

## 7. Metacarbonate and related rocks

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### Introduction

A Carbonate Study Group under the leadership of O. Rosen was set up to prepare the nomenclature of metacarbonate and related rocks. Questionnaires were sent to a world-wide panel of specialists on metasediments. Eleven agreed to cooperate with the Study Group. This paper presents the results of this work.

### Basis of the classification scheme

#### *Scope of the classification*

The following discussion is based on the classification of metacarbonate rocks (here taken to include metacarbonate-bearing rocks): the derived nomenclature is applicable to all carbonate and carbonate-bearing metamorphic and metasomatic rocks including all calc-silicate rocks (which may be carbonate-free).

#### *Difficulties in erecting a classification scheme*

In considering a nomenclature scheme for metacarbonate rocks the SCMR noted the lack of any systematic data on which to base their definitions. This situation existed even though the extent of metacarbonate rocks in regional fold belts is comparable to many other well-documented rock types (e.g. basic rocks). A brief summary of existing terminologies is given by Rosen et al. (2005). This highlights the great diversity of terms used by authors and the variable use of the same terms between authors.

In addition, the wide variety of mineral assemblages, even in a simple prograde metamorphic sequence of a single impure-carbonate rock type, is a typical feature of metacarbonate rock sequences and creates a major difficulty in erecting a systematic classification based on modal content.

#### *Erection and analysis of a database*

In order to address these difficulties a sizeable database of chemical and mineral compositions was collected and utilised to define systematic variations in the composition of metacarbonate rocks.

This database is representative of almost all known compositional varieties, from silicate-free to carbonate-free types. The data were derived from regional metamorphic belts, and comprise rocks from a wide geographical range and representatives of greenschist, amphibolite and granulite facies terrains.

Although the data were selected to be broadly representative of metacarbonate rocks it is noted that the study is only a preliminary attempt to produce such a systematic approach.

An analysis of this database was then used to underpin the nomenclature divisions presented below.

The proposed classification is based on an analysis of modal carbonate mineral contents supported by chemical compositions. The database, its analysis and discussion are published separately (Rosen et al., 2005)

### ***Variety of metacarbonate rocks***

Metacarbonate rocks form a large and complicated group of rocks ranging from pure carbonate to almost carbonate-free calc-silicate varieties. The metacarbonate rocks discussed in the database, referred to above, were derived from sedimentary basin sequences overprinted by near-isochemical regional metamorphism. Limestone and dolostone are precursors of marbles. Carbonate-bearing mudstones, sandstones, tuffaceous and evaporitic sediments and marlstones are the precursors of carbonate-silicate and calc-silicate rocks. The latter rock types are more widespread than marbles reflecting their relative abundance in the sedimentary sequence. The metamorphism of the impure carbonate rocks is characterised by decarbonisation reactions, whose net result may be the total consumption of the original carbonate minerals. In this way an original impure carbonate rock may be converted into a carbonate-silicate rock while a carbonate-bearing mudstone may be converted into a calc-silicate rock. By contrast, decarbonisation reactions in pure carbonate rocks (limestones and dolostones) are rare due to the high thermal stability of carbonate minerals under most metamorphic conditions. Therefore marbles are found in virtually all metamorphic environments.

### ***Isochemical metamorphism, contact metamorphism and contact metasomatism***

A distinction may be drawn between metamorphic carbonate rocks produced under isochemical metamorphism and contact metasomatism. The database and associated analytical results mentioned above are concerned only with rocks that are the products of regional (isochemical) metamorphism. The classification scheme is, therefore, supported by a study of the systematics of regionally metamorphosed carbonate rocks. However the recommended names given below apply to all metamorphic carbonate rocks regardless of their genesis.

In addition, certain specific terms given in the associated SCMR papers on 'Metasomatism' (Zharikov et al., this vol.) and 'Contact metamorphism' (Callegari & Pertsev, this vol.) also relate to metacarbonate rocks (e.g. **skarn, contact marble, predazzite**). The user is referred to these papers or the SCMR glossary for the relevant definitions.

## The classification scheme

Metacarbonate rocks may be named using the systematic compound names with structural root terms and mineral prefixes (e.g. calcite-diopside granofels) as set out in the SCMR recommended scheme (Schmid et al., this vol.). This section, however, is mainly concerned with the specific names (see Schmid et al.) related to metacarbonate rocks. These are defined below.

### *Subdivisions of metamorphosed Ca- and Mg- carbonate rocks*

The SCMR classifications are based on features visible or measurable at the hand-specimen scale (Schmid et al., this vol.). In metacarbonate rocks the modal content of carbonate minerals is the most evident and reliable criterion and may be selected as the basis of classification. The analysis of the database discussed above (Rosen et al., 2005) showed significant boundaries at 95%, 50% and 5% of modal Ca- and Mg-carbonate minerals and these boundaries are used to define the main nomenclature fields. Thus, the 95% level separates pure marble from impure marble; the 50% level separates marble from carbonate-silicate rock and the 5% level separates carbonate-silicate rock from calc-silicate rock and carbonate-bearing silicate rock. These divisions are shown on Figure 7.1.

In these names 'rock' is used as a general term; the more specific structural terms, *schist*, *gneiss* and *granofels* may be used as appropriate.

The SCMR considered various possible fields for calc-silicate rocks but concluded that, in general, these rocks only have carbonate minerals present as a minor phase. Therefore, the calc-silicate field is restricted to rocks with less than 5% modal carbonate minerals.

The name *carbonate-bearing silicate rock* is determined by the SCMR rules on mineral prefixes. A modal value of 50% or greater of calc-silicate minerals separates calc-silicate rocks from carbonate-bearing silicate rocks (Fig. 7.1).

*The SCMR noted that there was no precise definition of calc- silicate minerals that could be used to define this latter boundary. Consideration was given to selecting minerals with  $\geq 20\%$  CaO content (see Appendix) but this boundary excluded, inter alia, calcic plagioclase which was considered to be important, similarly other values of CaO% presented other anomalies. The SCMR, therefore, proposes the following list as the **main** calc-silicate minerals: calcic garnet (ugrandite), calcic plagioclase, calcic scapolite, diopside-hedenbergite, epidote group minerals, hydrogrossular, johannsenite, prehnite, pumpellyite, titanite, vesuvianite, wollastonite.*

*Note: In rare cases where other calc-silicate minerals (for example, cuspidine, danburite, larnite, melilite, merwinite, monticellite, rankinite, scawite, spurrite, xonotlite, etc.) are present in significant amounts and are used in determining the rock name, this should always be indicated. Similarly, If it is desired to include other minerals as calc-silicate minerals (e.g. calcic amphibole, laumontite, lawsonite, etc.) in calculating the rock name, then this should always be stated.*

It is characteristic of metacarbonate rocks, as with other metamorphic rocks, that with increasing grade an individual rock may move across fields and field boundaries (see above).

### **2. Siderite and magnesite rocks**

As discussed by Rosen et al. (2005) siderite and magnesite rocks can occur in substantial deposits. However it is recommended that such rocks, if known to be metamorphic, should not be given a specific name but should be defined using compound names with structural root terms and appropriate mineral prefixes (e.g. mica-siderite schist/gneiss).

### ***3. Boundaries with non-carbonate rocks***

In terms of quantitative mineral composition, marbles show a transition into carbonate-silicate rocks, which, in turn, pass into calc-silicate rocks and carbonate-bearing silicate rocks. The latter two, when free of carbonate, pass into the area of other felsic and mafic metamorphic rocks. Rosen et al. (2005) propose the following boundaries, based on empirical evidence: a maximum modal content of 35% of clinopyroxene and amphibole separates metacarbonate rocks from mafic silicate rocks and a maximum modal content of 50% of feldspar separates metacarbonates from feldspar-rich rocks. The SCMR definition of amphibolite also states that the boundary between a metacarbonate rock and an amphibolite is fixed at 75% of modal amphibole + plagioclase.

### ***4. Structural variation***

As with other varieties of metamorphic rocks the degree of schistosity in metacarbonate rocks varies with the degree of strain, the mineral content and with the metamorphic grade. For example, high degrees of strain or a high content of phyllosilicates will result in a well-developed schistosity, whereas lower strain values or the presence of more equant mineral grains will result in a poorly developed or absent schistosity. In each case the appropriate structural root term (schist, gneiss, granofels) may be used (e.g. carbonate-silicate gneiss).

The structure can also vary with the metamorphic grade. For example, metacarbonate rocks in the greenschist facies are more likely to have a relatively high modal content of phyllosilicates than at higher grades and may therefore display a well-developed schistosity (e.g. chlorite marble or carbonate-chlorite-mica schist). At higher grades, on the other hand, the phyllosilicate (muscovite, chlorite and/or biotite) content or degree of preferred orientation is likely to be lower and the rocks characteristically develop a granofelsic structure (e.g. calc-silicate granofels). Exceptions to this generality may, of course occur; abundant phyllosilicate minerals may exist in a rock but have a random orientation and also some phyllosilicate minerals may persist to relatively high grades.

## **Definitions**

### ***Recommended names***

**Marble:** *Metamorphic rock containing more than 50% vol. of carbonate minerals (calcite and/or aragonite and/or dolomite). Pure marble contains more than 95% vol. of carbonate minerals; a marble containing less than 95% of carbonate minerals is classified as impure marble.*

The specific carbonate mineral(s) may be given as an informal adjective (e.g. calcitic marble). Impure marbles may carry prefixes denoting the non-carbonate mineral components and structural state (e.g. diopside-grossular marble; tremolite-bearing quartz-diopside marble; gneissose phengite-omphacite marble).

**Carbonate-silicate rock<sup>1,2</sup>:** *Metamorphic rock mainly composed of silicate minerals (including calc-silicate minerals) and containing between 5 and 50% vol. of carbonate minerals (calcite and/or aragonite and/or dolomite).*

**Calc-silicate rock<sup>1,2</sup>:** *Metamorphic rock mainly composed of calc-silicate minerals and containing less than 5% vol. of carbonate minerals (calcite and/or aragonite and/or dolomite).*

***Common names with restricted or unnecessary status***

**Calciphyre** (Brongniart, 1813): *A metacarbonate rock containing a conspicuous amount of calcium-silicate and/or magnesium-silicate minerals. The term ‘carbonate-silicate rock’ should be used in preference if the non-carbonate mineral content is higher than 50% vol. and the term ‘impure marble’ should be used in preference if the non-carbonate mineral content is less than 50% vol.*

**Calc-mica schist** (Cotta, 1855): *A metacarbonate rock with a schistose structure and composed of calcite, oriented mica and quartz. The compound term ‘quartz-mica-carbonate schist’ should be used in preference.*

**Calc-schist** (Brongniart, 1813): *A metamorphosed argillaceous limestone containing calcite as a substantial component and with a schistose structure produced by parallelism of platy minerals. The term ‘carbonate-silicate schist’ should be used in preference if the non-carbonate mineral content is more than 50% vol. and the term ‘schistose impure marble’ should be used in preference if the non-carbonate minerals constitute less than 50% vol.*

**Cipolin** (Brongniart, 1813; Cordier, 1868): *A metacarbonate rock rich in chlorite and other phyllosilicates and displaying a saccharoidal structure. The term was also used in France for any crystalline limestone but this use is now obsolete. Terms such as ‘carbonate-chlorite schist’ should be used in preference if chlorite and other phyllosilicates comprise more than 50% vol. of the rock and the term ‘impure marble’ should be used if chlorite and other phyllosilicates constitute less than 50% vol.*

**Crystalline limestone** (Daubrée, 1867): *Metamorphosed limestone; a marble formed by recrystallisation of limestone as a result of metamorphism. The term ‘pure marble’ should be used in preference if the non-carbonate content is less than 5% vol. and the term ‘impure marble’ should be used in preference if the non-carbonate content is higher than 5% vol.*

***Other names***

**Ophicarbonat**

*A rock consisting of serpentinite and carbonate; the serpentinite is commonly fragmented or brecciated, and veined and impregnated by the carbonate material (calcite, dolomite, or*

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<sup>1</sup> Carbonate-silicate and calc-silicate rocks largely arise from the isochemical metamorphism of carbonate-sandstone and/or carbonate-mudstone sediments. These rocks, as defined above, may also be derived from these and other lithologies as a result of commonly complex processes associated with contact metasomatism. It is desirable when dealing with such rocks to make their context clear.

<sup>2</sup> More specific names may be given using mineral-structural root names, for example carbonate-zoisite-clinopyroxene-plagioclase granofels.

*magnesite*). It forms by the serpentinisation of ultramafic rocks and their reaction with CO<sub>2</sub> solutions. Hence *ophimagnesite* (where the carbonate is predominantly *magnesite*), etc.

### **Ophicalcite**

Strictly a form of *ophicarbonat*e in which calcite is the predominant carbonate. However, the term has traditionally been used in the meaning of *ophicarbonat*e, that is, it is taken to include rocks containing a variety of different carbonates.

Other names that relate to metacarbonate rocks produced by contact metamorphism or metasomatism (for example, *skarn*) are given in the relevant SCMR papers and in the Glossary.

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## Caption

Fig 7.1 Descriptive diagram for metacarbonate and related rocks. C, carbonate minerals: calcite, dolomite and aragonite. CS, calc-silicate minerals; see text for list of minerals. S, all other silicate minerals. 'Rock' is used as a non-specific root term; *schist*, *gneiss* or *granofels* may be used instead, as appropriate.

## Appendix

### *List of Ca-silicates arranged according to their CaO wt.% contents*

(on the base 100% including volatile components such as H<sub>2</sub>O, CO<sub>2</sub>, C, F, etc.)

Compiled by E. Callegari

This compilation is based on data from the Handbook of Mineralogy (Bideaux et al., 1995). The minerals given in plain letters have been found as main components of metacarbonate rocks, whereas those in italics are secondary or rare minerals (for detailed references see Bideaux et al., 1995).

**CaO >60%** Larnite/Bredigite, Spurrite/Paraspuirrite, Cuspidine, Hatrurite, Jassmundite, Nagelschmidite, Reinhardbraunsite, Rustumite, *Defernite*.

**CaO 50 to 60%** Tilleyite, Rankinite, Merwinite, Hillebrandite, Bultfontainite, Fukalite, Hydroxyllestadite, Chlorellestadite, *Killalaite*, *Foshagite*, *Trabzonite*.

**CaO 40 to 50%** Gehlenite/Åkermanite, Wollastonite, Katoite, Baghdadite, Götzenite, Gugiaite, *Xonotlite*, *Scawtite*, *Harkerite*, *Afwillite*, *Aminoffite*, *Jennite*, *Oyelite*, *Riversideite*, *Rosenhanite*, *Zeophyllite*.

**CaO 30 to 40%** Grossular, Andradite, Uvarovite, Hydrogrossular, Schorlomite, Vesuvianite, Datolite, Pectolite, Fe-Bustamite, Hardystonite, Jeffreyite, Kirschsteinite, Sarcolite, Monticellite, *Cebollite*, *Gyrolite*, *Bicchulite*, *Tobermorite/Clinotobermorite*, *Plombierite*, *Kimzeyite*, *Juanite*, *Kamaishilite*.

**CaO 20 to 30%** Diopside, Hedenbergite, Zoisite/Clinozoisite, Epidote, Titanite, Meionite, Pumpellyite, Prehnite, Esseneite, Charoite, Latiumite, Bavenite, Bustamite, Danburite, Glaucochroite, Johannsenite, Axinite, Mukhinite, Malayaite, *Carletonite*, *Chantalite*, *Natroapophyllite*, *Nekoite*, *Strätlingite*, *Ruizite*.

**CaO 20 to 15%** Bytownite, Anorthite, Lawsonite, Mizzonite, Piemontite, Augite, Babingtonite, Omphacite, Partheite, Serendibite, *Junitoite*, *Liottite*.

**CaO 15 to 10%** Labradorite, Tremolite, Actinolite, Fe-Actinolite, Ilvaite, Margarite, Clintonite, Britholite, Calderite, Dorrite, Ekanite, Rhönite, Welshite, *Thompsonite*, *Gismondine*, *Laumontite*, *Afghanite*, *Allanite*, *Franzinite*, *Trimerite*, *Wenkite*, *Chabazite*.

**CaO <10%** Sodic Plagioclases, Sodic Scapolites, Lazurite, *Heulandite*.

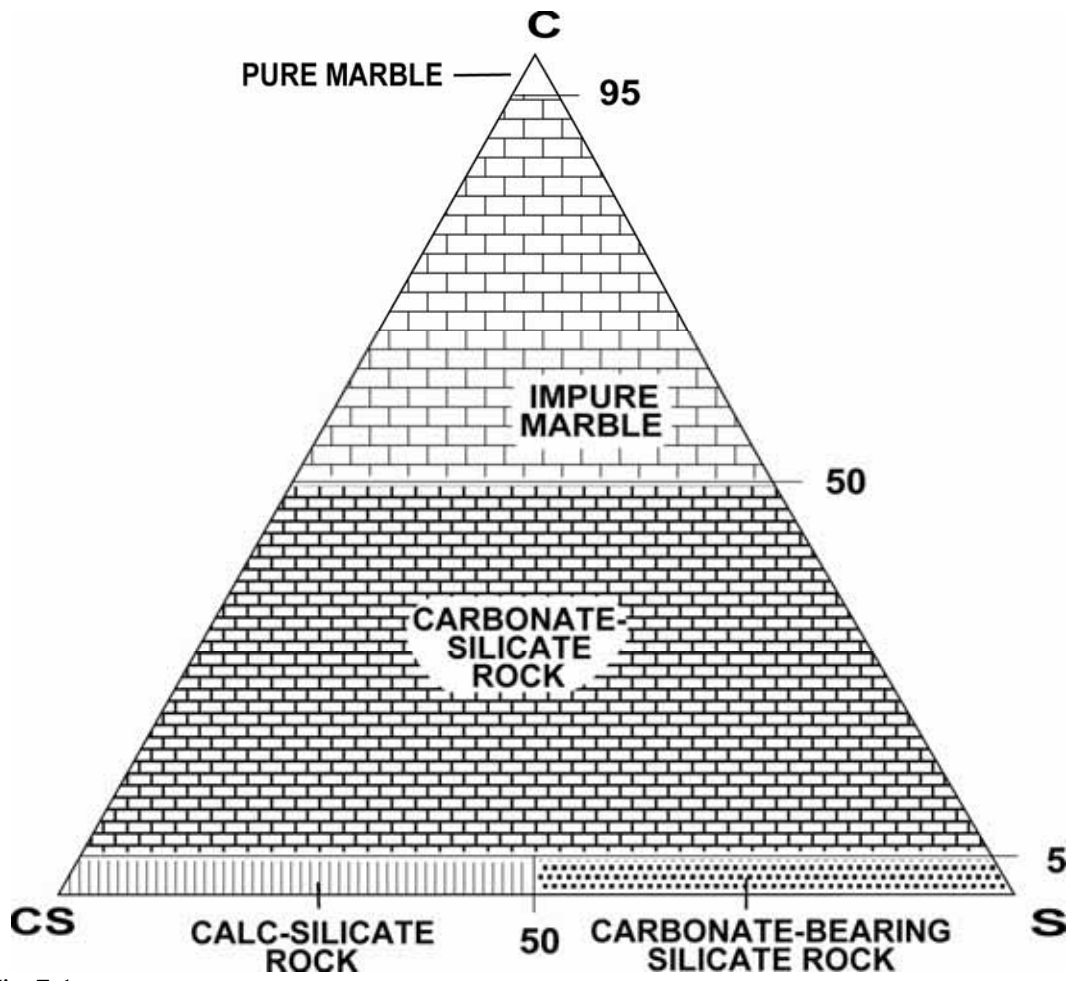


Fig 7.1