BENEFICIATION AND APPRAISAL OF A BEACH PLACER SAND DEPOSIT FROM MALAWI

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INTRODUCTION

The heavy mineral sand of Nkhudzi Bay, Lake Malawi, Malawi, occurs as an active beach placer deposit. The sands (which contain about 68% heavy minerals) are derived from the basement and consist of ilmenite, quartz, garnet, magnetite, feldspar and zircon, with small amounts of sphene, monazite and rutile and other minerals (Table 1). The aims of this study were to quantify the mineralogy and to determine the processing behaviour of the heavy minerals present. Ilmenite, zircon, rutile and monazite were separated using gravity, magnetic and electrostatic methods to produce concentrates and were analysed by scanning electron microscopy and electron microprobe. Monazite grains were also 'element mapped' in order to detect zoning or other intragrain element variation. The relative concentrations of elements within a grain were determined by EPMA (electron probe microanalysis) and plotted as a colour 'element map'.

BENEFICIATION

The sand was screened and the size fractions between 125 μm and 1 mm were processed. Gravity separation, using a shaking table (Mozley laboratory separator), removed most of the quartz and feldspar. The resulting heavy mineral concentrates were processed using a Carpco high-intensity induced-roll magnetic separator to obtain magnetic and non-magnetic products. The former contain high contents of ilmenite and the latter relatively high contents of zircon, rutile and monazite. Finally, a Carpco electrostatic separator, was used to process these magnetic products to give the following four products: magnetic conductive, magnetic non-conductive, non-magnetic conductive and non-magnetic non-conductive. From a combination of these, an ilmenite concentrate and a 'zircon' concentrate were produced.

Table 1 Mineralogy of Malawi beach

Ilmenite	35.0	Olivine	0.2
Quartz	25.4	Staurolite	0.1
Garnet	19.1	Pyroxene	0.1
Magnetite	7.8	Epidote	<0.1
Feldspar	4.9	Corundum	<0.1
Zircon	4.1	Cassiterite	<0.1
Sphene	1.5	Apatite	<0.1
Monazite	0.6	Perovskite	<0.1
Rutile	0.5	Wollastonite	<0.1
Spinel	0.5	Columbite	<0.1
Andalusite	0.2	Total	100.0

N.B. Figures (weight percentages) are derived from SEM analysis (with energy dispersive system) and converted to wt % by ratioing to mineral specific gravities. The chemical formulae quoted are generalised end-member compositions.

PROCESSING BEHAVIOUR

The ilmenite, zircon, rutile and monazite present in the products from electrostatic separation of the -250+125 μm size fraction were examined by EPMA in order to determine their processing behaviour.

Ilmenite is usually considered to be paramagnetic and conductive. However, in this case the processing behaviour of ilmenite was dependant on the Fe_2O_3 content. The Ilmenite that reported to the magnetic/conductive product contained an average of 48% Fe_2O_3, whereas the ilmenite found in the non-magnetic and non-conductive products had a lower Fe_2O_3 content (as low as 34% in the non-magnetic product). The lower iron content possibly accounts for the deviation from expected behaviour due to a variation in the magnetic susceptibility and electrical conductivity of the ilmenite.

Zircon is typically non-magnetic and non-conductive. The majority of the zircon reported to this product but it was also found in some conductive and magnetic products. Zircon in the magnetic product contains a small proportion of Fe_2O_3 which indicates the presence of magnetic inclusions, such as magnetite.

Rutile is typically non-magnetic and conductive (at elevated temperature, >200°C). Rutile found to occur in a non-conductive product differed from rutile in the non-magnetic/conductive product in that it had a lower TiO_2 content. This could cause a decrease in electrical conductivity sufficient enough for the rutile to report to the non-conductive product.

Monazite is typically paramagnetic and non-conductive. However the monazite from the Malawi beach sand was found to concentrate in the non-magnetic products. The monazite in these products has lower P_2O_5 and Nd_2O_5 with higher ThO_2, SiO_2, CeO_2 and La_2O3 than monazite in the magnetic/non-conductive product. This indicates that, for the monazite present in the non-magnetic products, a small amount of substitution of REE by Th has taken place, with the subsequent charge imbalance countered by replacement of P for Si. This substitution forms part of a solid solution between monazite and huttonite, $ThSiO_4$, and this could explain why most of the monazite is non-magnetic.

RARE EARTH ELEMENT DISTRIBUTION OF MONAZITE

The monazite has a rare earth element distribution which shows a typical enrichment in the light rare earth elements. The 'element maps' do not show significant elemental variation apart from a slight zoning of Ce, La, Nd and Th . The monazite has a rare earth element distribution which is characteristic of monazite from a granitic source rock and this can be seen in the comparison of chondrite-normalized REE plots).

CONCLUSIONS

The beach sand from Nkhudzi bay, Malawi contains 68% heavy minerals, mainly ilmenite and garnet, with a small amount of magnetite and zircon. Processing of the sand produced two concentrates, one containing a high proportion of ilmenite and the other with zircon, rutile and monazite. The processing behaviour of these minerals can partly be explained by variations in grain chemistries. The monazite present shows little intragrain element variation and has a typical rare earth element distribution for monazite from a granitic source rock.

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