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Sediment Fingerprints: A forensic technique using quartz sand grains…A response.

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Sediment fingerprints: A forensic technique using quartz sand grains – A response

Madam,

Pye raises five points with regard to our paper 'Sediment Fingerprints: A forensic technique using quartz sand grains' [1], which broadly relate to the nomenclature used in the classification system outlined in our paper (points 1–3) and the practicability of the technique (points 4 and 5). They are:

1. The misleading use of 'grain surface textures' in our paper.
2. The specific problem of our orders of classification.
3. Pye's claim that the grain types have no formal scientific standing and are not universally recognised.
4. The perceived issue of precision and of accuracy with different operators.
5. The representativeness of the number of grains analysed per sample and their effect on the number of grain types found in each sample.

We will deal with each of these points in turn:

1. The misleading use of 'grain surface textures' in our paper.

We are fully aware that there would be an apparent confusion in the designated names of our various orders of classification were the reader to be seeking a classification of surface textures or feature types. We have used the descriptors (at the first order of classification) of rounded, angular, metamorphic and diagenetic/chemical so as to provide some descriptive order. Grains vary between being rounded and angular, and indeed every degree in between, and we fully recognise that the angular and rounded groups are shape determined (and indeed if one was using Fourier analysis it would be edge-shape determined). The metamorphic and diagenetic groups are descriptive terms which actually infer provenance. All of the terms used here are descriptive and are not classification based. Imagine the difficulty of just calling the groups A, B, C or D without reference to what that means. The descriptors were designated to be an aide memoir.

The second order of nomenclature (e.g. A1, A2) is related to the provenance of a quartz grain. It further enhances the ability of the experienced electron microscopist to designate the grain type after viewing 3–40 textures and noting their presence or absence on a grain in order that a provenance designation can be made. Of course, in the context of a forensic case this academic interpretation is not needed for a meaningful presentation of findings to the court (see our Table 2 and related discussion [1]).

However, it is provided here for completeness as it is necessary for the palaeoenvironmentalist aiming to ascertain the geological context of what is being observed in the sample as a whole.

In terms of the provenance of flattened grains, not all flat grains are metamorphic in much the same way as one conchoidal fracture does not indicate glacial modification [2]. It is not that one grain is flat and is therefore designated metamorphic, it is a combination of features that are taken into consideration. Distorted grains, heart-shaped, s-shaped and c-shaped grains are present in metamorphic sediments, so too are elongate grains and elongate polycrystalline grains very much in the manner described in C1a, C1b and C1c.

Pye makes the mistake of considering this classification to be a particle morphology classification. It is not. It is a grain type classification which incorporates shape, surface texture and feature and allows for a more three-dimensional, temporally based appreciation of syn- or post-depositional alteration (by diagenesis or by chemical modification within a rock and a soil).

It can never be stressed enough that, as with every other forensic discipline, if you are not an expert in the field, do not attempt to be so in court [3]. It would be as foolish to deal with the quartz grain type classification without prior training as it would be, for example, for a geologist to undertake pollen analysis, or to provide a critique in court on the pollen analysis undertaken by another expert without being an expert in the field oneself. Imagine a geologist dissecting human tissue to determine provenance of the body or body parts without suitable medical training and laboratory facilities. The same applies to grain typing.

2. The specific problem of our orders of classification.

Pye still considers a morphological classification when viewing the grain type classification employed in our paper [1]. This is exemplified by his recognition that, at the first order, group B (rounded) contains angular grains and his subsequent questioning of how this can be. By reference to Table 4 [1] we can see that of the 738 samples retrospectively classified, in group B1c at the third order 0.5% of the grains had angular components attributed to them. In the third order category B2c 0% of the grains contained this feature. The answer to Pye's question is quite simple. Whilst the actual grain may have a rounded outline, the angularity could be identified from within the surface features produced. Rounded grains can have mechanical breakages and conchoidal fractures which do not affect the outline or shape of the grain as viewed, yet their edges can be extremely angular. As can be seen from Table 4 [1] these occurrences are rare. Indeed, other categories in Table 4 also show a 0% occurrence, but these are included for completeness and it is possible that as the database is expanded each category will be represented.

What is important for this classification is that it does not attempt to match samples. It only attempts to exclude. This is the basic tenet of forensic geoscience that is so often ignored or overlooked by geoscientists [4–7]. Unfortunately some practitioners still attempt to match samples [8–13] and this classification system and database was not constructed to be used in this way. If it is approached in such a manner the potential for false-positive and/or false-negative conclusions from the analysis of samples is very high, much in the same way as the results derived from other geoforensic analytical techniques.

In the 45 years that quartz surface texture analysis has been conducted, in excess of 100 textures [14] have been identified which in one way or another relate to environmental or palaeoenvironmental modifications to the sand grain. It is inevitable that people will add textures that are presented in samples in subsequent cases. For example, in a temperate estuarine environment very distinctive silica flowers can be formed on quartz grain surfaces. These are due to the presence of salts within the sediment which result in the deposition of an ephemeral silica gel [15]. The presence of such features would suggest (and only suggest) to the analyst that the soil sample may well have been derived from an estuarine environment. The presence or absence of this and other features and textures by subsequent analysis of comparator samples, taken for example from footwear, may indicate that these samples could or could not be excluded from having derived from this type of estuarine provenance.

We refute therefore, Pye's statement that Bull and Morgan effectively present a quartz grain morphological classification system but the terminology and the classificatory criteria which they employ to define different groups are severely confused. We look at quartz grain types more holistically in order to compare and exclude.

3. Pye's claim that the grain types have no formal scientific standing and are not universally recognised.

The contention of Pye that the surface textural features which provide the basis for the fourth and fifth order divisions have no universally agreed scheme for their description and classification is, we consider, to be short-sighted and to miss the point that we are making. We do not intend to provide an anthology of textures to determine genesis and environmental significance but rather to provide a method of comparing the quartz grain surface features present on the quartz grains in one sample to those present on the quartz grains comprising a comparator sample. The identification of different surface textural features on a particular quartz grain enables the assignment of a particular grain type. The database that we provide in our paper has been constructed in order to provide an indication of the occurrence of the different grain types and of course the groups of grain types present in a sample. Thus, it is possible to present the findings of quartz grain surface texture analysis to a jury and to give an indication of how common such a grouping of grain types in one sample might be. To date, as we state in our paper, no case has yielded samples with the same group of quartz grain types as samples from another case (and remember that this database was constructed from cases already finished and so has no a priori or sub-conscious operator bias). To this end we demonstrate that the provision of a database and formalisation of grain types can be a powerful tool in geoforensic investigations. Indeed one of the aims of our paper was to present these grain types in a formal setting in order that they can be recognised and utilised in a forensic context in the future.

It is worthy to note that Pye [16] has actually used our method of quartz grain typing despite not being formally trained in this field. However, he goes further than we have in our Table 2 [1] by attempting to indicate abundance or rarity of those types in a sample using somewhat randomised groupings ([16] p111). Perhaps his groupings in his Fig. 9 [16] where he identifies abundant (greater than 75%), common (22–75%), sparse (5–75%) and rare (less than 5%) somewhat confuse him and may well go some way to explaining why he concludes that …it is virtually impossible to reproduce the results ([16] p. 110).

Our classification is descriptive, exclusionary rather than inclusionary and capable of modification without affecting the database that already exists. To say that there is no formal scientific standing exhibits a nihilism which is answered with the publication of this peer-reviewed paper [1] in the forensic scientific literature.

4. The perceived issue of precision and of accuracy with different operators.

Pye raises a concern as to the precision of this technique relating to single or multiple operators. This issue has been raised before in the SEM environmental reconstruction literature. A detailed study (as cited in our paper) by Culver et al. [17] investigated the possibility of variability in results between SEM operators on a series of samples. They found, in the context of establishing the environmental history of quartz grains, that different operators (both experienced and inexperienced) arrived at the same conclusions regarding both the features of the grains and the subsequent reconstruction of the history of the grains and concluded that the technique was a reliable and statistically valid means of discriminating between samples from different environments ([17] p129). In translation in the forensic context, this would mean that the operators would be capable of identifying the second order of classification presented in our classification system. Whilst Pye may consider in his experience this not to be the case, the published literature provides evidence to the contrary that has not been challenged in the subsequent 24 years.

5. The representativeness of the number of grains analysed per sample and their effect on the number of grain types found in each sample.

We maintain that the examination of 30–50 quartz grains in a sample is generally sufficient to provide a characterisation of the sample in question. The issue of obtaining a sub-sample that is representative of the original parent sample is a fundamental one in any forensic analysis but we do not accept that an automated analysis is necessarily the way to eliminate this problem as Pye contends (with reference to others [18]). The technique that we present in our paper is, in its current form, reliant on skilled operators who are able to individually assess each quartz grain. Automated analysis in geoforensics has been deemed to be the holy grail [19] and the goal of much geoforensic research. However, the potential for erroneous interpretations of such data and the potential for disastrously misleading a court have been fully detailed by Morgan and Bull [7,20].

In terms of the concern Pye raises as to the number of quartz grains analysed in a sample we would like to point to our original discussion of this matter in our paper [1]. There has been considerable discussion in the geological palaeoenvironmental reconstruction literature ten grains were universally used for each sample and this proved adequate in many palaeoenvironmental studies [21], with new and improved electron microscopes, more grains were studied; thirty grains were deemed statistically appropriate [22]. To claim that 30-50 grains is unsupportable appears to be another claim that flies in the face of the established published literature. Indeed, we consider it compelling that this literature has not been seriously questioned in the last 30 years similarly to the literature addressing the question of operator precision as discussed above. Furthermore, we analysed quartz grains taken from samples collected in a grid pattern from two adjacent plots approximately 10 m^2. Three quartz grain types were identified in the first 20 grains analysed (D1 aia, A1 aiv, D1aiid), and these grain types did not increase in number after the analysis of a further 1440 grains. We do not claim this to be representative of every sample site but we do feel that the results are not surprising.

Whilst we contend that not only does the established published literature support our claim that 30-50 grains is sufficient for meaningful analysis, it is important to re-iterate the fundamental philosophical differences between geological and geoforensic investigations. This issue is dealt with in our paper [1] and also more fully in Morgan and Bull [7]. In forensic studies grain characteristics are used as a comparison technique and are primarily used to exclude samples from having originated from a source similar to that of the comparator sample ([1] p71). Thus, this Popperian exclusion is the primary aim of any analysis. In many forensic situations very limited quantities of sample will be available and a rigorous comparison is imperative. In some cases there will be insufficient quartz grains present in a sample to be able to derive any meaningful comparisons and indeed interpretations or conclusions. This can not be considered to be a fault of the technique and the database, rather it is the way of the geoforensic investigation.

Furthermore, we challenge the comment that ...since Bull and Morgan have analysed so few grains per sample in their studies, it is little surprise they conclude that the majority of samples in their database contain only three or four different grain types. One of the most interesting findings of our paper was the very fact that from 738 samples and the analysis of approximately 25,000 quartz grains, on average there were only two or three grain types present in a sample (see our Fig. 19 [1]). This is a crucial tenet of the technique we present; due to the small number of quartz grain types identified from each sample during retrospective analysis, it is possible to construct a database for an exclusionary approach to be undertaken in a forensic case. The small number of quartz grain types present in a natural environment sample is not due to only 30-50 grains being analysed, rather it reflects the widely held view that sediments and soils are found in distinct facies [23-26] reflecting ordered movement of sediment bodies both through time and space ([1] p79). The samples that exhibited larger numbers of grain types were not samples where more grains were analysed, rather they were samples that included additions of anthropogenic materials, and were typically samples taken from vehicles, clothing and footwear. This is not due to the number of grains analysed but rather a function of the mixed provenance of the sample, in forensic investigations, due to pre-syn-and post-forensic event mixing [7,20]. The fact that such a large number of samples were analysed to construct the database and the findings were found to be so consistent refutes the claim that the number of grain types found in a sample is a direct corollary of the number of individual quartz grains analysed in that sample. This is not withstanding the three grain types identified from 1460 grains mentioned above.

6. Final comments

Finally we would like to question the concessions that Pye makes towards the use of quartz and other minerals in forensic investigations. We agree that classification of the shape of quartz grains can be accomplished by binocular microscope examination and indeed the presence of other minerals and materials can be identified which has been shown to be very useful information to forensic enquiries in certain cases [6]. However, to suggest that it is possible to type the quartz grains in a way comparable to the technique that we present in our paper [1] is mistaken. We agree that the ...additional information about specific micro-textural features can be obtained from the SEM, but the point of our paper is not only to present the different quartz features that can be identified, but also to provide a classification system for the quartz grain types and a database which enables the presence of those quartz grain types to be interpreted meaningfully in an exclusionary manner and presented appropriately to the court. Without a database to provide a context for the results derived from the techniques that Pye suggests, these analyses can only ever be merely descriptive. This also applies to the information generated from the BSE mode of the SEM; a wealth of information can be generated but crucially for application to forensic casework, descriptive analysis can have limitations. Whilst in a particular case such a technique may prove to be diagnostic and highly useful, it can not be applied to all cases without great caution and appreciation of the different philosophical approach of the geosciences and forensic geoscience [7]. Indeed, each new case must be approached afresh in a way that is sensitive to the requirements of the case and that takes into account the type of samples presented for analysis.

Consider Physical evidence cannot be wrong; it cannot perjure itself, it cannot be wholly absent. Only in its interpretation can there be error. Only human failure to find, study and understand it can diminish its value ([27] p. 2). We do not challenge the potential for accuracy or precision in the analysis by the techniques that Pye outlines here, but we do wish to highlight a crucial point for geoforensic analysis that it is in the interpretation of results that there can be potential for error as Kirk so famously pointed out. In our paper [1] we presented an analytical technique that has been well established in the geological literature and provide the means for it to be successfully applied to forensic soil and sediment samples such that it adheres to the fundamental tenets and philosophical approach of forensic geoscience [7].

The classification system enables operators to identify important features of the quartz grains and the database allows the results of such analysis to be interpreted in the context of an exclusionary investigation. There is also potential for the database to be used to aid so-called 'seek and find' operations where the geological basis for the classification system can be interpreted to predict the provenance of the soil/sediment under investigation. This grain typing is therefore groundbreaking in terms of its scope and diagnostic capabilities. This is not to say that there will always be appropriate materials at a crime scene to undertake this analysis, but where there is soil or sediment that has been transferred, this technique and database provide the potential for highly meaningful comparative exclusionary analysis.

In final comment we must point out that this technique, as with many others, requires knowledge and experience in order that results can be accepted with confidence. The main aim of this technique is to exclude. This technique, together with any other geoscience-based forensic technique should never be used to match or to suggest that '...a sample almost certainly did come from a location of interest' ([28] p. 60). Such an approach would be fundamentally and philosophically wrong.

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