

SYNOPSIS

The project has progressed well, from a technical standpoint.

With completion of additional separatory tests and supporting assays, detailed characterization of the Delta resource is now finished. New results, though broadly agreeing with others obtained in the past, enlarge upon those and, more important, finally provide an acceptably representative picture of physical and chemical properties of the Delta's valuable components.

The data confirm earlier indications that recoverable fractions of the reserve's sulphur, cobalt, copper and precious metals are sufficient to sustain profitable exploitation. Cottesloe has already identified applicable, commercially-proven recovery methods.

A comprehensive review of possibilities of producing sulphur at other mining centers in Australia and New Zealand shows that the Delta deposit still stands in the forefront of those on which a domestic industry of this kind might be founded. There is ample justification for its foundation, given probable demand for the commodity over the long term, and today's reliance by Australia and its neighbors on sulphur imported from North America.

Further advance of the project has been delayed, however, by problems -- both within the Commonwealth and overseas -- arising from near-global recession. Cottesloe's prior plan for development of the Delta reserve as a whole has encountered difficulties, potential partners being reluctant, temporarily at least, to commit themselves to ventures requiring substantial capital investment.

Cottesloe has formulated a new plan, in response, calling for staged exploitation. It is proposed to confine first stage operations to the shoreward fourteenth of the Delta's mass. This sector would be mined either by Cottesloe and partners or, if more economical, under contract. Similarly, concentrating would be undertaken by Cottesloe, or on a toll basis. Concentrate would be sold without further treatment.

Some 7,000,000 tonnes of sediment are involved. Yield would be about half-a-million tonnes of pyritic concentrate containing 200,000 tonnes sulphur, 3,000 tonnes copper, 400,000 kg cobalt, and 400 kg silver/gold: Total value, in place, at current prices, approximately A \$72,000,000: estimated production cost, \$25/tonne concentrate.

This first stage in the revised programme can be begun fast, for it needs comparatively little capital and preparation. Dredging projected will remove all visible and shallow sections of the Delta, and partly re-open the King River channel. Extracting toxic components of the tailings and transferring cleaned residue to the deep-water floor of Macquarie Harbour will greatly reduce quantities of sediment at present remobilized by floodwaters and chop and then spread in suspension across much of the bay.

$$\begin{aligned} & \$25 \times 200,000 \\ & = 5,000,000 \end{aligned}$$

If Stage One proceeds successfully and economic conditions improve enough to warrant continuation and expansion of the project, a second stage will be embarked upon. This provides for mining the entire Delta, full treatment of concentrate, and ultimately for production of elemental sulphur and sulphur chemicals.

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I

TESTS

Objectives of lab work undertaken on sediment of the King River Delta during the 1991/92 report year were threefold

- to determine contents of valuable and of poisonous elements present in minor amount
- to size sulphide components
- to prepare a bulk sample of the heavy mineral fraction

Information on minor elements is needed to complement results of studies described in the previous report of this series in which data tabulated illustrate concentrations attained by valuable elements present in greater quantity.

Above certain levels some useful minor elements - silver for example - can be recovered by the same processes which extract principal target materials. Such byproducts boost overall value of sediment treated, in effect partly paying for mining and processing. By contrast, other minor elements, if concentrate is enriched in these, may interfere with efficient, economical performance of extractive methods employed, as well as contaminating waste discharges.

Size data on the sulphide fraction of Delta sediment are required in designing procedures allowing optimum separation of sulphidic and barren particles. Grain size distribution figures again are required in determining how concentrate will respond to subsequent stages of treatment such as leaching or smelting.

A bulk sample of Delta sediment's dense components provides feed from which to prepare concentrates of pyrite, barite or monazite for instance - concentrate which may be wanted for any hydrometallurgical or pyrometallurgical testing commissioned in future.

Sample

Sediment used in the lab work was selected from that given to Cottesloe by a previous partner in the Delta enterprise, Planet Resources. Planet drilled the shoreward fifth of the Delta's area, the section with its top generally above water. The wedge involved constitutes about one-fourteenth of the Delta's total mass. Holes were sited at 250-m centres on a NS/EW grid: see Figure 1. Each metre of every hole was sampled and assayed separately, but Planet made no distinction in overall grade determinations between samples in Delta materials proper and the many that wholly or in part represent barren, underlying sediment.

Figure 1 Composite KDC: Source auger holes
King River Delta, Macquarie Harbour

5 Hole number
E Revised designation

- 1 A
- 2 B
- 3 C
- 4 D
- 5 E
- 6 F
- 7 G
- 8 H
- 9 I
- 10 J
- 11 K
- 12 L
- 13 M
- [14 N]
- 15 O
- 16 P
- 17 Q
- 18 R
- 19 S
- 20 T
- 21 U
- 22 V
- 23 W
- 24 X
- 25 Y
- 26 Z

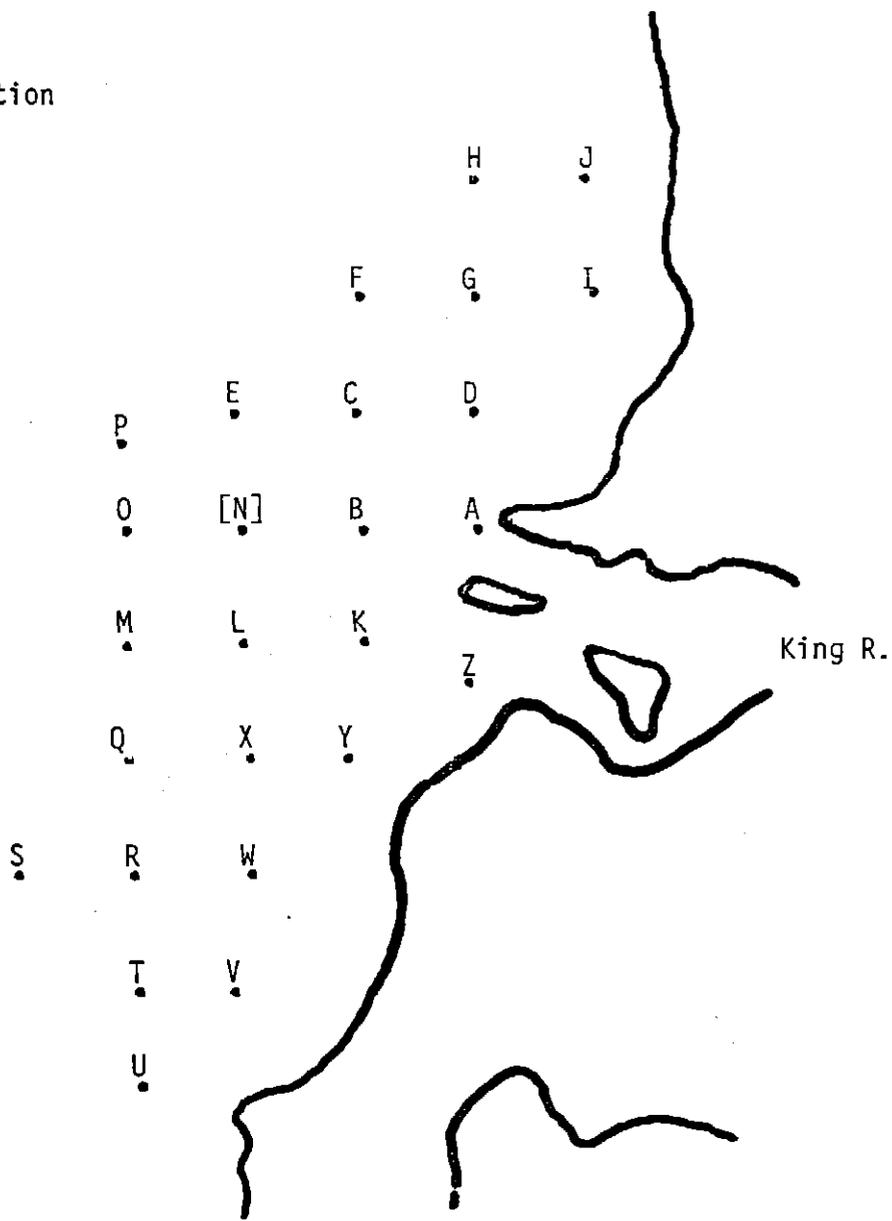


Table 1 Components, Composite KDC: KDC represents inshore fourteenth of King River Delta, Western Tasmania

Auger Hole		Thickness in metres, & no. of 1-m samples taken			
Planet number	Figure 1 designation	Layer KDY	Layer KDB	KDY/KDB	Total
1	A	1		1/0	1
2	B	1	1	1/1	2
3	C	2		2/0	2
4	D	1		1/0	1
5	E	5		5/0	5
6	F	1		1/0	1
7	G	1		1/0	1
8	H		1	0/1	1
9	I		1	0/1	1
10	J		1	0/1	1
11	K	1	3+	1/3+	4
12	L	1	2+	1/2+	3
13	M	2	6+	2/6+	8
14	N	1	4+	1/4+	5
15	O	9	4+	9/4+	13
16	P	8	7+	8/7+	15
17	Q	3	2	3/2	5
18	R	1	4	1/4	5
19	S	4	8+	4/8+	12
20	T		4	0/4	4
21	U	2		2/0	2
22	V		1	0/1	1
23	W	1	1	1/1	2
24	X		6+	0/6+	6
25	Y	?		?/0	≤1
26	Z	1		1/0	1
Holes		20	17	20/17	26
Samples		46	56	46/56	102

6+ = minimum thickness: hole unbottomed

Cottesloe has since classified the samples to reflect this layering: ref. 1989/90 Report. The four layers are

KDY upper; partly exposed and oxidized
 KDB lower; submerged, reducing conditions
 KDG basal; comprised of KDB & KDP material
 KDP sub-deltaic

For the minor element study and other tests described, a composite sample KDC was used: it embodies all Planet material from the two purely deltaic layers. Specific drill holes and intervals from which sediment forming the composite derives are listed in Table 1. Composite KDC is composed of portions of two other composites, KDY & KDB, made previously. In KDC they are mixed in the proportion 44:56, as composite KDB comprises about 56% of the Delta section represented by KDY plus KDB. This section is 5.6m thick, has an area of 1.14 sq. km, a volume of 6,375,000 m³ and, at a density of 1.15 mt/m³, a mass of 7,331,000 tonnes: ref. 1989/90 Report.

Separations

A private contractor was employed to prepare composite KDC, carry out the sulphide separation and screen the flote product.

All 1,500 g of KDC were subjected to flotation, with this result.

Product	Mass%
Flote	7.79
Sink	92.21

The flote product was sized. Table 2 shows the outcome. For comparison the table includes an estimate of size characteristics of Composite KDC as a whole. The estimate was prepared from size distribution data for KDC's component samples, KDY & KDB, given in last year's annual report.

Table 2 Sizing

Microns		KDC Flote Product		Microns	KDC Flote + Sink	
		Mass %	Cum.%		Mass%	Cum.%
	+300	1.4	1.4			
-300	+150	17.3	18.7	+150	50.4	50.4
-150	+75	35.0	53.7	+75	33.8	84.2
-75	+38	23.8	77.5	+38	7.2	91.4
-38		22.5	100.0	-38	8.6	100.0

Inspection of the figures shows that the coarser half of the Delta sediment carries less than a fifth of its sulphide. Rejecting > 150-micron material would confine 81.3% of all sulphide to 49.6% of the sediment mass. Pre-concentration of this type may be accomplished fast at low cost simply by screening or by cycloning sediment dredged. Recycling products would yield an even higher proportion of sulphide in a yet smaller fraction of headfeed.

Analyses

Screened products were recombined and submitted to Analabs for chemical tests. In addition, an aliquot of material representing the sulphide flotation's sink product was submitted.

The twelve minor or otherwise relatively unimportant elements investigated are

Ag, As, Bi, Cd, Ce, Cr, Mo, Ni, Pb, Sb, Se, Zn

As the lab responsible for these latest tests is not one of those employed in earlier phases of the Delta study, it also was required to determine contents of the six main target elements, Au, Ba, Co, Cu, Fe, & S, for each of which reliable assay figures exist already.

Ignition losses had not been measured before so a couple of these determinations were requested too.

Tests were run on both flote and sink products of KDC to depict the way in which each element is partitioned between sulphide and non-sulphidic fractions.

Results

Results of the chemical tests are presented in Table 3. Analabs' reports are attached as Appendix A.

Figures for gold, barium, copper, cobalt and iron match reasonably well those obtained previously by Mines Department Laboratories. This correspondence confirms both reliability

Table 3 Chemistry, Composite KDC: sample represents inshore wedge of King River Delta, Tasmania.

Method	Unit	Element	Detection minimum	Calc. head	Sink product	Flote product	Crustal abund.	Flote/crust	Distrib: % floted
Aqua reg/AAS:Sink Fire/AAS:Flote	ppb	Au	20 SP 8 FP	110 (136.4)	50	814	4	203	57.8
ICP/MS	ppm	Ag	0.1	1.7	1.29	7	0.1	70	31.6
	ppm	Bi	0.1	3.5	1.74	23.7	-0.2	118	53.6
	ppm	Cd	0-1	3.9	3.78	5.49	0.2	27.4	11.0
	ppm	Mo	0.1	49	43	122	1	122	19.3
	ppm	Sb	0.05	6.5	5.53	17.3	0.2	86.5	20.9
ICP-OES	ppm	Ba	5	2,995 (2,690)	3,240	88	400	0.2	0.2
	ppm	Cu	5	1,585 (1,617)	1,220	5,910	45	131.3	29.0
	ppm	Ce	15	207	210	165	46	3.6	6.2
	ppm	Co	5	79 (79)	22	760	23	33	74.5
	ppm	Cr	10	52	49	93	200	0.4	13.8
	ppm	Fe	1000	71,800 (70,884)	50,200	327,000	50,000	6.5	35.5
	ppm	Ni	10	70	58	215	80	2.7	23.8
	ppm	Pb	5?	372	355	579	15	38.6	12.1
	ppm	Zn	5	729	693	1,150	65	17.7	12.3
Hydride gen	ppm	As	1	31	18	190	2	95	47.1
	ppm	Se	0.1	1.2	0.8	6.1	0.09	67.8	38.8
Leco	%	S	100	3.3 (3.12)	0.44	37.2	0.052	715	87.6
Gravimetric		L.O.I.	0.01	5	3.3	25.25			

() values determined previously by Mines Labs

of the earlier results and the calibre of all recent work, from sulphide flotation to Analabs' assaying.

Note that besides running 37.2% S & 32.7% Fe, each tonne of sulphide flote product carries 5.9 kg copper, 0.76 kg cobalt and 0.8 g gold. Contents of other useful elements examined are: zinc, 1.15 kg/t; lead, 0.58 kg/t; silver, 7 g/t. Contents of potential contaminants are: arsenic, 190 g/t; antimony, 17 g/t.

The cerium content - with that of lanthanum, quite elevated - is of less interest than it might appear because the Delta's monazite, chief host of cerium, commonly is fine-grained, locked, and thus for the most part irretrievable.

Relative to crustal abundances 13 of the elements investigated display some concentration: sulphur, over 700 times; gold, 200 times; copper, molybdenum, bismuth, arsenic, antimony, silver and selenium, 100 ± 32 times; lead, cobalt, cadmium and zinc, 28 ± 12 times.

Mineral composition of the sulphide flote product appears to be approximately 68.4% pyrite, 0.4 limonite, 1.7% chalcopyrite, 0.2% sphalerite, 0.1% galena, 29.2% other sulphides and impurities. This assumes all copper to be resident in chalcopyrite, all zinc in sphalerite and all lead in galena. } 77
doubtful

The unidentified fraction might comprise the 25.25% L.O.I. plus 3.98% mineral matter except that there is no obvious host for much combined water. Limonite derived from and encrusting pyrite isolated in flotation is a candidate, but there is not enough surplus iron to yield more than the 0.4% limonite listed above. The L.O.I. figure could include 18.26% sulphur - the labile half of all pyritic sulphur - plus 6.99% combined water; but this would again leave composition of almost 30% of the flote unknown. That locked and entrained non-sulphides should constitute over a quarter of the product's mass seems too high [even when impurities clearly are present: for example, cerium figures show the flote carries 80% as much monazite as the sink product, though in theory none should have reported to KDC's sulphide fraction].

In full scale treatment of Delta sediment where economics would not permit all material dredged to be floted but instead would limit this step the pre-concentrate prepared by purely physical means, higher recoveries of sulphide and associated cobalt, copper and gold are achievable. Extracting sediment by suction cutter dredge, circulating the material through series of screens and cyclones, then transferring resultant pre-concentrate ashore are steps which each separate particles, reducing subsequent entrainment. In the flotation stage to follow, results would improve further

- by re-screening pre-concentrate and feeding different size fraction to separate flotation cells, further diminishing chances of entrainment
- by starting with richer feed - metal contents in pre-concentrate being substantially above those of untreated sediment typified by composite KDC

- by adjusting standard flotation chemistry used in present tests to meet characteristics of Delta pre-concentrate specifically
- by incorporating recent advances in flotation technology.

Percentage of sulphide minerals in KDC material as a whole, derived from head values obtained by Analabs and government laboratories are

pyrite	5.57
chalcopyrite	0.21
covellite	0.13
sphalerite	0.11
galena	<u>0.04</u>
total	6.06

An estimated 55% of all Delta copper appears to be secondary, occurring as thin films of covellite (?) plated indiscriminately on most mineral components of Delta sediment. The primary 45%, in chalcopyrite, is that reporting in gravity separation to the sediment's densest fraction: see '90/91 Annual Report. Sulphide flotation captures only two-thirds of the chalcopyrite, the remainder presumable being locked with non-sulphide particles. Despite this, copper grade of the flote product exceeds the average grade, in situ, of US porphyry copper deposits. Also, major costs in treating porphyry ores - mining, crushing, grinding - already have been met, in the case of sulphide recoverable from the Delta.

Comparing sulphide floated with total sulphide in Delta sediment shows a bare 9% remaining uncaptured. In the case of pyrite, flotation retrieved 95.7% of it. Two percent of all Delta sulphur is lost to the sulphate form as barite.

Elements present in the Delta's sulphides in subordinate amount are likely to be divided thus (sole or principal sites underlined)

in pyrite	<u>Co</u>	Au	<u>As</u>	Se	Ag	Cu	<u>Ni</u>			
in chalcopyrite		<u>Au</u>		<u>Se</u>	<u>Ag</u>					
in sphalerite		Au			Ag			<u>Cd</u>		
in galena		Au		Se	Ag	Cu		Cd	<u>Bi</u>	<u>Sb</u> Zn

Mo, Cr, Ce and Ba are believed to be confined to molybdenite, chromite, monazite and barite respectively.

On the basis of recent commodity prices, and the U.S. to Australian dollar exchange rate of 31 Dec. 1991, components of the sulphide concentrate have these values, approximately:

Co	A\$ 71
S	34
Cu	19
Au + Ag	<u>13</u>
Total	137

Other components of possible value are iron, and zinc/lead, respectively worth about \$20 and \$2.50 per tonne of pre-concentrate. Iron is reclaimable as an oxide, running approximately 67% Fe, in smelting pyrite.

At operating scale, recirculation and other refinements in separatory procedure would raise sulphur and metal grades and recoveries above those obtained in tests so far. This should increase value of sulphide concentrate shown by 5%, say.

Secondly, much of the cobalt, copper and gold remaining in the sink product of sulphide flotation of pre-concentrate may be recovered in a subsequent step aimed at isolating ferruginous components - principally limonite - formed at the Delta from and around particles of pyrite and chalcopyrite.

About 12.5 tonnes of Delta sediment yield 2 tonnes of pre-concentrate which, in turn, contain 1 tonne of recoverable sulphide.

Costs of extracting and processing Delta sand and silt - essentially pre-milled unconsolidated ore, already stacked, in water - are low. At 1991 rates dredging, gravity separation and sulphide flotation amount to A\$1.93/mt., that is, to \$24.19/mt concentrate.

Though we will not recapitulate here detailed economics given in the 1989 Retention Licence Application, the difference of \$112/tonne between the listed concentrate value and its preparation cost is considered great enough to absorb such negative factors as high recovery losses, smelting, refining and marketing expense, and lower commodity prices without eliminating the potential for profit.

environmental management

The inner fourteenth of the King Delta represented by Composite KDC will yield approximately 540,000 tonnes of concentrate. This yield assumes the same recovery rate as that of the recent flotation test and takes no account of improvements to it likely at operational scale. The yield also assumes a 5% sediment loss in extraction.

Such concentrate would contain some 400,000 kg cobalt; 3,000,000 kg copper; 900,000 kg zinc/lead; 3,750 kg silver; 400 kg gold; 200,000 tonnes sulphur; and sufficient iron to generate one-quarter million tonnes oxide. Value of the cobalt, copper, gold and sulphur, after deducting costs of dredging and pre-concentration is about \$60,000,000

II

SULPHUR

Cottesloe's study of the feasibility of establishing an Australian sulphur industry based on production of the elemental form from pyritic waste continued. In light of this additional work the concept looks more favourable than ever. Adequate supplies of feedstock are available at low cost, a commercial process with a profitable production history has been found and is available under licence. There is a substantial market for elemental sulphur both within Australia and in neighbouring countries. An industry set up to supply it would not only cut imports of sulphur, reducing the nation's overseas trade deficit but, once yielding a surplus for export, could generate foreign earnings as well.

With steep rises in sulphur price over the last twelve to fifteen years the annual cash outflow occasioned by Australia's sulphur purchases abroad has greatly increased. For 1974 the average value of imported sulphur F.O.B. overseas ports was A\$21.09/mt. By 1986, twelve years later, the figure stood at \$185.90 per tonne, 781% above the '74 value. As Australia generally imports at least 400,000 tonnes of sulphur a year - imports over the decade 1981 through 1990 averaged 427,000 tonnes per year -- the amount paid for the commodity overseas annually is considerable, \$53,000,000 in 1989 for example.

Per capita, New Zealand's sulphur consumption is even higher, approximately 50 kg per head of population per year versus 25 kg per head annually for Australia. Like Australia, New Zealand meets nearly all its needs with sulphur imported from North America. The nation's sulphur imports over the 1981/90 period averaged 161,000 mta, about 38% of Australia's.

Cumulatively, quantities imported and cash outlayed abroad in payment are substantial. Since early 1980 the two countries jointly have brought in over 7,000,000 tonnes of sulphur. Despite lower prices prevailing over the first four or five years of this span, the total spent on these purchases overseas is estimated to exceed two-thirds of a billion dollars, exclusive of insurance and trans-Pacific shipping costs. The latter add roughly \$20 per tonne to sulphur transported from Vancouver to Auckland or Brisbane. Customs charges further increase landed prices.

Table 4 lists sulphur imports by Australia and New Zealand in recent years and provides some data on unit value.

Table 5 gives an indication of the quantities of sulphur produced and imported by several SE Asian countries. Figures are for 1985 or 1986 only but are reasonable representative of any recent year. Countries listed are in the same predicament as Australia and New Zealand, lacking significant revenues and production of sulphur and having to import essentially all they use from North America - chiefly from Canada.

Table 4 Sulphur imported by Australia and New Zealand

YEAR	AUSTRALIA			NEW ZEALAND TONNES ³
	TONNES ¹	VALUE ² A\$,000	VALUE A\$/TONNE	
1974	685,282	14,451	21.09	
1975	281,757	7,534	26.74	
1976	205,766	7,408	36.00	
1977	407,675	12,8743	31.58	
1978	496,804	16,042	32.29	
1979	436,221	19,807	45.41	
1980	686,857	45,701	66.54	275,000
1981	555,517	42,807	77.06	202,000
1982	458,774	38,925	84.85	204,000
1983	392,581	32,930	83.88	182,000
1984	470,795	39,642	84.20	215,000
1985	392,344	57,863	147.48	210,000
1986	398,101	70,559	185.90	87,000
1987	379,560	55,544	146.34	110,000
1988	534,000			116,000
1989	430,000	53,552	124.54 ²	118,000
1990	257,000	27,938	108.71 ²	165,000

Sources:

¹ 1974/87 BMR; 1988/90 US Bu Mines² 1974/87 BMR; 1988/90 Australian Bureau of Agricultural & Resource Economics³ US Bu Mines

Manufacturing elemental sulphur from waste pyrite generated by its metal mines, Australia could cut sulphur imports to zero and soon produce sufficient sulphur to sell to New Zealand and other neighbours. This overseas market is approximately twice the size of Australia's internal one. Combined sulphur demand of the two markets is well in excess of 1,000,000 mta. Potentially, domestic production of sulphur could save the Commonwealth at least \$50,000,000 annually in spending abroad and in addition could generate up to, say, \$100,000,000 in foreign earnings. Shipping export sulphur in Australian vessels would produce additional overseas revenue.

Currently, about three quarters of all sulphur consumed by western economies is employed in manufacture of fertilizers. In Australia, 60% of these, particularly phosphatic fertilizers, are used by meat and wool industries on pastures and for fodder production. Winter grain farming consumes a further 25%; much of the balance goes to growing summer grains.

Although losses by wool and meat producers, falling wheat prices and adverse weather conditions have sharply reduced fertilizer use over the last couple of years, especially use of fertilizers depending for manufacture upon imported sulphur and rock phosphate, demand should soon improve. Most Australian wheatlands and pastures are phosphorus-deficient and thus rely on continual application of superphosphate to maintain productivity. Though indicative of a drop in superphosphate demand, recent closure of two Australian plants which made phosphoric acid has created openings for competitors to exploit when conditions return to normal.

In the long term sulphur consumption depicted by Tables 4 and 5 is likely to rise as global population and food requirements increase. An estimated 3,155,000,000 people or 58.6% of the world's total number live in Asia. The figure is growing by approximately 1% each year. Australia lies only 3,000 to 6,000 km away from main Asian ports and is thus far better positioned to meet many of that region's import needs - from foodstuffs to fertilizers to industrial chemicals - than any other country of advanced economy except Japan.

TABLE 5 Sulphur production and imports by Australia and other Western Pacific nations in 1985/6

		Australia	New Zealand	Indonesia	China	Taiwan	Thailand	Philippines
Production:								
Elemental								
Crude, incl. native & byproduct colloidal, precipitated, sublimed		1,000*	4,000*	300*				
Byproduct								
of metallurgy	190,000**							
of petroleum	13,000*							
all sources				300*	62,980*			
S content of pyrite	N/A		N/A	2,500*	5*	N/A	78,000*	
Imports:								
Elemental								
Crude, incl. native & byprod. colloidal, precipitated, sublimed	398,101* Δ	210,000 523	2,624 182,619	162,610 17	74,955 158,334	54,857 136	309 20,382	

* 1986 ° in acid

Sources: Mineral yearbooks, etc, US Bu Mines; Δ BMR

Note: Sulphur requirements of Malaysia, Myanmar, Hong Kong and Singapore are all met from abroad, but quantities are small.

III

COMPETITION

To identify a source which might rival that of the King Delta as one which would support domestic sulphur production Cottesloe has reviewed reserves found elsewhere in Australia and New Zealand.

Neither nation possesses salt-dome sulphur deposits. Reserves of natural gas found so far are too low in hydrogen sulphide to rank as sources of recovered sulphur. Oil refineries in Australia and New Zealand produce sulphur as a byproduct but, because of limited throughput and also the composition of crudes treated, amounts of the commodity extracted are small.

Elemental sulphur is found in sedimentary rocks of the Perth and Carnarvon Basins, WA, and at the surface of Lake Eyre, SA; but these concentrations are nowhere close to commercial scale.

Deposits of brimstone associated with an active volcanic belt occur in northern New Zealand, near Lake Taupo, and at White Island. Sulphur production from the deposits has proved difficult however. It has never exceeded 5,000 tpa, that is, about 3% of the country's average annual sulphur requirement.

Australia does have great quantities of the element available in sulphide form. Additional amounts are to be found in the sulphate, gypsum -- which, roasted with clay, yields sulphur and coproduct cement.

Extraction from gypsum is sub-economic because of clay and energy costs, and low sulphur return. Recovery from sulphides can be profitable though. In processing sulphides of copper, zinc, lead, nickel, etc. the worth of metals extracted covers smelting and all other upstream and downstream costs, so sulphurous offgases generated are free to that point. They can be converted into sulphuric acid at little extra expense.

The iron disulphides pyrite and marcasite, while generally containing only low concentrations of the more valuable metals, carry one-and-a-half to four times as much sulphur as sulphides of, say, copper, zinc or lead. Although half this sulphur is best converted to acid, the other 50% can be recovered directly in elemental state. With the right type of charge and smelting method, usable iron oxide is also produced. More bonuses may result from gold, cobalt and other elements - originally present in trace proportions - which, during smelting, become concentrated in vapour phases or in slag. A fourth benefit is that pyrite, marcasite and even the monosulphide of iron, pyrrotite, contain little of the cadmium or other poisonous elements commonly concentrated in base metal sulphides, toxins which generally are released during smelting. Principal sulphide deposits of mainland Australia are described below.

Western Australia

The larger sulphide concentrations are associated with nickel mineralisation and with that embodying gold. Most of these deposits lie in the Yilgarn Block which forms the State's southwest quadrant. The gold deposits are pyritic. The others contain both nickel and iron sulphides.

Gold is recovered at a smelter in Kalgoorlie and nickel from a smelter at Hampton, close by. Sulphur dioxide generated at these plants is wasted to the atmosphere. Cottesloe estimates that sulphur lost in emissions at Hampton over the past 24 years has averaged about 100,000 tonnes annually, equivalent to 65% of the imported sulphur Western Australia consumes each year.

At Hampton most of the dioxide's sulphur derives from pentlandite, a monosulphide. At Kalgoorlie however, the main mineral smelted - pyrite - is capable of yielding free sulphur, besides the dioxide form. We do not have figures showing pyrite content of ore extracted or the tonnage of concentrate smelted, but as annual gold production is over 10 tonnes it is likely that the sulphur content of dioxide gas liberated amounts to 25,000 tonnes per year, at least.

A deposit at Yindarlgooda east of Kalgoorlie containing an estimated 50,000,000 tonnes pyrite remains unmined. So do Archaean banded ironstones of the Yilgarn, locally enriched in pyrite.

About half-a-million tonnes of acid were produced from sulphides mined south of Kalgoorlie, at Norseman. Reserves there total approximately 1,500,000 tonnes of similar ore.

South Australia

The State has many millions of tonnes of pyrite concentrated in beds of granofels, gneiss and schist which constitute the basal member of the Cambrian Brukunga Formation. This formation occurs in a metamorphic belt east of Adelaide. The sulphidic beds have been followed along strike for over 100 km. The richest zone is exposed near Nairne. Between 1955 and 1972 some 5,400,000 tonnes of pyrite were extracted from it, at a surface pit 2 km long. Defined reserves of 32,000,000 tonnes remain in the area, extending over a 5-km strike length.

Mined ore averaged 20.6% pyrite. A concentrate running 89.6% pyrite was prepared by crushing, jigging and flotation.

Pyritic tailings remain at Wheal Ellen, Kadina, Kanmantoo, Kapunda, Dome Rock, Waukaringa, Wadnaminga and Tarcoola but quantities are comparatively small - of the order of a few tens of thousands of tonnes at most of these sites.

Victoria

Sulphide resources here are not significant.

A polymetallic sulphide body has been discovered at Banambra, in the State's eastern highlands, but is still being developed.

Sulphide-rich gold ores occur in the metamorphic belt in NE Victoria; none of the deposits exploited was large though. Most tailings carry high concentrations of arsenic.

New South Wales

Chief sources of sulphur are lead-zinc sulphides at Broken Hill and Cobar. Concentrate from mines at these centres is smelted at - respectively - Port Pirie, and Cockle Creek near Newcastle. Pyritic sulphide occurs at Captain's Flat.

The State's largest known reserves of sulphide probably are those in pyritic base metal ore at Woodlawn, west of Port Kembla.

Queensland

Great quantities of sulphide occur at mines in the northeastern half of the state

The largest amounts, whether discharged in smelter offgases, in tailings or in reserves awaiting exploitation are at Mt Isa, the world's biggest underground copper mine.

The copper ores carry a considerable percentage of pyrite. After separation the mineral is fed to tailings dams. Cottesloe has not endeavoured to find out tonnage involved, but with 6,000,000 tonnes of ore averaging more than 3% copper mined per year and reserves at this grade exceeding 150,000,000 tonnes the amount of such sulphide both available and being added annually clearly is most substantial.

According to Queensland's Minerals and Energy Centre Mt Isa's smelters waste an estimated 450,000 tonnes of sulphur dioxide to the atmosphere each year treating copper and lead concentrates.

Pyritic ore mined at Mt Morgan yielded 600,000 tonnes of copper and 300 tonnes of gold. Grades averaged roughly 0.5% Cu and 3g/t Au, indicating that over the mine's life about 100,000,000 tonnes of ore were extracted. If this ran approximately 1% pyrite there should be 1,000,000 tonnes of the mineral in tailings.

A multimetal sulphide deposit under development at Thalanga may contain localised concentrations of pyrite. So may massive sulphide bodies under investigation at several localities along the State's eastern edge.

Northern Territory

The Territory's base metal mines and gold mines generally contain pyrite. Sulphide facies of iron formations also carry the mineral; locally, concentrations within these reach 15%.

Principal gold deposits bearing pyrite are The Granites, Pine Creek, Cosmo Howley and Tanami. Zinc-lead-silver bodies containing it are those of McArthur's River and Woodcutters.

Reserves at McArthur River are extensive, exceeding 200,000,000 tonnes, but mining cannot begin unless difficulties in separating and concentrating the sulphides can be overcome; these minerals are very fine grained. A pyritic dolomitic shale unit associated with the ore horizons is over 400m thick and carries up to 20% pyrite.

Woodcutters reserves at the beginning of 1991 amounted to 3,000,000 tonnes running 23.5% combined sphalerite and galena; sulphur content, about 210,000 tonnes.

Ore reserves at gold mines listed range from 1.9 million tonnes assaying 2 g/t Au to a high of 8.8 million tonnes averaging about 3 g/t Au. If running 2% pyrite the four deposits contain approximately 250,000 tonnes sulphur.

New Zealand

Aforementioned reserves of native sulphur associated with the North Island's central volcanic belt are best developed at Lake Rotokawa. The element occurs colloiddally in fossil lake beds lying at depths of 25 to 75 metres. Sulphur content reaches 60 to 80% locally, but, for the total 50,000,000 tonnes of host sediment, averages 10% only. Crystalline sulphur was found close by, at the surface, invading pumiceous material. However, this surface resource has now been mined out.

Attempts to extract the buried sulphur have not yet succeeded, despite efforts by several companies over the last thirty years. A recent proposal envisages opencast mining and subsequent vaporisation and sublimation of the sulphur.

Pyrite concentrated in propylitised andesites at gold deposits of the Coromandel Peninsula and at low grade base metal deposits near Nelson could rank as another potential source of sulphur.

Coal is a third possibility. Sulphur content of New Zealand coal varies between 0.1 and 13.6%. Though most of this sulphur is organic, some occurs in pyrite. The James coal of the Greymouth Field has the highest content overall. Like the majority of pyritic coals it lies immediately beneath marine beds.

Summary

In summary, mainland Australia possesses great quantities of sulphur in sulphides. Principal concentrations are in auriferous and nickeliferous mines of Western Australia's Eastern Goldfields; in pyritic strata of the Mt Lofty Range, South Australia; in zinc/lead deposits of New South Wales; at copper/gold and other polymetallic mines of Mt Morgan and Mt Isa respectively, Queensland; and in pyritic shale and base metal bodies at McArthur River, Northern Territory.

Any of these sources could compete with the King Delta deposit in terms of quantity of sulphur each contains. On grounds of recoverability though, the Tasmanian reserve is considered superior; this is because of

- i mineralogy and
- ii amounts already milled and quasi-concentrated

Mineralogically, iron disulphide is a better sulphur source than sulphides of copper, lead, zinc or nickel, not only due to disulphide's greater percentage of sulphur but also because half is relatively unstable and therefore recoverable with less energy consumption than sulphur of base metal or other metallic monosulphides.

With respect to recoverability, only pyrite mined, partly separated and stored in tailings, such as that at Mt Morgan and Mt Isa, ranks with the King Delta's. The Delta however has at least five times as much of the mineral as Mt Morgan, and reserves of it at Mt Isa are remote.

Reserves at Yindarlgooda, Nairne and McArthur River while the largest, would cost too much to extract, crush and grind. Pyrite mined and roasted at Kalgoorlie is limited by grade and output of gold ore of which it is part.

Only a fraction of monosulphide sulphur released in smelting base metal concentrate is recovered, for the majority of smelters have no acid-manufacturing capability. Even if they had however, direct production of sulphur from disulphide is to be preferred, acid being hazardous to handle and ship and, on sulphur content, three times bulkier to transport than the elemental form.

Cottesloe's review of sulphur sources included investigation of those in western Tasmania from which pyrite might be obtained to augment amounts retrievable from the King Delta. Ores mined at Hellyer, Rosebery and Mt Lyell all include pyrite, most of which is separated in producing base plus precious metal concentrates.

Treatment of Hellyer ore yields about 600,000 tpa pyritic tailings from a zinc scavenger circuit. These tailings are diluted at the storage dam by admixture of material from the bulk scavenger circuit but, if useful, could be kept separate. The material runs about 64% pyrite and carries leachable quantities of lead, zinc, copper and silver. Unfortunately, it is contaminated by arsenic, reputedly to the extent of 1.2% As; antimony content is high too. The other detrimental factor is grain size, that of nearly three-quarters of the material being under 38 microns and approximately half of this fraction under 9 microns.

The finer fraction of Rosebery tailings, also, is fed to a storage dam. The material is 84% pyrite, again displaying quite high concentrations of base metals and silver; arsenic content is 800 ppm. Like Hellyer's pyritic tailings, three-quarters of Rosebery's material is under 38 microns, and almost half of that under 9 microns. The fraction in the dam exceeding 38 microns in grain size is believed to total some 1,750,000 tonnes.

From the amount present in the King Delta it appears that Mt Lyell's annual output of pyrite averages roughly 100,000 tonnes. In chemistry and grain size distribution Lyell pyrite should be virtually identical to the Delta's, described here under Section I.

Recently, Mt Lyell has been separating the mineral from other mill wastes and selling resultant concentrate abroad. The possibility of drawing on Lyell pyrite as a supplementary supply thus is somewhat questionable. Moreover, falling copper grade, depressed gold prices and the increasing cost of mining at progressively greater depth make the mine's long-term survival unlikely.

Cottesloe has investigated one more potential source of additional pyrite. Screening and gravity concentration of the host tailings yield a sulphidic concentrate comprising 5.6% of headfeed mass. Pyrite appears to make up 79.8% of the concentrate. Cobalt and gold contents are virtually identical to those of Delta concentrate, and copper about half the latter's. The quantity of pyritic concentrate retrievable from this extra source is 2,240,000 tonnes at the recovery rate of the test. Test figures indicate that grain size of four-fifths of the concentrate is between 38 and 300 microns, an acceptable distribution. It appears these tailings could be reprocessed in the same way as the Delta's, using a dredge and floating preconcentrator.

Delta pyrite treated in conjunction with that from the reserve above would yield enough elemental sulphur each 12 months for 15 years to reduce Australia's average annual import of the commodity by fully a third. Only one mainland source has comparable reserves. They are less favourably located than west Tasmania's in relation to centres of sulphur use and regions of heaviest consumption of fertilizer.

Economic downturn over the last couple of years has made it increasingly hard to fund and begin start-up ventures. This has been especially noticeable in the minerals field, where flagging demand and lower price for the majority of raw materials has discouraged both mining companies and other investors from embarking on most new projects offered.

Endeavours to replace companies which were obliged to withdraw from participation in the Delta enterprise are still in progress. The goal should be achieved under a different strategy Cottesloe has devised for the project. This modified approach involves two stages, commencement of the second being conditional upon the first progressing satisfactorily

Stage One is designed to be set up and run fast at little cost. Operations would be limited to the inshore fourteenth of the reserve, that is, to the wedge surfaced by the emergent, visible part of the Delta. This is the section re-examined via the second, more recent drilling, carried out by Planet/Cottesloe and represented by sample material KDY, KDB and KDC. The wedge contains the Delta's coarser sands and silts, amounting to 7,331,000 tonnes, and displays the highest copper grades.

Dredging followed by preconcentration aboard a trailing barge will result in complete removal of the wedge, with preconcentrate bearing most toxic components of the sediment being abstracted from it for upgrading elsewhere, and most of the residue -- cleaned sands and silt - - being redistributed on the floor of Macquarie Harbour in deep water south of the Delta toe.

It is planned to stack the balance of such residue at a corner of the Delta's existing exposed surface, just seaward of the high water mark, to create a permanently dry site for plant required if the venture proceeds beyond Stage One.

Dredging the inshore wedge will benefit the environment in several ways besides that stemming from removal of the sediment's more poisonous components. First, dust storms that commonly arise over the exposed section in dry weather and subsequently carry finer particles far afield will be prevented. Second, dredging will eliminate the source of contaminants which, eroded from the Delta by chop, are dispersed in suspension over large tracts of Macquarie Harbour. Third, re-opening upper levels of that part of King River channel buried by deltaic sediment will allow tailings clogging reaches of the channel in the gorge behind the mouth to be flushed clear.

The approach preferred at the moment is to have Stage One dredging and preconcentration carried out by contractors or tributors, and preparation of concentrate by sulphide flotation conducted at some existing plant on a toll basis. Concentrate would then be sold, as is.

While this scheme postpones production of contained metals, sulphur, acid and usable cinder,

thus reducing maximum return attainable, it has various advantages beyond the environmental three listed.

- Capital requirements are modest and in consequence should be readily provisable.
- Little or no equipment need be bought, permitting operations to be begun without much of the lead time otherwise necessary.
- Revenue generated will fund a pilot plant and studies directed at optimising metallurgical procedures for treating the remaining 93% of Deltaic and extra reserves.
- The two to three years it will take to conduct Stage One allow time for economic recovery and for resurgence of sulphur, acid and fertilizer demand.
- Many preliminary arrangements for implementing Stage Two can be completed during the course of the first stage, for instance, those concerning the extra reserve, process licence, plant design, construction estimates.

Stage Two calls for mining the other 93,000,000 tonnes of the Delta's established mass of sediment plus additional tailings laid down since the 1975 drilling and tonnage calculation. This section lies in deeper water than the Stage One reserve but its cobalt content is 50% more than the latter's. Also, less of its chalcopyrite is locked so a greater percentage is separable.

As the project is currently conceived, concentrate obtained in Stage Two would be completely processed, either by the venturers, or on their behalf, to yield sulphur, acid, and byproduct cinder and metals.

It is intended to use some of the elemental material produced to manufacture compound chemicals. Vertically integrated industrial projects of this nature are needed if Australia is to realize the full worth of at least some of its raw material output.

For example, the monohydrate form of copper sulphate, with a US price per carload ex works equivalent to A\$2.73/kg, contains copper and sulphur worth to \$1.20. Value of these raw materials thus is increased over 2¼ times by converting them to a compound. Cost of the manufacturing step involved is minor. Even if only one-quarter of the King Delta's copper is recoverable, the amount is enough to yield 87,000,000 kg of the monohydrate above, or 122,000,000 kg of the pentahydrate.

V

PROGRAMME

Implementing the first stage in progressive development and exploitation of the King Delta deposit requires several steps:

- first, completion of a revised plan describing projected mining and processing of the innermost fourteenth of the Delta mass
- second, costing this, assuming operations are conducted by
 - a. Contractors
 - b. Cottesloe
- third, collection and review of estimates by firms able to undertake the necessary dredging pre-concentration, transport, and flotation under contract
- fourth, preparation of an investment proposal describing the deposit and the mining, treatment and marketing plans
- fifth, discussions with prospective partners having technical skills needed in the venture; there are eight such companies besides the US/Australian investment group with which negotiations continue.

Individually, companies among the eight dredge mineral sands, treat tailings, separate sulphides, transport ore, buy sulphur and produce and market fertilizer.

Some of the five steps may be taken together or may overlap.

If progress so warrants, a start will be made on drafting an environmental impact statement.

APPENDIX A

027

ANALABS

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104028

ANALYTICAL DATA

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REPORT NUMBER

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CLIENT ORDER No

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05/12/91

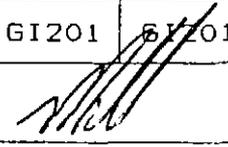
R. Harvey

1 OF 3

TUBL No	SAMPLE No	Cu	Pb	Zn	Fe	Ba	Ce	Co	Cr
1	Float. Con	5910	579	1150	32.70	88	165	760	93
2	Float. Tail	1220	355	693	5.02	3240	210	22	49
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23	DETECTION	5	100	5	0.01	5	15	5	10
24	UNITS	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm
25	METHOD	GI201							

Results in ppm unless otherwise specified
 T = element present; but concentration too low to measure
 X = element concentration is below detection limit
 — = element not determined

AUTHORISED OFFICER



ANALYTICAL DATA

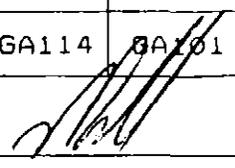
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SAMPLE PREFIX			REPORT NUMBER			REPORT DATE		CLIENT ORDER No.		PAGE	
			103300.60.08413			05/12/91		R. Harvey		2 OF 3	
TUBE No.	SAMPLE No		Ni	Ag	Bi	Cd	Mo	Sb*	As	As	
1	Float. Con		215	7.00	23.70	5.49	122.0	17.30	>100	190	
2	Float. Tail		58	1.29	1.74	3.78	43.0	5.53	18	-	
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23	DETECTION		10	0.10	0.10	0.10	0.1	0.05	1	100	
24	UNITS		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
25	METHOD		GI201	GI222	GI222	GI222	GI222	GI222	GA114	GA101	

**acid soluble*

Results in ppm unless otherwise specified
 T = element present but concentration too low to measure
 X = element concentration is below detection limit
 --- = element not determined

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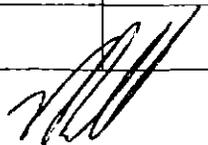
R. Harvey

3 OF 3

TUBE No.	SAMPLE No.	S	S(R)	Se	LOI				
1	Float. Con	>30.000	37.2	6.1	25.25				
2	Float. Tail	0.440	-	0.8	3.30				
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23	DETECTION	0.005	0.1	0.1	0.01				
24	UNITS	%	%	ppm	%				
25	METHOD	OM613	OM613	GA117	OM615				

Results in ppm unless otherwise specified
 T = element present, but concentration too low to measure
 X = element concentration is below detection limit
 - = element not determined

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ANALABS

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104031

030

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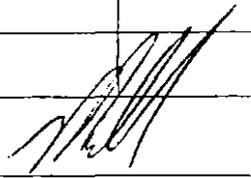
23/12/91

Verbal

1 OF 1

TUBE No.	SAMPLE No.	Au								
1	Float. Con	0.20								
2	Float. Tail	0.05								
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23	DETECTION	0.02								
24	UNITS	ppm								
25	METHOD	GG329								

Results in ppm unless otherwise specified
T = element present, but concentration too low to measure
X = element concentration is below detection limit
-- = element not determined

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03/01/92

Verbal

1 OF 1

TUBE No.	SAMPLE No	Au	Au						
1	Float. Con	0.30	0.814						
2	Float. Tail	0.05	-						
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23	DETECTION	0.02	0.008						
24	UNITS	ppm	ppm						
25	METHOD	G6329	G6309						

Results in ppm unless otherwise specified
 T = element present, but concentration too low to measure
 X = element concentration is below detection limit
 - = element not determined

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