COAL FLOTATION: THE EFFECT OF GRAIN SIZE ON RECOVERY

H. Bustamante and L.J. Warren

CSIRO Division of Mineral Chemistry,
P.O. Box 124, Port Melbourne, Victoria 3207, Australia

SUMMARY

The effect of grain size on the floatability of four selected coals of various rank and ash yields (Great Northern, Young Wallsend, Wongawilli and Bulli coals) was studied in the presence of methyl isobutyl carbinol (MIBC) as frother.

The floatability increased with decreasing size of the grains over the range 500 to 26 µm. The grain size effect was much greater for low rank coals (Great Northern and Young Wallsend) than for high rank coals (Wongawilli and Bulli).

Most of the ash yield in the concentrates was derived from mineral matter (mainly clay and quartz) present in composite grains rather than from free mineral particles. For Great Northern and Young Wallsend coals the flotation recovery was more dependent on the grain size than on the ash content of the grain.

INTRODUCTION

There are conflicting reports in the literature about the effect of grain size on the floatability of coal. Sun and Zimmerman (1950) reported that the maximum size of bituminous coal which can be efficiently floated was -6.6+3.3 mm. They interpreted the flotation of such coarse grains by means of a multi-bubble hypothesis in which several bubbles were attached to a grain. Zimmerman (1948) reported that bituminous coal floated in the following order: medium size grains down to 20 µm, then smaller size grains, then the coarsest grains. Lynch et al. (1981) measured the effect of grain size on the recovery of coal in three operating preparation plants and found that the recovery was highest for grains in the size range 70-350 µm. There was a gradual decrease in recovery as size increased from 350 to 700 µm and a more rapid decrease as the average size decreased from 75 to 20 µm.

The aim of this study was to determine the effect of grain size on the recovery, by batch flotation of four selected coals of various ranks and ash yields. The flotation was carried out in the presence of a frother only; no collector was added.

EXPERIMENTAL

COAL SAMPLES

Coal samples from four Australian collieries were selected for this study, namely, coal from Newvale colliery (Great Northern seam), from Stockton Borehole colliery (Young Wallsend seam), from the Huntley colliery (Wongawilli seam), and from Coalcliff colliery (Bulli seam). In the same order the reflectance of the vitrinites ($\bar{R}_{max}$%) were 0.74, 0.77, 0.99 and 1.26. Ash yields of all four coals are given in Table 1.

TABLE 1
Ash yields of the different coals and their concentrates after 5 min flotation.

	Ash yield (wt.%)	
Coal	Feed	Concentrate
Great Northern	23.4	10.7
Young Wallsend	32.4	13.6
Wongawilli	23.6	19.7
Bulli	15.5	8.4

TECHNIQUES

Flotation test were conducted in a 2.5 l subaeration Denver flotation cell on 250 g coal samples at 11 wt% pulp density. The following experimental procedure was used in all the flotation tests: (i) stirring of the coal in water for 5 min at 1300 rpm, (ii) addition of methyl isobutyl-carbinol (MIBC) at a dosage of 300 grams per tonne and conditioning for 1 min, (iii) collection of concentrates at four time intervals: 0-0.5; 0.5-1.5; 1.5-3.0 and 3.0-5.0 minutes. Zero time was taken as the time at which the air valve was opened. The froth was fully established a few seconds later. The concentrate from each time interval, and the total tailing after 5 min, were separated by dry screening into seven size fractions: +500; -500+250; -250+149; -149+105, -105+74; -74+53 and -53 µm. The ash yield of each size fraction was determined. The weight and ash yield of each size fraction in the flotation feed were calculated from the corresponding values for the concentrates and the tailing. It was then possible to calculate the recovery of carbonaceous matter (total weight - ash weight) from each size fraction after 0.5, 1.5, 3 and 5 min of flotation.

RECOVERY OF CARBONACEOUS MATTER

The recovery of carbonaceous matter also called "combustibles" (Lynch et al., 1981) from each size fraction of all four coals is given after 0.5, 1.5, 3 and 5 min flotation as a function of the average grain size of each size fraction (Figs. 1-4). For the fraction +500 µm, the average size was taken as 500 µm; for the fraction -53 µm, the average size was taken as 26.5 µm. All sizes refer to screen apertures, not to hydrodynamic sizes.

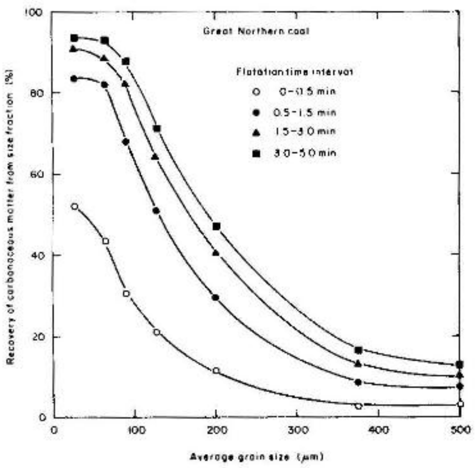

FIG. 1
Effect of grain size on the recovery of carbonaceous matter from Great Northern coal.

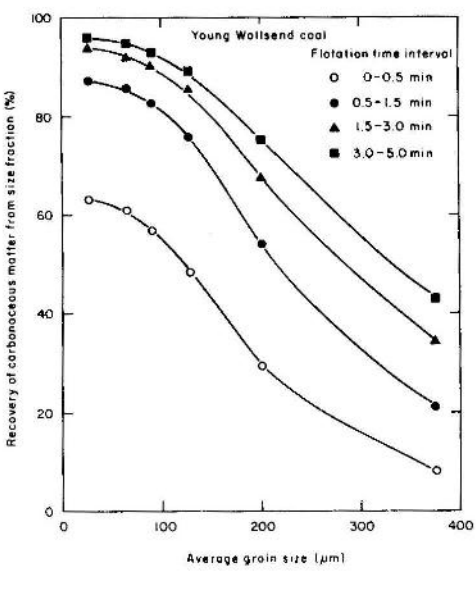

FIG. 2
Effect of grain size on the recovery of carbonaceous matter from Young Wallsend coal.

For each of the coals, the flotation recovery increased as the grain size decreased from 500 to 26 μm. This recovery-size relationship was found to hold irrespective of the time of flotation, except for an apparent dip at 64 μm in the recovery-size curves for Wongawilli coal after 0.5 and 1.5 min flotation (Fig. 3). (At present we are studying the flotation of the fine fraction of Wongawilli coal in more detail).

Grain size had a pronounced effect on the recovery of Great Northern and Young Wallsend coals (Figs. 1, 2) but only a slight effect on the recovery of Wongawilli and Bulli coals (Figs. 3, 4). Thus, in the flotation of Young

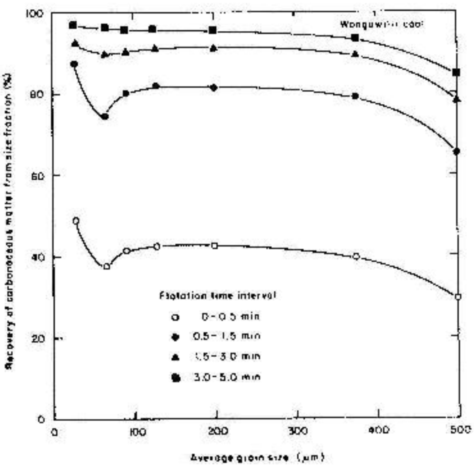

FIG. 3
Effect of grain size on the recovery of carbonaceous matter from Wongawilli coal.

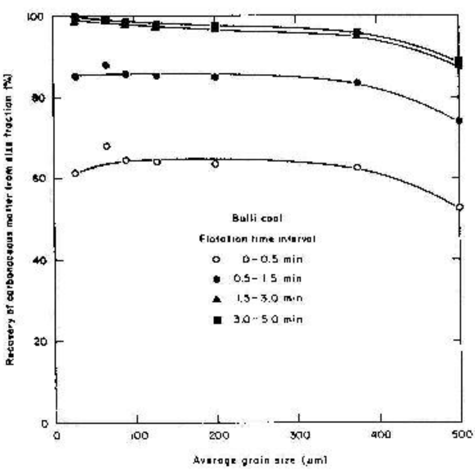

FIG. 4
Effect of grain size on the recovery of carbonaceous matter from Bulli coal.

Wallsend coal with MIBC as frother and no collecor, recovery of carbonaceous matter after 5 min flotation fell from 95 to 43% as grain size increased from 26 to 375 μm. Under similar conditions, and over the same size range, recovery of Wongawilli carbonaceous matter only dropped from 97 to 93%.

DISCUSSION

SHAPE OF RECOVERY-SIZE CURVES

Our recovery-size curves, obtained from laboratory batch tests with no collector, show a trend towards increasing recovery with decreasing size over the range 500 to 26 μm.

For the high-rank Wongawilli and Bulli coals, this increase in the recovery of carbonaceous matter was quite small (Figs. 3, 4). Lynch et al. (1981, p. 46), in their studies on high-rank coals treated at the coal preparation plants at Blackwater, Goonyella and Peak Downs in Queensland, Australia, also found that the recovery increased gradually as size decreased from 500 to 100 μm. However, below 100 μm Lynch et al. reported a fall in the recovery of combustibles whereas we observed a further small rise in recovery.

Trahar (1981) reported that hydrophilic minerals such as quartz can be recovered in the concentrate by entrainment rather than by genuine flotation. Such a recovery by entrainment is very dependent on particle size and gives rise to characteristic recovery-size curves in which the recovery steadily increases with decreasing particle size. The shapes of the recovery size curves for Great Northern and Young Wallsend coals seem to follow this trend. However, tests on Great Northern coal suggest that it is being recovered primarily by flotation. When the coal was conditioned with 0.2 kg/t of sodium dodecyl sulfate (SDS) before flotation, total recovery of carbonaceous matter dropped from 47% to 22%. Evidently the SDS was acting as a depressant, reducing the hydrophobicity of the coal surface and thereby reducing its floatability. If the coal were being recovered entirely by entrainment in the interbubble water, changes in the surface chemistry of the grains would not be expected to have much effect on the recovery. Also entrainment of quartz (s.g. 2.65) only becomes significant for particles finer than ~30 μm (Trahar, 1981). If we assume that the corresponding critical size below which coal grains will be recovered to a significant extent by entrainment is given by the diameter of a coal grain which has the same Stokes' settling velocity as a 30 μm quartz particle then this diameter can be calculated from eqn. [1]:

$$\frac{d^2_{coal}}{d^2_{quartz}} = \frac{\rho_{quartz}-1}{\rho_{coal}-1} \qquad \ldots[1]$$

where d_{coal} = diameter of coal grain with same Stokes settling velocity as a quartz particle of diameter d_{quartz}

ρ_{quartz} = s.g. of quartz

ρ_{coal} = s.g. of coal

If the value of ρ_{coal} is taken as 1.3 and that of ρ_{quartz} as 2.65, then

$$d_{coal} = 2.35\ d_{quartz} \approx 70\ \mu m \qquad \ldots[2]$$

On this basis coal grains larger than ~70 μm should not be recovered to any significant extent by the process of entrainment and their presence in the concentrates can be ascribed to genuine flotation.

EFFECT OF RANK ON RECOVERY-SIZE CURVES

The value of the vitrinite refectance of a coal is an accurate index of the rank of the coal and is largely uninfluenced by petrographic variations (Davis, 1978). According to the reflectance values given above, rank increases in the order Great Northern < Young Wallsend < Wongawilli < Bulli, with Great Northern and Young Wallsend both being of lower rank and Wongawilli and Bulli both being of higher rank. The shapes of the recovery-size curves in Figs. 1-4 correlate approximately with these differences in rank. The higher the rank of the coal the wider the size range of high recovery, especially for the coarser grains.

If we assume that in our flotation tests grains were recovered mainly by genuine flotation then the total recovery (of all sizes) after a given time of flotation may be used as a first approximation to the relative hydrophobicity of the surfaces of coal grains from different samples. When the total recovery of carbonaceous matter was plotted against the vitrinite reflectance it was found that the recovery values increased with increasing rank (Fig. 5), indicating that the hydrophobicity of the carbonaceous matter also increased with increasing rank.

However, the correlation between recovery and reflectance was not linear and also depended on the time of flotation (Fig. 5). Some of this variability may be related to the differences in ash yield and maceral composition of the four coals.

Despite these complications, it is clear that the two coals of high rank, Wongawilli and Bulli, had a wide size range of high floatability irrespective of their ash yield or maceral composition, whereas the two coals of low rank, Great Northern and Young Wallsend, had a much narrower size range of high floatability. It would appear from these results that the rank of the coal has an effect on flotation recovery which generally overrides effects arising from the type and grade of the coal. It also appears that, within the range we have studied, the higher the rank the more

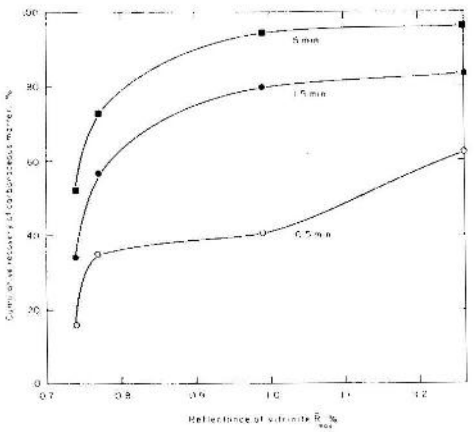

FIG. 5
Relationship between floatability and rank of the coal as measured by the reflectance of their vitrinites.

hydrophobic is the carbonaceous matter, and the larger are the coal grains which can be easily floated. This is similar to the hydrophobicity-grain size relationship observed for sulfide mineral flotation (Trahar, 1981).

LIBERATED AND COMPOSITE MINERAL MATTER

Significant amounts of ash were recovered in all four concentrates after 5 m flotation (Table 1). Liberated clay, quartz or carbonate particles would not be expected to be recovered by genuine flotation (some may be recovered by entrainment but only if they were finer than ~30 μm), and the possibility that there was a slime coating of fine mineral matter on the coaly grains of the concentrates can be discounted since ultrasonic cleaning in water of the concentrates in all size fractions, except -53 μm, did not cause any substantial reduction in the ash yields. Thus, the results suggest that much of the mineral matter in all four coals was present in composite grains with the carbonaceous matter. Some of these composite grains were hydrophobic enough to float fairly quickly and carry with them an amount of mineral matter which varied from coal to coal. The shapes of the recovery-size curves for ash and carbonaceous matter above ~90 μm were similar which is further evidence of the composite nature of the coal. Previous studies on similar samples of Great Northern and Wongawilli coals (Bustamante and Warren, 1982) showed that most of the mineral matter was present in composite grains with the carbonaceous matter.

CONCLUSIONS

1. Laboratory batch tests of four selected coals of various rank and ash yields showed that the flotation recovery in the absence of collectors increased with decreasing size of the grains over the range 500 to 26 μm.

2. The decrease in recovery with increasing grain size was much greater for the low-rank Great Northern and Young Wallsend coals than for the high-rank Wongawilli and Bulli coals. The carbonaceous matter in the high rank coals was evidently more hydrophobic and allowed larger grains to be floated more easily, giving a wide size range of high recovery.
3. Most of the ash recovered in the concentrates was derived from mineral matter present in composite grains.

ACKNOWLEDGEMENTS

This work was supported in part by National Energy Research Development and Demonstration Council, Canberra Australia.

REFERENCES

Bustamante, H. and Warren, L.J. 1982. Relation between the relative density of composite coaly grains and their flotation recovery. Paper submitted for publication.

Davis, A. 1978. The reflectance of coal. In Analytical Methods for Coal and Coal Products, ed. C. Karr, Jr. Acad. Press, 1, 27-81.

Lynch, A.J., Johnson, N.W., Maulaping, E.V. and Thorne, C.G., 1981. Mineral and Coal Flotation Circuits. Their simulation and control, Elsevier Pub. Comp. N.Y.

Sun, S.C. and Zimmerman, R.E., 1950. The mechanism of coarse coal and mineral froth flotations, Min. Eng., 2, 616-622.

Trahar, W.J. 1981. A rational interpretation of the role of grain size in flotation. Int. J. Min. Process., 8, 289-327.

Zimmerman, R.E., 1948. AIME Tech. Publ. 2397.