

Towards a unified nomenclature of metamorphic petrology:

5. Structural terms including fault rock terms

Recommendations by the IUGS Subcommittee on the Systematics of Metamorphic Rocks.
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INTRODUCTION

The Subcommittee for the nomenclature of Metamorphic Rocks (SCMR), aims to publish international recommendations on how metamorphic rocks and processes are to be defined and named, as was previously done for igneous rocks by the Subcommittee on the Systematics of Igneous Rocks (Le Maitre, 1989, 2002).

The principles used by the SCMR for defining and classifying metamorphic rocks are outlined in Schmid et al. (2004).

A Study Group (SG), under the leadership of Dr Kate Brodie, was set up to look at nomenclature relating to structural terms. At an early stage a questionnaire was sent to around 60 structural geologists throughout the world, with a series of initial definitions. The response did much to guide the work of the SG and the SCMR in finalizing its recommendations.

BACKGROUND

Many of the definitions given below were adopted by the SCMR without difficulty; others gave rise to considerable debate. Problems arose for a variety of reasons, namely: the variable usage of terms across the geological community (for example, gneiss and schist); terms such as slate and cleavage proved difficult because there are no similar terms in many non-English speaking countries; equally, the difference between cleavage and schistosity and the use of texture and microstructure proved major sticking points. In other cases it was difficult to differentiate between rock types solely on features observable in the field at hand-specimen scale or in thin section examination as required by the SCMR scheme (Schmid et al., 2004). Also, although the SCMR scheme seeks to avoid terms based on processes wherever possible, this was not practical with many terms related to fault rocks (for example, mylonite and cataclasite).

The following sections discuss two of the main problem areas and the basis that the SCMR used in deciding on its recommended definitions.

1. The Terms Schist, Gneiss and Granofels.

The SCMR decided to base its systematic rock names on structural root terms with mineral qualifiers (Schmid et al 2004). One possibility would have been structural root terms based on grain size. However, although the sequence slate – phyllite – schist – gneiss could be used in this way, it was generally felt that these terms were too specific to be widely applicable and that there was an absence of other suitable names. The SCMR therefore decided that the most appropriate structural root terms were those reflecting the degree of fissility or development of schistosity in a rock. The terms selected for this purpose were schist, gneiss and granofels. These names are well entrenched in the literature and are generally acceptable as terms reflecting different degrees of fissility. However, the adoption of these names as purely structural based terms gave rise to considerable debate within the SCMR.

The following section discusses the current definitions of these names and considers the advantages and disadvantages of their use as structural root terms.

SCHIST

The term schist is derived from the Greek *schistos* – to split and according to Tomkiewff (1983) was first used by Pliny. In its simplest form schist can be regarded as a rock possessing a schistosity. In the English language, however, many workers differentiate between a slate which is a fine-grained rock possessing a well-developed schistosity and a schist which is a medium-grained rock with a good schistosity (for example, Holmes, 1920; Spry, 1969; Barker, 1990)

The SCMR decided, however, that defining schist as a rock with a well-developed schistosity and thus making use of it as a structural-root term was acceptable within general usage. In this way schist becomes the systematic root term covering all rocks with a well-developed schistosity including slates and phyllites. These latter names, however, are still retained within the SCMR nomenclature scheme as recommended specific names (see, Schmid et al., 2004)

GNEISS

Gneiss is thought to be a term originally used by miners in Bohemia for the host rock in which the metalliferous veins occurred. According to Tomkiewff (1983) it was first recorded by Agricola in 1556. The basis of modern usage was probably laid down by Werner (1786) who refined the list of components and defined gneiss as a feldspar-quartz- mica rock with a coarse schistosity (*dickschiefrig Gewebe*) or gneissosity.

In modern usage gneiss may be taken as a medium- to coarse-grained rock with a poorly developed schistosity, and feldspar and quartz as characteristic (to some, essential) components. The rock commonly has a banded structure reflecting compositional and/or structural variations. Gneiss is also generally presumed to be the product of medium- to high-grade metamorphism. Definitions of gneiss, however, vary greatly between authors, reflecting the emphasis they place on the various features. Two main areas of division may be considered.

1. Mineral Content and Structure.

Schist has a better-defined schistosity than gneiss. This may be taken to reflect the mineral content: that is, schist is richer in phyllosilicates and poorer in granular minerals, such as quartz and feldspar, than gneiss. The emphasis placed on these interdependent criteria has polarised the definition of gneiss.

Much of European literature has built on the definitions of the early workers and places emphasis on the mineral content. As such, related definitions of gneiss regard feldspar + quartz as essential components. As an extension of this requirement Fritsch et al. (1967) proposed a boundary between gneiss and schist at >20% modal feldspar. (see also, Lorenz, 1996).

On the other hand for other workers, particularly those writing in English, the definition of gneiss has evolved with an increasing emphasis on the structure (Winkler, 1974; Barth, 1978) and to some workers the mineral content is no longer regarded as an essential part of the definition (Harker, 1954; Bates and Jackson, 1987).

2. The Significance of Banding

The significance of banding in the definition of gneiss also varies, for example, Yardley (1989) notes: *English and north American usage emphasises a tendency for different minerals to segregate into layers parallel to the schistosity, known as gneissic layering; typically quartz and feldspar rich layers segregate out from more micaceous or mafic layers. European usage of gneiss is for coarse, mica-poor, high-grade rocks, irrespective of their fabric.*

Banding may be defined in a variety of ways; some workers place the emphasis on the alternation of schistose and granulose layers (Tyrrel, 1929; Bates and Jackson, 1987; Tomkeieff, 1983), while others regard mineral banding as the characteristic feature (Barker, 1990; Mason, 1978)

The SCMR debated these differences at length, particularly the requirement for feldspar +quartz in the definition of gneiss. However, the strong association in geological usage of gneiss as a rock possessing a poorer fissility than schist and the usefulness of gneiss as such a term proved decisive. Also, although this could be construed as showing a bias towards English-language usage, it was felt that this was acceptable because of the SCMR's decision to make its definitions in English.

The SCMR also noted that a structural-only definition did not exclude any rocks currently defined as gneiss. On the other hand a major concern for the SCMR was that a structure-only definition might include rocks that in current usage would never be considered as gneisses, for example, metasediments of low metamorphic grade. In these cases it was felt that a guideline encouraging the use of protolith based names would provide an adequate safeguard (Schmid et al., 2004).

The SCMR chose the boundary between schist and gneiss based on the definition proposed by Wenk (1963, as given by Winkler 1974), namely: "When hit with a hammer, rocks having a schistose fabric (schists) split perfectly parallel to 's' into plates, 1-10mm in thickness, or parallel to the lineation into thin pencil-like columns."

GRANOFELS

Granofels was introduced by Goldsmith (1959) as a term to describe rocks in which schistosity was absent or virtually absent. Previously, the term granulite had been used but as it also had grade and lithological connotations it was generally considered unsuitable.

2. Fault Rocks

While some fault rocks might be considered to fall outside the remit of metamorphic nomenclature, many undergo chemical as well as structural changes, and the deformation occurs within the P-T range of metamorphism. The definition of fault rocks is problematic and many of the definitions involve processes. Different minerals deform in different ways depending on the temperature conditions and precludes definitions of fault rock terms that are mineralogically based. The definitions presented are systematic and general.

As might be expected, **mylonite** proved difficult to define. Since its original definition by Lapworth (1885) there have been many nomenclature schemes proposed for mylonites and related rocks (for example, Quensel, 1916, Knopf, 1931, Spry, 1969, Higgins, 1971, and Sibson, 1977). More recently a Penrose conference on mylonites (Tullis et al., 1982)) failed

to arrive at an agreed definition of a mylonite, mainly because of the problem of knowing if, for example, plastic processes have been involved in the grain size reduction. Commonly detailed microstructural analysis of thin sections is required which makes it difficult to apply these definitions on a hand specimen scale. The definition given below is non-genetic from the point of view of the mechanism of deformation. The definition of mylonite also covers cohesive foliated cataclasites and this is in recognition of the fact that in many cases these are difficult to distinguish in the field. It is sometimes difficult to look at a very fine-grained fault rock in the field and know whether it is an ultramylonite, an ultracataclasite or indeed a pseudotachylite. Any division on the basis of percentage of crystal plasticity v. brittle deformation is not practical using thin sections let alone from field observations. In addition, grain size sensitive flow is being recognized as an important deformation mechanism in many mylonites. Thin section observation may allow more specific terms or qualifiers to be applied. A review of the historic perspective of the nomenclature and classification of fault rocks is provide in Snoke et al. (1998) Deformed **ultramafic rocks** have there own descriptive terminology (e.g., Boullier and Nicolas 1975, Harte 1976) that grew from detailed petrographic studies of kimberlite xenoliths. Many of these terms can be replaced with more general terms such as mylonite and cataclasite, and have not been re-examined by the SCMR.

These examples serve to illustrate the considerable difficulties that have arisen within the SCMR in attempting to erect a practical and widely acceptable scheme. Some notes are included after particular definitions in order to explain the reasoning behind the recommended definition. In considering the definitions it is important to remember that they may be a compromise but one that is hopefully workable.

Unless otherwise stated all the terms fall into the SCMR category of 'recommended names' as defined by Schmid et al. (2004).

DEFINITIONS: 1. STRUCTURAL TERMS

Layer: *One of a sequence of near parallel, tabular shaped rock bodies.*

Layering: *The feature displayed by layered rocks.*

Band: Used as a synonym for layer.

Banding: Used as a synonym for layering.

Structure: *The arrangement of the parts of a rock mass irrespective of scale, including spatial relationships between the parts, their relative size and shape and the internal features of the parts.*

The terms micro-, meso- and mega- can be used as a prefix dependent on the scale of the feature.

Microstructure: *Structure on the thin section or smaller scale.*

Mesostructure: *Structure on the hand specimen scale.*

Megastructure: *Structure on the outcrop or larger scale.*

Texture: *The relative size, shape and spatial interrelationship between grains and internal features of grains in a rock.*

Note: the use of 'texture' as defined above is common in geological literature (for example, Spry 1969), and as such is synonymous with *microstructure*. Because of this widespread usage the SCMR decided to accept 'texture' as a recommended term. However, in material science and in some languages 'texture' is used for the presence of a preferred orientation on the microscopic scale (microfabric) (for example, Barker 1990). In cases where confusion might occur with this restricted meaning then the use of *microstructure* as an alternative to 'texture' is recommended.

Fabric: *The relative orientation of parts of a rock mass.*

This is commonly used to refer to the crystallographic and/or shape orientation of mineral grains or groups of grains, but can also be used on a larger scale. Preferred linear orientation of the parts is termed *linear fabric*, preferred planar orientations *planar fabric*, and the lack of a preferred orientation is referred to as *random fabric*.

Foliation: *Any repetitively occurring or penetrative planar feature in a rock body.*

Examples include:

- layering on a cm. or less scale
- preferred planar orientation of inequant mineral grains
- preferred planar orientation of lenticular or elongate grain aggregates

More than one kind of foliation with more than one orientation may be present in a rock. Foliations may become curved or distorted. The surfaces to which they are parallel are called *s-surfaces*. More precise terms should be used wherever possible.

Schistosity: *A preferred orientation of inequant mineral grains or grain aggregates produced by metamorphic processes.*

A schistosity is said to be well developed if inequant grains or grain aggregates are present in a large amount and show a high degree of preferred orientation. If the degree of preferred orientation is low or if the inequant grains or grain aggregates are only present in small amounts the schistosity is said to be poorly developed.

Schistose structure: *A type of structure characterised by a schistosity which is well developed, either uniformly throughout the rock or in narrowly spaced repetitive zones such that the rock will split on a scale of one cm or less.*

Gneissose structure: *A type of structure characterised by a schistosity which is either poorly developed throughout the rock or, if well developed, occurs in broadly spaced zones, such that the rock will split on a scale of more than one cm.*

Cleavage: *The property of a rock to split along a regular set of parallel or sub-parallel closely spaced surfaces.*

More than one cleavage may be present in a rock.

Note: cleavage is a term that is not used in some non-english language countries, and causes confusion due to the overlap in meaning with schistosity. It has hence been defined as a *restricted term* (sensu Schmid et al, 2004), and schistosity may be used instead.

Slaty cleavage: *A well developed planar schistosity in a rock in which the individual grains are too small to be seen by the unaided eye and the schistosity is developed on the grain scale.*

Spaced schistosity: *A type of foliation characterised by regularly spaced zones with schistose structure that are structurally distinct from, and separating rock layers (called microliths). The structure is visible by the unaided eye.*

Fracture cleavage: *A regular set of closely spaced parallel or subparallel fractures along which the rock will preferentially split.*

Crenulation: *A type of regular folding with a wavelength of 1 cm or less.*

Crenulation schistosity: *A type of spaced schistosity developed during crenulation of a pre-existing foliation, and orientated parallel to the axial plane of the crenulations.*

Crenulation cleavage: *A type of cleavage related to crenulation of a pre-existing foliation.*

Gneissose structure: *A type of structure characterised by a schistosity which is either poorly developed throughout the rock or, if well developed, occurs in broadly shaped zones, such that the rock will split on a scale of more than one cm. Mineralogical or lithological layering is commonly present.*

Gneissosity: *Synonymous to and to be replaced by gneissose structure.*

Granofels structure: *A type of structure resulting from the absence of schistosity such that the mineral grains and aggregates of mineral grains are equant, or if inequant have a random orientation. Mineralogical or lithological layering may be present.*

Lineation: *Any repetitively occurring or penetrative visible linear feature in a rock body.*

It may be defined by:

- alignment of the long axes of elongate mineral grains (=mineral lineation)
- alignment of elongate mineral aggregates
- parallelism of hinge lines or small scale folds (=crenulation lineation)
- intersection of two foliations (=intersection lineation)
- slickenside striations or fibres.

More than one kind of lineation, with more than one orientation, may be present in a rock. Lineations may become curved or distorted. The lines to which they are parallel are called l-lines. Where possible the type of lineation should be indicated.

Fracture: A general term for any break in a rock mass, whether or not it causes displacement. Fracture includes cracks, joints and faults.

Slate: *An ultrafine- or very fine-grained metamorphic rock displaying slaty cleavage.*

Slate is usually of very low metamorphic grade, although it may also occur under low-grade conditions.

Phyllite: *A fine- to medium-grained metamorphic rock characterised by a lustrous sheen and a well-developed schistosity resulting from the parallel arrangement of phyllosilicates.*

Phyllite is usually of low metamorphic grade.

Schist: *A metamorphic rock displaying schistose structure.*

For phyllosilicate-rich rocks the term schist is commonly used for medium- to coarse-grained varieties, whereas finer-grained rocks may be given the more specific names *slate* or *phyllite*.

The term schist may also be applied to rocks displaying a linear fabric rather than a schistosity, but in which the rock will split on a scale of 1cm or less. In which case the expression '*lineated schist*' is applied.

Gneiss: *A metamorphic rock displaying a gneissose structure.*

The term gneiss may also be applied to rocks displaying a dominant linear fabric rather than a gneissose structure, but in which the rock will split on a scale of more than 1cm. In which case the term '*lineated gneiss*' is applied.

Granofels: *A metamorphic rock displaying a granofelsic structure.*

For granofels containing layers of different composition the term '*layered (or banded) granofels*' may be used.

DEFINITIONS: 2. FAULT ROCK TERMS (see Figure 1)

Fault: *A fracture surface along which rocks have moved relative to each other.*

Fault zone: *A zone of sheared, crushed or foliated rock, in which numerous small dislocations have occurred, adding up to an appreciable total offset of the undeformed walls. This includes shear zones.*

Fault rock: *Rock formed as a result of deformation in a fault zone.*

Mylonite: *A fault rock which is cohesive and characterized by a well developed schistosity resulting from tectonic reduction of grain size, and commonly containing rounded porphyroclasts and lithic fragments of similar composition to minerals in the matrix.*

Fine scale layering and an associated mineral or stretching lineation are commonly present. Brittle deformation of some minerals may be present, but deformation is commonly by crystal plasticity. Mylonites may be subdivided according to the relative proportion of finer-grained matrix into protomylonite, mesomylonite and ultramylonite.

When the protolith is known terms such as mylonitised granite, granite mylonite or granite-derived mylonite can be used.

Note: in the field it is often not possible to distinguish a foliated fault rock formed by brittle deformation (foliated cataclasite) from one formed by crystal plastic or grain boundary sliding processes, or a combination of different deformation mechanisms. Hence these are all defined in the field by the term mylonite.

Protomylonite: *A mylonite in which less than 50% of the rock volume has undergone grain size reduction.*

Mesomylonite: *A mylonite in which more than 50% and less than 90% of the rock volume has undergone grain size reduction.*

Note: As mylonite is the general term, to be consistent it is necessary to have a prefix for the more specific term intermediate between proto- and ultramylonite.

Ultramylonite: *A mylonite in which more than 90% of the rock volume has undergone grain size reduction.*

An ultramylonite need not be 'ultra' fine grained.

Augen Mylonite: *A mylonite containing distinctive large crystals or lithic fragments around which the foliated fine-grained matrix is wrapped, often forming symmetric or asymmetric trails.*

Blastomylonite: *A mylonite that displays a significant degree of grain growth related to or following deformation.*

Phyllonite: *A phyllosilicate-rich mylonite which has the lusterous sheen of a phyllite.*

Cataclasite: *A fault rock which is cohesive with a poorly developed or absent schistosity, or which is incohesive, characterised by generally angular porphyroclasts and lithic fragments in a finer-grained matrix of similar composition.*

Generally no preferred orientation of grains of individual fragments is present as a result of the deformation, but fractures may have a preferred orientation. A foliation is not generated unless the fragments are drawn out or new minerals grow during the deformation. Plastic deformation may be present but is always subordinate to some combination of fracturing, rotation and frictional sliding of particles.

Cataclasite may be subdivided according to the relative proportion of finer-grained matrix into protocataclasite, mesocataclasite and ultracataclasite.

Protocataclasite: *A cataclasite in which the matrix forms less than 50% of the rock volume.*

Mesocataclasite: *A cataclasite in which the matrix forms more than 50% and less than 90% of the rock volume.*

Note: As cataclasite is the general term, to be consistent it is necessary to have a prefix for the more specific term intermediate between proto- and ultracataclasite.

Ultracataclasite: *A cataclasite in which the matrix forms more than 90% of the rock volume.*

Tectonic or Fault Breccia: *A medium- to coarse-grained cataclasite containing >30% visible fragments.*

Fault Gouge: *An incohesive, clay-rich fine- to ultrafine-grained cataclasite, which may possess a schistosity and containing <30% visible fragments. Lithic clasts may be present*

Pseudotachylite: *Ultrafine-grained vitreous-looking material, usually black and flinty in appearance, occurring as thin planar veins, injection veins or as a matrix to pseudoconglomerates or breccias, which infills dilation fractures in the host rock.*

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