska överskjutnings- tektoniken inom Torneträskområdet. *Geologiska Föreningens i Stockholm Förhandlingar 61*, 168–176.

Kulling, O., 1960: On the Caledonides of Swedish Lapland. *In* N.H. Magnusson, P. Thorslund, F. Brotzen, B. Asklund & O. Kulling: *Description to accompany the map of the pre-Quaternary rocks of Sweden. Sveriges geologiska undersökning Ba 16*, 150–177. [References in the Swedish edition of Ba 16, printed 1962]

Kumpulainen, R.A. & Nystuen, J.P., 1985: Late Proterozoic basin evolution and sedimentation in the westernmost Baltoscandia. *In* D.G. Gee & B.A. Sturt (eds.): *The Caledonide Orogen – Scandinavia and Related Areas*, 213–232. John Wiley & Sons, Chichester.

Lagerlund, E., 1987: An alternative Weichselian glaciation model, with special reference to the glacial history of Skåne, south Sweden. *Boreas 16*, 433–459.

Lagerlund, E. & Björck, S., 1979: Lithostratigraphy of the Quaternary deposits in Blekinge, Sweden. *University of Lund. Department of Quaternary Geology. Report 17*, 1–65.

Le Maitre, R.W. (ed.), 2004: *Igneous Rocks. A Classification and Glossary of Terms. 2nd edition. Recommendations of the IUGS Subcommision on the Systematics of Igneous Rocks*. Cambridge University Press, Cambridge, 236 pp.

Lidmar-Bergstrom, K., 1988: Denudation surfaces of a shield area in South Sweden. *Geografiska Annaler. Series A, Physical Geography 70*(4), 337–350.

Lidmar-Bergström, K., 1996: Long term morphotectonic evolution in Sweden. *Geomorphology 16*, 33–59.

Lidmar-Bergström, K., Bonow, J.M. & Japsen, P., 2013: Stratigraphic landscape analysis and geomorphological paradigms: Scandinavia as an example of Phanerozoic uplift and subsidence. *Global and Planetary Change 100*, 153–171.

Linnaeus, C., 1747: Kinne-Kulle, aftagen i profil och beskrifven af volontairen vid Kongl. Fortification Herr Johan Svenson Lidholm. *Kongliga Svenska Vetenskaps-Academiens Handlingar 8*, 54–57.

Magnusson, N.H. (ed.), 1958: *Lexique Stratigraphique International*. Vol 1, Europe. Fascicule 2c. Suéde. 498 pp. Centre national de la recherché scientifique. 13, quai Anatole-France, Paris-VII.

Miall, A.D., 1984: *Principles of Sedimentary Basin Analysis*. Berlin, Springer, 490 pp.

Miall, A.D., 2010: *The Geology of Stratigraphic Sequences*, 2nd ed. Heidelberg, Springer-Verlag, 522 pp.

Murphy, M.A. & Salvador, A., 1999: International Stratigraphic Guide – An Abridged Version. International subcommission on stratigraphic classification of IUGS International Commission on Stratigraphy. *Episodes 22*, 255–272.

NACSN (North American Commission on Stratigraphic Nomenclature), 1983: North American stratigraphic code. *American Association of Petroleum Geologists, Bulletin 67*, 841–875.

NACSN (North American Commission on Stratigraphic Nomenclature), 2005: North American stratigraphic code. *American Association of Petroleum Geologists Bulletin 89*, 1547–1591 [also available at http://ngmdb.usgs.gov/Info/NACSN/05_1547.pdf].

Nathorst, A.G., 1879: Om de äldre sandstens- och skifferbildningarne vid Vettern. *Geologiska Föreningens i Stockholm Förhandlingar 4*, 421–436.

Neuendorf, K.K.E., Mehl Jr., J.P. & Jackson, J.A., 2011: *Glossary of Geology*, 5th ed., revised. Alexandria, VA, American Geological Institute, 800 pp.

Nielsen, A.T., 1995: *Trilobite Systematics, Biostratigraphy and Palaeoecology of the Lower Ordovician Komstad Limestone and Huk Formations, Southern Scandinavia*. Scandinavian University Press, Oslo, 374 pp.

Nikishin, A.M. & Kopaevich, L.F., 2009: Tectonostratigraphy as a basis for paleotectonic reconstructions. *Moscow University Geology Bulletin 64*, 65–74. doi:http://dx.doi.org/10.3103/S014587520902001X.

Norling, E. & Bergström, J., 1987: Mesozoic and Cenozoic tectonic evolution of Scania, southern Sweden. *Tectonophysics 137*, 7–19.

Nystuen, J.P. (ed.), 1986: Regler og råd for navnsetting av geologiske enheter i Norge. *Norsk Geologisk Tidskrift 66* (Supplement 1), 1–96.

Nystuen, J.P. (ed.), 1989: Rules and recommendations of naming geological units in Norway. *Norsk Geologisk Tidskrift 69* (Supplement 2), 1–111.

Owen, D.E., 2009: How to use stratigraphic terminology in papers, illustrations, and talks. *Stratigraphy 6*, 106–116 [also available at: http://www.agiweb.org/nacsn/10570_articles_article_file_1642.pdf].

Potter, P.E. & Pettijohn, F.J., 1977: *Paleocurrents and Basin Analysis*. Berlin, Springer-Verlag, 425 pp.

Salvador, A. (ed.), 1994: *International Stratigraphic Guide: A Guide to Stratigraphic Classification, Terminology, and Procedure.* The International Union of Geological Sciences (IUGS) and Geological Society of America, Boulder, CO. 214 pp. [also available at http://www.stratigraphy.org/index.php/ics-stratigraphicguide].

Sjöström, H., 1983: The Seve-Köli Nappe Complex of the Handöl-Storlien-Essandsjøen area, Scandinavian Caledonides. *Geologiska Föreningen i Stockholm Förhandlingar 105*, 93–117.

Solli, A., Naterstad, J. & Andresen, A., 1978: Structural succession in a part of the outer Hardangerfjord area, west Norway. *Norges geologiske undersökelse 343*, 39–51.

Srivastava, S.N.P., Roy, R.K., Singh, R.N. & Adiga, K.S., 1978: Tectonostratigraphy of the ophiolite belt of the Naga Hills, northwestern India. *Himalayan Geology 8*, 550–559.

Stephens, M.B. 1977: Stratigraphy and relationship between folding and metamorphism and thrusting in the Tärna – Björkvattnet area, northern Swedish Caledonides. *Sveriges geologiska undersökning C 726*, 146 pp.
Strand, K., Köykkä, J. & Kohonen, J. (eds.), 2010: Guidelines and procedures for naming Precambrian geological units in Finland. 2010 Edition Stratigraphic Commission of Finland: Precambrian Sub-Commission. *Geological Survey of Finland, Guide 55,* 41 pp.
Strand, T. & Kulling, O., 1972: *Scandinavian Caledonides*. London, Wiley, 302 pp.
Strömberg, A.G.B, 1955: Zum Gebirgsbau der Skanden im mittleren Härjedalen. *Bulletin of the Geological Institutions of the University of Upsala 35*, 199–243.
Surlyk, F., 1991: Tectonostratigraphy of North Greenland. *In* J.S. Peel & M. Sønderholm (eds.): *Sedimentary basins of North Greenland. Bulletin Grønlands Geologiske Undersøgelse 160*, 25–47.
Thelander, T., 1982: The Torneträsk Formation of the Dividal Group, northern Swedish Caledonides. *Sveriges geologiska undersökning C 789*, 1–41.
Thelander, T., Bakker, E. & Nicholson, R., 1980: Basement-cover relationships in the Nasafjället Window, central Swedish Caledonides. *Geologiska Föreningens i Stockholm Förhandlingar 102*, 569–580.
Tjernvik, T. 1972: Volkhov stage – limbata limestone. *Geologiska Föreningens i Stockholm Förhandlingar 94*, 301–310.
Tjernvik, T.E. & Johansson, J.V., 1980: Description of the upper portion of the drill-core from Finngrundet in the South Bothnian Bay. *Bulletin of the Geological Institution of the University of Uppsala, New Series 8*, 173–204.
TNC [Swedish Centre for Technical Terminology], 1988: *Glossary of Geology*. Swedish Centre for Technical Terminology, Publication 86, Stockholm, 482 pp.
Troedsson, G., 1929: On the middle and upper Ordovician Faunas of Northern Greenland, Part II. *Meddelelser om Grønland 72*.
Törnebohm, A.E., 1888: Om fjällproblemet. *Geologiska Föreningens i Stockholm Förhandlingar 10*, 328–336.
Törnebohm, A.E., 1896: Grunddragen av det centrala Skandinaviens bergbyggnad. *Kongliga Vetenskaps-Akademiens Handlingar 28*(5), 212 pp.
Twiss, R.J. & Moores, E.M., 1976: *Structural Geology*. W.H. Freeman and Company, New York, 532 pp.
Warr, L.N., Greiling, R.O. & Zachrisson, E., 1996: Thrust-related very low grade metamorphism in the marginal part of an orogenic wedge; Scandinavian Caledonides. *Tectonics 15*, 1213–1229.
Watkinson, M.P., Hart, M.B. & Joshi, A., 2007: Cretaceous tectonostratigraphy and the development of the Cauvery Basin, southeast India. *Petroleum Geoscience 13*, 181–191.
Winge, K., 1896: Om diabas-granitgången vid Brefven. *Geologiska Föreningens i Stockholm Förhandlingar 18*, 187–200.
Zachrisson, E., 1964: The Remdalen Syncline – stratigraphy and tectonics. *Sveriges geologiska undersökning C 596*, 1–53.

Appendix A: Topostratigraphy

The term topostratigraphy was introduced into Swedish stratigraphy by Jaanusson (1960) for a stratigraphy that was based on lithology as well as fossil content and age of rock units. It was characterized as a "preliminary or introductory stratigraphy, including lithostratigraphy and biostratigraphy" in the International Stratigraphic Guide (Salvador 1994). Further discussions of the concept have been published by Tjernvik (1972), Tjernvik & Johansson (1980), Nielsen (1995) and Ebbestad & Högström (2007).

Jaanusson's initial experience as a geologist and palaeontologist was with the extensive and nearly continuous Ordovician section along the north coast of Estonia. The western continuation of this succession is in Sweden, where Jaanusson worked for most of his life. The Estonian Ordovician is complete insofar as each major part of the Ordovician is represented, but interruptions of deposition were frequent, extensive and apparently lasting for considerable time. Because shifts of biota and carbonate sedimentology occurred during these intervals of non-deposition, differences in lithology are combined with faunal differences. Under these circumstances, topostratigraphy could appear to be a more expedient approach than making the distinction between lithostratigraphy, biostratigraphy and regional chronostratigraphy.

However, in Sweden, where the lithologies vary less, and the interruptions of sedimentation are less distinctive and less extensive than in Estonia, the principal difference between topostratigraphic units is commonly faunal rather than lithological. Although the topostratigraphic units carry local and lithological names, as if they were lithostratigraphic, they are partly biostratigraphic. To compound the confusion, some workers have dealt with them as if they were chronostratigraphic units.

Therefore, the topostratigraphic usage should be abandoned. Topostratigraphic names have been used in Sweden for decades. Despite this, their definitions should be revised and type localities (or sections) defined in order to validate them as lithostratigraphic units in all cases where this is possible.

In connection with the revision of topostratigraphic nomenclature so as to adapt it to lithostratigraphy, the Ordovician regional stage nomenclature should also be scrutinized in order to ascertain its applicability throughout Baltoscandia; some regional stages might be abandoned. However, this is of regional concern throughout Baltoscandia and must be dealt with accordingly.

Appendix B: Tectonostratigraphy: development of the term in Scandinavia and its use in some other connotations

Similar to other geological terms, *tectonostratigraphy* has been used with different connotations in the geological literature, such as (a) stacks of nappe units to oblique or sub-horizontal tectonic successions, (b) development of sedimentary basins related to pulses of tectonic deformation and sequence stratigraphy, reminiscent of basin analysis of earlier days (e.g., Potter & Pettijohn 1977; Miall 1984).

In Scandinavia, the identification of large-scale allochthonous nappe units in the Caledonian orogenic belt by Törnebohm (1888, 1896) inspired the workers in that orogen, during the first half of the 20th century to carry out systematic work on its tectonic structure. Compositionally, structurally and metamorphically different allochthonous rock units (tectonic units) were possible to trace over long distances laterally within the mountain chain.

The first steps towards establishing a "nappe stratigraphy" in the Caledonides of northern Scandinavia were taken by Kulling (1939). Other pioneering scientists worked with certain selected portions of the orogenic belt (e.g., Asklund 1938; Kautsky 1953). Later, names such as Lower Caledonian Bedrock, Middle Caledonian Bedrock and Upper Caledonian Bedrock of the Swedish Caledonides were established (Kulling 1960) and a detailed "tectonic scheme" for the Swedish Caledonides was presented and described by Kulling (in Strand & Kulling 1972). Subsequent work has primarily built on the pioneering work by Kulling.

In the Scandinavian Caledonides, the orogenic structure was shown to resemble the stratigraphy in an ordinary sedimentary succession. *The term tectonostratigraphy*, which, in the Scandinavian context, refers to the spatial relationships of rock units brought into juxtaposition by tectonic activity, was introduced in studies of the Appalachians, the Norwegian Caledonides and the Himalayas (Dean & Strong 1977; Solli et al. 1978; Srivastava et al. 1978) as a way to study and organize rock units in an orogenic belt. The term tectonostratigraphy soon became a standard expression in the Scandinavian geological literature and was first introduced in Swedish geological literature by Gee & Zachrisson (1979).

Elsewhere, the term tectonostratigraphy has *also* been used in the geological literature with other connotations, reminiscent in certain aspects of lithostratigraphy and sequence stratigraphy. In those cases, tectonostratigraphy identifies structural features, e.g., unconformities, to subdivide regional, sedimentary successions into mega-sequences or tectonostratigraphic sequences that can be interpreted to respond to tectonic events or episodes that span millions to tens of millions of years (Watkinson et al. 2007; Nikishin & Kopaevich 2009; Miall 2010). Surlyk (1991) distinguished a succession of separate tectonostratigraphic (sedimentary) basins in northern Greenland, in most cases separated by episodes of deformation and defined "the basins to correspond to plate tectonic events and periods of plate reorganization and they are thus categorised as first order, tectonostratigraphic units in the hierarchy of basinal stages". These concepts of tectonostratigraphy related to basin analysis are not discussed in further detail in this guide.

Appendix C: Naming of bedrock landforms in Sweden

In this appendix, the use of the term peneplain (*peneplan*) in the description of large-scale landforms is briefly presented. Several Swedish landscape types are described, and guidelines for the identification and naming of these geomorphic features are proposed. Some advice for the naming of bedrock landscape elements of restricted spatial extent is also provided.

A variety of large-scale erosional surfaces, cut into bedrock, have long been identified in Sweden. The interpretation of these features has played an essential role in understanding Sweden's tectonic and erosional history, particularly for the latest Precambrian and the Phanerozoic interval preceding the Quaternary. Such large-scale geomorphological landforms may be given informal names, but since the definitions of the terms below not are fully established and to some degree overlap, this guide does not recommend their use in formal naming.

Peneplains (peneplan)

Peneplains are surfaces of low relief graded to a specific base level (Davis 1899). They can have residual relief. In the beginning of the 20th century, Swedish geologists (e.g., Högbom 1910) identified large parts of the flat bedrock surface of eastern and southern Sweden as a re-exposed sub-Cambrian peneplain. Later the South Småland Peneplain was described by Lidmar-Bergström (1988) and a re-exposed inclined sub-Cretaceous denudation surface with a hilly relief in southern Sweden has also been labelled a peneplain (Lidmar-Bergström et al. 2013).

Re-exposed peneplains *(återexponerade peneplan)* should be named by the word "sub" (=below) and the chronological denomination of the immediately overlying cover rocks. This is an exception from the general rule of naming geological units. Epigene peneplains (*epigena peneplan*), never covered by sedimentary strata, should be named with a geographical name.

Landscapes developed on the Precambrian basement

A joint valley landscape *(sprickdalslandskap)* is characterized by a mosaic of bedrock highs with intervening narrow valleys governed by joints, fractures and faults. The landscape type is characterized by large-scale low relative relief (0–100 m) and small-scale steep slopes. The naming should give an indication of the geographical location and extent.

Undulating hilly relief *(vågig bergkullterräng*) is characterized by a general lack of horizontal segments in the landscape. It is an all-slopes terrain with a relative relief of 20–200 m. The naming should give an indication of the geographical location and extent.

A plain with residual hills, also called inselberg plain and monadnock plain *(bergkullslätt*) is characterized by a low-relief bedrock surface with scattered erosional remnants.

Landscape elements of restricted spatial extent

In accordance with the general recommendations for naming of structures, meso- and small-scale geomorphological landforms should not be given formal names. Morphologically important landscape elements of restricted spatial extent such as mountain groups, summits, valleys and lake basins almost invariably already have official names in Sweden, and no additional naming principles are in these cases necessary. Such landscape-related names with well-established historical roots should not be changed.

Some second-order landscape elements such as cirques (*nischer*) may lack official names. They should be named after the larger scale feature (e.g., mountain) on which they are developed. If there are several adjacent features on the same mountain, they should be separated by adding a defining aspect (e.g., the Storberget SE-cirque). Escarpment (*brant*) is a non-genetic term applied to steep slopes separating areas of low relief. The name should give an indication of the geographical location.