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DEPARTMENT OF SUPPLY AND DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

MINERAL ECONOMICS SECTION

# SUPPLIES OF FLUORSPAR FOR AUSTRALIAN INDUSTRY

*by*

*I. C. H. Croll*

REPORT NO. 1949/15

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## INTRODUCTION.

Attention was directed to the inadequacy of supplies of acid grade fluorspar in Australia when the Bureau of Mineral Resources was asked to sponsor an application to import a quantity from England in 1948. The British Ministry of Supply released a proportion of the amount required but advised that the supply position in England was not secure and only limited quantities could be released for export in future. The Ministry suggested that if known Australian requirements were likely to be heavy, some material might be supplied as a matter of urgency. An investigation of the fluorspar industry in Australia was then undertaken to estimate future requirements and the extent to which these could be met from domestic sources; the results of the investigation are the subject of this report.

## USES AND GRADING OF FLUORSPAR.

Fluorspar is used in Australia in the manufacture of certain types of glass, as a constituent of enamels, as a flux in foundries and in steel manufacture, and as a raw material for hydrofluoric acid. Specifications for the various uses are not standardised but three distinct grades of material are generally recognised, viz. (a) Acid grade, (b) Ceramic grade, (c) Metallurgical grade. Owing to wartime restriction of imports and a decline in output from domestic sources some consumers in Australia have been forced to use lower grade material than would be accepted for similar purposes overseas, but this position is as unsatisfactory as it is uneconomical, and rectification is essential. The accompanying table sets out the generally accepted specifications for each use and the grades which have been used in Australia in recent years. The latter fluctuate within wide limits and those shown in the table may be regarded as representative of the figures supplied by a number of consumers in each industry.

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| Industrial Use. | Form. | | $CaF_2$ (min.) | $SiO_2$ (max.) | $Fe_2O_3$ (max.) | S. (max.) | $CaCO_3$ (max.) |
|---|---|---|---|---|---|---|---|
| Steel making & Foundry flux | Lump or gravel. Not more than 15% fines. | Normal Specification | 85% | 8% | | 0.3% | |
| | | Average grade used in Australia. | 70% | | | | |
| Glass making | Ground or lump | Normal Specification | 95% | 3% | 0.12% | nil | 1% |
| | | Average grade used in Australia | 83% | | 0.25% | | 1% |
| Enamels & Ceramics generally | Ground | Normal Specification | 95% | 3% | 0.12% | nil | 1% |
| | | Average grade used in Australia | 85% | 14% | 0.3% | nil | |
| Acid Manufacture | Lump gravel or fines | Normal Specification | 98% | 1% | - | nil | 1% |
| | | Average grade used in Australia | 94% | 4% | - | nil | - |

The most critical requirements are those of acid manufacturers. Any free silica in the raw material reacts with hydrofluoric acid to form fluosilicic acid, which is an undesirable impurity. The amount of silica should therefore be as low as possible and 1% maximum is generally regarded as the limit. Use of fluorspar containing as much as 4% silica has emphasised to the Australian manufacturer of hydrofluoric acid the necessity of using higher grade material, of which supplies have recently been imported from England and Germany.

Fluorspar is used in the ceramic and glass industries as a flux and opacifier. Since enamels and glasses are dominantly siliceous in composition, free silica in the fluorspar may be regarded as a diluent rather than an impurity, and the tolerance is higher. The most undesirable impurities are those which may impart a colour to the end product (e.g. ferric oxide), and calcium compounds. In producing opaque glass or enamel the ratio of calcium to fluorine must be carefully controlled, as an excess of calcium tends to clarify the product. For this reason, consumers of ceramic grade fluorspar specify a calcium carbonate content of not more than 1%. Comparatively low grade fluorspar is accepted for glass making in Australia if the iron and lime content is low, but manufacturers of enamels require fluorspar containing at least 90% $CaF_2$. Lower grade material has been used, but only when unavoidable.

Metallurgical grade fluorspar, used to impart fluidity to slags, should contain more than 85% $CaF_2$ and less than 0.3%

sulphur. The requirements are not critical, however, and material with as little as 70% $CaF_2$ has been used in Australia.

Significant advances in fluorine chemistry have been reported from America and England in recent years and it is appropriate to mention some of the products which are being produced and which are most likely to be manufactured in Australia as markets expand. The raw material for the fluorine in most of these compounds is acid grade fluorspar, and the potential increase in the demand for these purposes cannot be overlooked.

Freon 12 ($CCl_2F_2$) used in refrigeration, air conditioning, and a propellant for the dispersal of insecticides from aerosol bombs. Estimated production capacity for Freon 12 in the U.S.A. is 29,000 tons per year, equivalent to a consumption of 20,000 tons of acid grade fluorspar. Fluorocarbons are analagous to hydrocarbons and have nearly the same freezing and boiling points but much greater densities. They resist oxidation, are chemically stable, and are used in heat transfer and dielectric media, fire extinguishers, high temperature lubricants, thermal and chemically resistant plastics, dyes, pharmaceuticals, tanning, fluxes, fumigants, insecticides, solvents, fire-proofing, etc. Sulphur hexafluoride is used as a high voltage insulator and in X-ray work. Sodium fluoroacetate is an effective rodenticide. Boron-trifluoride is a catalyst for certain organic reactions. Fluorine gas is produced in fairly large quantities as an intermediate product in the synthesis of the above compounds.

## CONSUMPTION IN AUSTRALIA.

A canvass of producers and principal consumers reveals an estimated consumption of 1350 tons of fluorspar per year during 1947 and 1948. Consumption by industries and grades is as follows:-

| Industry. | 1947. | 1948. |
|---|---|---|
| | tons. | tons. |
| Foundry & Steel | 470 | 490 |
| Enamels | 430 | 450 |
| Glass | 410 | 350 |
| Acid manufacture &c. | 40 | 60 |
| Total: | 1,350 | 1,350 |

| Grade. | 1947. | 1948. |
|---|---|---|
| | tons | tons. |
| Acid | 40 | 60 |
| Ceramic | 430 | 450 |
| Metallurgical | 880 | 840 |
| Total: | 1,350 | 1,350 |

These figures indicate a slight rise in consumption during 1948 for purposes other than glass manufacture, the demand for this industry having shown a downward tendency during the past three years. All consumers expected a rising demand for fluorspar in 1949, but the coal strike in July and August will have had an adverse effect on consumption and it is unlikely to exceed the 1948 figure.

Unpredictable factors which may affect future consumption are changes in industrial techniques and the use of substitutes for fluorspar in some industries, but it is reasonable to assume an increased demand when the market for fluorine derivatives is firmly enough established in Australia to warrant local manufacture. Apart from these hypothetical considerations two major industries which are users of fluorspar are scheduled to reach the productive stage within the next five years, and their known requirements may be taken into account in estimating the future demand in this country. Use of fluorspar for the production of steel for tinplate is expected to be from 500-750 tons per year (metallurgical grade), and for the production of aluminium from 1200 to 1500 tons per year (acid grade). The following estimate of consumption five years hence assumes (a) that consumption by present users, other than acid manufacturers, may be 120% of the 1948 figure; (b) that consumption for acid manufacture &c. may be 150% of the 1948 figure plus 1000 tons for aluminium manufacture; (c) that 500 tons of metallurgical grade fluorspar may be required for steel (tinplate) manufacture.

| | |
|---|---|
| Acid manufacture &c. | 1100 tons. |
| Foundry & steel | 1100 tons. |
| Enamels | 550 tons |
| Glass | 450 tons |
| Total: | 3200 tons. |

Consumption by grades, assuming that the glass industry continues to use metallurgical rather than ceramic grade, would then be:

| | |
|---|---|
| Acid | 1100 tons. |
| Ceramic | 550 tons. |
| Metallurgical | 1550 tons. |
| | 3200 tons. |

With full capacity reached in tinplate and aluminium production, and with increased use of acid grade fluorspar for fluorine derivatives conservatively estimated at 200% of the 1948 amount, consumption could rise to:

| | |
|---|---|
| Acid manufacture &c. | 1600 tons. |
| Foundry & Steel | 1350 tons. |
| Enamels | 550 tons |
| Glass | 500 tons. |
| | 4000 tons. |

Consumption by grades in this case would be:

| | |
|---|---|
| Acid | 1600 tons |
| Ceramic | 550 tons |
| Metallurgical | 1850 tons. |
| | 4000 tons |

A possibility which would upset these estimates is that the Aluminium Commission would import cryolite in preference to manufacturing it in Australia.

## SUPPLY OF FLUORSPAR.

### Past Domestic Production.

The earliest recorded production of fluorspar in Australia was in 1915 from the Woolgarlo Mine near Yass, N.S.W., the site of which has since been submerged by the waters of

Burrinjuck Dam. Small production from the Mistake Mine at Emuford, Queensland, in 1917 marked the start of fluorspar mining in that State, and production from the Pine Mountain lode, Victoria, commenced in the following year. Minor quantities of fluorspar were mined at Plumbago Station, South Australia between 1932 and 1936.

Total production from 1915 to 1948 and for the past three years is shown in the accompanying table, which is based on published records of the State Mines Departments. Values of production have been omitted, as no uniform basis of valuation has been established between States.

Fluorspar production by States - 1915-1948.

| State. | 1915-1945. | 1946. | 1947. | 1948. | Total 1915-1948. |
|---|---|---|---|---|---|
| | Tons | Tons. | Tons. | Tons. | Tons. |
| Queensland | 25,149 | 861 | 873 | 355 | 27,238 |
| N.S.W. | 9,932 | - | - | - | 9,932 |
| Victoria | 2,753 | 321 | 327 | 156 | 3,557 |
| South Australia | 581 | - | - | - | 581 |
| Total: | 38,415 | 1,182 | 1,200 | 511 | 41,308 |

Some fluorspar is mined from areas which are not held under mining tenure, and the data in the table are not necessarily complete. It is reasonably certain that the 1948 production was higher than is shown in the table, although it was probably less than in 1946 and 1947. The recorded production is shown in graphical form in figure 1.

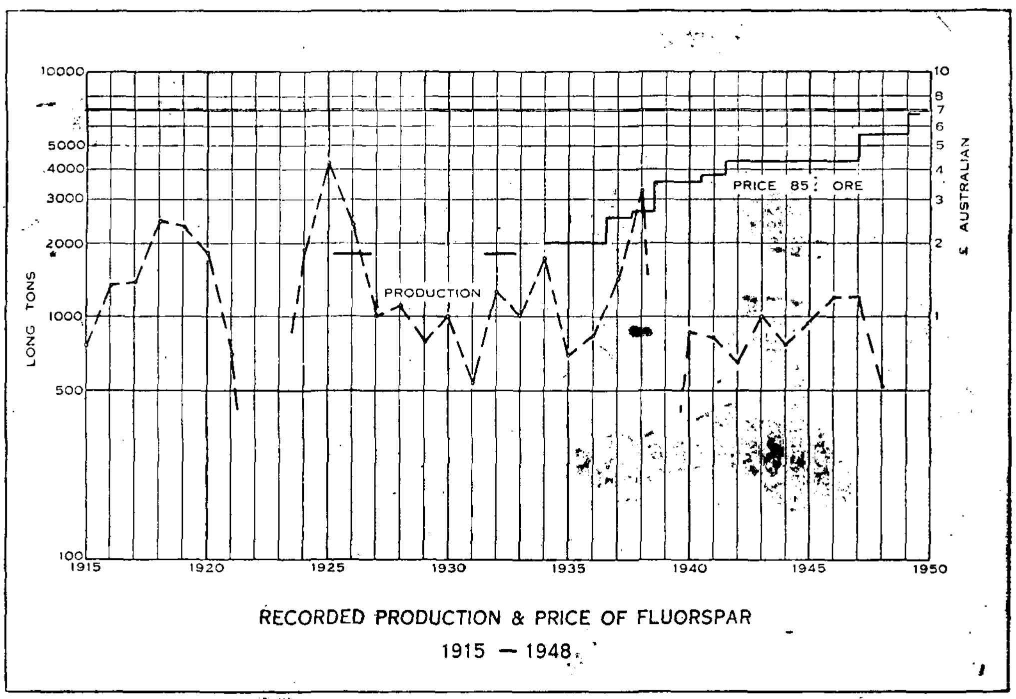


Figure I.

The greater part of the ore produced in Australia has been of metallurgical grade and it is improbable that more than 90% of local requirements of all grades has been met from domestic sources in the past, even with the use of sub-standard material for ceramic purposes.

## Domestic Sources.

The only fluorspar lodes now being worked in Australia are those in the Mungana-Chillagoe region in North Queensland. These have been described in detail by Ridgway (1945) and there is nothing important to add to his description. In August, 1949 only 11 men were actively engaged in fluorspar mining - two at the Victory Amalgamated workings on the Perseverance lode, 3 miles from Fluorspar siding; three at the Phar Lap workings; four at the Muldiva, Midway, and Horseshoe workings on the Fluoric lode; and two at the Mt. Richard workings about 16 miles from Mungana (not mentioned by Ridgway). Climatic conditions limit working time to about 8 or 9 months of the year. With the exception of workings on the Perseverance lode, mining operations consist of stoping from the surface to a depth of from 20 to 40 feet and an average width of about 2 feet. The depth at which stoping is discontinued is usually determined by deterioration of the grade of material, although it is commonly stated that deeper mining would be unprofitable, regardless of grade. The Victory Amalgamated workings differ from all others in being below water level, and two pumps are required to keep the water down. Access is by a 40-ft. shaft with a drive to 30 feet east at 18 feet. Bulk grade of ore from various workings along Muldiva Creek and Mt. Richard is from 85% to 90% with some hand picked material exceeding 90%. Hand picked ore from the Victory Amalgamated contains 91 to 92% $CaF_2$.

Development of the lodes has not been systematic and reserves of high grade fluorspar (85% or better) can only be guessed at. Ridgway summed up the position thus:

> "There seems no doubt that low prices rather than any diminution in grade or size of ore-shoots were responsible for cessation of mining at relatively shallow depths, and the continuation for some distance below these depths without any appreciable change in size or quality is anticipated.
>
> Possibly upwards of 50,000 tons of marketable fluorspar could be obtained by mining high-grade ores from Perseverance, Phar Lap, Simpson's, Relief, Peter Pan, Condon-Ogilvie, Victory, and Christmas Gift, with the Perseverance likely to be the most important supplier. Smaller tonnages would be expected from McCord's, Stewart's, Shaw's, Condon's, Mt. Sirius, Sunset, Midway and Muldiva.
>
> In addition to these there are several lodes that could not be inspected during the present field work which may prove capable of future production. The finding of new lenses of good quality fluorspar, and the exploitation of lodes outside a 30-mile radius from nearest railhead - previous economic limit for carting ore - can almost certainly be counted on to add to production.
>
> The above has dealt only with clean shoots of fluorspar and does not take into account the low-grade or "bony" sections, some of which were observed during the present examination. These, in my opinion, may prove on further investigation to be a source of very large supplies, provided market conditions were such as to warrant organised mining operations accompanied by flotation treatment, as practised in other countries."

A relatively small lode of fluorspar at Pine Mountain, Victoria, was worked until early in 1949, at which time it was decided that labour difficulties and other factors made operations unprofitable and the mine was closed.

Lodes occur at Carboona, Broken Hill and the Gulf (New England district) in N.S.W. but no production has been recorded since 1937. The lode at the Gulf is stated to be high grade, but the district is inaccessible and transport costs have made operations unprofitable.

Fluorspar occurs as a gangue mineral in the silver-lead ore body at Broken Hill, but no commercial recovery has been attempted. Some experimental work by Zinc Corporation Ltd. indicates that a rougher concentrate containing 83% of fluorspar can be obtained from the final residue of the lead-zinc concentrator, and it has been estimated by the company's general manager that under normal operating conditions about 4,000 tons of fluorspar per year could be produced from this source. He considered it unlikely, however, that any appreciable quantity of acid grade fluorspar could be produced. A similar conclusion was reached by the Mine Superintendent of Broken Hill South Ltd. at which mine the tailings assay 1.7% fluorspar.

The possibility of obtaining fluorspar from the Broken Hill tailings cannot be overlooked or disregarded, as the low cost of recovering what is now a waste product might offset the additional cost of beneficiating to acid grade.

<u>Imports and overseas availability.</u>

Imports of fluorspar were suspended from 1941 to 1945, and the undermentioned quantities have been landed since 1st. July, 1945:

| | | |
|---|---|---|
| 1945/1946 | 100 | tons from the U.K. |
| 1946/1947 | 40 | " " " " |
| 1948 | 40 | " " " " |
| 1949 (to June) | 37 | " " Germany. |

It may be assumed that these imports consisted of acid grade fluorspar with perhaps a little ceramic grade (+95% $CaF_2$).

The very substantial rise in the world demand for fluorspar in recent years has emphasised the problem of supply, and the indications are that Australia will find it increasingly difficult to obtain material from other countries. The largest fluorspar production is in the U.S.A., but consumption in that country is approximately 125% of her domestic production and imports have been necessary, principally from Mexico, Spain and Newfoundland. Known reserves in the U.S.A. are sufficient for about 30 years at the present rate of consumption. Canada produces only about 20% of her requirements, the balance being imported from Mexico and Newfoundland.

Production in the United Kingdom has increased to 170% of the pre-war figure, but exports have almost ceased and acid grade fluorspar had to be imported from Spain during 1948. In a recent report published by the Ministry of Fuel & Power it is estimated that the U.K. resources are sufficient for not more than 20 years at present rate of output, and the supply position is stated to be serious.

Other producing countries which might have an export surplus are Mexico (which is closely tied to the American market), Newfoundland (now part of Canada and having close links with the Canadian market), France, Spain, Germany, and possibly Italy and Korea.

## PRICES & COSTS.

Prices of fluorspar in Australia were increased in July, 1949, and current rates are as follows:-

Buying - For ore containing 85% $CaF_2$ -- £6.15.0 per ton, in bulk, f.o.r. Mungana (Q).
For ore containing 90% $CaF_2$ -- £8 per ton, in bulk, f.o.r. Mungana (Q).

In each case plus 2/6 per unit $CaF_2$ above 85% or 90%.

Selling - 85% $CaF_2$ -- £13.9.0 delivered in Sydney.
90% $CaF_2$ -- £14.14.0 delivered in Sydney.

The following figures indicate the rising trend of fluorspar buying prices since 1932:

1926 - £1-16/- per ton (? 85% ore)
1932 - £1-16/- per ton (? 85% ore)
1935/36 - £2 to £2-2-6 per ton; 85% ore.
1936/37 - £2-10/- per ton; 85% ore.
1938 - £2.12.6 to £2.15.6 per ton; 85% ore.
1939/40 - £3-10/- per ton; 85% ore.
1940/41 - £3-10/- to £3-15/- per ton; 85 ore.
23rd. June, 1942 - 14th. October, 1947 - £4-5/- per ton; 85% (Controlled)
14th. October, 1947 - July 1949 - £5-5/- per ton; 85% ore (Controlled to 14th. Sept. 1948).

The trend of prices is graphically compared with the trend of production in Fig. 1.

It was contended that fluorspar prices prior to July 1949 were not in keeping with the costs of production, and that men were leaving the industry for more remunerative employment, with consequent loss in fluorspar production. It is true that men have left the industry for more secure and remunerative employment elsewhere, but there is little to support the contention regarding the price-costs ratio if pre-war figures are used as a basis of comparison. According to estimates quoted by miners themselves, the cost of mining fluorspar and carting it to rail does not exceed £2 per ton - in fact the average cost would be considerably below that figure. (Cartage rates are approximately 2/6 per ton mile). The margin of profit on 85% ore was therefore not less than £3-5/- per ton up to July, 1949. If pre-war (1938) costs were only 30% of the present costs the profit at that time would be about £2 per ton or 25/- per ton less than in 1948. Actually, mining costs in 1938 were nearer 70% of the 1948 figure, and the return to the miner at that time would be about 24/- per ton or less than half the amount he cleared before the most recent price rise. Having regard to the general rise of about 50% in the wages level in the period 1938-1948, the miners are at least no worse off than they were in 1938, when fluorspar production was at a peak.

These figures merely show that present prices compare favourably with pre-war prices, but do not prove that the prices at either time were adequate. Taking all aspects into consideration - costs of production, cost of living, world prices, etc. - the current Australian prices are reasonable. At present rates a miner may clear at least £4-15/- per ton for 85% ore, and he would have no difficulty in making enough in eight or nine months to provide a gross income of £800 per annum.

Increase of prices as a stimulant to production is of very doubtful value as far as fluorspar is concerned. Theoretically it would induce men to return to fluorspar mining; actually there are very few men in northern Queensland likely to be attracted by any increase the industry could afford to offer. The source of supply of fluorspar in Australia is remote from the principal markets and the consumer has to pay heavy freight charges which raise the cost of the material to a comparatively high level. Any undue increase in the cost of locally produced ore may raise the price to a level which would force consumers to buy overseas. It is estimated that the difference between the cost of local and imported fluorspar, 85% grade, delivered in Sydney, is about £A4 per ton in favour of Australian ore, and although this may appear to be a substantial margin it is not more than some firms might be prepared to pay to ensure continuity and uniformity of supplies.

The following overseas prices are quoted for comparison with Australian selling prices:

England - Derbyshire Grade A3 (83-85%) £stg.6-8-3 (£A8-0-4) per ton f.o.r.
Derbyshire Grade A1 (88-90%) £stg.7-15-0 (£A9-14-0) per ton f.o.r.
Durham Grade 2 (83-85%) £stg.6-0-9 (£A7-10-11) per ton f.o.r.

Germany - Acid Grade (98%) £A19-5-2 per ton f.o.b. Hamburg (1948).

U.S.A. - Acid Grade (97%) $45 per short ton (£A22-10/- per long ton) f.o.r. Kentucky or Illinois mines.

70% grade $37 per short ton (£A18-10/- per long ton) f.o.r. mines.

## FUTURE SUPPLIES.

The point emerging from the preceding paragraphs is that on present indications, the production of higher grades of fluorspar in Australia is unlikely to keep pace with requirements. Domestic supplies of metallurgical grade ore appear to be adequate, but the use of sub-standard ceramic and acid grades cannot continue when the demand is trebled within the next five years, and consideration must be given to the means by which the gap between production and consumption may be bridged. Either we must rely on overseas sources for future supplies of higher grades, or a complete revision of production and treatment methods in Australia must be made.

As noted earlier, the difficulty of obtaining overseas supplies cannot be overlooked, and it would be unwise for consumers to adopt a long-term policy of reliance on imports, particularly where strategic requirements are concerned. The next year or two may be regarded as transitional between the present period of low consumption of ceramic and acid grades and the more stable period of much greater consumption; imports which may be necessary during this stage should be regarded as a temporary expedient only. Every effort should therefore be made by the industry to ensure that the increase in consumption is met from local sources of supply, and detailed consideration should be given to the possibility of a revision of production and treatment methods in this country.

It is clear that no acid or ceramic grade fluorspar can be mined, as such, from any known deposit in Australia, and any ores produced in this country must be beneficiated to raise the grade to commercial specifications. In the past this treatment has been confined to hand picking and rough tabling, neither of which has been successful in producing the quantities or grades required. With the certain prospect of a greatly increased demand, more elaborate and efficient treatment methods must be introduced if this demand is to be met from domestic sources.

An analogous position occurred in Great Britain just before the outbreak of the second World War, and it is relevant to quote from a paper (Pearson, 1946) in which the proposals made at the time are described. The author stated inter alia:

> "Shortly before the outbreak of war the Geological Survey had initiated an investigation into fluorspar occurrences in Durham and East Cumberland. A report covering this investigation was submitted to the Non-ferrous Metallic Ores Committee early in 1941 and a few months later it became evident that if a serious shortage of fluorspar in this country was to be avoided measures would have to be taken to organize production and distribution. The Non-ferrous Mineral Development Control, in collaboration with the Geological Survey, therefore authorized a detailed investigation into the various sources of supply with a view to determining reserves and increasing output.
>
> The joint survey emphasized the uncertain, wasteful, and sometimes uneconomic nature of many of the operations conducted for the production of fluorspar in this country. It was further demonstrated that unless active steps were taken in the development of existing, and the initiation of new projects, demand would very soon exceed the available supply."

He pointed out that about 60% of the fluorspar produced in England was from the retreatment of base-metal mine dumps, and that the dominance of fines in the material being treated reduced the recoveries by gravity separation alone. The conclusion was reached that only a combination of gravity and flotation, or of flotation alone would permit of reasonable recoveries being obtained over all size ranges in which the fluorspar occurred in these dumps.

Regarding the size of the mill which it was proposed to erect, Pearson stated -

> "In 1943 a deficiency of 5,000 to 6,000 tons of high-grade spar for acid makers, light alloy, and ceramic work was anticipated by the Fluorspar Control and to meet this demand it was decided to erect a new mill.
>
> As a mill based on such a limited tonnage was considered to be an uneconomic unit it was decided to instal a plant of larger capacity with a section capable of producing the high-grade product required, whilst the main production could be marketed as a good quality metallurgical spar, for which there was also an increasing demand."

Features of the proposed mill were to be as follows:-

Capacity: 100 tons per day (24 hours) throughput.
Output: 25-30 tons acid grade and 30-35 tons metallurgical grade fluorspar per 24 hours.
Capital Cost; £56,300 exclusive of agglomerating unit.
Milling cost: Not to exceed 35/- per ton of finished product (plus 7/6 per ton for agglomeration where necessary).
Treatment: Jaw crusher, drum washer, screen; ½" to jigs for separation of lead and (metallurgical) fluorspar; -⅛ to ball mill, classifier, 5 Denver cells for lead flotation and 10 Denver cells for fluorspar flotation, filters.

The mill was never erected, the reasons given by Pearson being "Owing to the efforts of the producers, particularly in Derbyshire, the threatened deficiency in supplies of both metallurgical and acid-grade spar has been averted and priority for construction of the new mill was considered unjustified in the face of urgent demands on labour and plant for more pressing war needs".

A less elaborate and smaller mill would suit the Australian scale of operations, but the foregoing details suggest that the capital cost of any plant is likely to be high in relation to turnover. Plante (1947) and others have shown that an acid grade concentrate can be obtained by flotation from Pine Mountain and Chillagoe ores, but the metallurgical problem needs further attention before costs of a mill could be estimated. The heavy media process is popular in the U.S.A. for fluorspar separation, and the possibility of its use in Australia must be investigated. Other aspects which also have to be considered are (a) the location of the mill with respect to the supply of raw material; (b) the minimum capacity for economic operation and the disposal of fluorspar produced in excess of Australian requirements; (c) the cost of the finished product in relation to the cost of similar material from alternative (overseas) sources of supply.

Reserves of fluorspar in the North Queensland lodes would have to be more accurately determined before the establishment of a mill in that area could be considered. If Ridgway's estimate was correct, a mill with a throughput of 5,000 tons per year would exhaust the reserves in 10-15 years, which may be regarded as too short an economic life at one site. Even if the reserves are much greater and would ensure continuity of supplies for a longer period, the high freight and other charges in a remote locality might make operations uneconomic. The alternative to North Queensland (from which metallurgical spar could still be obtained) is Broken Hill, where continuity of supplies would be assured and where operating costs and capital expenditure may be lower because the tailings would be already uniformly ground before entering the mill.

The minimum economic capacity of a plant in Australia is estimated by Frank Hambridge Pty. Ltd. to be not less than 4,000 tons throughput per year. If this is based on 70% fluorspar the annual output would exceed 2,500 tons of acid grade, which is more than the estimated demand in this country. There should be no difficulty, however, in finding an export market for the surplus, even if it is much higher than is estimated.

In determining whether the cost of the finished product is within reason, the ruling prices in Australia do not provide a criterion since no comparable grade of material is being produced. The only criterion is the cost of imported acid grade fluorspar, which is landed at present at about £A28 per ton ex Germany. If a local mill product can be delivered to the consumer at less than this amount the Australian market will be secured. The export market, however, depends to some extent on ability to sell the fluorspar in competition with other exporting countries, and for this reason the cost would have to be at a level which would allow sales at not more than about £A20 per ton f.o.b. port of shipment.

Whilst only two means of meeting the expected deficit of high grade fluorspar have been considered, there is a third which cannot be entirely disregarded. Approximately 17,000 tons of fluorine per year are imported into Australia as a constituent of rock phosphate. In the manufacture of superphosphate, some of this fluorine may be recovered by absorption of flue gases in water to give fluosilicic acid, a process which was actually being carried out for a period during the war. Fluosilicic acid may be used as a raw material for the synthesis of cryolite, but it has disadvantages which rule it out of consideration while hydrofluoric acid is available. The principal disadvantage in Australia, which uses imported rock phosphate with a very low silica content, is that silica must be added to induce formation of a silica-fluorine compound, and then removed from the fluosilicic acid before it can be used for cryolite manufacture. For this and other reasons, the possibility of relieving the fluorspar shortage by using fluorine from rock phosphate seems remote and unattractive.

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