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# The quartzite problem revisited

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# GEOLOGICAL NOTE

## The Quartzite Problem Revisited

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**ABSTRACT**

A review of past terminology and previous petrological studies suggests that quartzite should be classified descriptively as both a sedimentary and a metamorphic rock. Quartzite is identified in the field as a quartz-rich rock (exclusive of chert and vein quartz) that is exceptionally hard and, when broken by a rock hammer, fractures irregularly through both grains and cement (where present) to form an irregular or conchoidal fracture surface. Quartzite is differentiated from quartzose sandstone (arenite), which is softer and fractures around individual grains, and from chert and vein quartz by a bright vitreous luster. Quartzite is classified further on the basis of microscopic features into orthoquartzite and metaquartzite by the presence of clastic and metamorphic microtextures, respectively. Low-grade, medium-grade, and high-grade subtypes of metaquartzite are differentiated by mortar, foam, and porphyroblastic microtextures, respectively. Composition is not used as a criterion for classification; hence, quartzite may contain a significant proportion (>10%) of nonquartz minerals. As defined here, quartzite is readily identified by megascopic features in outcrop, and subtypes of quartzite can be distinguished microscopically, even when the geologic context of the sample is unknown.

### Introduction

Forty years have passed since Skolnick (1965) lamented over the "quartzite problem," that is, the difficulties and controversy associated with the identification and classification of quartzite. Since that time, a great deal has been learned about the nature and origin of this type of rock, yet the quartzite problem is unresolved. Today, many geologists utilize the term quartzite only for metamorphic rocks, others continue to use the term for quartzose sandstones in which the overgrowth process is complete, and a few have abandoned the term quartzite altogether. Resolution of the problem is important because quartzitic bedrock is widespread, and because of its exceptional hardness and chemical stability, quartzite is one of the most common types of detrital sedimentary particles. The purpose of this note is to propose a descriptive classification of quartzite based on a review of past terminology and previous petrological studies.

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### Previous Work

The earliest use of the term "quartzite" appears to be that of Murchison (ca. 1840) for a rock formed by metamorphism of quartzose Silurian sandstone (Skolnick 1965). The term was in common usage by the late 1800s in both Europe and North America, where it was often applied to exceptionally hard quartzose sandstones (e.g., Hayden 1872). The pioneering study of quartzitic sandstone with the petrographic microscope, in which Sorby (1880) recognized that quartz overgrowths developed in optical continuity with detrital host grains, also dates from the late nineteenth century. Early investigators generally used quartzite as a field term for any exceptionally hard, impermeable, quartzose rock with a characteristic vitreous luster that breaks irregularly through both grains and cement to form an irregular fracture surface. Quartz-rich rocks with less cement, which break around individual grains, were called quartz sandstone or quartz arenite (Skolnick 1965). By this definition, quartzite may form by either diagenesis or meta-

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morphism. Hence, Krynine (1948) coined the terms orthoquartzite and metaquartzite to differentiate rocks of sedimentary and metamorphic origins, respectively. Quartzitic sandstone was known to be common and well developed worldwide in craton-derived successions of Late Precambrian and Cambrian age, and such strata were generally perceived as being characterized by textural and compositional supermaturity. Consequently, early workers classified orthoquartzite as a type of supermature sandstone containing >95% quartz (Krynine 1948; Pettijohn 1949, 1954; Folk 1954), although less mature types of quartzite were recognized (Dapples et al. 1953; Hubert 1962). In later sandstone classifications, orthoquartzite is replaced by the term quartz arenite (Williams et al. 1954; Crook 1960; Dott 1964; Folk 1974). This terminology is still common today, and quartzite is often classified simply as a nonfoliated metamorphic rock.

By the time Skolnick (1965) discussed the quartzite problem, the processes of pressure solution, plastic deformation, and metamorphic recrystallization of quartz were reasonably well understood. However, petrographic studies were generally limited to standard (light) microscopy, and unresolved problems remained. For example, Skolnick (1965) questioned the presence of cement as a key criterion for identification because pressure solution appeared to result in the development of some orthoquartzites without cement. This apparent discrepancy was resolved with the development of cathodoluminescence microscopy, which revealed clastic microtextures in rocks lacking the usual "dust lines" and showed that cement was present in orthoquartzite affected by pressure solution (Sippel 1968; Sibley and Blatt 1976). A great deal of petrologic information was obtained during the later part of the twentieth century from the application of various technological advances after scanning electron microscopy revealed interesting new details about the process of quartz cementation (Pittman 1972).

Previous work shows that quartz possesses many unique optical properties visible with the petrographic microscope (table 1) and that a predictable sequence of microtextures (fig. 1) develops in quartzite with progressive diagenesis and metamorphism (see Howard 2000 for photomicrographs). Orthoquartzite is formed diagenetically from quartz arenite by quartz cementation and is characterized by clastic texture. It is found in sedimentary and low-grade metasedimentary settings, occasionally with relict sedimentary structures. Recrystallization of orthoquartzite begins at upper greenschist grade with the development of mortar texture, wherein much of the original depositional texture remains, but the boundaries of highly strained detrital quartz grains are obliterated by the growth of new, small, strain-free quartz crystals (Hobbs 1968; Sylvester and Christie 1968; Wilson 1973; Groshong 1988). As mortar texture develops, detrital lithic and feldspar grains are progressively altered into mica (Howard 2000). Amphibolite and granulite-grade metaquartzites are characterized by foam texture and duplex (porphyroblastic) microtextures, respectively (Wilson 1973; Groshong 1988). Similar metamorphic textures are present whether the protolith is quartzose sandstone (Sylvester and Christie 1968; Wilson 1973) or chert (Carter et al. 1964; Keller et al. 1977, 1985). Cataclastic microtextures formed by regional dynamic and fault zone metamorphism of quartzose sandstone (Means 1975; Wilson 1975; Bowler 1989) and chert (Masuda 1982) have also been documented.

Recently, I studied the petrographic characteristics of a variety of quartzitic bedrock units, along with suites of quartzite clasts found in fluvial mid-Cenozoic conglomerates (Howard 2000). The samples collectively span a wide spectrum of quartzite types. The results show that different types of quartzite, distinguished on the basis of microscopic features, cannot be identified reliably on the basis of megascopic features alone. In particular, granular texture is a megascopic characteristic of hand specimens of orthoquartzite, low-grade metaquartzite with mortar texture, and high-grade porphyroblastic metaquartzite containing abundant quartz metacrysts. Samples are readily identified as quartzite by hardness and fracture in the field, but laboratory analysis with both standard and cathodoluminescence microscopy is required to fully classify different varieties of quartzite.

## Proposed Classification of Quartzite

Hardness, conchoidal fracture, and (usually) vitreous luster differentiate quartzite lithologically from most other types of rocks, and given the practical necessity of megascopic identification during routine field work (mapping, clast counting, etc.), a field-based definition is desirable. In the classification proposed here (fig. 2), quartzite is defined as a quartz-rich rock (exclusive of chert and vein quartz) that it is exceptionally hard and, when broken by a rock hammer, fractures irregularly through both grains and cement (where present) to form an irregular or conchoidal fracture surface. Quartzite is differentiated from quartzose sandstone (arenite) by a propensity in the latter to frac-

**Table 1.** Microscopic characteristics of quartz and quartzite

| Term | Definition | References |
|---|---|---|
| Straight extinction | Crystal extinguishes as a single unit upon slight rotation of microscope stage | Folk 1974 |
| Undulatory extinction | Crystal extinguishes in irregular sweeping sections as microscope stage is rotated over several degrees | Folk 1974 |
| Syntaxial overgrowth | Quartz cement added with the same crystallographic orientation as the host crystal | McBride 1989 |
| Tangential intergranular contact | No interpenetration; results from original packing | Taylor 1950; Dapples 1962 |
| Long, straight intergranular contact | Results from original packing or formed by juncture of authigenic overgrowths; rarely sutured | Taylor 1950; Tada and Siever 1989 |
| Concavo-convex intergranular contact | Interpenetrating grain boundary; caused by pressure solution | Taylor 1950 |
| Sutured intergranular contact | Irregular, interlocking boundary between two grains; caused by pressure solution | Taylor 1950 |
| Microstylolitic intergranular contact | Irregular interlocking boundary involving an aggregate of multiple grains; caused by pressure solution | Park and Shott 1968 |
| Fluid inclusion planes | Closed, intragranular or transgranular microfractures, 1–5 $\mu$m wide, decorated by bubbles or fluid inclusions | Onasch 1990 |
| Microveins | Closed, transgranular microfractures, 10–200 $\mu$m wide | Onasch 1990 |
| Deformation lamellae | Narrow $<2$ $\mu$m, closely spaced, subparallel bands of lighter and darker extinction that terminate at the boundaries of a host crystal | Fairbairn 1941 |
| Deformation bands | Wide $>2$ $\mu$m, distinct, independent bands of undulose extinction crossing a host grain | White 1973 |
| Triformal texture | Mosaic of interlocking equant polygonal grains with smoothly curved to straight interfaces forming 120° angles and triple junctions; caused by diagenesis | This note |
| Polygonized texture | Polycrystalline mosaic of irregularly shaped or lensoid subgrains separated by distinct boundaries; segmented undulosity of Young 1976; transitional from diagenesis to metamorphism | Bailey et al. 1958 |
| Mortar texture | Partially preserved clastic depositional texture with fine, strain-free crystals along grain boundaries; caused by metamorphic recrystallization | Wilson 1973; Groshong 1988 |
| Foam texture | Medium-grained granoblastic mosaic of interlocking polygonal grains with straight boundaries forming 120° angles and triple junctions; garnet metacrysts common; caused by metamorphic recrystallization | Groshong 1988 |
| Porphyroblastic texture | Coarse-grained granoblastic to porphyroblastic mosaic of irregularly shaped grains; quartz and sillimanite metacrysts common; duplex structure of Wilson 1973; caused by exaggerated metamorphic grain growth | This note |

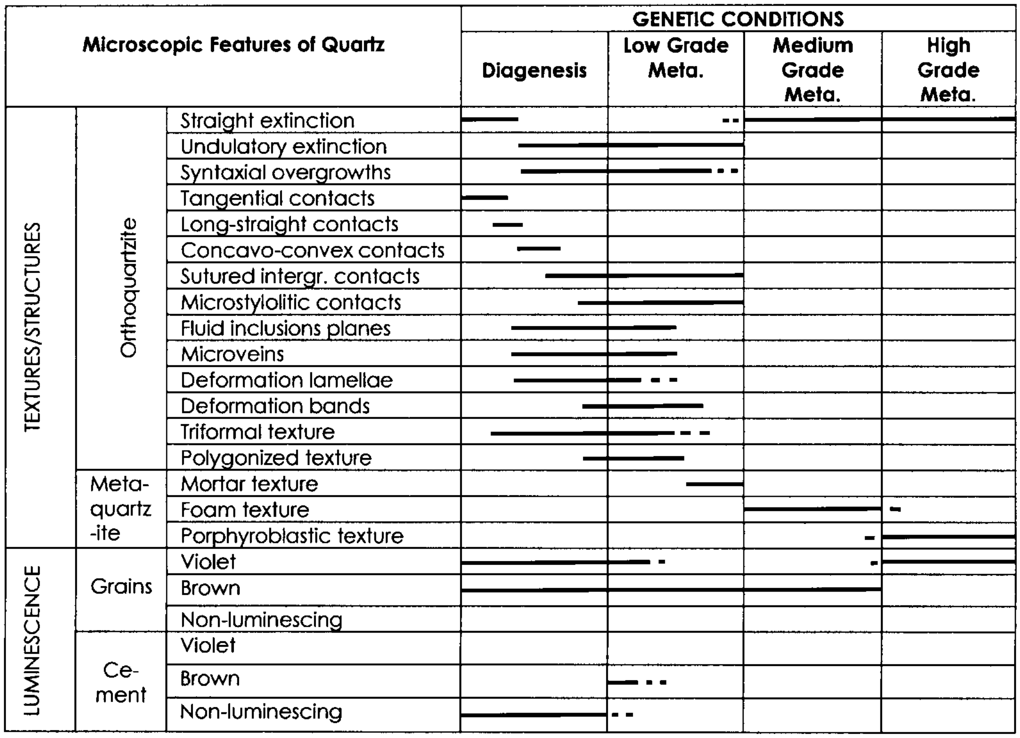


**Figure 1.** Microscopic characteristics (see table 1) and cathodoluminescence features (Zinkernagel 1978; Matter and Ramseyer 1985; Marshall 1988) of quartzite as a function of petrogenesis.

ture around individual grains. A bright, translucent, vitreous luster usually distinguishes quartzite megascopically from chert, which is opaque with a dull waxy luster, and vein quartz, which has a dull vitreous luster and a cloudy or milky white appearance. The proposed classification of quartzite conforms precisely to the field-based definition of early workers and emphasizes the petrogenetic significance of quartzite in terms of its durability and abundance as sedimentary clasts in the geologic record.

Krynine's (1948) original definition of orthoquartzite, based on composition, is ambiguous because similar rocks containing <95% quartz are excluded even though they meet the field definition based on hardness. His genetic basis for differentiating orthoquartzite and metaquartzite also creates problems because interpretations based on presumed mode of origin are subject to change and controversy. The modern approach is descriptive, but orthoquartzite is undefined in current sandstone classifications that include it as a type of arenite. It is proposed here that because the terms orthoquartzite and metaquartzite have historic precedence, they should be used to distinguish fundamentally different types of quartzite on the basis of the presence of clastic and metamorphic microtextures, respectively (fig. 2). Low-grade, medium-grade and high-grade subtypes of metaquartzite are differentiated by mortar, foam, and porphyroblastic microtextures, respectively (fig. 1). Microscopically, quartzite consists of an interlocking mosaic of mainly sand-sized (0.06–2.0 mm) quartz crystals with <1% intergranular porosity and may contain a significant proportion (>10%) of nonquartz minerals. Crystal size distinguishes quartzite (>0.06 mm) from chert (<0.06 mm). Quartzite is polycrystalline, whereas vein quartz is monocrystalline, has straight extinction, and contains very abundant fluid inclusions (vacuoles). Quartzite is distinguished from mylonite, which is characterized by cataclastic microtexture, and from obsidian and pseudotachylite, which are composed partly or totally of glass. Note that orthoquartzite of diagenetic origin often has a microtexture in which polygonal grain boundaries are formed by long, straight intergranular contacts ("triformal" texture; table 1). Triformal and foam textures are similar, and in the absence of dust lines, they may be distinguished only by cathodoluminescence microscopy.

Although megascopic features are generally un-

| Petrographic Characteristics | | Orthoquartzite | Metaquartzite | | |
|---|---|---|---|---|---|
| | | | Low-Grade | Medium-Grade | High-Grade |
| Microscopic Features | | clastic texture | mortar texture | foam texture | porphyroblastic texture |
| Megascopic Features | Color | red, light gray to black, white | red, gray and greenish-gray to black, white | light gray to black, white | light gray to black, white |
| | Texture | granular | granular | massive | massive or pseudogranular |
| | Luster | bright vitreous | bright vitreous | dull vitreous or waxy | bright vitreous |
| | Sedimentary Structures | bedding and burrows possible | bedding and burrows possible | rare | none |
| | Foliation | none | variable | variable | variable |
| | Magnetism | none | none | possibly weak | weak to strong |

**Figure 2.** Classification of quartzite by microtexture.

reliable for identification of quartzite types when used alone, color is somewhat useful because it is usually related to colored nonquartz minerals that vary as a function of petrogenetic history. Quartzites containing fine particles of hematite are red (5R, 10R), whereas those with coarse crystals of hematite (specularite) appear black (N1–N6), according to the Munsell system. Quartzites containing clumps of hematite or abundant biotite are also black (N1–N6); finely disseminated chlorite yields a green color (5GY, 5G, 5Y); and white types (N7–N9) simply lack a pigmenting agent (Howard 2000). Medium-grade metaquartzite with foam texture may be identified by a distinctive waxy luster, although this feature is masked by dark coloration. Hematite is replaced by magnetite in prograde regional metamorphic settings (LaBerge 1964; Jansen and Schuiling 1976). Hence, medium- to high-grade metaquartzites are typically white or black, and the latter may be highly magnetic. Metaquartzite is occasionally red as a result of hematite produced by deuteric alteration. Cataclastically deformed metaquartzite is typically characterized by megascopic foliation.

## Discussion and Conclusions

In the proposed classification, quartzite includes rocks of both sedimentary and metamorphic origin. However, this is not unlike other descriptive classifications wherein a given type of igneous rock is known to form by different processes, or the same metamorphic lithology is formed from more than one type of protolith. The proposed criteria of exceptional hardness, conchoidal fracture, and vitreous luster are readily evaluated with a hand lens and rock hammer and therefore accommodate the practical necessity of megascopic identification during field work. The subtypes of quartzite defined here on the basis of microtexture avoid the problems created by Krynine's definition based on composition. As redefined here, quartzite may range in composition from quartzose to quartofeldspathic and quartzolithic.

Sandstone classifications that consider orthoquartzite to be a type of arenite fail to distinguish quartzite as a distinctive lithology whose durability has important petrological implications. They also fail to distinguish clast types in rudites because it is not possible to differentiate quartzitic sandstone from metaquartzite in the field. Similar problems are encountered with classifications that use quartzite only as a metamorphic rock name. Unlike bedrock, where geologic setting indicates whether a given outcrop of quartzite is sedimentary or metamorphic, there is no geologic context with which to interpret quartzite clasts in rudites. Furthermore, the classification of quartzite as a nonfoliated metamorphic rock is both inaccurate and inadequate for provenance analysis. Abandoning the term quartzite is not necessary if a descriptive classification is used, and it seems inadvisable because quartzite is a long-standing term with historic precedence that has been used widely in the literature. From a petrographic standpoint, particularly in the case of provenance analysis of quartzite clasts in rudites, it is essential that quartzite with clastic texture be distinguished from that with metamorphic texture. With the proposed classification, the differentiation of orthoquartzite and metaquartzite based on microtexture is applicable not only to bedrock, but also to quartzite clasts in rudites and hand specimens in general. As defined here, orthoquartzite is derived from quartz-rich sandstone and may be of diagenetic or low-grade metamorphic origin. Metaquartzite is formed, under metamorphic conditions of upper greenschist to granulite grade, from orthoquartzite or chert protoliths.

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