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SHORT NOTES

Accretionary lapilli-filled clastic dykes: a comparison of compaction strain estimates from dyke folding and lapilli shape factors

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Abstract—Within pyroclastic and tuffaceous sediments of the late Archaean Fortescue Group, Western Australia, small-scale clastic dykes have been infilled by accretionary lapilli. This unusual occurrence allows quantification of compaction by two independent means using the folded nature of the dykes and the shape factors of the accretionary lapilli. The dyke-fold method consistently gives a much lower estimate of the compaction strain than the accretionary lapilli. Two dykes giving shortening of 20 and 2% by the dyke method both contain accretionary lapilli recording 40% compaction.

INTRODUCTION

There are many records of clastic dykes in the literature (see Dionne & Shilts 1974, for a cross-section of citations). The majority of infills are sandstone, but range from conglomerate to mudstone. This paper describes unusual clastic dykes with infills of accretionary lapilli. Many authors (e.g. Donovan & Foster 1972) have used clastic dykes as compaction strain gauges. The strain is usually quantified by comparing the dyke median line length (original length) with the present length perpendicular to bedding; more sophisticated analyses take into account fold flattening components. Calculations of original sediment volume and porosity are then possible although the dyke method appears often to fall short of expected values (Donovan & Foster 1972). The locality described provides the first record of dykes containing compaction sensitive markers which allow an independent measure of the compaction strain.

REGIONAL SETTING

The specimens described are from the late Archaean Fortescue Group, Hamersley Basin, Western Australia, which was deposited in the age range 2.8 to 2.5 Ga (Compston *et al.* 1981). The Fortescue Group is mainly composed of mafic lavas, sills, and pyroclastics, whilst all terrigenous sediments in the group show a tuffaceous component (Gee 1979). Within the group there are two extensive horizons characterised by accretionary lapilli, one having a 500 km strike length and the other occurring over 200 km (Trendall 1965).

The locality described (119°46′E, 22°5′S) is along the northern margin of the Hamersley Basin where the Fortescue Group forms a cover sequence to the Archaean granite–gneiss–greenstone terrain of the Pilbara Block (Gee 1979). These two tectonic elements comprise the Pilbara Craton and Gee (1979) has reported that regional deformation increases in the cover southwards. The area of interest in this paper is within 6 km of the unconformity between the Fortescue and the granite/greenstone basement in a zone where bedding dips at a steady 5° towards the southeast. Regional tectonic effects are minimal and there are no signs of superimposed tectonite fabrics.

CLASTIC DYKES—DESCRIPTION AND STRAIN QUANTIFICATION

The dykes are tabular bodies cutting tuff beds at high angles. They usually extend about 10 cm from the source bed with an average but variable width of about 5 mm (Fig. 1). Bedding-parallel sections show a crude polygonal pattern but as the dykes are not abundant the data are limited for this plane. All dykes are folded with hinge surfaces sub-parallel to the bedding—a style of deformation commonly attributed to compaction. The tightness of the folds is variable (cf. Figs. 1 and 2). In Fig. 2 the folds are open, rounded, and symmetrical apparently as a response to a near homogeneous host rock. This latter feature probably produces a regular initial fracture and a semi-uniform response to compaction. By contrast the dyke which crosses more than one bed (Fig. 1) shows irregular folds and thickness; some of the variations may be due to non-planar initial fracturing controlled by the bedding. If the folding was produced by buckling of an originally planar dyke, the common assumption, the overall shortening normal to the layering can be measured using the string technique (final length minus initial length; divided by initial length). A line along the mid-point of the dyke is measured and taken to be the original length perpendicular to bedding. This value is then compared with the present extent of the dyke normal to layering and percent shortening calculated. Any pre-compaction departures from dyke planarity would produce an overestimate of the strain by the above method. For Fig. 1, compaction strain measured by the dyke method is 20% and for Fig. 2 it is 2%.

Because the infilling accretionary lapilli are sensitive to compaction, they provide an alternative means of quantifying the strain. The lapilli in the dykes were measured for axial ratio and orientation, and plotted in such a way that these parameters were linked for each object. There are several strain analysis methods available for handling these data but the approach of Elliott (1970) is preferred because the nature of fabrics is more clearly displayed (e.g. imbricate, planar, unimodal, bimodal, random, etc.; see Boulter 1976). When plotted in this fashion each object is represented by a point on a polar graph; its distance from the origin is proportional to half the natural logarithm of the axial ratio and the angular distance on the graph is twice the angle the ellipse long axis makes with a reference line (Fig. 3). For the examples described, bedding was used as the reference.

The shape/orientation data for the accretionary lapilli within the dykes are presented in Fig. 3 and show a near symmetrical distribution of lapilli around bedding particularly for Fig. 3(b). In this latter case the observed pattern can be produced from an initially random fabric by a strain which has its XY plane (principal axes $X \geqslant Y \geqslant Z$) nearly coincident with bedding; i.e. of a compactional type. The strain ratio required for the transformation is 1.63 to 1. The majority of the pre-compaction ratios would have been less than 1.2 to 1 with near random orientation; elsewhere in the district this is the type of fabric generally seen in bedding-parallel sections (Boulter 1983). The overall strain type is compaction with $X = Y > Z$ and for Fig. 3(b) a shortening of 39% normal to bedding is indicated.

The example shown in Fig. 3(a) is somewhat more complicated than in Fig. 3(b) because the bisector of the population is 5° (true) from the bedding. However, there is a marked concentration of high axial ratios coincident with the bedding suggesting that compaction took place normal to the bedding and that the initial fabric was not quite random perhaps because some accretionary lapilli were aligned during infill of the dyke. As most axial ratios were probably less than 1.2 to 1 during filling, the preferred orientation would not have been high. The compaction strain ratio obtained from Fig. 3(a) is 1.66 to 1 which is remarkably close to that determined from Fig. 3(b).

The petrography of the accretionary lapilli units has been described in some detail by Trendall (1965). In the context of the present discussion the main feature to note is that the matrix to the accretionary lapilli in the dykes is richer in carbonate than the host tuffs (Figs. 1 and 2). The greater abundance of carbonate in the dykes relative to the host tuff means that the latter has undergone more compaction than the dykes which were more viscous than their hosts. In some intercalated tuffs at the same locality, sufficient carbonate was introduced very early during diagenesis to virtually prevent compaction of the accretionary lapilli (Trendall 1965). Unfortunately it is not known in the case of the dykes whether carbonation was largely early or was more progressive. The latter would mean a gradually increasing viscosity contrast between host and dyke.

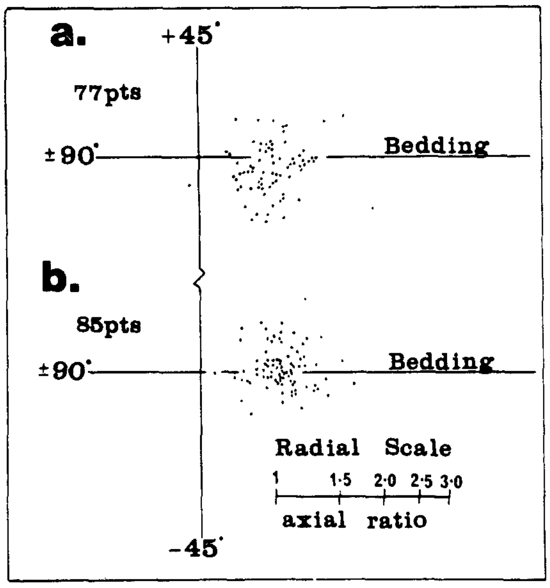

Fig. 3. Elliott polar graphs for accretionary lapilli within the dykes showing combined orientation and shape data for sections perpendicular to bedding. (a) is for the dyke in Fig. 1; (b) is for the dyke in Fig. 2. The compaction ($X:Z$ or $Y:Z$) strain ratios plot close to the centres of the populations; see text for details.

CONCLUSIONS

The main conclusion from this case study of compacted clastic dykes, and contained accretionary lapilli, is that strain estimates on dykes alone can be considerably lower than more sensitive markers. Also, preferential carbonate introduction into the accretionary lapilli tuff probably arrests/retards compaction and strain estimates based on this method may still be lower than that experienced by the host tuff.

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REFERENCES

Boulter, C. A. 1976. Sedimentary fabrics and their relation to strain analysis methods. *Geology* **4**, 141–146.

Boulter, C. A. 1983. Compaction-sensitive accretionary lapilli: a means for recognising soft-sedimentary deformation. *J. geol. Soc. Lond.* **140**, 789–794.

Compston, W., Williams, I. S., McCulloch, M. T., Foster, J. J., Arriens, P. A. & Trendall, A. F. 1981. A revised age for the Hamersley Group. *Geol. Soc. Aust. Abstr.* **3**, 40.

Dionne, J. C. & Shilts, W. W. 1974. A Pleistocene clastic dyke, upper Chandiere Valley, Quebec. *Can. J. Earth Sci.* **11**, 1594–1605.

Donovan, R. N. & Foster, R. J. 1972. Subaqueous shrinkage cracks from the Caithness Flagstone Series (middle Devonian) of northeast Scotland. *J. Sediment. Petrol.* **42**, 309–317.

Elliott, D. 1970. Determination of finite strain and initial shape from deformed objects. *Bull. geol. Soc. Am.* **81**, 2221–2236.

Gee, R. D. 1979. Structure and tectonic style of the Western Australian Shield. *Tectonophysics* **58**, 327–369.

Trendall, A. F. 1965. Pisolitic tuffs in Western Australia. *Geol. Surv. West. Aust. Ann. Rept.*, 1964, 51–55.

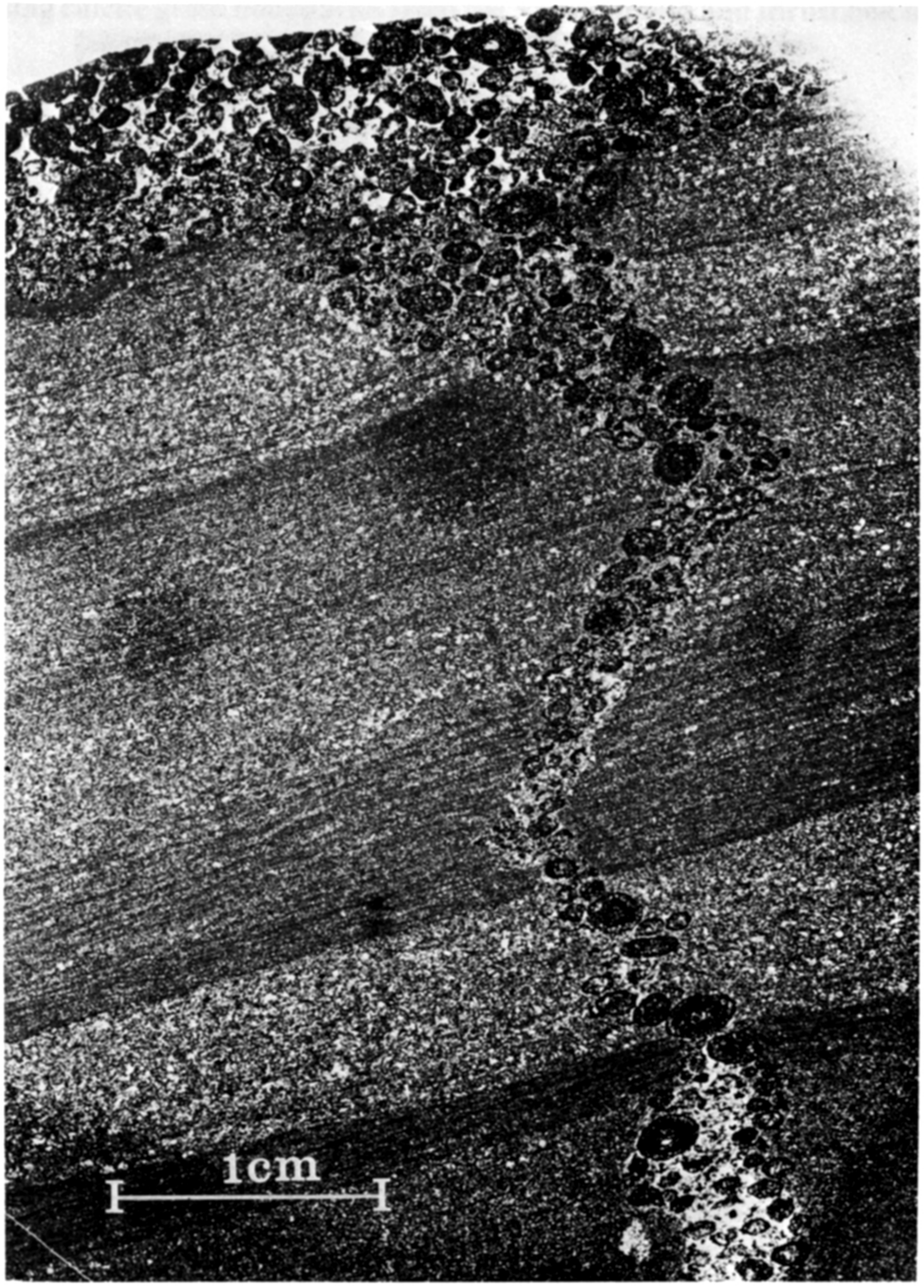

Fig. 1. A four centimetre long accretionary lapilli dyke cutting variably bedded sediment composed entirely of pyroclasts of differing grainsize. The white material between the lapilli is sparry calcite. Photograph—K. C. Hughes.

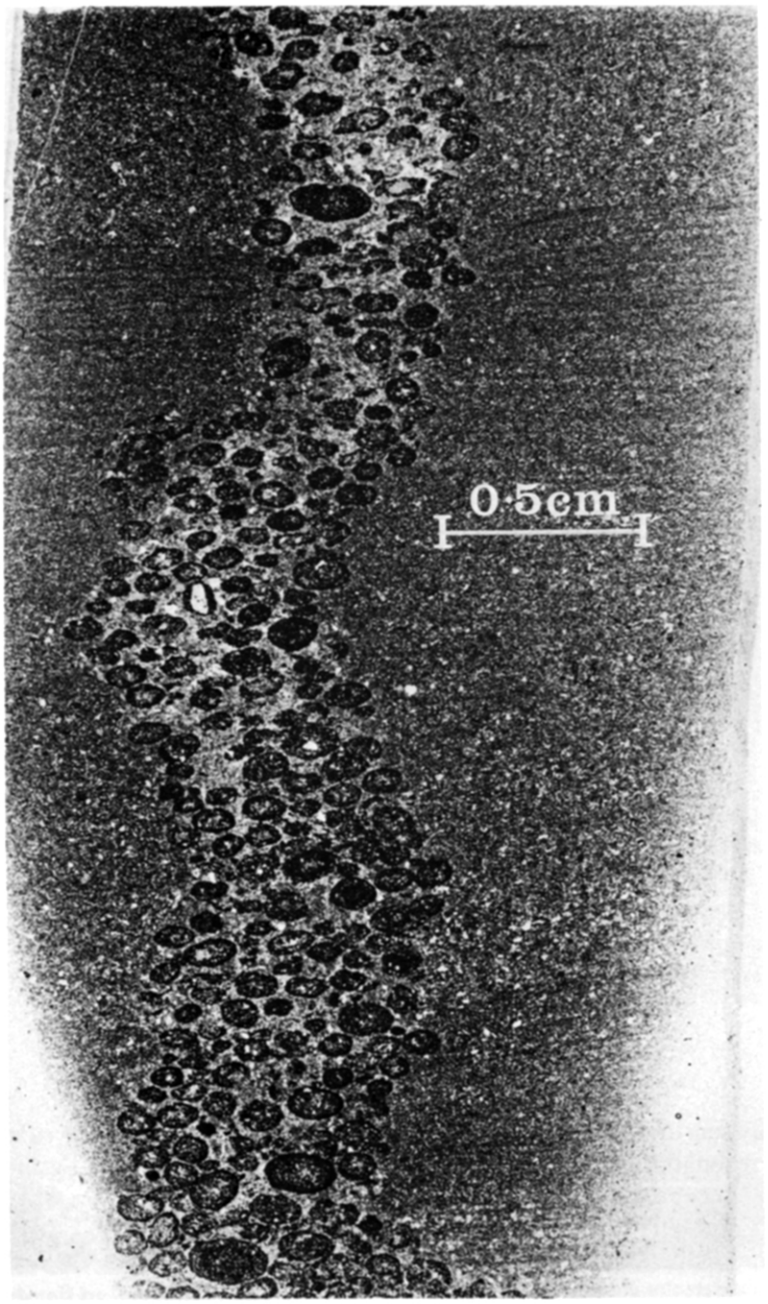

Fig. 2. A four centimetre long portion of an accretionary lapilli clastic dyke in a uniform host rock. Note the accretionary lapilli showing a strong preferred orientation subparallel to bedding. Again the lighter colour of the dyke is due to a carbonate binding agent. Photograph—K. C. Hughes.