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FIGS. 1–3, SEPTEMBER, 1964

WACKE, GRAYWACKE AND MATRIX—WHAT APPROACH TO IMMATURE SANDSTONE CLASSIFICATION?[1]

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ABSTRACT

Huckenholz (1963) showed that the original *arkose* and *graywacke* overlap completely in both texture and composition; perhaps suppression of one or both terms is indicated. Graywacke has the longer, if not more significant (albeit confused), history. For 100 years in Germany and 50 in Britain, before development by Sorby of thin section petrography, graywacke was used as a purely hand specimen term based chiefly upon texture. It seems pointless to change this emphasis for an important, large, texturally-similar yet compositionally-varied rock clan.

Modal analysis and interpretation of immature sandstones presents many problems, especially that of matrix which is increasingly attacked as a classificatory parameter, chiefly of maturity. But it matters not how or when conspicuous matrix of graywackes formed for it to be useful for descriptive "coarse" separation of pure (arenite) and impure (wacke) sandstones; genesis of fine material must be interpreted in *any* sand, recent or ancient. Finer subdivision can be made on a compositional basis following flexible schemes such as Gilbert's. Sedimentary structures, tectonics, provenance, depositional process and environment should be avoided in petrographic classification. If textural and compositional maturity be accepted as the prime guides in classification, then purely quantitative placing of a rock within each maturity spectrum could replace all troublesome varietal names.

INTRODUCTION

"Geologists differ much respecting what is, and what is not, Gray Wacce" (Mawe, 1818).

Huckenholz's recent paper (1963) on composition and texture of the original ("type") graywacke and arkose reopens an old wound; now there are new overtones as arkose joins the ranks of ill-behaved rock terms. Impressions gained from many recent papers suggest that we have arrived at a point of near absurdity in the classification of immature sandstones. Huckenholz, for example, has now shown that the "type" arkose completely overlaps the "type" graywacke in texture, and only slightly less so in composition, and concludes that matrix can not be used to classify graywacke. A more obvious conclusion might be to discard one or both of these old terms; it is indeed puzzling that he did not suggest this.

Arkose, as generally used in North America, is defined by rather different criteria than other sandstones; that is, it is linked to a very specific source rock, therefore is a very narrow category. In light of Huckenholz's data, the term seems of little value, whereas graywacke has an older and, I think, more significant meaning. Furthermore, the name arkose itself has little descriptive merit; *feldspathic, sandstone* would seem far more useful.

The chief object of this discussion, however, is the graywacke problem. The following remarks attempt to show that only *megascopic* qualities were used to characterize graywacke long before the birth of thin section petrography. Restriction 200 years later of graywacke to the narrow compositional confines of the "type" example seems an empty exercise in semantics as Huckenholz's data now emphatically show.

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The "Type" Dogma and Grauewacke

The almost endless list of concepts of graywacke sandstones fall reasonably well into five categories. These are:

1. Megascopic appearance: dark, dull, "dirty" looking; and/or firmly indurated, implying slight metamorphism.
2. Textural immaturity irrespective of sand grain composition: commonly expressed as percentage of fine matrix, whether primary or secondary; angularity typically implied.
3. Compositional immaturity: many rock fragments, or many metamorphic fragments, or "mafic" composition, thus linking with specific sources.
4. Combinations of any of the first three.
5. Combinations of the first three, plus: genetic implications of sedimentary structures, or tectonic setting, or inferred process and environment.

Following what amounts to a "type" philosophy, many authors insist upon the originally named *grauewacke* (Lasius, 1789) of the Upper Devonian-Lower Mississippian Kulm strata of the Harz Mountains as the only ultimate standard for correct application of this venerable, battle-scarred rock name. Several previous papers as well as Huckenholz's have been written to provide detailed petrographic and chemical analyses so that other sandstones could be more closely compared with the original. This approach apes the zoological "archetype" and stratigraphic reference-standard procedures which have proven over the years to be tolerably successful in their respective contexts.

A rigid "type" approach to defining rocks is today considered archaic by many if not most petrologists; igneous petrologists have succeeded enviably in emancipating themselves almost completely. But even more significant is that, as commonly practiced for graywacke, it seems to me the "type" doctrine has acquired a serious fallacy, namely the assumption that we should place primary emphasis upon microscopic petrographic and chemical analyses (i.e., composition) of the Harz graywackes. Huckenholz indicates that *grauewacke* was first used by miners to refer to barren country rock at least as early as the mid-eighteenth century. A point which apparently has not been emphasized in the long furor over graywacke, is that *this transpired 100 years before invention of the petrographic microscope and use of thin sections.* Moreover, Huckenholz cites an early megascopic or hand lens description published in 1789 (Lasius) which characterized the *grauewacke* as quartz "breccia" with mica flakes and fragments of chert or sandstone in a clay cement. The name itself, of course, also implies a gray or dark color. However, the same reference is quoted by Howell (1957, p. 130) as characterizing graywacke as "sandstone made up of fragmental granite debris," the usual American definition of arkose. This ambiguity supports Huckenholz's claim that the two rocks overlap, but also further beclouds the true original meaning of graywacke. One must keep in mind, however, that these compositional remarks were of necessity hand lens observations only, and presumably were just amplifications of Lasius's other, primarily textural remarks.

Use of graywacke is found in English literature at least as early as 1808, and this is, in many ways, more relevant for North American geologists. Robert Jameson, the arch Wernrian of Edinburgh, used the name extensively, and it is indeed very probable that he himself first introduced it to the English-speaking geologic fraternity when he returned to Scotland from his great pilgrimage to the Freiburg papacy. Not having available a copy of his 1808 *Geognosy*, I quote Jameson's description of "greywacke" from his notes to a translation of Cuvier's *Essay on the Theory of the Earth* (1818, p. 220):

> "This rock, including in a basic [matrix] of quartzy clay slate, variously shaped masses of clay slate, greywacke slate, flinty slate, and sometimes also masses and grains of felspar, and scales of mica. It very rarely contains petrifactions [fossils]."

This passage apparently is nearly identical with his 1808 description (see Cummins, 1962). The term was soon used throughout Britain by many, if not most, geologists there, although certainly not with whole-hearted unanimity even then (see quotation at the beginning of this paper). As mapping and stratigraphic investigations proceeded rapidly in Britain, the name *greywacke* became for a time more or less synonymous with Transition Rocks (now Lower Paleozoic) which include many dark, "clay-rich" sandstone types. Thus the term acquired a quasi time-stratigraphic connotation much as Old Red Sandstone, Chalk and certain other lithologic terms have done. This usage of *greywacke* has long-since ceased, and in fact was practiced for only a few decades before the Cambrian and Silurian were named by Sedgewick and Murchison.

For the half century after 1800 when study of strata first went forth at a rapid rate, graywacke had to be a field (and at best hand lens) term until Sorby perfected thin section techniques in the 1850's. Although some chaos had already appeared, if one can find *any* common denominator in early megascopic usage, it was the emphasis of dark color and abundant matrix; angularity and overall heterogeneity, though implied, seem to have been secondary. Subsequently, Europeans, particularly in Britain have more consistently emphasized texture as the prime quality of graywacke, though they have not been free of dissension (Boswell, 1960). It is on our side of the Atlantic that compositional emphasis has flowered most luxuriantly. The most unfortunate compositional restriction of all was that of Wentworth and Twenhofel who defined "greywacke as the ferromagnesian equivalent of an arkose" (Twenhofel, 1932, p. 231). This reflects a natural desire to have specific rock names or clans contain built-in source-rock connotations, but how ironical this is in light of Huckenholz's data showing almost complete overlap of the "type" arkose and graywacke! It is a noble, but impractical goal. Only a rare sand, indeed, represents but one source material, and it is wishful thinking to suppose that a useful petrographic classification can be based primarily upon provenance composition. For example, some of the "type" arkoses even contain appreciable sedimentary and metamorphic rock fragments (Huckenholz, 1963).

By popular criteria either of original or majority usage of *graywacke* over the years, at least outside North America, the "texturalist" school appears vindicated, and apparently the wrong properties have been over-emphasized by the "compositionists." Clearly the original or "type" definitions both in German and English could not have been truly petrographic. In biology or stratigraphy, admittedly, a *type* can be re-defined, as has been attempted with graywacke. I submit that in this case redefinition came too late to be taken so seriously, that is long after megascopic field usage had become well established and widely applied. Furthermore, re-definitions have tended to make the term less useful and it seems absurd to restrict a long-standing name to the rigid petrographic compositional limits of the "type" examples 200 years after its use was well established. Whether we subscribe to precedent alone or to a dominant pervasive property as the best basis for definition, then either the dark, ill-sorted appearance should be retained as *the* definition of graywacke, or else the term should be abandoned and replaced with newly defined ones. While the latter procedure is logically sound, it is not very practical; old terms *will* be used, so it is more propitious to leave for them very broad meanings which are still applicable in the field and to establish refined new varietal types.

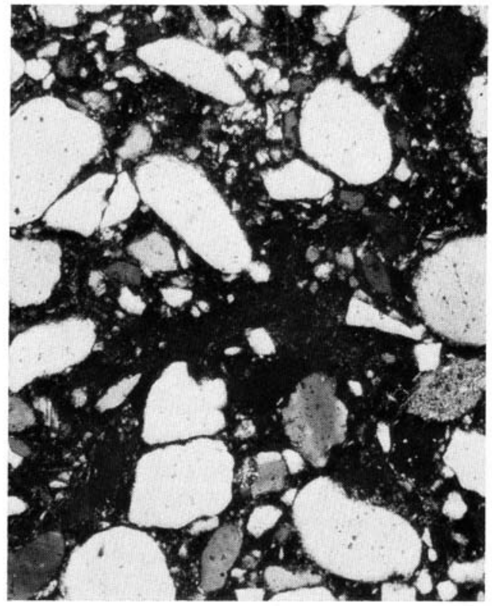

FIG. 1.—Quartz wacke, Precambrian Mineral Fork Formation, Wasatch Mountains, Utah. Compositionally very stable, but texturally very immature (quartz 56%, feldspar 6%, mica 1%, other accessory minerals 3%, metamorphic rocks 7%, matrix 27%; standard deviation >1.50). Crossed nicols, ×63.

Textural Supremacy

This writer has heartily endorsed Gilbert's conclusion (in Williams and others, 1954) and that of Boswell (1960) that graywacke was, and is, basically a field textural term for rocks that are grossly similar in appearance. Gilbert, as well as Pettijohn (1957), Cummins (1962) and many others, have reckoned that the textural peculiarities derive chiefly from an abundance of fine matrix material. Graywacke, then, is not *a* rock but an extremely large and widespread rock clan with many compositions. Figures 1 and 2 illustrate this; the first rock is compositionally very stable (mature) and the second is compositionally very unstable (immature), yet both have in common qualities of very dark gray to black color and between 10 and 20 percent matrix.[2] Quartz wackes such as figure 1 are very important, but are adequately recognized only by Gilbert; the writer has encountered many examples, particularly in the Precambrian. Wide range of compositional variation suggests further that it is somewhat illusory to speak of "average" or "typical" graywacke in either a mineralogic or chemical sense. There may well be no real rock in the world with any published "average" composition; range of composition is far more significant. Furthermore, texturally mature "pure" sandstones (arenites) also show equally wide compositional variation, though as a clan, they may be statistically somewhat less heterogeneous than graywackes. Thus compositional stability and textural maturity are largely, though not entirely, independent, and Gilbert's classification clearly recognizes this fact. Folk (1951; 1961) has made this distinction even more sharply, and many of his suggestions can advantageously be combined with Gilbert's classification.

Part of the arguments over sandstone classification seem to me to result from failure to acknowledge fully the need for different levels of classificatory refinement. The very coarsest level should be megascopic, with refinements being microscopic or chemical. Clearly the ternary and quaternary diagrams have imposed mental straitjackets upon rock classification; as a consequence, much argument ensues directly from the supposed need to squeeze all major constituents into one of only three or four categories. It should be obvious that such diagrams can apply only at a fairly "coarse" level of subdivision. For immature sandstones, for example, more precisely-defined hybrids can be established by grain petrography (i.e., compositional

[2] Compositional *stability* instead of *maturity* may better emphasize the distinction of composition and texture. At present, unqualified reference to maturity obscures the distinction that Folk urged (1951).

FIG. 2.—Feldspathic lithic (volcanic) wacke, Eocene Tyee Formation, east of Reedsport, Oregon. Both compositionally and texturally very immature (quartz 32%, feldspar 30%, volcanic rocks 13%, ferromagnesian minerals 12%, matrix 13%; standard deviation 1.45, average roundness 0.22). Crossed nicols, ×63.

stability) without impairing the over-riding importance of their textural common denominator. Following an appropriate suggestion of Fischer (1933), Gilbert adopted a binomial, multi-leveled approach using *wacke*, from the German for "residue," as a large textural category, the impure sandstones, with compositionally-defined varieties such as quartz wacke (fig. 1). Further modifiers can be added to describe textural maturity more fully. Pettijohn's (1957) classification is basically similar, but the categories are somewhat less flexible; for example quartz wackes are not recognized. Though consistent with original usage and providing maximum flexibility for refinement, Gilbert's scheme has received surprisingly limited acceptance. Perhaps this reflects early preoccupation of North American sedimentary petrologists with simpler, mature sandstones so that classificatory schemes more adapted to these types were already strongly rooted by 1950.[3]

Workers concerned only with grain mineralogy and wishing to circumvent the matrix problem, may simply speak of "feldspathic sandstone," "quartz sandstone," etc., with little or no reference to texture. But further breakdown is generally desirable at least in terms of presence or absence of appreciable fine matrix. Figure 3 is a conceptual adaptation of Gilbert's scheme re-drawn in one diagram better to portray the continuous nature of textural variation from mudstone to arenite and from stable to unstable grain composition. The horizontal axis represents only the most sensitive of the three parameters of textural maturity, because it is impossible to include all; the vertical portrays compositional stability. The three front apices represent relative physical and chemical durability. The most stable common end-members, or resistates, are various types of quartz and "chert." In terms of stability, and also for sake of objectivity, cryptocrystalline siliceous volcanic material such as devitrified acidic glass is included as "chert." Some would group all "chert" with rockfragments, but this makes an already heterogenous category even more of a catch-all. It seems more objective as well as genetically significant to employ relative stability as the basis for the front apices. Feldspar requires a separate corner because of its abundance in the earth's crust and its intermediate stability; it is nearly as ubiquitous in unstable sands as quartz. Relatively few clan names are urged, because it appears that an inverse relationship exists between the practical utility of a classification and its number of formal subdivisions. The names themselves produce a semantical jungle, and prefix modifiers can provide a more acceptable and flexible means of subdivision. It will be noted that "feldspathic" is preferred to "arkose" for reasons outlined earlier. The most labile materials, including most rock fragments and ferro-magnesian minerals, are grouped collectively at the lower right corner. The diagram provides only a "coarse" breakdown of sandstones, and resort to other schemes is essential to adequately name and characterize a very heterogeneous sandstone which may have six or eight or more important components. For example, separation of common, strained, and polycrystalline quartz and chert may be very important on a finer scale of separation, particularly in the more stable sandstones, as these types appear to have slightly differing durabilities. Separate diagrams can be erected, ratios of critical constituents can be calculated or simple modifiers can be appended.

Time and again it has been shown that a purely descriptive approach to sandstone classification is the only acceptable one, although it has been hoped that criteria chosen will have genetic significance. It is especially important to avoid overtones of tectonics, provenance, environment and process of deposition (Boswell,

[3] If the reader finishes reading this discussion, he may well feel that such preoccupation was wise, indeed.

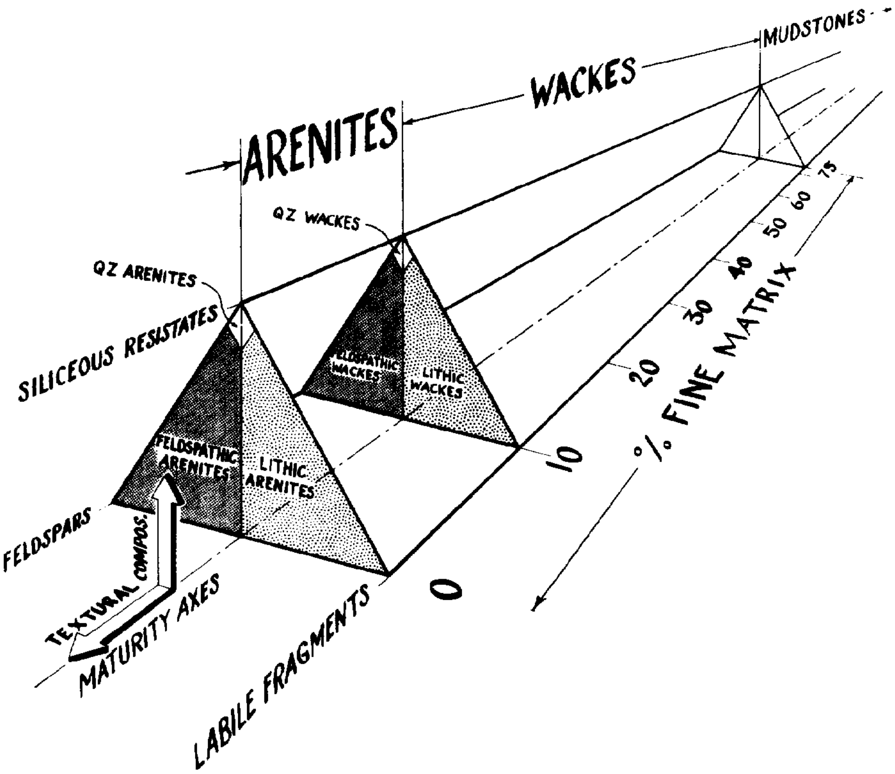

FIG. 3.—Modified portrayal of Gilbert's classification of silicate sandstones incorporating Folk's dual maturity concepts.

1960; Dott, 1963, p. 123–124). These are subjective and involve separate and distinct interpretations to be made from the rocks described. Nor should sedimentary structures be entwined in rock classification. Folk's (1951) dual textural and compositional maturity concept seems to provide the most lucid guiding basis for classification. By evaluating texture and composition separately, varietal names could be abandoned completely. The act of classifying could ultimately become simply a process of placing a sediment quantitatively within the two continuous maturity spectra. Textural maturity can be quantified as in table 1, and compositional stability can be expressed as an index such as the ratio of quartz to all other grains (Walton, 1955). Such procedures would save much printers' ink and page charges and tend to eliminate long-winded discussions of sticky nomenclatural problems.

The Matrix Problem

Overall *compositional stability* is easily established by conventional grain point counting in thin section. However, following Gilbert, this only serves to establish varietal types of impure sandstones (wackes), which first and foremost comprise a *texturally immature* group. Folk (1951; 1961) has defined textural maturity in the three-fold terms of percent "clay" (matrix), sorting, and rounding. He also recognized differing rates of change of these properties (table 1); the spectrum of ideal textural evolution is essentially an exponential one with much more rapid changes at the immature end. Matrix and rounding can be measured fairly readily in thin section, but rigorous size analysis for calculating sorting (standard deviation) is very tedious and can not be justified in many studies.

It has become common practice to employ percentage of fine matrix, determinable by point counting all grains smaller than some arbitrary diameter (generally 20 or 30 microns), as an approximate estimate of sorting and for differentiating the impure and pure sandstones by some arbitrarily chosen volume percent (generally 10 or 15 percent). This would seem at first blush a valid procedure, but it is questioned by Huckenholz (1963) and others. Curray (1960) has emphasized that fine mud has been introduced extensively into originally "clean" sands by burrowing animals; Cummins (1962) believes that most matrix results from diagenetic breakdown of unstable sand grains. Cummins maintains that there is a direct correlation between percent matrix and age of graywackes. He contends that modern and most Tertiary sands, presumed otherwise similar in origin to ancient graywackes, lack matrix, and that matrix derives from diagenetic alteration of labile grains. Klein (1963) also attributes some matrix to secondary infiltration, however this would be limited to sands with moderately large original pores Huckenholz argues that, to be used for classification, matrix must show a sharp size-frequency separation from the sand grains (i.e., bimodality). This is the first time that I have encountered this special restriction which, even if of some fundamental genetic significance, seems wholly impractical.

Diagnetic origin of some matrix material is undeniable. Williams and others (1954) and Pettijohn (1957) discuss this origin, and recently Allen (1963) has shown convincing evidence of it. The writer has encountered many vague, ill-defined grain boundaries clearly indicative of diagnetic alteration in volcanic-rich Tertiary sandstones from Oregon, but many associated sandstones with equal volumes of matrix also have exceptionally fresh grains (fig. 2); the latter matrix must have been detrital. Much "diagenetic" matrix almost certainly has resulted from alteration not of sand-sized grains, but of an original detrital matrix; although some change of composition and form has taken place, there need not have been any change of size distribution. Whether detrital or secondary, it is self-evident that matrix in ancient, compacted sandstones is not exactly comparable in its volumetric relationships with that of uncompacted sands. Use by Pettijohn (1957) of matrix as a *fluidity index* has also been criticized because of the suspect origin of that matrix. This may be defensible in a general way, however, because in pebbly mudstones with dispersed fabrics, the largest conglomeratic clasts tend to occur consistently in the most dispersed examples, i.e., those which possessed greatest fine matrix and least fluidity.

The "matrix problem" is partly an operational matter, and if I would defend the honor of matrix against the infidels' attack, it is necessary to discuss several of the rarely-cited practical problems that arise in studying immature sandstones. The average grain size of rocks being point-counted should always be indicated, for composition as well as texture is strongly affected by size alone. Sample size, or number of points, should also be given, and in rounding studies, the scale used as well as the method of determination should be indicated as there is variation among published rounding classifications. Medium to coarse sandstones are optimum for optical identification purposes, and tend to be the most sensitive compositional stability indicators, but magnification is obviously a factor, too. Therefore, it would be helpful if authors would state the magnification used during counting as this may strongly bias results, particularly the discrimination of matrix. Magnification of 75–100 seems to be ideal for counting most medium and coarse sandstones

Many authors fail to indicate the upper size limit chosen for matrix. Williams and others (1954) arbitrarily suggested 20 microns (0.02 mm or 5.7 ϕ) but Folk (1961) chose 30 microns (0.03 mm or 5 ϕ) for his "clay" limit. It would appear that 30 microns is preferable for three reasons. First it falls almost exactly at an even phi division. Second, as Chayes (1956) has shown, the standard thin section thickness of 30 microns imposes severe bias on any estimates made from fine grains, particularly if opaque. Thirdly, it is suspected that a genetically significant clastic

TABLE 1.—*Folk's (1961) ideal textural maturity spectrum modified for greater discrimation at the immature end*

Immature		Submature	Mature	Supermature
Very Immature (Wackes)	Moderately Immature			
>10% Matrix (<0.03 mm)	>5%< Matrix	—	—	—
—	—	Sorting>0.5<Sorting		—
—	—	—	Rounding>	0.35 (Wadell scale) < 3.0 (Folk scale)

size break may occur in the silt range. Spencer (1963) suggests 30 microns as the best boundary for separating two fundamentally different size populations, sand and matrix. He contends that "silt as a genetic class does not exist" (p. 189), and that size sorting is a matter of degree of truncation or mixing of two or three distinct size populations. Therefore most clastic sediments consist of grains and matrix. If real, such a natural tendency for bimodality would strengthen Huckenholz's procedure for using matrix in classification, but as Spencer shows, ideal bimodal separation is not always clear.

Choice of the amount of matrix necessary to divide pure from impure sandstones is even more elusive, but the writer's experience has been that relatively few sandstones have less than 10 percent matrix, while many have 10 to 15 percent and more. But if standardization remains impossible, as it probably shall, at least workers should state the percentage and size limits as well as magnification used in their studies. This is of paramount importance because percent matrix alone may completely change the rock name, and certain names such as arkose have developed very specific genetic implications. I have found in working with students that there is a wider range of matrix determination than of any other petrographic parameter. However, in some cases of exploratory replication by different operators, acceptable reproducibility has been obtained. There is a high degree of judgment and uncertainty in point counting immature sandstones, and because of these inherent problems and biases, the comparability of many published modal analyses of graywackes is in doubt. Many may not even be reproducible. Much of this could be alleviated, however, with more complete specification of analytical procedures and limits used.

The Matrix Question

Obviously the origin of matrix is complex, but the "matrix question" should not be so much *whether* it can be used in classification, but *how* it is to be interpreted genetically. History shows that presence or absence of matrix is a conspicuous and measurable property. As such it is a perfectly valid descriptive and classificatory criterion. Even Cummins (1962), the most extreme advocate of a secondary origin of matrix, does not for a moment seem to question its overriding significance in characterizing graywackes. If a choice is possible, point counting can be avoided on samples in which grain alteration or burrowing have been extreme; fortunately, these effects generally are readily detectable. Even use of matrix as one index of maturity is perfectly defensible, although primary detrital matrix is related strictly to texture and diagenetic matrix more to composition. Careful microscopic and X-ray analysis may provide bases for judging relative contributions of each. But if both are present in quantity, then matrix clearly would be an index of both maturities, which is further evidence that texture and composition are not, after all completely independent. This need not be totally unnerving, however, for texture first must be objectively considered a quality that a rock or sediment possesses at the time it was collected and studied. Muddy, burrowed sands and much-altered ones are today texturally immature, i.e., they encompass a wide range of sizes, regardless of how they got that way! This conclusion generally would be reached from sieve or settling tube analysis of sorting just as from point counting of matrix. Size distribution statistics must be interpreted as to origin of the fines just as much as thin section data. Yet, curiously, when modern sands are analyzed and interpreted texturally, the "matrix question" never seems to arise, reflecting inherent problems and view points generated by the different methods of study of ancient and recent sands. Yet, does not the question still exist? Matrix will appear in the clay-silt fraction of any size distribution regardless of origin.

What to measure, then? Measurement of matrix in thin section is not a completely satisfactory substitute for sorting, for standard deviation is affected by both ends of the size distribution, while matrix percentage only considers the fine end. In other words, winnowing of fines is not entirely synonymous with sorting as we normally think of it. Apparently there is no short-cut to complete analysis of textural maturity. Therefore, ideally it is desirable to know both matrix percent and sorting as well as rounding, but this is often impractical. Perhaps matrix coupled with some other, readily obtainable measure such as maximum size to give a total size range might provide a reasonable compromise approximation of sorting for rapid analysis of large numbers of thin sections; comparative sorting charts provide another practical compromise (Folk, 1961).[4] Rapid visual estimate of size distribution is claimed to have high reproducibility after some practice (Swann

[4] The Zeiss TGZ3 Electric Particle Size Analyzer may offer a solution for rapid size analysis from photomicrographs, though its cost and certain scale and conversion limitations detract somewhat from its appeal. Figure 2 was so analyzed, in a slightly larger field, yielding Md=4.8 s=1.03, and 35% finer than 0.03 mm. The full thin section, however contains scattered pebbles, therefore this is not fully representative. Point counting showed 27% matrix, and indicates, for the entire sample, s>1.50.

and others, 1959, Emrich and Wobber, 1963). But matrix determination alone still is defensible as better than no measurement for immature sandstones. In fact, as Folk originally suggested and as Spencer implies in the suggested overlapping or truncation of sand and matrix populations, winnowing of detrital matrix is the first and most sensitive change in ideal textural evolution, thus is the most important single property to measure in texturally immature sands.

CONCLUSION

From the premise that sandstone classification must be basically descriptive to be useful and durable, textural maturity and compositional stability provide the clearest guides. Huckenholz (1962) seems to have proven the great variability and overlap of two classic immature sandstone types which suggests immediately that one or both terms be abandoned, though he did not draw this seemingly mandatory conclusion. *Arkose* has little descriptive value and could be replaced by *feldspathic sandstone*. *Graywacke* has a longer and more significant history. As Pettijohn (1957) remarks, those who would abolish it offer no satisfactory substitute name for an immense family of very important rocks. History shows that for 100 years prior to the development of thin section petrography, usage of *graywacke* emphasized (if anything) primarily its peculiar textural properties, chiefly its matrix and dark color. And if classification is to be descriptive, it matters not one whit how or when the texturally-conspicuous matrix of graywackes originated for it to be used in classificatory distinction of two major "coarse" separations of sandstones by gross texture, i.e. pure sandstones or *arenites*, and impure or *wackes*. Further subdivision of either group should be made secondarily according to compositional differences following schemes like that of Gilbert. Sedimentary structures as well as the genetic implications of tectonics, provenance depositional process and environment, (and the circular reasoning involved) should be avoided rigidly in establishing petrographic varieties. Clearly mere mortals, not the rocks, have become confused. If we ask the rocks only straightforward questions, they shall reply in kind, and classification should serve to help us better to phrase those questions.

REFERENCES

ALLEN, J. R. L., 1962, Petrology, origin and deposition of the highest lower Old Red Sandstone of Shropshire, England: Jour. of Sedimentary Petrology, v. 32, p. 657–697.

BOSWELL, P. G. H., 1960, The Term Graywacke: Jour. Sedimentary Petrology, v. 30, p. 154–157.

CHAYES, F., 1956, Petrographic modal analysis: New York, John Wiley and Sons, Inc., 113 p.

CUMMINS, W. A., 1962, The greywacke problem: Liverpool and Manchester Geol. Jour., v. 3, p. 51–72.

CURRAY, J. R., 1960, Sediments and history of holocene transgression, continental shelf, northwest Gulf of Mexico, p. 221–266, *in* Shepard, and others, *Editors*, Recent sediments, northwest Gulf of Mexico: Tulsa, Okla., Amer. Assoc. Petroleum Geologists, 394 p.

DOTT, R. H., JR., 1963, Dynamics of subaqueous gravity depositional processes: Amer. Assoc. Petroleum Geologists Bull., v. 47, p. 104–128.

EMRICH, G. H. AND WOBBER, F. J., 1963, A rapid visual method for estimating sedimentary parameters: Jour. Sedimentary Petrology, v. 33, p. 831–843.

FISCHER, G., 1933, Die petrographie der grauwacken: Preussische Geologische Landesanstalt, Jahrbuch, v. 54, p. 320–343.

FOLK, R. L., 1951, Stages of textural maturity in sedimentary rocks: Jour. Sedimentary Petrology, v. 21, p. 127–130.

———, 1961, Petrology of sedimentary rocks: Austin, Texas, Hemphill's Book Store, 154 p.

HOWELL, J. V., 1957, Glossary of geology and related sciences: Washington, D. C., Amer. Geol. Institute, NAS-NRC Publ. 501, 325 p.

HUCKENHOLZ, H. G., 1963, Mineral composition and texture in graywackes from the Harz Mountains (Germany) and in arkoses from the Auvergne (France): Jour. Sedimentary Petrology, v. 33, p. 914–918.

JAMESON, ROBERT, 1818, Mineralogical notes, p. 185–317 *in* translation of Cuvier, M., Theory of the Earth: New York, Kirk and Mercein, 431p.

KLEIN, G. DEVRIES, 1963, Analysis and review of sandstone classifications in the North American geological literature, 1940–1960: Geol. Soc. America Bull., v. 74, p. 555–576.

LASIUS, GEORGE, 1789, Beobachtungen im Harzgebirge: Hannover, p. 132–152.

MAWE, J., 1818, Catalog of Minerals, London, 1818.

PETTIJOHN, F. J., 1957, Sedimentary Rocks: 2d ed., New York, Harper and Brothers, 718 p.

SPENCER, D. W., 1963, The interpretation of grain size distribution curves of clastic sediments: Jour. Sedimentary Petrology, v. 33, p. 180–190.

SWANN, D. H., FISHER, R. W., AND WALTERS, M. J., 1959, Visual estimates of grain size distribution in some Chester sandstones: Ill. Geol. Survey Circ. 280, 43 p.

TWENHOFEL, W. H., 1932, Treatise on sedimentation: 2d ed., Baltimore, Williams and Wilkins Co., 926 p.

WALTON, E. K., 1955, Silurian greywackes in Peeblesshire: Proc. Roy. Soc. Edinburgh, B. v. 56, p. 327–357.

WILLIAMS, H., TURNER, F. J., AND GILBERT, C. M., 1954, Petrography: San Francisco, W. H. Freeman Co., 406 p.