

## CLASSIFICATION OF ARENITES

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**ABSTRACT.** A critical examination of the classificatory schemes of Pettijohn (1954), Gilbert (1955), Packham (1954), and Folk (1954) leads to the conclusion that only Packham's, which uses sedimentary structures as a parameter, is validly based genetically. Packham's scheme is expanded by the introduction of a generalized, non-genetic, 'arenite' diagram which is congruent with the genetic graywacke and arkose-quartzose sandstone (here termed simply 'sandstone') diagrams and which enables it to deal with arenites when data on sedimentary structures are not available.

A new QFR diagram is introduced having quartz, feldspar, and rock fragments plus other labiles as parameters. The non-genetic classes of labile arenites recognized are feldspathic, lithofeldspathic, feldspatholithic, and lithic. Congruent graywacke and sandstone QFR diagrams may be employed where appropriate. Two classes of sublabile arenite are recognized—feldspathic sublabile arenite and lithic sublabile arenite. The term 'arenite' may again be replaced by 'sandstone' or 'graywacke' where appropriate. The use of 'feldspathic sandstone/arenite/wacke' as descriptive of sublabile arenites should be discontinued.

### INTRODUCTION

Since the publication of Krynine's classic paper on sedimentary rock classification (Krynine, 1948), in which ternary diagrams were first utilized for classifying arenites, a number of classificatory schemes for detrital arenites have appeared. Those of Pettijohn (1949), replaced by his scheme of 1954, Gilbert (1955), Packham (1954), and Folk (1954) have found the widest acceptance, and have largely superseded Krynine's scheme. Certain shortcomings exist in each of the newer classifications, but, as will be shown, only those in Packham's can be remedied without destroying the classification.

Concerning the aim of classifications, Pettijohn (1948) writes:

No classification independent of rock genesis can be worthy of consideration. Genesis is the ultimate aim of any study of rocks, and no descriptive classification—so-called—can be worth much unless the characters used for the classification are meaningful and significant. The only test for significance is whether they are or are not basic to the understanding of origin.

It would seem proper, therefore, to judge the current classifications on the extent to which they are truly genetic.

A useful way of assessing the genetic basis of a given classification is to classify a group of arenites deposited under similar conditions, and compare the names given with concepts of genesis derived from other sources. For example, graywacke and orthoquartzite are commonly held to be characteristic of different tectonic and environmental settings. The occurrence of these two rock-types in one formation would suggest most unusual conditions or a certain arbitrariness in the classificatory scheme used. If, after several analyses, a continuous gradation were found between graywacke and orthoquartzite, the latter alternative could be asserted with confidence.

### TERMINOLOGY

*Arenite.*—Arenite is used in the literature in two senses. The most commonly accepted is that of Pettijohn (1957, p. 16); a descriptive term for clastic

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material of sand size without genetic or mineralogical connotations. All clastic rocks composed of sand-sized fragments are arenites in this definition.

Gilbert (1955, p. 289) proposed limiting the term "arenite" to a group of sand-sized sediments which contain less than 10 percent detrital argillaceous material. Gilbert considers "arenites" to be genetically distinct from 'wackes' which contain more than 10 percent detrital argillaceous material.

In the proposed expansion of Packham's classification which follows, the term 'arenite' is used in the broader, non-genetic, sense of Pettijohn. This usage is followed throughout the paper, except when discussing Gilbert's "arenites". In such cases the change in sense is apparent from the context.

*MLQ and QFR diagrams.*—Two types of triangular diagrams have been widely employed in the classification of arenites. Pettijohn (1949) and Packham (1954) have used MLQ diagrams which have as parameters percentages (on a cement-free basis) of matrix (M), labiles (feldspar, rock fragments, ferromagnesian, chlorite) (L), and quartz plus chert (Q).

Gilbert (1955) on the other hand, utilized QFR diagrams, whose parameters are percentages (on a matrix- and cement-free basis) of quartz plus chert (Q), feldspar (F), and rock fragments plus other labiles (R).

Detrital carbonate is excluded from both types of diagram. Arenites containing abundant detrital carbonate require other treatment.

#### DISCUSSION OF CLASSIFICATIONS

*Pettijohn's 1954 classification.*—Pettijohn (1954) recognized three factors to be of greatest genetic significance: a maturity factor (ratio of quartz plus chert to labiles on a matrix-free basis); a provenance factor (ratio of feldspar to rock fragments), which he considers to be a measure of the plutonic and supracrustal rocks exposed in the source area; and a fluidity factor (ratio of sand detritus to matrix), which gives an indication of the viscosity of the depositing medium. His classification, which is shown in the form of an MLQ

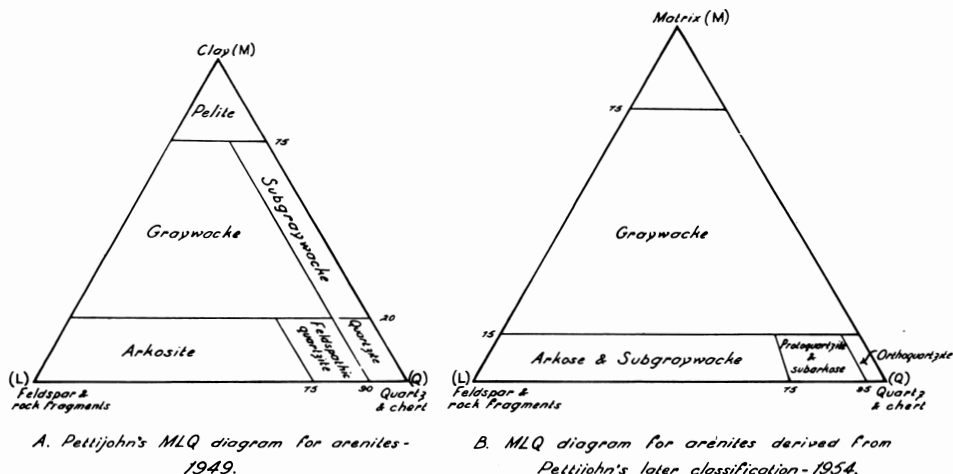


Fig. 1. Comparison between Pettijohn's 1949 and 1954 classifications.

diagram in figure 1B, is based on these factors. A noteworthy feature is the location of the graywacke field boundary at a 15 percent level of matrix.

*Criticisms.*—First, as originally defined, Pettijohn's provenance factor measures the nature of the source area only in the special case where all feldspar is plutonic and all rock fragments are supracrustal. If this factor is applied to the Miocene graywackes of the Aure Trough, Papua, described by Edwards (1950), for example, it leads to completely erroneous conclusions, for these rocks are dominantly of andesitic derivation. This difficulty seems to have been realized subsequently by Pettijohn (1957, p. 290), as his phraseology is somewhat modified.

Second, the choice of the boundary of the graywacke field, while not without reason, is arbitrary. The arenites of the Burrell Formation, Triassic, of New South Wales (Crook, 1957, p. 69), for example, belong to a formation that was deposited under broadly similar conditions, but they lie over the graywacke, protoquartzite and orthoquartzite fields of Pettijohn's diagram.

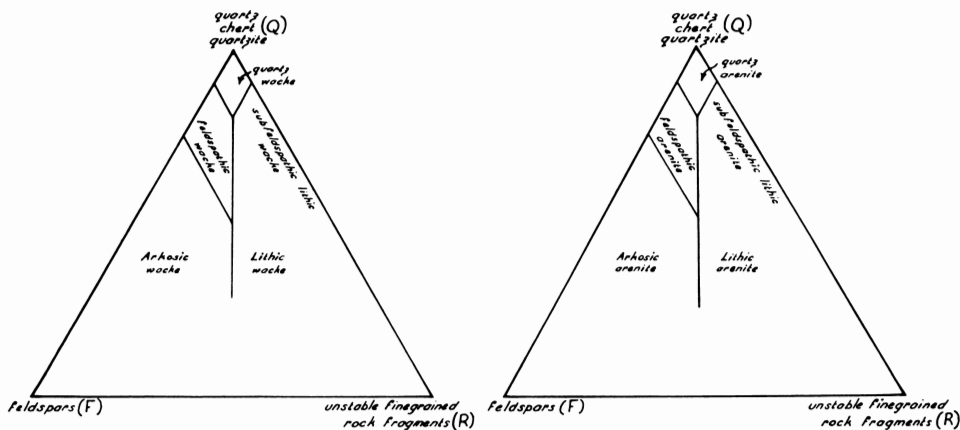
Packham (1954, fig. 1) has plotted the frequency of matrix percentages for arenites deposited from traction and turbidity currents. An overlap is shown between 8 and 32 percent of matrix, so that Pettijohn's decision to characterize graywackes by a minimum level of 15 percent matrix must be recognized as a good first approximation, but nonetheless arbitrary. Its use destroys the truly genetic nature of the classification, since the occurrence of cases such as the Triassic example cited is inevitable. This point has been well made by Folk (1954, p. 353), in discussing the confusion between texture and composition in certain classifications: ". . . one's terminology would fluctuate back and forth . . . merely at the whim of the depositional agent."

A final criticism lies in the changed definition of 'subgraywacke' from the 1949 to the 1954 classifications (see figs. 1A and 1B). This change, while bringing the term more into line with Continental usage, has added to the confusion in nomenclature.

*Gilbert's classification.*—Gilbert's classification is basically similar to Pettijohn's 1954 classification; it employs the same three factors, by implication, but uses two diagrams of the QFR type. The first (fig. 2A) is the 'wacke diagram' for arenites with more than 10 percent detrital matrix. Thus it is the equivalent of those parts of Pettijohn's 1954 MLQ diagram (see fig. 1B) which lie above the 10 percent level of matrix. The second QFR diagram (fig. 2B) is the 'arenite diagram', for arenites with less than 10 percent detrital matrix. It is the equivalent of the remainder of figure 1B.

*Criticisms.*—Gilbert's classification can be criticized in one aspect on the same grounds as Pettijohn's 1954 classification. The choice between the two diagrams depends on the arbitrary level of 10 percent matrix. Like the 15 percent level of Pettijohn it fails, and for the same reasons.

A further criticism lies in Gilbert's usage of the term 'arenite'. It is most unfortunate that this term, previously without mineralogical or genetic connotations, should have been so restricted, as it destroys the only existing satisfactory term for the general description of sand-sized sediments. Pettijohn (1957, p. 17) has already commented on the inadequacy of the term 'sandstone' for such general descriptions.



A. Wacke QFR-diagram  
 > 10% argillaceous matrix

B. Arenite QFR-diagram  
 < 10% argillaceous matrix

Fig. 2. QFR diagrams of Gilbert's classification (1954).

*Packham's classification.*—Packham (1954) utilizes, by implication, two of Pettijohn's factors: the fluidity factor and maturity factor. A new parameter is introduced, however, sedimentary structures (Packham, 1954, table 1). On the basis of sedimentary structures arenites are assigned to one of two groups, the 'graywacke suite' and the 'arkose-quartzose sandstone suite'. Each group has its own MLQ diagram on which arenites may be plotted in the normal manner. The name so derived will be at once both descriptive and genetic.

Whether Packham's classification is truly genetic depends on the value of sedimentary structures as indicators of the type of depositing current. Data obtained by numerous workers during the last ten years strongly suggest that

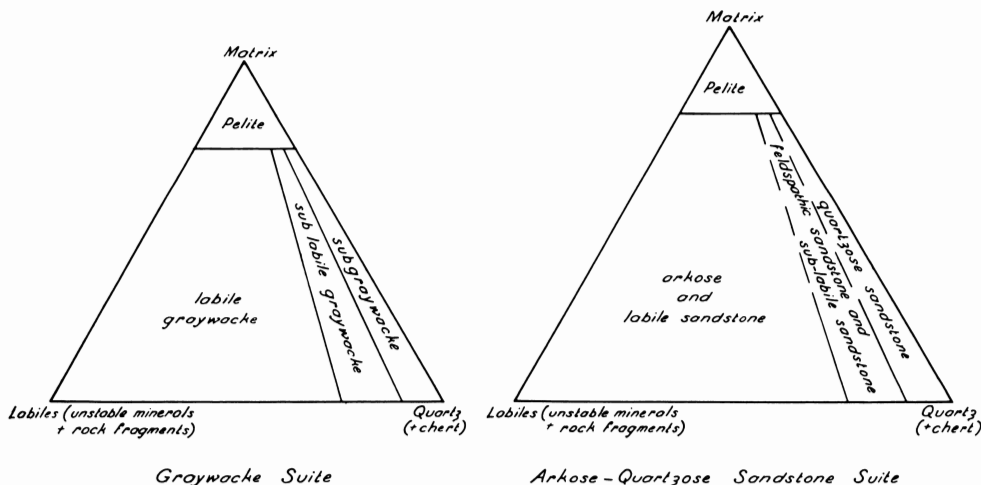


Fig. 3. MLQ diagrams for arenites on Packham's classification (1954).

sedimentary structures can be validly used in the manner Packham has suggested.

By using two MLQ diagrams, Packham has avoided the arbitrariness found in Pettijohn's and Gilbert's classifications, and it is impossible for specimens from a single genetically homogeneous formation to have names implying different geneses because of slight variations in the detrital matrix content.

*Criticisms.*—Packham's classification, in its present form, is usable only when data on sedimentary structures are available. No provision has been made for field and laboratory nomenclature which does not imply genesis.

The term 'sandstone' is used by Packham in two senses, broadly, as a synonym of 'arenite' as used herein, and in a restricted sense, always with a qualifying adjective, to refer to arenites deposited by traction currents, for example, 'labile sandstone', 'quartzose sandstone'. This homonymy causes difficulties if one is dealing with arenites without knowledge of their associated sedimentary structures. They cannot be descriptively named on Packham's scheme without prejudging the issue. An arenite rich in quartz, but of unknown associations, cannot be called a 'quartzose sandstone' without implying the association of certain sedimentary structures, which are however unknown.

The classification is inadequate when attempting to name arenites which contain large percentages of labile material. For rocks derived from non-granitic sources only the terms 'labile graywacke' and 'labile sandstone' are available.

*Folk's Classification.*—Folk's classification does not utilize either QFR or MLQ diagrams, but uses a ternary diagram having quartz plus chert; feldspar plus all igneous rock fragments; and mica plus metamorphic rock fragments plus metaquartzite as parameters. The diagram is subdivided in the manner shown in figure 4. Unlike the classifications already discussed, Folk's scheme does not utilize matrix-content as a parameter, and the names given to arenites in his scheme are thus uninfluenced by the matrix-content of the rock. Al-

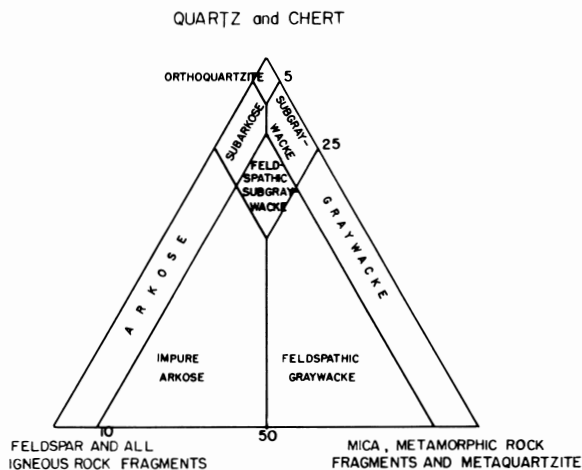


Fig. 4. Triangular diagram for Folk's classification (1954).

though matrix-content effects the plotting of arenites on MLQ diagrams in Packham's scheme (see fig. 3), the end result is the same, for variation in matrix-content does not result in changes in arenite nomenclature.

Folk's scheme does not attempt to convey information concerning mode of sedimentation, the parameters being chosen with the intent to classify arenites according to provenance. The three parameters given above are held to measure (a) detritus of sedimentary origin, or detritus which has undergone a prolonged period of chemical and/or physical modification; (b) detritus of igneous origin; and (c) detritus of metamorphic origin.

*Criticisms.*—The most important criticisms of Folk's classification find their source in his choice of parameters. The quartz plus chert parameter is not a completely satisfactory measure of detritus of sedimentary origin, because it may incorporate an unknown quantity of first cycle plutonic or volcanic quartz, and volcanic "chert", which may not have undergone prolonged chemical or physical weathering. Furthermore sedimentary rock fragments find no place in his parameters, and their insertion poses great difficulties.

The grouping of all igneous detritus into one parameter is unfortunate, for the mineralogical and tectonic significance of plutonic as against volcanic components in a sediment is considerable, and they should be separated in arriving at a rock name.

The lack of emphasis on mode of sedimentation is, in the author's opinion, a fundamental weakness of the scheme. It leaves no possibility of distinguishing an arenite deposited by a turbidity current in deep water from one deposited by fluvial agencies on land in those cases, which are not uncommon, where both have a large igneous component.

The extent of the difficulties raised by the choice of parameters and lack of emphasis on mode of sedimentation may be seen by comparing arenites derived from (a) an andesitic island arc; (b) a granite mass of low relief being covered by a transgressive sea; and (c) a complex orogenic belt with prominent exposures of volcanics. It is not unlikely that the arenites derived from each source will fall in the "arkose" field on Folk's diagram (fig. 4). Although this contingency can be met by the use of suitable qualifiers as Folk has suggested (1954, p. 357), it is rather unwieldy and confusing.

#### EXPANSION OF PACKHAM'S CLASSIFICATION

From the foregoing Packham's classification seems to be the only existing one soundly based, genetically speaking. It is proposed to use this classification as a basis for an expanded classification which will not be subject to the criticisms mentioned above.

To meet the difficulties encountered in dealing with arenites when data on sedimentary structures are not available, the author proposes a non-genetic 'arenite MLQ diagram'. This diagram (fig. 5) employs the same parameters as the graywacke and arkose-quartzose sandstone suite diagrams of Packham, and is subdivided in the same manner on the basis of the maturity factor, into 'labile arenite', 'sublabile arenite', and 'quartzose arenite'. The relationship between this new diagram and those of Packham is shown in figure 6. Arenites of unknown associations, provided they are not rich in detrital carbonate, can

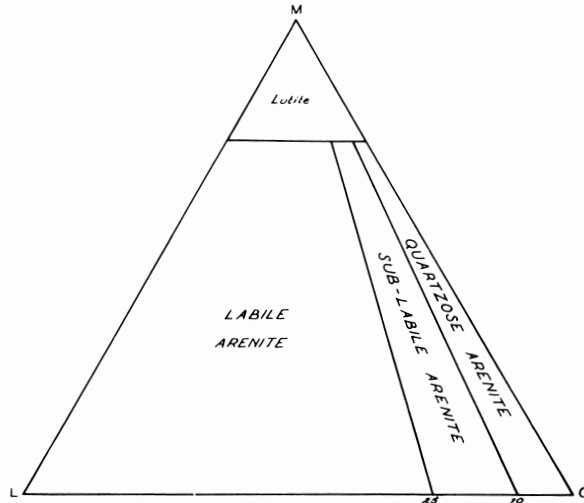


Fig. 5. Generalized MLQ diagram for arenites.

be named by reference to this diagram, and the names derived will be descriptive and non-genetic.

'Sandstone', will be restricted to sediments of inferred traction-current origin, and 'arenite' used as the generalized non-genetic term for sand-sized clastic material. This avoids the homonymy in Packham's usage and his 'arkose-quartzose sandstone suite' can then be termed simply the 'sandstone suite'.

Amplification of the terms descriptive of labile rock-types is desirable, particularly to enable distinction between labile arenites rich in feldspar and those rich in rock fragments. This can be effected by using a QFR diagram with suitable subdivisions. For simplicity only one, generalized, QFR diagram is proposed, which gives a series of names for arenites of various compositions: congruent 'graywacke' and 'sandstone' QFR diagrams may be used if data on sedimentary structures are available.

The QFR diagram proposed (fig. 7) is subdivided congruently with the arenite-MLQ diagram (fig. 6) into quartzose arenite and sublabile arenite at levels of 90 and 75 percent quartz, respectively. The sublabile arenite field is subdivided as discussed below.

The field containing rocks with less than 75 percent quartz is subdivided on the basis of ratio of feldspar to rock fragments + other labiles (the FR ratio), this ratio being calculated on a quartz-free basis. The subdivided fields are designated as follows, and have the following range of values for the FR ratio:

feldspathic arenite	FR— $\infty$ to 3	}	feldspathic
lithofeldspathic arenite	FR—3 to 1		labile arenites
feldspatholithic arenite	FR—1 to 1/3	}	lithic
lithic arenite	FR—1/3 to 0		labile arenites

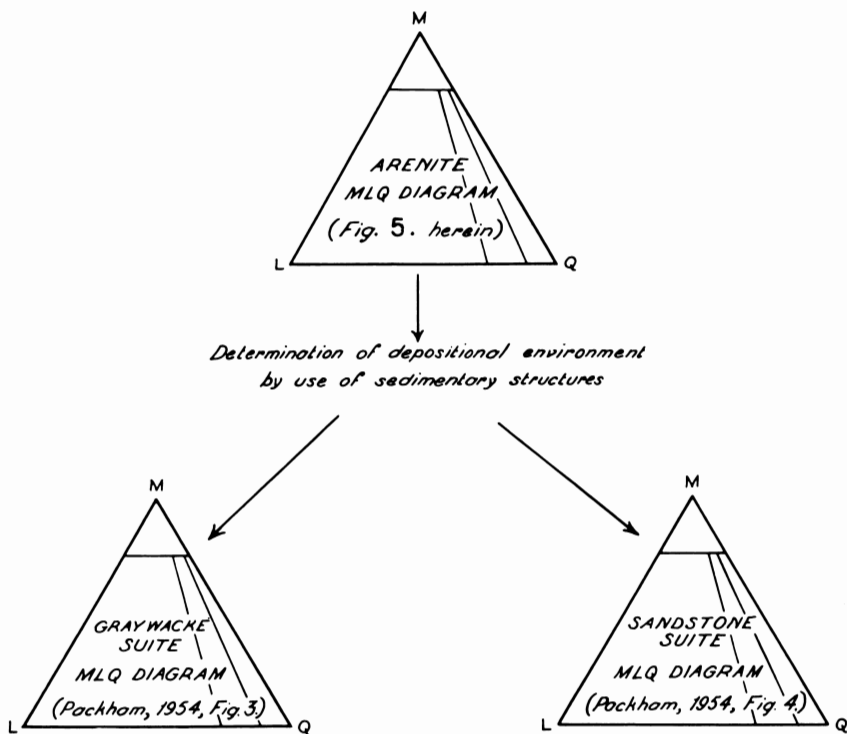


Fig. 6. Diagram showing relationship between arenite MLQ diagram proposed herein, and those of Packham (1954).

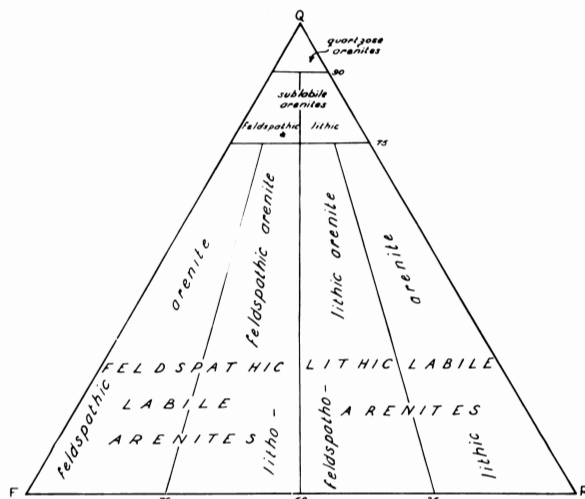


Fig. 7. Generalized QFR diagram for arenites.

The author has followed Pettijohn (1954) in using the term 'lithic' to designate arenites with abundant rock fragments.

Labile arenites rich in feldspar should logically be termed 'feldspathic arenites'. Unfortunately the adjective 'feldspathic' has been commonly applied to certain kinds of sublabile arenites. Packham (1954, p. 475) describes the sublabile equivalent of an arkose as 'feldspathic sandstone'. Gilbert (1955) uses the terms 'feldspathic arenite' and 'feldspathic wacke' for rocks which would mostly plot in the 'sublabile arenite' field of figure 6.

It is here proposed that the term 'feldspathic arenite' be reserved for labile arenites with less than 75 percent quartz and an FR ratio exceeding 3 (see fig. 7). The genetically flavored congruent terms, 'feldspathic sandstone' and 'feldspathic graywacke', should be reserved for arenites of this composition which are members of the sandstone and graywacke suites, respectively. Each of these three feldspathic rock-types includes, as derivatives of granitic terrains, the varieties 'arkosic arenite', 'arkose', and 'arkosic graywacke' respectively.

The use of the terms 'feldspathic arenite, sandstone or wacke' as descriptive of any variety of sublabile arenite should be discontinued. Pettijohn, realizing the desirability of this, has coined the term 'subarkose' which is roughly synonymous with his 1949 'feldspathic quartzite' (see figs. 1A and 1B). The genetic connotation of 'arkose' limits the value of this term, and it should be restricted to sublabile derivatives of granitic terrains, deposited by traction currents.

To overcome this difficulty it is proposed that two broad classes of sublabile arenite be recognized, 'feldspathic sublabile arenite' and 'lithic sublabile arenite', having FR ratios exceeding and less than 1, respectively (see fig. 7). As before, the term 'arenite' can be replaced by 'sandstone' or 'graywacke' when data on depositional environment are available. Subarkose then becomes a variety of feldspathic sublabile sandstone, and is, in this usage, synonymous with Packham's 'feldspathic sandstone'.

#### CONCLUSION

So many classificatory schemes for arenites have been proposed in recent years that it seems necessary to justify a further increase in their number. The following arguments are cited in defense of the scheme presented here:

a. It is not basically a *new* classification, but an expansion of an existing classification which removes certain shortcomings present in that classification. It should therefore be used in conjunction with this existing classification of Packham (1954).

b. Taken in conjunction with Packham's classification the present scheme enables the naming of an arenite in the field, in the laboratory, and, after examination of evidence from sedimentary structures, the assigning of a final name with both descriptive and genetic connotations.

It should be noted that the scheme proposed herein does not attempt to assign names to all kinds of arenites. This must await further work. Cases which are not covered are, for example, pyroclastic arenites, glacial arenites, and arenites with abundant detrital carbonate.

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