8. Amphibolite and Granulite

Recommendations by the IUGS Subcommission on the Systematics of Metamorphic Rocks: Web version 01.02.07

[1]José Coutinho, [2]Hans Kräutner, [3]Francesco Sassi, [4]Rolf Schmid and [5]Sisir Sen.

[1] J. Coutinho, University of São Paulo, São Paulo, Brazil
[2] L M University, Munich, Germany
[3] F. Sassi, Department of Mineralogy and Petrography, University of Padova, Italy
[4] R. Schmid, ETH-Centre, Zürich, Switzerland
[5] S. Sen, Indian Institute of Technology, Kharagpur, India

Introduction

This paper summarises the results of the discussions by the SCMR, and the response to circulars distributed by the SCMR, which demonstrated the highly variable usage of the terms granulite and amphibolite. It presents those definitions which currently seem to be the most appropriate ones. Some notes are included in order to explain the reasoning behind the suggested definitions. In considering the definitions it is important to remember that some of them are a compromise of highly different, even conflicting, opinions and traditions.

The names ***amphibolite*** and ***granulite*** have been used in geological literature for nearly 200 years: amphibolite since Brongniart (1813), granulite since Weiss (1803). Although Brongniart described amphibolite as a rock composed of amphibole and plagioclase, in those early days the meaning of the term was variable. Only later (e.g. Rosenbusch, 1898) was it fixed as *metamorphic* rock consisting of hornblende and plagioclase, and of medium to high metamorphic grade. In contrast, the use of the name granulite was highly variable, a position which was further complicated by the introduction of the facies principle (Eskola, 1920, 1952) when the name granulite was proposed for all rocks of the granulite facies.

The aim of the SCMR was to define amphibolite and granulite in accordance with its general principles (Schmid et al., this vol.) and, as mentioned above, principally according to their mineral composition and macroscopic characteristics, without, as far as possible, any genetic connotation.

Amphibolite

Evolution of the meaning of the term

It is generally accepted that amphibolite is a metamorphic rock consisting mostly of plagioclase and hornblende. However, different opinions have been presented concerning the modal proportions of hornblende and plagioclase, and the presence or absence of other minerals in the rock. Several classifications have been proposed, commonly based on triangular classification diagrams with plagioclase and amphibole (hornblende) at two apices. Quartz was frequently chosen for the third apex. These three components (expressed in volume %) were recalculated to 100%, other minerals were either not considered in the calculation, or combined with quartz, plagioclase or hornblende. When the transition of amphibolite to quartzofeldspathic rock (para- or ortho-) was described, the main candidate for the third apex was quartz, sometimes with biotite and K-feldspar. In the classification of Matthes & Kramer (1955), quartz is the critical mineral: these authors define amphibolite as essentially composed of amphibole and plagioclase with only traces of quartz, rocks with less than 5% of quartz are called quartz-bearing amphibolites, rocks with 5 to 20% of quartz are quartz-amphibolites, and rocks with more then 20% of quartz are hornblende gneisses. According to Oen (1962) amphibolite should contain less than 70% of hornblende, rocks with more hornblende are classified as hornblendic rocks and hornblendites; the lower limit of hornblende content is not given. According to Cannon (1963) the amount of hornblende as the dominant mafic mineral should normally exceed 50% of the total mineral content, quartz and plagioclase should be present in equal proportions or plagioclase should predominate. In the case when the amount of quartz is greater than plagioclase, the rock is classified as quartz-amphibolite.

A double triangle was used by Fritsch et al. (1967) for classifying rocks of the amphibolite (metabasite) group; pyroxene, plagioclase, amphibole and zoisite (epidote group) were placed at the apices. According to the definition of Fritsch et al. amphibolite should contain more than 40% of amphibole; rocks with less amphibole (40 to 20%) were called leuco-amphibolites.

Other varieties of the classification triangle were proposed and used with different groupings of the minerals at the apices, for example:

Fsp - Am - Qtz (Lorenz, 1980); Pl (Kfs) - Hbl - Qtz (Pešková, 1973); Pl (Kfs) - Hbl - Grt + Cpx (+Ep) (Tonika, 1969); Pl (Kfs) - Hbl (+Cpx, Grt, etc.) - Qtz (Fišera 1968).

There are no great differences in the principles used by these classifications, and in all of them most samples commonly called amphibolite plot in the respective amphibolite fields.

Wholly different is the proposal of Berthelsen (1960), who includes in the classification the transition of amphibolite to basic granulite (trappgranulite, pyriclasite). The presence of orthopyroxene in the rock is critical, and the classification is based on the relation of hornblende to clinopyroxene + orthopyroxene (the corresponding triangle was constructed by Lorenz, 1981).

To determine the range in the modal composition of amphibolites, Fišera (1973) collected about 260 modal analyses from the literature (Fig. 8.1a). More than 80% of them contain less than 10% of quartz, and more than 50% have no quartz at all, or contain quartz only as an accessory mineral. It may be concluded that most of the amphibolites described in the literature correspond to the common definition of amphibole + plagioclase rocks. The same

conclusion may be drawn from the descriptions and modal compositions of about 130 amphibolites from the Moldanubicum of the Bohemian Massif, as illustrated in Figures 8.1a and 8.1b. From these collected data, which may serve only as an example of the extensive literature, it follows that in the triangular plots the amphibolites cluster mostly in the field between 50 to 90% of amphibole. The field between 30% and 50% of amphibole is also densely populated, and contains no more than 10% of quartz. K-feldspar is generally absent or only present in small quantities, and has no influence on amphibolite nomenclature.

The SCMR definition

The SCMR arrived at a definition of amphibolite after extensive discussion, and consideration of the questionnaire results. The wording is based on the following statements.

1. Since the beginning of petrography, the term amphibolite has been used for a rock composed of amphibole and plagioclase. This name is therefore recommended for further use, even if it does not fit the general SCMR rules, for use of the suffix 'ite' (see Schmid et al., this vol.)

2. The modal compositions of amphibolites show that most of them contain more than 50% of amphibole, but those with 50 to 30% are not unusual. The content of amphibole and plagioclase together is mostly higher than 90%, and may be as low as 75%. The value of 75% is therefore taken as the lowest boundary of Pl+Am.

3. The colour of amphibole is green, brown or black in hand specimen and green or brown in thin section. The common varieties are tschermakitic and magnesio- and ferro-hornblende as defined in the IMA classification (Leake, 1997). Other types of amphibole, although less common, for example, cummingtonite or anthophyllite, may also be constituents of amphibolites.

4. Plagioclase is the prevalent light-coloured constituent, the quantity of quartz or epidote or scapolite should be lower than that of plagioclase.

5. Clinopyroxene, where present, should be less abundant than amphibole (hornblende). When pyroxene prevails, the rock should be named hornblende-pyroxene rock or calc-silicate rock, depending on its composition and on the composition of the clinopyroxene. The name *pyribolite,* proposed for Pl-Hbl-Px (Cpx+Opx) metamorphic rocks (Berthelsen, 1960) is not recommended for use by the SCMR (see below).

6. The presence of other major mineral constituents (>5%) is expressed by the corresponding prefix according to general SCMR rules (e.g. garnet amphibolite, pyroxene amphibolite, quartz amphibolite, etc.).

7. The amphibolite is characterised by the presence of hydroxyl-bearing minerals (amphibole, biotite), which prevail over the hydroxyl-free ones (garnet, diopside). The boundary with the higher grade, granulite-facies metamorphic rocks, is determined by the appearance of orthopyroxene.

8. The names ortho-amphibolite, para-amphibolite and meta-amphibolite may be found occasionally in the literature. The prefixes ortho-, para- and meta- have been used for the description of very different properties of rocks or processes, and in very different meanings (e.g. ortho- was used for the following rocks: metamorphic rocks of igneous origin, rocks containing K-feldspar, SiO_2-saturated rocks, sediments with defined contents of matrix, contents of carbon in coals, type of cumulates, etc.). The use of the prefixes ortho- and para- is accepted by SCMR in the classical concept of Rosenbusch for metamorphic rocks derived

from igneous and sedimentary parents respectively, but difficulties may exist in determining the nature of the protolith by directly observable features. The prefix meta- must never be used for repeatedly metamorphosed rocks according to SCMR guide-lines. If in amphibolites, amphibole is partly replaced by chlorite, and plagioclase by albite ± epidote ± calcite, due to alteration by retrograde metamorphism (retrogressive overprint), the term retrograde (retrogressive) amphibolite may be used in accordance with the SCMR rules.

The recommended definition of amphibolite reads:

Amphibolite *is a gneissose or granofelsic metamorphic rock mainly consisting of green, brown or black amphibole and plagioclase (including albite), which combined form ≥75% of the rock and both of which are present as major constituents; the amphibole constitutes ≥50% of the total mafic constituents and is present in an amount of ≥30%. Other common minerals include quartz, clinopyroxene, garnet, epidote-group minerals, biotite, titanite and scapolite.*

The boundaries of the amphibolite field as defined here are presented on Figure 8.2.

Relation to other rock groups

Transition amphibolite – quartzofeldspathic rock

Transitions of amphibolite to biotite-quartz-feldspar gneisses (or to schists) are relatively common. The boundary between the amphibolite and the quartzofeldspathic rock is set at a modal content of 25% of minerals other than amphibole and plagioclase.

Transition amphibolite - metacarbonate rock

The transition from amphibolite to *metacarbonate* rock (calc-silicate rock and carbonate-bearing silicate rock, sensu Rosen et al., this vol.) is generally marked by increasing amounts of calcic pyroxene and plagioclase in the rock. The critical boundary is again the 25% content of minerals other than amphibole and plagioclase.

In some metamorphic rocks there are alternating millimetre- to decimetre-thick layers of amphibolite and biotite-quartz-feldspar gneiss or layers of amphibolite and *calc-silicate* rock (or even marble). For such rock associations the name banded amphibolite was used occasionally by some authors. Because rock names, even with adjectives, cannot be used for mixed or juxtaposed rocks of different petrographic types, these complex rock associations may be called an ***interlayered amphibolite and quartzofeldspathic gneiss****, or* ***interlayered amphibolite and calc-silicate rock*** *(*or ***interlayered amphibolite and marble****).*

Rocks composed entirely of amphibole, other minerals being present only as accessories, set another nomenclature problem. Under the SCMR guidelines (see Schmid et al., this vol.), the term hornblendite is reserved for rocks with 90% hornblende. The terms ***hornblende granofels*** or ***hornblende gneiss*** may be used as an alternative. However, as may be seen from the triangular diagrams, rocks containing more than 90% of amphibole are rare.

Granulite

Evolution of the meaning of the term

In contrast to the name amphibolite, the name granulite is burdened by many ambiguities and was used with different meanings in different countries. In France it was applied to fine-grained granitic rocks (Michel-Lévy, 1874; Cogné & von Eller, 1961), but this use did not find common acceptance. In Scotland and England the term granulite was applied to high-grade metamorphic products of psammitic rocks. Most widespread is the use of the term granulite for light-coloured, quartzofeldspathic, high-grade metamorphic rocks. This meaning for the name was introduced by Weiss (1803) and later defined by many authors, mainly in consideration of the Central European fine-grained granulites of the Granulitgebirge in Saxony and of the Bohemian Massif (among others, Lehmann, 1884; Scheumann, 1961; Scharbert, 1963). The introduction of the facies principle (Eskola 1920, 1952) further complicated the terminology, the name granulite being proposed and used for all rocks of the granulite facies, even for those with intermediate and basic compositions. To avoid these ambiguities, Winkler & Sen (1973) proposed the name ***granolite*** instead of granulite for rocks with mineral associations diagnostic of the granulite facies (regional hypersthene zone). But this suggestion was not widely accepted.

By the end of the sixties, an international group, referred to as the Granulite Commission[1], tried to define the term granulite and published two reports (Behr et al., 1971; Mehnert, 1972). The results of the discussion were excellently summarised by Mehnert (1972, p.148-9) and the proposed definition of granulite was:

> "Granulite is a fine- to medium-grained metamorphic rock composed essentially of feldspar with or without quartz. Ferromagnesian minerals are predominantly anhydrous. The texture is mainly granoblastic (granuloblastic), the structure is gneissose to massive. Some granulites contain lenticular grains or lenticular aggregates of quartz ('disc-like quartz'). Granulite is the type rock of the granulite metamorphic facies. The composition of the minerals corresponds to granulite P-T conditions. The following rock types should not be included in the definition of 'granulite': medium- to coarse-grained rocks (>3mm) of corresponding composition and origin should be termed **granofelses**. Granulites that are rich in ferromagnesian minerals (>30%) should be termed **pyriclasites, pyribolites,** or **pyrigarnites**, depending on their composition".

The SCMR definition

The definition given by the Granulite Commission was an important basis for discussions in the SCMR and for the questionnaires. The comments on the proposed definition were strongly contrasting; a clear distinction from ***leptynite*** was also required (proposed mainly by French geologists). The results of the discussion are summarised as follows:

1. The main constituents of granulites are feldspars (perthitic alkali feldspar, plagioclase) and quartz. Typical mafic minerals are garnet (pyralspite), orthopyroxene (commonly with a high alumina content) and clinopyroxene (diopsidic); other typical constituents are kyanite,

[1] H.J.Behr, GDR; E. den Tex, Netherlands; D. de Waard, USA; K. H. Mehnert, Berlin; H.G. Scharbert, Austria; V. S. Sobolev, USSR; A. Watznauer, GDR; V. Zoubek, Czechoslovakia; H.J. Zwart, Netherlands.

sillimanite, rutile and ilmenite. Many granulites contain biotite (Mg- and Ti-rich) and hornblende (with high Ti-contents). In some granulites cordierite may also be present.

2. In some types of granulites the fine grain size and the presence of platy quartz crystals (‘Diskenquarze‘) are very typical (e.g. Scheumann, 1961; Behr et al., 1971). However the SCMR proposes to omit the structural and grain size criteria from the granulite definition. The structural criteria were based on the classical Central European terrains, whereas in the basement complexes of the world, the granulite facies rocks are prevalently coarser-grained and have a massive microstructure/random fabric.

3. The main problem of the granulite definition is the nomenclature of mafic high-grade metamorphic rocks (‘basic granulites‘) and their relation to granulites. These rocks, of mostly basaltic composition, were named in older papers *pyroxene granulites* (e.g. Lehman, 1884) and this name remained the only one generally used, even though it was considered to be not wholly appropriate. The necessity of a special name for ‘basic granulites‘ was mentioned by many authors (Lehmann, 1884; Scheumann, 1954), and if a special name could be adopted, ‘one of the main difficulties of the granulite nomenclature could be settled‘ (Mehnert, 1972). But the proposed and practical new term pyriclasite (Berthelsen, 1960) did not find general acceptance during the SCMR discussions. The informal name ***mafic granulite*** (Harley, 1989) seems, therefore, to be the most appropriate at present.

4. Contrasting opinions were expressed by the SCMR Study Group about the facies characterisation of the term granulite. Because it is difficult in the field to determine the metamorphic facies of rocks, especially where the critical mineral (orthopyroxene) is missing, the SCMR does not preclude granulites belonging to the amphibolite facies, because the characteristic mineral composition may be strongly influenced by the rock bulk chemistry.

Considering the above comments the recommended definition of granulite reads:

Granulite *is a high-grade metamorphic rock in which Fe-Mg-silicates are dominantly hydroxyl-free; the presence of feldspar and the absence of primary muscovite are critical, cordierite may also be present. The mineral composition is to be indicated by prefixing the major constituents. The rocks with >30% mafic minerals (dominantly pyroxene) may be called* ***mafic granulites****, those with <30% mafic minerals (dominantly pyroxene) may be called* ***felsic granulites****. The term should not be applied to ultramafic rocks, calc-silicate rocks, marbles, ironstones or quartzites.*

Detailed names and subdivisions may be given using mineral-root names, for example, garnet-clinopyroxene-plagioclase granulite, biotite-garnet-plagioclase granofels.

Related rock names

Several rock names are associated with the nomenclature of granulite rocks. They are briefly mentioned below with the SCMR recommendations on their use.

Charnockite, enderbite, etc. The nomenclature of these orthopyroxene-bearing granitoid rocks was given by Le Maitre (1989, 2002).

Hälleflinta (Cronstedt, 1758). Obsolete term, used mainly in Sweden and Finland, for a fine-grained compact quartzofeldspathic rock of horny aspect, which may be banded and/or blastoporphyritic. It is derived from acid igneous rocks or acid tuffs and is partly synonymous with *leptynite*. Not recommended for further use.

Leptynite (Haüy, 1782, in Cordier 1868). Name created by Haüy and probably first published by Brongniart, initially applied to a fine-grained granulite-facies rock, predominantly consisting of alkali feldspar, containing minor quartz, white mica, garnet and tourmaline, and with a planar gneissose structure. Later, used for any white-coloured, quartzofeldspathic rock, typically forming bands alternating with metabasic rock, irrespective of the intensity of metamorphism (Cogné & von Eller, 1961). It is not recommended for further use.

Leptite (Sederholm, 1897). Old term used by Swedish geologists for fine-grained gneissose to granulose metamorphic rocks of sedimentary origin mainly composed of feldspar and quartz with subordinate mafic minerals. The grade of metamorphism is higher than that of hälleflinta. Partly synonymous with leptynite; not recommended for further use.

Namiester Stein (v.Justi 1756). An obsolete name for granulite from the locality Námiešt in the Bohemian Massif, from where this rock was initially described.

Pyribolite (Berthelsen 1960). According to the original definition, a high-grade metamorphic rock composed of plagioclase, hornblende, clinopyroxene, orthopyroxene + garnet. The presence of orthopyroxene is essential, according to the original definition, hornblende and pyroxene being present in approximately equal amounts. The SCMR does not recommend the use of this term, which may be substituted by pyroxene amphibolite or hornblende mafic granulite according to the quantities of the respective minerals present.

Pyriclasite (Berthelsen 1960). High-grade metamorphic rock consisting mainly of feldspar (plagioclase) and pyroxene (Cpx and/or Opx) with or without garnet. The presence of Opx is essential according to the original definition. As redefined by the Granulite Commission, the contents of mafic constituents should be higher than 30% (in vol.). As this name was not generaly accepted by the SCMR, the term *mafic granulite* is most appropriate at present.

Pyrigarnite. Initially defined by Vogel (1967) as a high-grade metamorphic rock composed of pyroxenes and garnet, in which the presence of plagioclase may be expressed by a prefix (plagio-pyrigarnite). This definition was modified by Mehnert (1972), and plagioclase was added to the characteristic constituents of pyrigarnite. According to this revised definition pyrigarnite is composed of plagioclase, garnet and pyroxenes (Cpx and/or Opx), the contents of mafic constituents being higher than 30% (vol). The SCMR does not recommend the use of this term, which may be replaced by *garnet-rich mafic granulite* or, according to the general rules, by *Px-Grt-Pl-granofels* respectively (Schmid et al., this vol.)

Pyroxene granulite. Name for mafic granulites, mostly of basaltic composition. The term *mafic granulite* is recommended instead.

Stronalite (Artini & Melzi, 1900). Regional term for high-grade metamorphic rock mainly composed of garnet, feldspar and quartz. Biotite and cordierite may be present, as well as kyanite and sillimanite. The name may be replaced by *granulite*, or according to the SCMR general rules, by *Grt-Qz-Pl gneiss*/*granofels* (see also Schmid, 1968; Schmid et al., this vol.).

Trappgranulite (Stelzner, 1871). Obsolete term for *mafic granulites* ('pyroxene granulites') mostly of basaltic composition and consisting of plagioclase, quartz, pyroxene (originally described as a micaceous mineral), pyrrhotine and garnet.. Not recommended for further use.

Weisstein (Engelbrecht, 1802). Obsolete term for a granulite from the earliest descriptions of these rocks in Saxony. Not recommended for further use.

References

Artini, E, and Melzi, G., 1900. Ricerche petrografiche e geologiche sulla Valsesia. - Memorie del Regio Istituto Lombardo di Scienze e Lettere., **18**, 219-390. Milano.

Behr, H. J., den Tex, E., D. de Waard, D., Mehnert, K.H., Scharbert, H.G., Sobolev, V.S., Watznauer, A., Zoubek, V. and Zwart, H.J. 1971. Granulites - Results of a discussion. - N. Jb. Mineral., Mh., **1971**, 97-123. Stuttgart.

Berthelsen, A., 1960. Structural studies in the Precambrian of western Greenland. II. Geology of Torqussap Nuná. - Grönlands geologiske Undersogelse. Bulletin No. **25**, 1-223. Kobenhavn.

Brodie, K., Fettes, D., Harte, B., Schmid, R. 2004. A systematic nomenclature for metamorphic rocks. 3. Structural terms including fault-rock terms. Recommendations by the IUGS Subcommission on the systematics of metamorphic rocks. SCMR website (www.bgs.ac.uk/SCMR).

Brongniart, A., 1813. Essai d une classification minéralogique des roches mélangées. - J.des Mines, **34**, No.199, 5-48.

Cannon, R. T., 1963. Classification of amphibolites. Bull. Geol. Soc. Amer., **74**, 1087-1088.

Cogné, J., Eller, J. P. von, 1961 Défense et illustration des termes leptynite et granulite en pétrographie des roches métamorphiques. Bull. Serv. Carte Géol. Als. Lorr., **14**, 59-64. Strasbourg.

Cordier, P.L.A., 1868. Description des roches composant l'ecorce terreste et des terrains cristallins constituant le sol primitif (Ch D'Orbigny, ed.). Savy, Dunod, Paris, 533pp.

Cronstedt A., 1758 Försök til Mineralogie eller Mineral-rikets Uppstålning, 2nd edition, Stockholm, 303pp.

de Waard, D., 1973. Classification and nomenclature of felsic and mafic rocks of high-grade regional-metamorphic terrains. - N. Jb. Mineral., Mh., **1973**, 381-392. Stuttgart..

Engelbrecht, Ch.A., 1802. Kurze Beschreibung des Weisssteins, einer im geognostischen System bis jetzt unbekannt gewesenen Gebirgsart. Schr. Linneschen Gesell., 26-34. Leipzig.

Eskola, P., 1921. The mineral facies of rocks. - Norsk Geologisk Tidskrift, **6**, 142-194. Oslo.

Eskola, P., 1952. On the granulites of Lappland. Amer. J. Sci., Bowen vol., 133-172.

Fišera, M., 1968. Problémy geneze amfibolitů. MS (unpubl.), Charles University, Prague.

Fišera, M., 1973. Petrografie kutnohorského krystalinika mezi Plaňany a Kolínem. PhD thesis (unpubl.), Charles University, Prague, 129pp.

Fritsch, W., Meixner, H. and Wieseneder, H., 1967. Zur quantitativen Klassifikation der kristallinen Schiefer. N. Jb. Miner. Mh., **1967**, No. 12, 364-376. Stuttgart.

Grubenmann, U. and Niggli, P., 1924. Die Gesteinsmetamorphose. Gebr. Borntraeger, Berlin. 539 pp.

Harley, S.L., 1989. The origins of granulites: a metamorphic perspective. Geol. Magazine, **126**, 215-247. Cambridge.

Justi, J.H.G.v., 1756. Grundriss des gesamten Mineralreiches. 233pp. Göttingen.

Klápová, H., 1977. Metabazity strážeckého moldanubika. MSc thesis (unpubl.), Charles University, Prague. 114pp.

Lehmann, J., 1884. Unterschungen über die Entstehung der altkrystallinischen Schiefergebirge, mit besonderer Bezugnahme auf das Sächsische Granulitgebirge. 278pp. Bonn.

Le Maitre, R.W. (Ed.) et al., 1989. A classification of igneous rocks and glossary of terms. Blackwell Sci. Publ., Oxford. 193 pp.

Le Maitre, R.W. (Ed.) et al., 2002. A classification of igneous rocks and glossary of terms. Cambridge University Press, Cambridge,. 236pp.

Leake, B. E. et al., 1997. Nomenclature of amphiboles: Report of the Subcommittee on Amphiboles of the International Mineralogical Association, Commision on New Minerals and mineral Names. Am. Mineral., **82**, 1019-1037.

Lehmann, J., 1884. Untersuchungen uber Entstehung der altkrystllinischen Schiefergebirge, mit besonderer Bezugnahme auf das Sachsische Granulitgebirge. Hochgürtel, Bonn, 278pp.

Lorenz, W., 1980. Petrographische Nomenklatur metamorpher Gesteine. I. Grundlagen, Konzeption, Systematik. Z.geol.Wiss., **12**, 1479-1509. Berlin.

Lorenz, W., 1981. Petrographische Nomenklatur metamorpher Gesteine. II. Klassifikatorische und nomenklatorische Spezialfragen. Z. geol. Wiss., **9**, 137-156. Berlin.

Matthes, S., and Krämer, A., 1955. Die Amphibolite und Hornblendegneise im mittleren kristallinen Vor-Spessart und ihre petrogenetische Stellung. Neu. Jb. Mineral., **88**, 225-272. Stuttgart.

Mehnert, K. R., 1972. Granulites. Results of a discussion II. N. Jb. Mineral., Monatshefte, **1972**, 139-150. Stuttgart.

Michel-Lévy, A., 1874. Note sur une classe de roches éruptives intermédiaires entre les granites porphyroides et les porphyres granitoides: Groupe des granulites. Bull.Soc.géol.Fr., **III, 2,** 177-189. Paris.

Oen Ing Sen, 1962. Hornblendic rocks and their polymetamorphic derivatives in area NW of Ivigtut, south Greenland. Meddedel. Groenland, No.**6**, 169-184. Copenhagen.

Pešková J., 1973. Amfibolitové horniny moldanubika z oblasti Dolní Rožínky. MSc thesis (unpubl.), Charles University, Prague. 124pp.

Rosenbusch, H., 1898. Elemente der Gesteinslehre. 546pp. Schweitzerbartsche Verlagsbuchhandlung, Stuttgart.

Scharbert, H. G., 1963. Zur Nomenklatur der Gesteine in Granulitfazies. Tschermaks mineral. Petrogr. Mitt., **8**, 591-598. Wien.

Scheumann, K. H., 1954. Bemerkungen zur Genese der Gesteins- und Mineralfazies der Granulite. Geologie, **2**, 99-154. Berlin.

Scheumann, K. H., 1961. "Granulit", eine petrographische Definition. – N. Jb. Mineral., Mh., **1961**, 75-80. Stuttgart.

Schmid, R., 1968. Schwierigkeiten der Nomenklatur und Klassifikation massiger Katamorphite, erläutert am Beispiel der Zone Ivrea-Verbano (Norditalien). Schweiz. miner. petr. Mitt., **48**, 81-90. Zürich.

Schmid R., Fettes, D., Harte, B., Davis, E., and Desmons, J., 2007. A systematic nomenclature for metamorphic rocks: 1. How to name a metamorphic rock. Recommendations by the IUGS Subcommission on the systematics of metamorphic rocks. SCMR website (www.bgs.ac.uk/SCMR).

Sederholm, J.J., 1897. Über eine archäische Sedimentformation im südwestlichen Finland und ihre Bedeutung für die Erklärung der Entstehungsweise des Grundgebirges. Bull.Comm. geol. Fin., No.**23**, 91-110. Helsinki.

Šichtářová I., 1977. Amfibolitové horniny východní části moravského moldanubika. MSc thesis (unpubl.), Charles University, Prague. 121pp.

Stelzner, A., 1871. Untersuchungen im Gebiete des sächsichen Granulitgebirges. Neu. Jahrb. Mineral. Geol. Paläont., **XX,** 244-249.

Tonika, J., 1969. Survey of classification and terminology of metamorphosed amphibole-bearing rocks.(in Czech). Čas.Mineral. Geol., **14**, 373-377. Prague.

Vogel, D. E., 1967. Petrology of an eclogite and pyrigarnite-bearing polymetamorphic rock complex at Cabo Ortegal, NW Spain. Leidse geol. Meded., **40**, 121-213. Leiden.

Weiss, C. S., 1803. Über die Gebirgsart des sächsischen Erzgebirges, welche unter dem Namen Weisstein neuerlich bekannt gemacht worden ist. Neue Schr. Gesellsch. Naturf. Freunde Berlin, **4**, 342-366.

Winkler, H. G. F. and Sen S. K., 1973. Nomenclature of granulites and other high grade metamorphic rocks. N. Jb. Mineral. Mh., **1973**, 393-402. Stuttgart.

Captions

Fig. 8.1a. Qz - Pl (Kfs) - Am (Cpx,Grt) diagram with contoured plots of 260 rocks described as amphibolites from various localities. Straight lines at 30%, 75% and 95% indicate limits of the amphibolite field recommended by the SCMR. Modal data from Fišera (1968)

Fig. 8.1b. Qz (Ttn) – Pl (Ep) – Am and Cpx (Grt, Bt, Chl) – Pl (Ep) – Am diagrams with contoured plots of 127 rocks described as amphibolites from the Moldanubicum of the Bohemian Massif. Straight lines at 30%, 75% and 95% indicate limits of the amphibolite field recommended by the SCMR. Modal data from Fišera (1973), Pesková (1973), Klápová (1977) and Šichtářová (1977).

Fig. 8.2. Amphibolite field according to the SCMR definition.

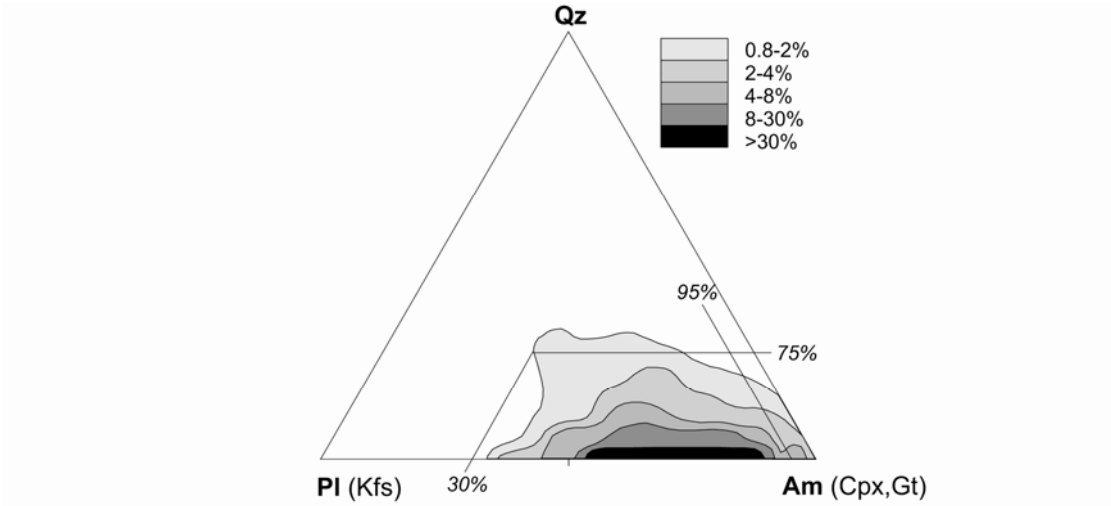

Fig. 8.1a

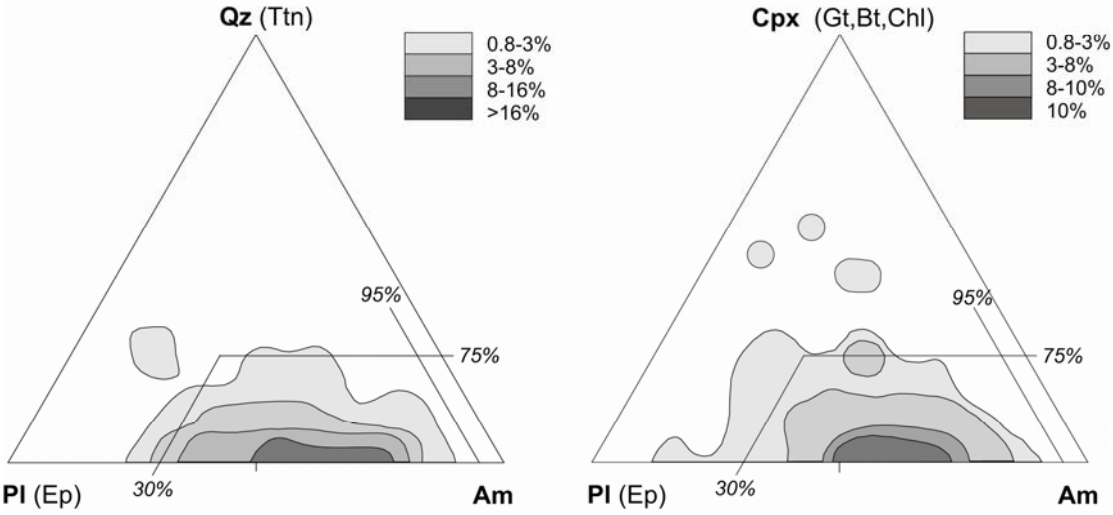

Fig8.1b

Fig 8.1

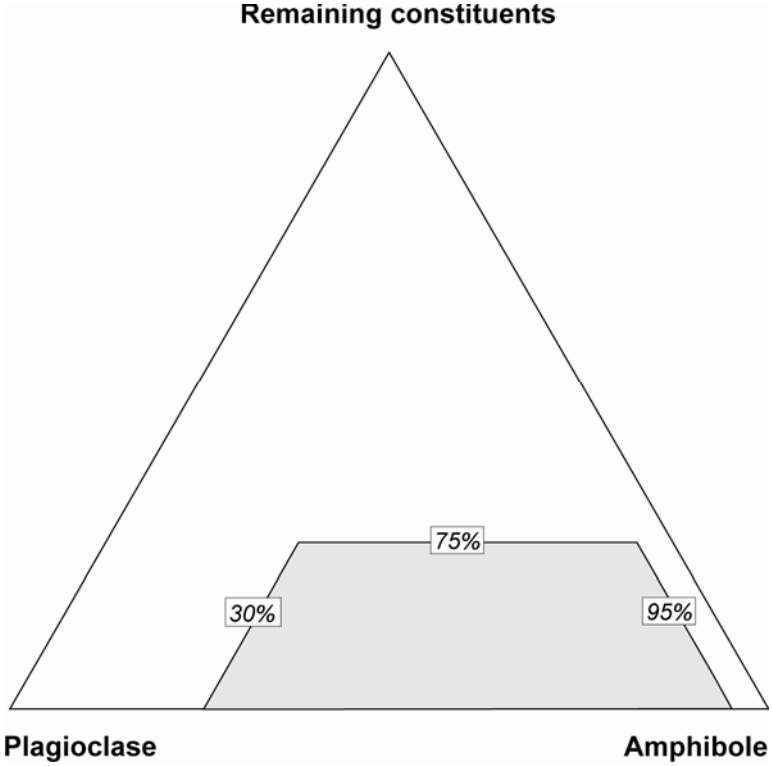

Fig 8.2