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CLASSIFICATION OF WITWATERSRAND QUARTZITES

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by

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ABSTRACT

Although regional metamorphism and pervasive alteration have converted all the original sedimentary rocks of the Witwatersrand Basin into slates, schists, quartzites, and metaconglomerates, the textures, sedimentary structures and bulk rock compositions still allow the original nature of most of the metasediments to be determined.

Quartzites, the main component of the Witwatersrand succession, have been subdivided into "arenites" and "wackes" based on original matrix, stratification, and sorting. It is possible to further subdivide many of these using the inferred ratio of original components (quartz content, lithic fragments, feldspar, matrix type, and amount), stratification, and texture. In some cases the rock may be unambiguously identified while in others labile components of the original detrital assemblage are completely altered and "lithic" and "feldspathic" precursors are indistinguishable.

Sedimentary precursors may thus be reconstructed using sedimentary structures and petrographic characteristics preserved in the present assemblage to discriminate between primary "wackes" and those that result from post-depositional alteration processes ("pseudo-wackes"). "Arenites" are distinguished from "wackes" in that they are better sorted, and stratified and/or cross-stratified, indicating deposition as a granular sediment by traction currents. "Wackes" are generally massive, poorly sorted, and contain in excess of 15% argillaceous matrix.

The scheme proposed differs from classification schemes for unaltered sedimentary rocks in that it recognises post-depositional alteration and metamorphism of the original detrital assemblage. This classification scheme is also applicable to other sedimentary sequences with secondary diagenetic or metamorphic mineral assemblages.

Detailed studies at selected localities in active mines indicate the presence of many different types of "quartzites" in the Central Rand Group, including quartz arenites, quartz wackes, and lithic arenites. An important association common to the major economic reef in each of the major goldfields appears to be one of a thin (less than 1m thick) quartz arenite immediately above the reef. The type of quartzite in the footwall to the major reefs is highly variable, although quartz arenites are poorly represented below rich reef, possibly reflecting the relatively low abundance of quartz arenites within the Central Rand Group stratigraphy.

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INTRODUCTION

Sandstones are classified in terms of their *primary* detrital composition immediately after deposition. Different authors have favoured a variety of different components in their classification schemes (see reviews by Scholle, 1979; Blatt *et al.*, 1979). Most recent classification schemes have used components with genetic implications either with respect to source (e.g. feldspar, lithic fragments), depositional environment (e.g. clay content), or mineralogical maturity (e.g. quartz content).

These schemes are not directly applicable to sediments that have undergone either mineralogical or textural transformations after deposition. In weakly altered sedimentary rocks, where the original assemblage may be estimated from textural and mineralogical data, these schemes may still be satisfactorily applied. In pervasively altered sediments where the present mineralogy/texture is, however, no longer representative of the original detrital assemblage, classification schemes of this type are not appropriate. Instead, a classification scheme is developed that relies on those parameters that are least modified after burial.

Pervasive alteration and metamorphism of the Witwatersrand Supergroup has obscured the primary detrital composition of the sediments and resulted in the growth of minerals in equilibrium with the peak metamorphic conditions (350° ± 50° C; 1-2 kb; Phillips, 1987). Although this means that the mineralogical composition of many of the rocks has changed since burial, other criteria have been preserved to allow a fairly definitive assessment of likely precursors to be made.

A successful classification scheme requires that detail pertaining to the original detrital nature of the sediment be included in addition to characteristics relating to post-depositional alteration and metamorphism. A standardized classification system is required to enable comparisons to be made between different data sources.

Samples used in this study were collected from the Central Rand Group at various localities within the Witwatersrand Basin (Figure 1). A number of samples from the West Rand Group were also included and use was made of data published by various authors to strengthen the database of this investigation.

PROBLEMS IN "QUARTZITE" CLASSIFICATION

The classification of Witwatersrand "quartzites", particularly in hand-specimen, poses a problem which has yet to be resolved by the formation of a scheme that can be practically implemented and accepted. Fuller (1958, p. 40) noted that: "The fact that the rocks have been altered since burial makes it necessary to interpret the original mineralogy in order to arrive at a satisfactory classification". Standard classifications of sandstones are not applicable to Witwatersrand "quartzites" because of pervasive fluid alteration related to diagenesis and metamorphism of the original detrital assemblage (Law *et al.*, 1988a, b). Parameters required to define sediments in terms of detrital components (e.g. feldspar, rock fragments, and primary clay content) are commonly obliterated or modified in Witwatersrand "quartzites".

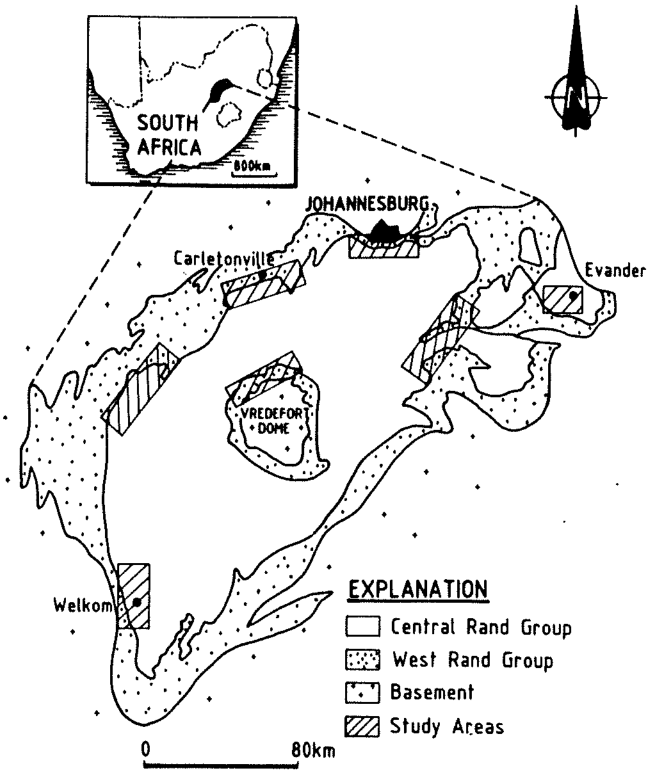


Figure 1: Map of the Witwatersrand Basin showing the distribution of sample locations.

Textural, mineralogical, and geochemical classification schemes are commonly used in the study of sedimentary rocks. Pettijohn *et al.* (1972) proposed an empirical geochemical classification scheme for sandstones based on a large number of analyses (Figure 2). In this diagram increasing values on the SiO_2/Al_2O_3 axis reflect increasing mineralogical maturity, i.e. increasing quartz content. The Na_2O/K_2O axis reflects the relative abundances of lithic fragments (generally Na_2O rich) and feldspar (generally K_2O rich) in the sediments. In this way the composition of sandstones may be represented by the fields shown in the diagram. A number of "quartzites" from the Central Rand Group in the Welkom Goldfield plot in the arkosic to sub-arkosic fields (Figure 2) which requires that the sediments contain abundant feldspar. However, mineralogical examination of the same suite of samples by thin section and XRD techniques reveals the complete absence of feldspar and hence precludes the fields of arkosic sediments in terms of the mineralogical/textural classification schemes (Figure 3) used by most sedimentary petrographers. This contradiction between chemical and textural/mineralogical classification schemes suggests post-depositional alteration of the original detrital assemblage which may or may not involve element migration (Law *et al.*, 1988a, b). In unaltered sandstones with a predominately detrital mineralogy/composition, both methods of classification are compatible. However, "quartzites" from the Central Rand Group are not

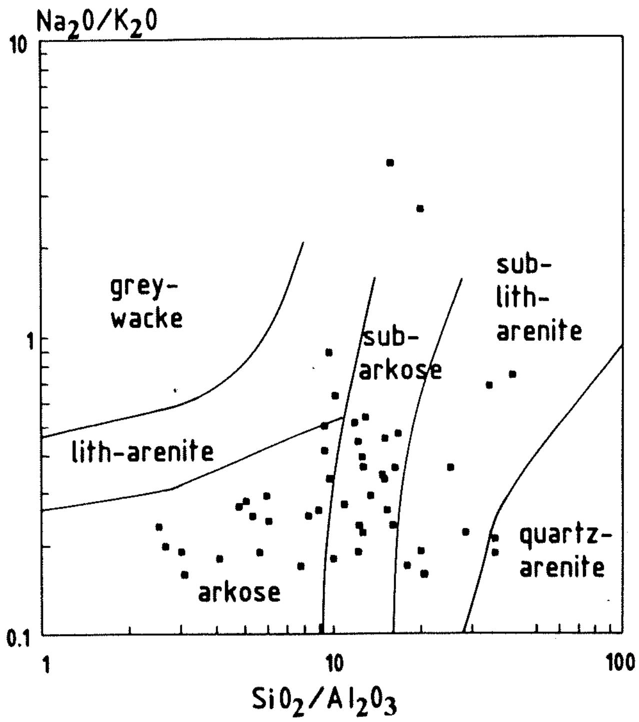


Figure 2: Geochemical classification scheme for sandstones (redrawn from Pettijohn et al., 1972). The points plotted represent 60 "quartzites" from the Welkom Goldfield.

accommodated within both classification schemes. The contradiction between classification schemes can thus be readily explained in terms of post depositional alteration of the original detrital assemblage.

PROPOSED CLASSIFICATION SCHEME

Following the terminology of Nanz (1954) "arenites" contain framework grains in contact with one another (i.e. a continuous framework) while "wackes" contain framework grains commonly separated and supported by clay matrix (i.e. a discontinuous framework). The abundance of argillaceous matrix is thus commonly used to distinguish between "arenites" and "wackes" although a continuum exists between the two types. *"Arenites"* are often stratified and/or cross-stratified, contain <15% primary argillaceous matrix, and have a continuous framework of sand grains during deposition. *"Wackes"* are generally massive, contain >15% argillaceous matrix, and tend to have a discontinuous framework of sand grains at the time of deposition. Alteration of these assemblages may produce similar end products.

The following parameters are considered to be important criteria in the classification of Witwatersrand Supergroup "quartzites" and are easily identified in the field in both fresh and weathered rocks. The parameters are divided into three groups reflecting: (1) mineralogy, (2) mode of deposition, and (3) additional diagnostic features.

Mineralogy of Detrital Components

Four detrital components are useful in the classification of sandstones. These components have been affected to various degrees by post depositional processes within the Witwatersrand Basin and are discussed below.

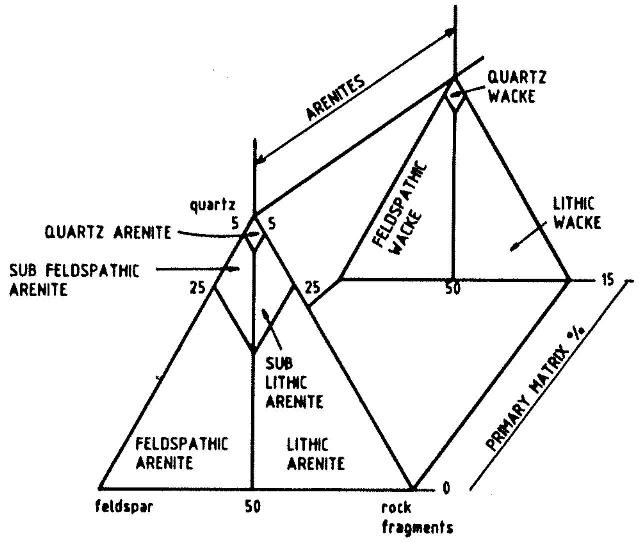


Figure 3: Proposed classification scheme for relatively unaltered sedimentary rocks (modified after Pettijohn et al., 1872)

Quartz content: The original margins of detrital quartz grains are rarely preserved in relatively argillaceous "quartzites". This is due to the reaction of quartz grains with mica in the enclosing matrix. However, the abundance of granular quartz is still considered to be the best indicator of the original quartz content and hence mineralogical maturity (Folk, 1974) of the sediment at the time of deposition. Chert is also included with this component because it represents a relatively stable detrital phase analogous to quartz (e.g. Pettijohn *et al.*, 1972; Dapples *et al.*, 1953; Okada, 1971; Folk, 1974; Dott, 1964). Furthermore, the relevance of chert as a rock fragment to source identification is somewhat obscured because of the pervasive alteration of other, less stable, source indicators. The relative importance of various source components is thus obliterated.

Lithic fragments: Unstable rock fragments have been included in many classification schemes (e.g. Pettijohn, 1949; Dapples *et al.*, 1953; Folk, 1974; McBride, 1963). However, after alteration, rock fragments within "quartzites" and conglomerates of the Witwatersrand Supergroup are commonly indistinguishable from the enclosing matrix on the basis of mineralogy and, in some cases, even texture. For example, the yellow speckling frequently encountered in Witwatersrand "quartzites" may represent either altered rock fragments (e.g. shale and volcanic clasts) or altered pre-existing mineral grains (e.g. feldspar altered to quartz and mica). Also, many "quartzites" within the Central Rand Group consist of quartz grains in a fine-grained phyllosilicate matrix and represent the alteration of an originally granular sediment (Fuller, 1958, Law *et al.*, 1988a, b).

Feldspar: Feldspar has not been documented in the Central Rand Group of the Welkom Goldfield (Law *et al.*, 1988a, b) or Central Rand area (Fuller, 1958). The absence of feldspar probably reflects post-depositional alteration processes rather than the absence of feldspar in the original detrital assemblage (Fuller, 1958; Law *et al.*, 1988a; 1988b). Feldspar has, however, commonly been described from the West Rand Group where it may represent up to 30 modal % (Meyer and Tainton, 1986; Fuller, 1958).

Matrix: The matrix component of sedimentary classification schemes refers to fine-grained argillaceous material interstitial to framework grains. Pervasive alteration of Witwatersrand "quartzites" makes the distinction between primary and secondary phyllosilicates difficult. For this reason additional criteria are required to constrain the sediment composition at the time of deposition. Matrix includes fine-grained intergrowths of micas and quartz in addition to other phases which cannot be identified as having granular precursors, such as pyrophyllite and chlorite porphyroblasts.

Significant amounts of original clay matrix (>15%) commonly occur in sediments deposited by debris flow processes in which stratification/cross-stratification is absent or crudely developed. Matrix content is therefore useful for the separation of sediments deposited by traction currents ("arenites") as opposed to debris flow processes ("wackes") on the basis of their primary frameworks. The distinction between "wackes" and "arenites" on the basis of their argillaceous matrix content in unaltered sediments has been arbitrarily chosen as 15% by Pettijohn (1949), McBride (1963), Dott (1964), and Pettijohn *et al.* (1972) and is considered by Selley (1982) to be the critical value above which grains become supported by the enclosing matrix.

Each of the four components discussed above may be individually described by subsidiary ternary diagrams reflecting their constituent parts (e.g. Folk, 1974; Okada, 1971). End-member components of subsidiary diagrams for the Witwatersrand Supergroup may be selected to best describe a particular suite of rocks. For example:
(1) quartz grains; monocrystalline - polycrystalline - chert;
(2) lithic fragments; shale - igneous - other rock fragments;
(3) feldspar: Na - K - Ca - feldspar; and
(4) matrix: muscovite - pyrophyllite - chlorite.

Any mineral assemblage may be chosen to reflect a variety of parameters (e.g. source, maturity, chemistry, bulk mineralogy, or diagnostic metamorphic assemblage of the rock) as required. For example, in a pervasively altered and metamorphosed suite of rocks comprising detrital quartz grains in a phyllosilicate matrix, the matrix mineralogy may be represented on AFM or A'FK compositional diagrams showing the types, rather than the abundances, of the mineral species present. The types and abundances of secondary minerals thus reflect post-depositional processes while primary detrital components reflect pre- and syn-depositional processes.

Depositional Criteria

Where the original labile components of the "quartzites" have been partially or pervasively altered the classification scheme of Pettijohn *et al.* (1972; Figure 3) *is no longer applicable*. However, a number of criteria (Table 1) are useful in order to "see through" the metamorphic overprint and interpret the original nature of the sediments and distinguish between primary "wackes", secondary "wackes", and "arenites". These include:

Stratification/cross-stratification: Packham (1954) introduced the

Table 1: Characteristics for the separation of primary "wackes" and "arenites"

WACKE	ARENITE
1) $>15\%$ matrix required but not diagnostic	1) $<15\%$ original matrix required
2) massive (no evidence of stratification	2) stratified (deposition by traction currents)
3) sorting of quartz grains and clasts extremely poor	3) sorting (moderate to well sorted)

use of sedimentary structures as a criterion to differentiate his "graywacke" and "arkose - quartzose sandstone" suites (equivalent to "wacke" and "arenite" suites of this study). This genetic classification, using sedimentary structures as indicators of depositional processes and currents, has been supported by numerous authors (Crook, 1960; Martin *et al.*, 1989). In some instances, unstable granular fragments are not preserved, but the arenitic nature of the original sediment is reflected in bedding, including cross-stratification with foresets commonly defined by concentrations of chlorite, pyrite, chromite and zircon. Stratified/cross stratified sandstones are deposited as granular sediments with little interstitial clay (e.g. arkoses and lithic arenites) rather than as poorly sorted clay-sand mixtures (e.g. lithic wackes) because clay and other fine-grained material would have been removed by the winnowing effects of the transporting currents (Eslinger and Pevear, 1988, p.6-4; Pettijohn *et al.*, 1972, p.207; Packham, 1954). Simultaneous deposition of clay and sand by debris-flow processes produces largely unstratified sediments. Stratified and/or cross-stratifie "wackes" described from the Witwatersrand Basin are, therefore, interpreted as representing the alteration products of re-existing arenitic sediments deposited by traction currents (i.e. arkoses or lithic arenites). In such cases any matrix component of the rock should be assessed in conjunction with the unstable (labile) granular fragments (feldspar or lithic fragments).

Sorting: Sorting of quartz grains (i.e. grains of a constant density) reflects the processes operating during transport and deposition of a sediment (Selley, 1982). Sediments deposited by traction currents are generally well sorted reflecting the winnowing effects of the transporting currents. In contrast, sediments deposited by chaotic processes (e.g. debris flows) are relatively poorly sorted. In altered sediments with significant corrosion of detrital quartz grains by reaction with matrix phyllosilicates, numerical estimates of sorting may be invalid. However, sorting is still a valid criteria which may be estimated with the use of comparative charts (Figure 5). Moderate sorting has been chosen as a convenient boundary to distinguish between primary "wackes" and "arenites" as all of the cross-stratified "quartzites" interpreted as primary "arenites" display equivalent or better than moderate sorting.

Amount of matrix: In altered sediments with a significant amount of secondary matrix the distinction between "arenites" and "wackes" on the basis of matrix content is no longer diagnostic in terms of genetic interpretation. However, any Witwatersrand "quartzite" with $<15\%$ matrix can still validly be classified as an "arenite" whereas the matrix content of sediments with $>15\%$ matrix is not diagnostic and represents the combined percentage of original labile components and clay matrix. Stratification and sorting preserved within the rock may then be used to distinguish between "arenites" and "wackes" on the basis of depositional style. The application of these aspects is well clay matrix. Stratification and sorting preserved within the rock may then be used to distinguish between "arenites" and "wackes" on the basis of depositional style. The application of these aspects is well demonstrated by the transition from "wacke" to "arenite" preserved in the Middling quartzite (Harmony Formation, Welkom Goldfield) where massive, poorly sorted, unstratified wackes, interpreted as debris flow deposits (Bailey, in prep.), have been reworked to form well-sorted, cross-stratified arenites. Detailed textural studies on the behaviour of clay minerals during diagenesis have shown that many of these minerals may be introduced or removed in solution after burial (e.g. Dott, 1964; Eslinger and Pevear, 1988). Diagnostic textural evidence is destroyed by metamorphic recrystallisation of the diagenetic mineral phases. The effects of this process are, however, generally considered to be quantitatively insignificant in terms of rock classification. Authigenic (diagenetic or metamorphic) feldspar is also included within this component.

Additional Diagnostic/Qualifying Criteria

A number of prefixes or qualifying observations (listed below) may also be included in addition to any other features that make the rock distinctive;

Meta-: reflecting the secondary diagenetic/metamorphic origin of the mineral assemblage (e.g. metalithic arenite; metalithic wacke);

Colour: colour is a rough indicator of the phyllosilicate mineral assemblage in unweathered rocks with dark-green colours reflecting chlorite-rich samples and lighter colours reflecting white micas. Light-brown colours generally reflect an abundance of pyrophyllite which gives the rock a characteristic waxy appearance and texture. Colour variations also result from changes in grain size and in the total amount, rather than the relative abundances, of the phyllosilicate minerals present. The mineralogical implications of colour variations are not universally similar, but the relationship between colour and mineralogy can readily be determined for a particular study area.

Grain size: grain size is an indicator of the energy of the depositional system and is important in interpretations of hydrodynamic regimes, based on sedimentary structures. It is important to note that reaction between the matrix phyllosilicates and detrital quartz grains commonly reduces the primary grain size and even alters the size distribution of detrital quartz, particularly in more argillaceous lithologies. The calibration and validity of grain size estimations is thus best determined by thin section analysis of representative samples.

DISCUSSION

The classification scheme discussed below aims to "look through" the metamorphic/diagenetic overprint to extract genetic information about the protolith that is applicable to sedimentary analyses of the Witwatersrand Basin.

Witwatersrand "quartzites" contain both primary and secondary phases in the argillaceous matrix which partly reflect the alteration of original framework grains. The distinction between "arenites" and "wackes" is, therefore, based on texture and the abundance and distribution of argillaceous material. Massive sediments with a discontinuous framework and homogeneous distribution of argillaceous matrix material in excess of 15% favour "wacke" precursors. Cross-stratified sediments with an irregular distribution of argillaceous matrix (reflecting alteration of unstable granular fragments) and a continuous framework favour "arenite" precursors. The modal percentage of argillaceous matrix is not a diagnostic parameter, but is included as an indication of the combined original clay and altered labile constituents in relatively unaltered equivalents.

The nomenclature adopted in this classification scheme (Figure 3) is modified after that of Pettijohn *et al.* (1972) and is based ultimately on the classification scheme of Dott (1964) but differs, in terms of the above discussion, to allow for the post-depositional modification of the original detrital assemblage referred to above. The following modifications to the terminology of Pettijohn *et al.* (1972) have been introduced:

(1) the term "arkosic" is replaced by "feldspathic" to avoid the strictly quantitative estimate of feldspar content required for arkose classification. In addition, it allows for the term "arenite" to be retained for all cross-stratified and/or well-sorted sandstones;

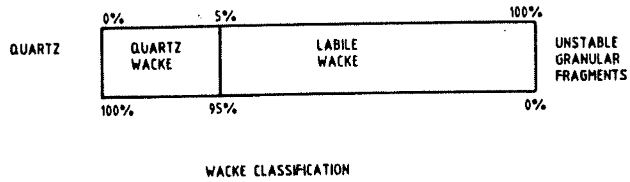
(2) the term "greywacke" is replaced by "wacke" to avoid the genetic connotations associated with this term and to retain the term "wacke" as a general class of argillaceous, poorly sorted and generally massive sandstones; and

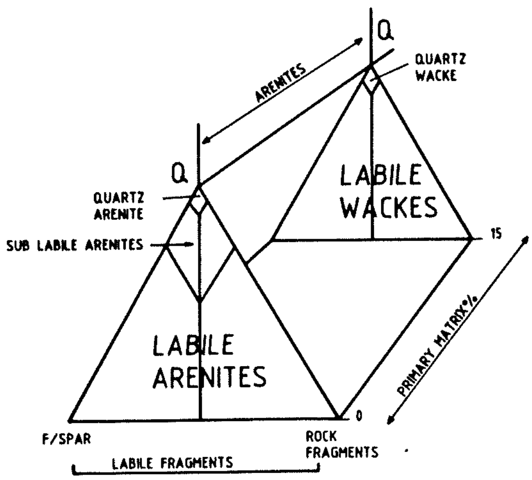
(3) the term "labile" is introduced to include all unstable fragments that are no longer distinguishable as either feldspathic or lithic fragments.

This classification scheme thus has relevance to both the genetic deposition of the sediment and the post- depositional processes that have affected its present form. Increasing degrees of alteration of the original assemblage result in the progressive destruction of unstable mineral and rock fragments producing secondary "wackes" or mixtures of quartz and matrix by post-depositional processes irrespective of the appearance of the original sediment.

Ternary systems for the classification of "arenites" and "wackes" are applicable where all the required primary components are still readily identified (e.g. Figure 3). However, where one or more of the labile components (feldspar and/or lithic fragments) are no longer preserved, or cannot be readily distinguished from primary matrix material, the classification of "arenites" and "wackes" may be simplified to a binary system (Figure 4). Thus feldspar, lithic fragments and other unstable granular fragments are combined as a single component (labile fragments). However, where feldspar or lithic grains can be identified as the dominant labile phase, the scheme of Pettijohn *et al.* (1972) may be directly applied (Figure 3).

A flow chart (Figure 5) is useful for the practical application of this classification scheme and rock names may be readily abbreviated. The quartz content (reflecting mineralogical maturity) of Witwatersrand "quartzites" is considered to be relatively unaffected by post-depositional processes, and as such forms the starting criteria in this classification





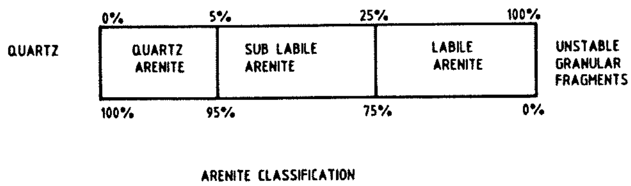


Figure 4: Simplified ternary system for the classification of altered Witwatersrand Supergroup "quartzites" (fields as for Figure 3). The "wacke" and "arenite" fields may be simplified to the binary systems shown. In cases where feldspar or lithic fragments can be identified as the dominant labile phase, the scheme outlined in Figure 3 may be directly applied.

scheme. Sediments with in excess of 95% quartz are classified as quartz arenites (synonymous with orthoquartzites of Selley, 1982) irrespective of the initial composition of the matrix material. The compositional fields of "arenites" and "wackes" are distinguished on the basis of stratification and sorting with the presence of stratification and moderately to well-sorted sediments favouring "arenites". In addition to these criteria, the field of "wackes" requires at least 15% matrix material. Within the "wacke" and "arenite" fields further subdivisions are defined on the basis of quartz content.

Within the "arenite" field, sub-labile arenites (synonymous with protoquartzites of Selley, 1982) contain in excess of 75% quartz, while

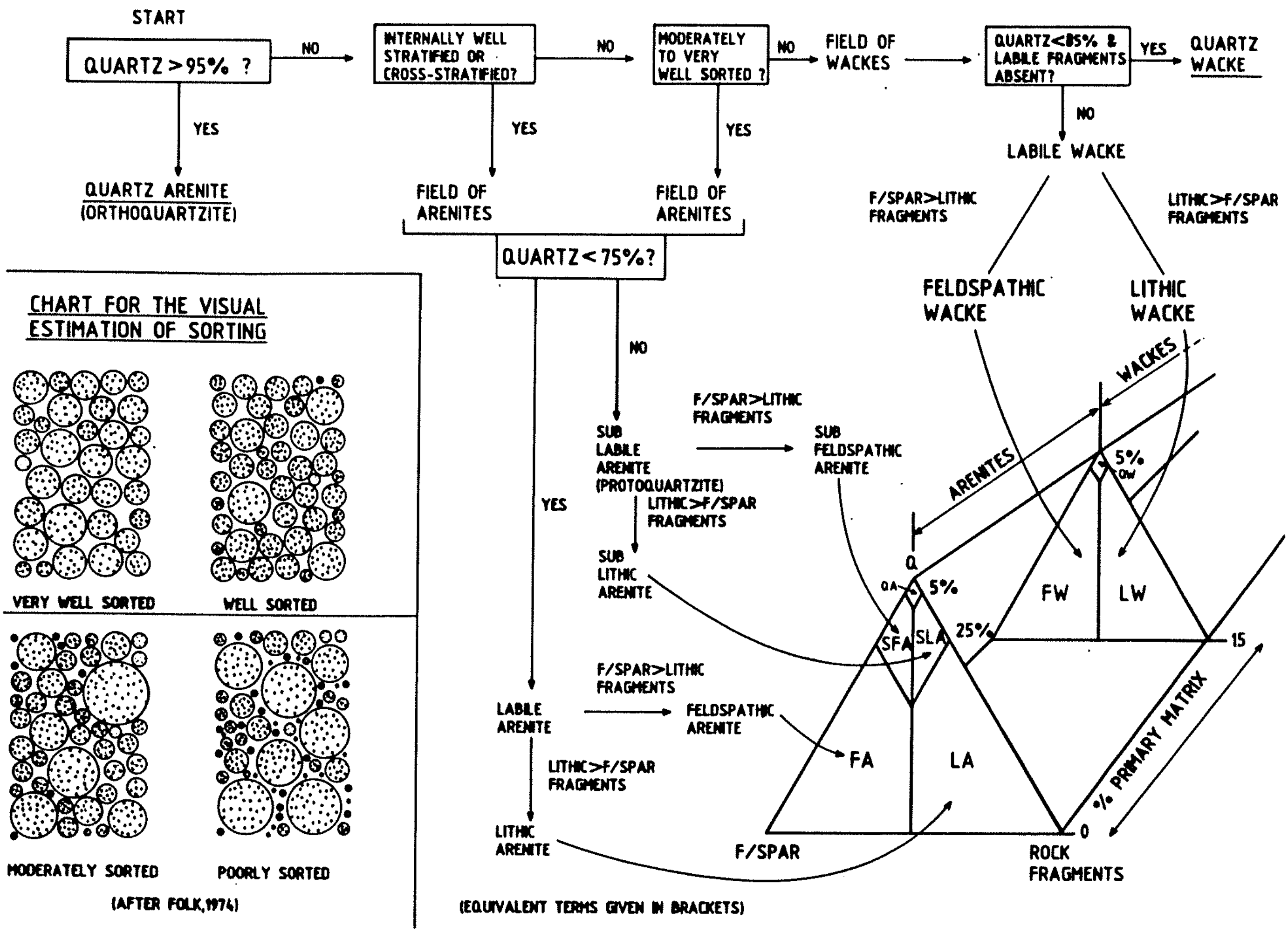


Figure 5: Flow chart for the classification of Witwatersrand Supergroup "quartzites". Representations (after Folk, 1974) of sorting values are included for visual estimations. Rock names are abbreviated equivalents of those in Figure 3.

labile arenites contain less than 75% quartz. "Labile" fields are further subdivided into "feldspathic" or "lithic" arenites on the basis of the dominant labile component. An excess of feldspathic over lithic fragments thus defines the field of "feldspathic" arenites while an excess of lithic over feldspathic fragments is indicative of the field of "lithic" arenites. This distinction may only be made for those samples where the original nature of the labile components can still be readily distinguished.

Within the "wacke" field, quartz wackes contain less than 85% quartz and less than 5% feldspathic and/or lithic fragments. The field of labile wackes is subdivided into "feldspathic" and "lithic" fields according to the dominant labile component.

The reasoning process applied in this classification scheme is best illustrated in a number of representative examples:

(1) Quartz Arenite: The Zandfontein Quartzite Formation (Evander Goldfield) is internally cross-stratified (Figure 6a), well sorted and highly siliceous (Figure 6b) and is classified as a quartz arenite. This classification is confirmed in thin section (Figure 6c) which shows well-sorted quartz grains (constituting in excess of 95% of the sample) in a matrix of phyllosilicate minerals. Note the abundance of quartz-quartz grain intersections, triple junctions and quartz overgrowths;

(2) Quartz Wacke: The Middling quartzite (Harmony Formation, Welkom Goldfield) generally lacks internal stratification (Figure 7a), is very poorly sorted and contains in excess of 15% matrix material (Figure 7b). Feldspathic and lithic fragments are absent and this sample is classified as a quartz wacke. This interpretation is supported by thin section analysis which shows very poorly sorted quartz grains "floating" in, and reacting with, the phyllosilicate matrix (Figure 7c); and

(3) Lithic Arenite: The "quartzites" of the Aandenk Formation (Welkom Goldfield) are cross-stratified (Figure 8a) and contain well- to very well-sorted quartz grains and up to 50% lithic fragments (Figure 8b). This sample is thus classified as a lithic arenite. Thin section analysis shows well-sorted quartz grains "floating" in, and reacting with, the phyllosilicate matrix. Altered lithic arenites may thus be indistinguishable from quartz wackes in terms of matrix abundance, mineralogy, and even texture in thin section. In some samples, the lithic nature of some of the phyllitic fragments may still be identified.

Detailed studies at selected localities in active mines indicate the presence of many different types of "quartzites" in the Central Rand Group including quartz arenites, quartz wackes, and lithic arenites. One important association common to the major economic reef in each of the major goldfields appears to be one of a thin (less than 1m thick) quartz arenite immediately above the reef. Examples include the Main Reef Leader/South Reef of the Central and East Rand, the Carbon Leader at Carletonville, the Vaal Reef at Klerksdorp, and the Basal Reef at Welkom. The type of quartzite in the footwall to the major reefs is highly variable, although quartz arenites are poorly represented below rich reef, reflecting the relatively low abundance of quartz arenites within the Central Rand Group stratigraphy.

SUMMARY AND CONCLUSIONS

Ideally, arenitic sediments are classified in terms of the relative proportions of their detrital components (Figure 3). It is suggested here that in altered lithologies, primary "arenites" be distinguished from "wackes" in terms of cross-stratification, sorting, and amount of matrix material (Table 1). All of these parameters are readily observed and/or estimated in hand-specimen and are easily confirmed by thin section analysis. In this way a reconstructive approach may be used to estimate original compositions for the classification of "quartzites" (Figures. 4 and 5).

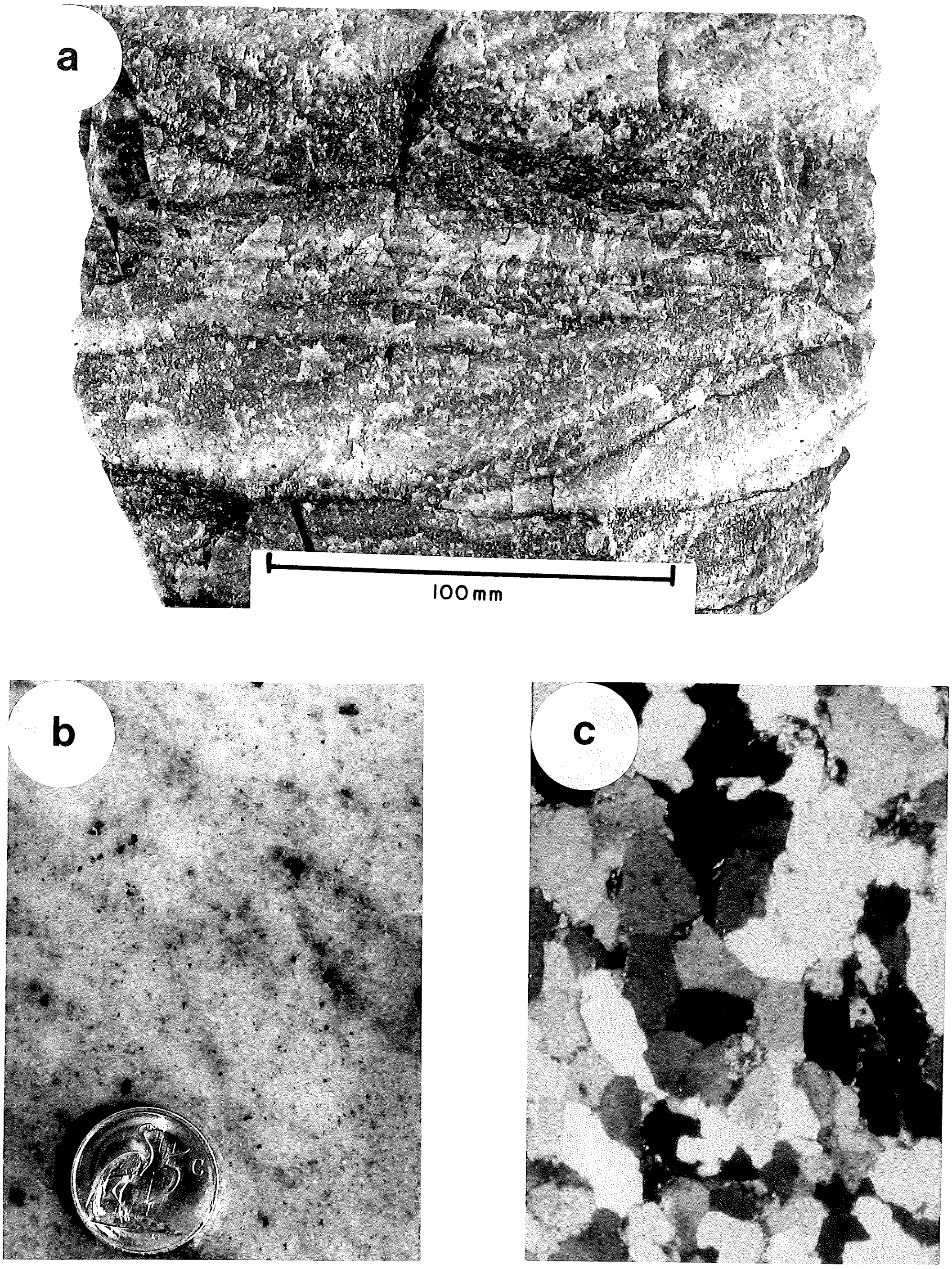


Figure 6: The Zandfontein Quartzite Formation (Evander Goldfield) showing a) small-scale trough cross-stratification, b) well-sorted, siliceous quartzite, and c) photomicrograph of well-sorted quartz grains constituting in excess of 95 modal percent. Horizontal field of view is 2.5mm.

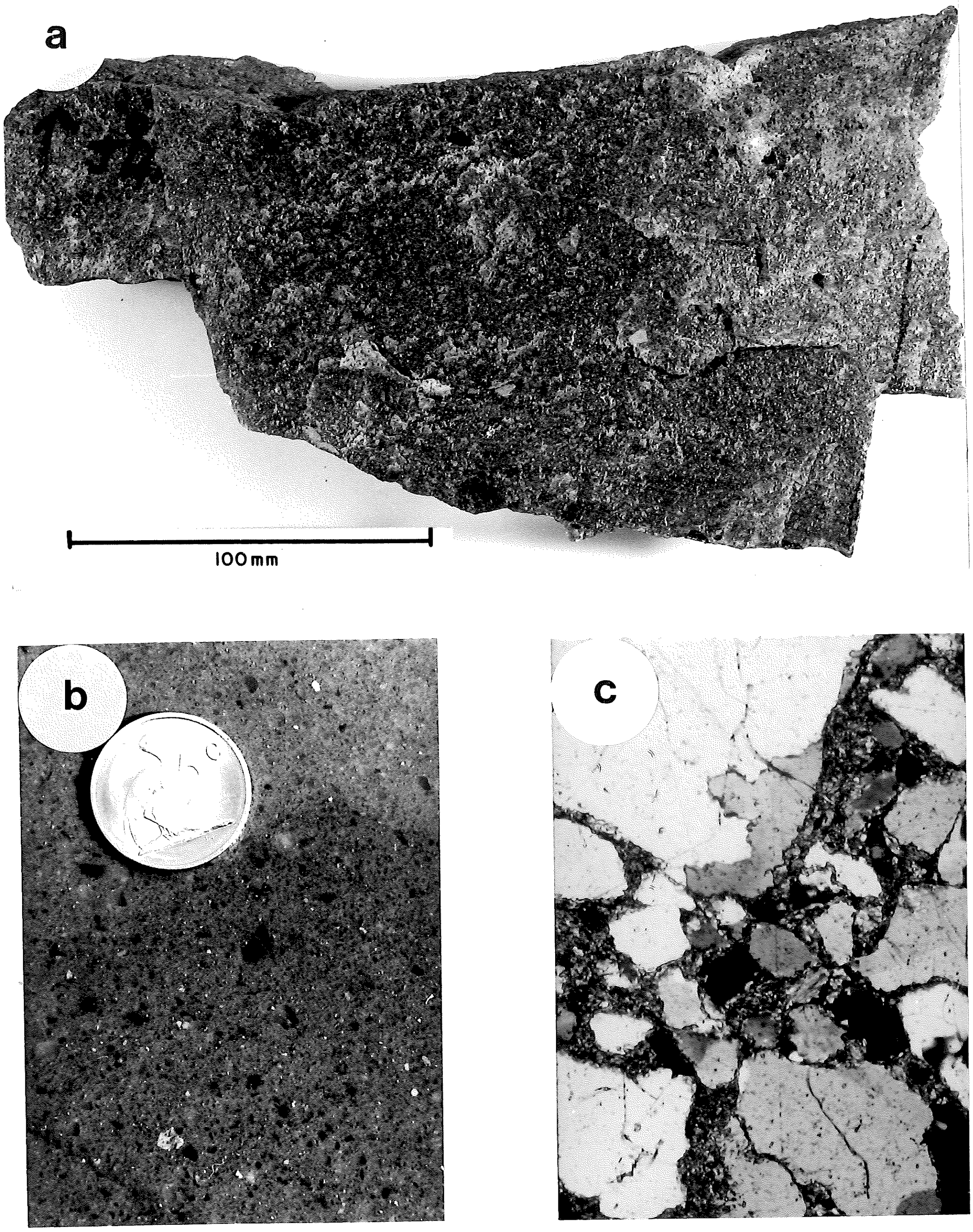


Figure 7: The Middling quartzite (Harmony Formation, Welkom Goldfield) showing a) absence of internal stratification, b) poor sorting and abundance of matrix material, and c) photomicrograph of very poorly-sorted quartz grains "floating" in, and reacting with, the phyllosilicate matrix (> 15 modal percent). Horizontal field of view is 2.5mm.

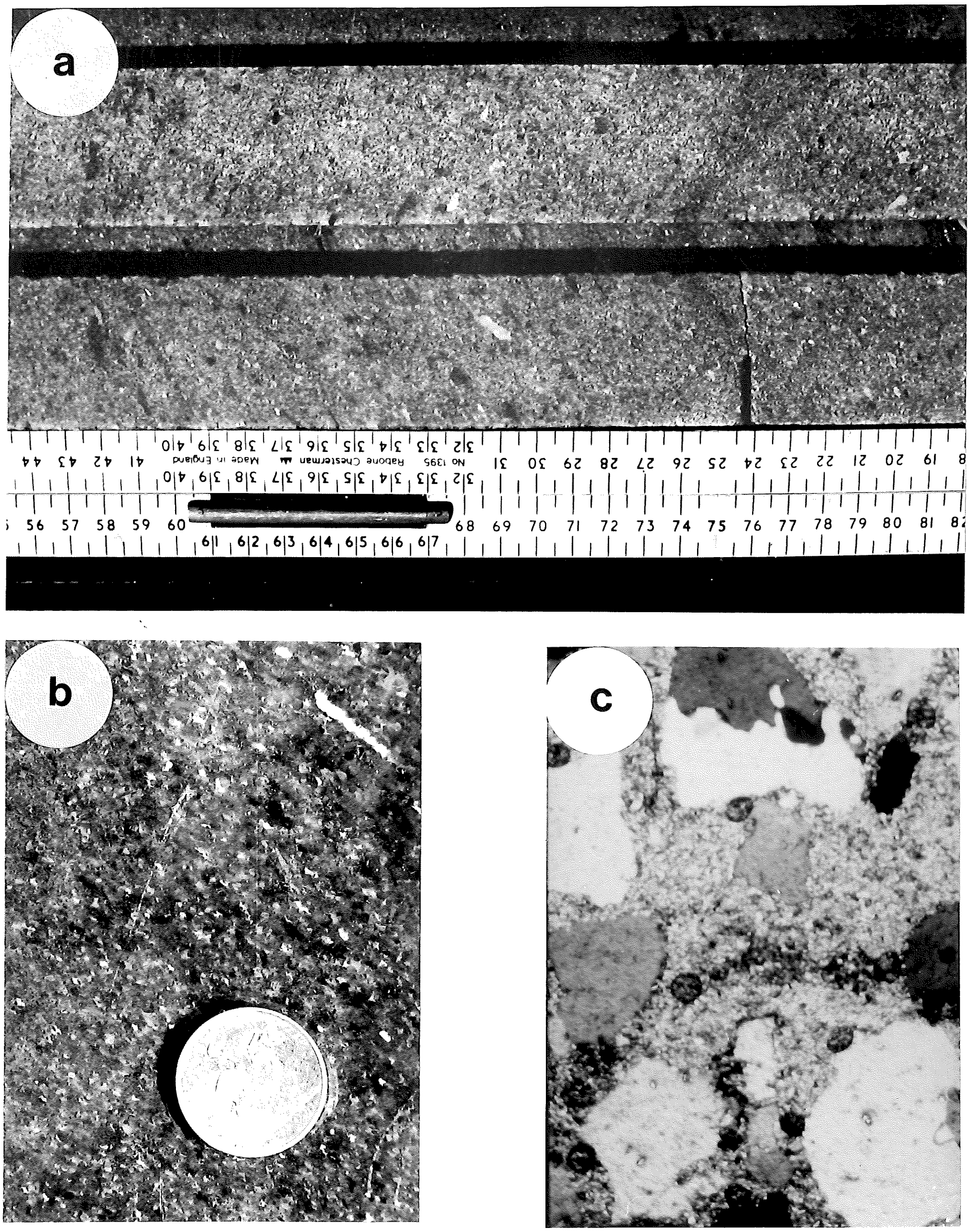


Figure 8: The Aandenk Formation (Welkom Goldfield) showing: a) cross-stratification, b) well-sorted quartz grains and lithic (yellow shale) fragments, and c) photomicrograph of well-sorted quartz grains and partially altered lithic fragments. Note the reaction between phyllosilicate minerals and detrital quartz grains. Horizontal field of view is 2.5mm.

With increased metamorphism and/or fluid alteration of a sandstone, the original detrital assemblage becomes more obscured. Eventually, a rock composed of quartz grains in a fine-grained phyllosilicate matrix may be produced from an originally granular sediment. In this way, some information pertaining to the source and transporting and depositional environments of the sediments is lost. However, by applying a reconstructive approach to "quartzite" classification, much information related to the depositional environment may be retained. Data pertaining to the sedimentary environment and the post-depositional history may thus be systematically recorded.

The classification scheme proposed differs from sandstone classification schemes in use by other authors in that it is modified to allow for the post-depositional alteration of the original detrital assemblage. This system is also applicable to other sedimentary sequences with secondary mineral assemblages.

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