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URANIUM MINERALS IN AUSTRALIA.

by

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SUMMARY

The uranium ores of the Mt.Painter area, in South Australia, although inadequately developed or proved, are the most important sources of uranium compounds yet discovered in Australia. Their chemical treatment is relatively easy, whereas the extraction of uranium from certain other recorded ores is difficult. The possibility of the Mt.Painter ores being amenable to appreciable beneficiation is not remote. The uran-ilmenite from Radium Hill (in South Australia) can be considered as a comparable source of uranium only if the ore is processed for its titanium content so as to obtain the uranium as a by-product. This ore is not amenable to significant beneficiation as regards its uranium content.

The remaining minerals listed require several modifications of chemical treatment, detailed consideration of which is not yet justified by the known reserves of ore.

The recovery of the associated radium can be effected from any uranium ore without substantial modification of the processes advocated for the extraction of the uranium.

The methods suggested for the recovery of uranium from these several minerals aim at the production of sodium diuranate which is a convenient intermediate for conversion into other uranium derivatives. The methods discussed were formerly applied on a small commercial scale to the treatment of South Australian uranium ores, particularly those from the Mt.Painter field.

PART 1 - OCCURRENCE.

The most important deposits of uranium minerals known to occur in Australia are located near Mt.Painter and Olary in South Australia. (1) Very small amounts of pitchblende have been detected in association with tin and wolfram ores in the Herberton district of North Queensland. The granitic pegmatites of Hart's Range, in Central Australia, have been shown to contain very small amounts of pitchblende and samarskite. A tantalite-bearing albite pegmatite formation at Wodgina, in Western Australia, has yielded minor amounts of maitlandite and its decomposition products thorogummite and pilbarite while detrital euxenite and fergusonite have been recovered in small quantities at Cooglegong, in Western Australia. (2). (3). Pyrochlore is recorded as having been detected in alluvial wash near Table Cape, in Tasmania. (4). Apart from the main occurrences of uranium minerals at Mt.Painter and Olary in South Australia, some very minor occurrences of torbernite and carnotite have been recorded at Yeldulknie Creek and the Hundred of Minbrie, West of Cowell, on Eyre Peninsula. Somewhat more significant amounts of torbernite have been recorded also from the copper lodes at Moonta in South Australia. (1).

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With the exception of the Mt.Painter and Olary deposits in South Australia, none of the above occurrences has yet been shown to be of any industrial significance. With the continued development of various Australian pegmatite formations for felspar, tin, tungsten, beryl, tantalite and mica, it is probable that further occurrences of uranium minerals will be located. In such cases, the production of s small parcels of uranium ores might be possible by combining the by-product output from several localities. Types of chemical treatment applicable to various ores are discussed later.

RADIUM HILL:

The deposit of uraniferous ore at this locality is easy of access from the railway at Olary, 250 miles from Adelaide, on the Broken Hill line. Carnotite was discovered here in 1906. The ore-bodies consist of a number of lodes conforming to the schistosity of the enclosing rock. The country rock is composed of highly altered sediments intruded by a large number of granitic and pegmatitic dykes. The mineral constitution of the uraniferous lodes is very complex. The principal mineral is a peculiar titaniferous iron ore containing uranium, rare earths, vanadium and other constituents as primary integral components. Carnotite as a secondary alteration product, is of common occurrence on joint planes and weathered ore. Where titanium is absent from the lode, the iron minerals (chiefly haematite and magnetite) contain little or no uranium.

There is no recent description of the workings at Radium Hill, Olary. In 1913, (since which time there has been considerable further development), the main workings consisted of two vertical shafts sunk on a north-east to south-west lode to a depth of 45 ft. These shafts were connected at the bottom by a drive which extended about 130 ft. south-west beyond shaft No.2A. A block of ore approximately 200 feet by 15 ft. by 4 ft. 6 ins. had been stoped above the 45 ft. level, and a small amount had been removed from about No.1 shaft.

A typical analysis of a gravity concentrate of the titaniferous iron ore is quoted by R.G.Thomas (1). (5):-

TiO_2	51.85%	
FeO	17.37	also (SC_2O_3) ThO_2 - 0.13
Fe_2O_3	17.87	
U_3O_8	2.25	and small amounts PbO MnO, CaO.
Rare earth oxides	3.29	
Ce_2O_3	1.26	
Cr_2O_3	1.60	
V_2O_5	0.93	
SiO_2	1.15	

This gravity concentrate represents a heterogeneous product, and the uranium oxide content of the separated pitch-like ore may reach a value of 4%, but it is impossible to increase the tenor of the ore above this value by mechanical means.

MOUNT PAINTER:

The Mt.Painter field is about 380 miles north of Adelaide. The Central Australian railway, at Copley, is some 60 miles from the area. Portion of the intervening country between the deposit and the railway is very rugged and transport is difficult.

Prospecting for corundum at Mt.Painter lead to the discovery of the uranium-bearing minerals torbernite and autunite in 1911. Here also, the lodes have a complex mineral constitution and iron and manganese oxides are prominent. Only secondary uranium minerals have so far been located in quantity, although small amounts of the primary minerals fergusonite and monazite have been recognised.

The principal deposit of uranium ore occurs at the intersection of a fault zone with a strongly ferruginous lode trending meridionally. This seemingly favourable structural feature is not apparently repeated elsewhere on the field. The uraniferous minerals in the lode include chiefly torbernite and autunite, with very minor amounts of uranophane, gummite, uranium ochre and carnotite. Gangue minerals present are quartz, hematite, magnetite, fluorite, barite, psilomelane and pyrolusite. Here, and at other points on the Mt. Painter field, the secondary uranium ores are generally, but not invariably associated with manganese. The principal workings, known as No.6, have been developed in the deposit abovementioned. A rich shoot above the 50 ft. level yielded more than 40 tons of ore containing between 2 and 5% U_3O_8, with considerable amounts of pure crystallised torbernite.

These workings are comparatively extensive, although little ore has been extracted below the 50 ft. level owing to its poor uranium content. The main shaft was sunk vertically in ore to 50 ft. at about which point the lode passed out of the shaft dipping south at 70°. A cross-cut from the shaft at 100 ft. revealed poor values. An adit driven in an easterly direction from the hillside for about 120 ft. connects with the 100 ft. level. Another adit has been driven 173 feet at a level 187 feet below the collar of the main shaft, but is too far north to penetrate the ore body. The total driving on the 100 feet level, including the adit, amounts to 250 feet and discloses much lower values than the shallower workings. The 50 feet level has been carried from the shaft westerly until it has broken through the hillside about 90 feet from the shaft. East of the shaft it is connected with the 36 feet level by two rises. Above the 36 feet level a stope about 10 feet wide by 20 feet long by 15 feet high has been taken out.

In 1927, the Mine Manager estimated ore reserves (proved on two sides only) at 700 tons containing 0.75% U_3O_8, and this estimate was somewhat tentatively endorsed at the time by the Government Geologist.

In 1929, (since which time it is believed that the Mine has remained unworked) the Chief Inspector of Mines sampled the No.6 workings at Mt.Painter and reported that it was impossible to estimate reserves with any degree of accuracy. He qualified this opinion by stating that it is reasonably probable that a few hundred tons of ore averaging 0.5% U_3O_8 might be available above the eastern end of the 50 feet level. The samples taken at this time were assayed with the following results:-

<u>50 feet level.</u>

Eastern end of drive (average of four samples) ...	0.93% U_3O_8
Just west of shaft " " three " ...	0.42 "
15 feet west of shaft " " " " ...	0.13 "

<u>100 feet level.</u>

Eastern end of drive (one sample)	0.04 "
" " " " " "	0.02 "

The low grade revealed in the above analyses of bulk ore should be considered in conjunction with the fact that no satisfactory method for concentrating the autunite and torbernite has yet been devised. For the most part, these secondary ores are friable, and some degree of concentration is possible by a process of rumbling followed by screening, but such methods are very inefficient. Leaching or selective flotation of the torbernite and autunite offer interesting possibilities as a means of concentrating the uranium values. The Paralana hot springs offer local opportunities for ore concentration of this type in an area which is otherwise devoid of permanent water.

Developmental work so far undertaken on the Mt.Painter field has been confined mainly to prospecting what appear to be the gossans of lode formations. It would be irrational to suppose that the autunite and torbernite found in such matrices represented the only uranium minerals of importance in the area. The primary uranium minerals from which these secondary ores are presumably derived should be sought at depths considerably greater than those hitherto prospected.

It seems unlikely that fergusonite is the only primary uranium mineral on the Mt.Painter field, because the activation of fergusonite, where observed, has not given rise to either autunite or torbernite.

A study of the Mount Gee area, in the centre of the field, strongly suggests that the secondary uranium phosphates have been brought up from deeper levels by hydrothermal agencies. The Mount Gee zone is characterized by an extreme development of crystalline and opaline silica in which large geodes and vughs lined with pink and amethystine quartz crystals are a characteristic feature. The occasional presence of small amounts of torbernite in these closed vughs suggests that the torbernite is syngenetic with the silica, stilbite, fluorite, barite, and other associated minerals of the general complex lode system.

In any future deep exploratory work in the Mt.Painter field, it is desirable that the central Mt.Gee area should receive more attention than the outlying peripheral gossany formations on which most of the previous work has been done. The relatively high radon concentration in the gas emitted from the Parallana hot spring may well be related to the presence of significant bodies of uranium ore in the deeper unprospected zones of the Mt.Painter field.

Although no specific comparison is made in the official reports of the South Australian Mines Department, it is evident that for direct production of uranium, apart from by-products, the Mt.Painter field offers much greater opportunity for development than Radium Hill. It is probable that structural features at Mt.Painter are more favourable and that the ore is higher grade. Also, the Mt.Painter ore is more amenable to treatment than that from Radium Hill, and the ore offers greater opportunities for beneficiation than does the ore from Radium Hill.

PRODUCTION:

Total production of "Radio-active ores" in South Australia is valued at £12,073, but it is not possible to apportion this between the two producing fields, and it is difficult to determine exactly what this figure means. Some uranium ore was sold overseas and some treated in Sydney and Adelaide. Some pure radium bromide was prepared in Australia and uranium compounds also were made and sold. To the end of 1937, records of production were given under the heading "Radium and Radio-active ores", but since then the caption has been changed to "Radio-active ores" but the figures for previous years remained unaltered.

Exports from Australia of uranium ores from Mt.Painter amounted to 54½ tons of average grade 2.7% U_3O_8, but it is not known what fraction of total production from Mt.Painter this represents.

PART II - PROCESSING

The types of uranium ores recorded as occurring in Australia comprise a diversity of mineral species to which no generally applicable method of chemical treatment can be applied for the extraction of uranium. In a number of instances, the recorded occurrences are so small in extent that consideration of detailed methods for extraction of the uranium content need not be attempted.

The proximate chemical compositions of the main Australian uranium ores of which significant amounts are known to occur, are as follows:-

Mineral	Proximate Composition	Uo_3 %	Locality
Torbernite	Hydrous uranyl copper phosphate	61.2	Mt.Painter, S.A.
Autunite	Hydrous uranyl calcium phosphate.	62.7	" " "
Uran-Ilmenite	Complex titaniferous iron oxide with uranium and rare earths.	2-4	Radium Hill, S.A.
Carnotite	Hydrous uranyl potassium vanadate.	68	" " "
Fergusonite	Complex niobate and tantalate of rare earth metals, uranium, etc.	1-4	Mt.Painter, S.A. Cooglegong, W.A.
Euxenite	Complex niobate and tantalate of titanium, rare earths, uranium, etc.	5-8	Cooglegong, W.A.
Maitlandite & decomposition products.	Complex silicate of uranium, titanium, rare earths, etc.	35	Wodgina, W.A.

From the point of view of chemical processing it may be said that these minerals form two groups. One group comprising torbernite, autunite and carnotite, includes those minerals which are relatively easily amenable to chemical processing while the members of the remaining group comprising uran-ilmenite, fergusonite, euxenite and maitlandite, etc. show varying degrees of refractoriness in yielding their uranium content when treated chemically. The recorded occurrences of fergusonite, euxenite, and samarskite are so restricted and apparently limited, that it is not proposed to detail the methods available for the isolation of uranium from such material. It is sufficient to say that niobo-tantalate minerals of this class, and to a lesser extent, the silicate types represented by maitlandite, are more amenable to preliminary alkaline fusions followed by subsequent acid treatment whereby the niobic and tantalic acids (and also silica), are eliminated as relatively insoluble products while the uranium and other components remain in the soluble fraction. The addition of appropriate alkali carbonates to the neutralised soluble fraction will enable the uranium to be selectively removed as a double alkali carbonate from which it may be recovered, after filtration, by precipitation as sodium di-uranate with either acids or caustic alkali.

Alternative methods for the extraction of uranium from niobo-tantalate and silicate ores might be based on the decomposition of the minerals with hydrofluoric acid.

The only economic justification for carrying out these difficult separations would be to secure the tantalum and niobum contents in addition to the uranium, and if such ores were known to occur in sufficiently large quantities to attract attention to their exploitation for several of the constituent elements. Present indications do not suggest that fergusonite, samarskite, euxenite, or maitlandite (and its decomposition products thorogummite and pilbarite) are sufficiently abundant in Australia to warrant consideration as a source of much uranium.

Uran-Ilmenite.

The mechanical separation of a clean concentrate of uraniferous ilmenite from the Radium Hill ore is easily effected by tabling or other well-known means of ore-dressing. The gangue is chiefly biotite mica and quartz. The concentrates thus produced contain only about 2% U_3O_8 and are normally devoid of carnotite which finds its way into the slime fractions of the sediment of the mill circuit water. It is possible, by magnetic separation methods, to raise the uranium content of the concentrates to 3-4% U_3O_8 by rejection of barren iron minerals present in the gravity concentrate. This aspect has not been fully investigated because the extent of possible beneficiation is strictly limited by the actual mineral composition of the uraniferous ilmenite. The extraction of the uranium present in such concentrates is a matter of very considerable difficulty because of the complexity of the ore and its refractory nature. The uranium is preferably to be regarded as a by-product in the making of titanium products from this ore. The mineral is amenable to direct sulphuric acid attack only under autoclave conditions. Fusion with nitre cake will effect its decomposition to sulphates as will a process of fritting with soda ash and subsequent acid digestion of the residue left after a water leach which removes vanadium and chromium in part. By these or similar methods, it is possible to obtain a solution of the sulphates of titanium, iron, rare earths and uranium together with small amounts of many other metals.

The radium present remains insoluble together with lead sulphate, etc. The separation of the uranium from such a solution is preferably preceded by removal of the titanium by hydrolysis after reduction of the iron to the ferrous state in the usual manner. The titanium product has been found suitable for certain pigments, but owing to contamination with chromium and other deleterious materials, the pigment produced from Radium Hill ore has hitherto been of an inferior degree of whiteness. From the mixed iron and uranium sulphates left after the titanium hydrolysis the uranium may be separated by digestion with excess sodium carbonate. This digestion is necessarily preceded by re-oxidation of the iron and partial neutralisation of the solution. The recovery of the uranium from the soluble sodium uranyl tricarbonate solution can be effected in the usual way by appropriate additions of either sulphuric acid or caustic soda. By this means, the uranium is obtained as crude sodium diuranate in the yellow or orange variety. Methods such as these have been used to extract uranium and radium and titanium compounds from Radium Hill ore on a commercial scale.

Carnotite.

The amount of carnotite so far discovered in Australia is so small that separate consideration of its chemical treatment is unnecessary. The uran-ilmenite from Radium Hill shows sparse distribution of carnotite on joint planes and on the micaceous matrix. The development of carnotite is further enhanced by natural weathering of the ore. Small amounts of carnotite have been recovered in the past as slimes separating from the mill circuit water, but the amount so recovered was of no importance.

Efficient methods of recovering radium, vanadium and uranium from carnotite have been devised by the United States Bureau of Mines. (H.A.Doerner, Serial No.2873, U.S.Bureau of Mines).

Autunite-Torbernite.

The recovery of uranium salts from these phosphatic ores which are characteristic of the oxidised zone of the Mt.Painter field is comparatively easy. As yet, no successful method has been devised for mechanical concentration of autunite and torbernite. Laboratory tests have indicated that these ores are amenable to selective flotation to some extent, but the ready friability of the minerals and the consequent tendency to slime production may be found to discount the apparent advantages of flotation as a means of producing concentrates. The ideal distinction between autunite and torbernite is seldom realised in ores from Mt.Painter. There is usually a significant amount of copper in the autunite and merging of the two types is quite common. This may have a bearing on any flotation work undertaken in the future. Scarcity of water on the field has also to be considered if accumulation of salts in the flotation circuit is likely to affect adversely any scheme that may be developed in the future.

Apart from hand picking of the richer ore obtained from fault zones, etc., the method of concentration formerly used consisted of a process of rumbling and screening the ore. By this means, the friable uranium ores were freed to some extent from the manganiferous ironstone or granitic gangue.

Autunite and torbernite are both soluble in mineral acids of moderate concentration and the uranium may be separated from the resulting solution in an impure form by addition of appropriate caustic alkali. Separation of the uranium from associated iron, etc., may be effected in the usual way by selective solution of the uranium in sodium carbonate, and its reprecipitation as sodium diuranate as mentioned previously. The uranium in both autunite and torbernite may also be leached out of the ore by digestion with hot concentrated sodium carbonate and recovered in the usual way.

The associated radium would be dissolved in acid extraction processes using hydrochloric acid except where uranic ochres, or other sulphates, are common, in which case weak nitric acid is effective. The radium would remain insoluble in processes using sulphuric acid or alkaline extraction methods for recovery of uranium. Soluble radium would be easily recovered by co-precipitation with barium sulphate in the uranium liquors. Insoluble radium would become concentrated in the slime fractions of the mill circuit liquors from which it could be largely recovered by known methods.

The autunite-torbernite ores of Mt.Painter are thus amenable to either acid or alkaline treatment for recovery of the uranium content. The simultaneous extraction of the associated radium in a relatively concentrated form would not complicate the procedure unduly. The various processes outlined have all been used on a commercial scale for extraction of uranium and radium compounds from the Mt.Painter ores. A study of the mechanical concentration of these phosphatic ores would be very desirable in the event of future developments on the Mt.Painter field, but the uranium content of the crude unconcentrated ore would also be amenable to leaching by acid or alkaline reagents. The degree of efficiency of extraction of the uranium from the broken ore which could be attained by leaching methods operated at the mine would depend more on economic considerations than on chemical difficulties.

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