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URANIUM PRODUCTION FROM LOW GRADE SWEDISH SHALE

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INTRODUCTION

In spite of the uncertain future for nuclear power utilization it seems reasonable to believe that large parts of the existing nuclear program will be implemented. Accordingly, a steep increase in the demand for uranium is to be expected, particularly in view of the reduced prospects for recycling uranium and plutonium. This increase in uranium demand will pose big problems for the uranium industry. The annual addition to uranium ore reserves must almost treble within the next 15 years in order to support the required production rates. During this period it does not seem realistic to expect a large-scale replacement of nuclear energy by coal or other alternative energy sources.

Although there are good prospects for the discovery of additional conventional deposits of uranium, low grade uranium deposits will become more important in the fairly near future. So far relatively little has been done to quantify the available high-cost uranium sources. It is known, however, that uranium occurs in large quantities in black shale, phosphates, granites, sea water and other unconventional sources. There are, however, factors which limit the exploitation of these low grade materials. The main factors include production costs, environmental constraints on the mining and milling of huge amounts of ore and the disposal of associated wastes.

To illustrate the feasibility of producing uranium from low grade ore, a description is given of the Swedish Ranstad uranium shale project, its potential constraints and technical solutions. The development in Sweden during the last 20 years is perhaps the only comprehensive technical study of the utilization of an unconventional low grade uranium resource.

The Ranstad 75 Project

At the beginning of 1975 Luossavaara-Kiirunavaara AB, AB Atomenergi and the Swedish Power Board formed a group named "Project Ranstad 75". Its object was the large scale exploitation of Swedish shale in accordance with the mining techniques and process chemistry developed by AB Atomenergi. The long term aim of this project was to fulfil the total demand for uranium in Sweden as presented by the nuclear energy program of 13 reactors by the beginning of the 80's approved by parliament in 1975.

The project has now reached the stage where it should be possible to make an investment decision. This allows for the mining of 6 million tons of shale per year and an annual uranium output of about 1 300 tons, corresponding to about 2 700 000 pounds of U_3O_8. The development of the uranium market has made it possible to cover production costs and to give a reasonable return on investments if world market prices are applied.

In recent years considerable development work has been devoted to problems related to the environmental impact of the project as a result of which there is confidence that the stringent rules and limits set by the authorities can be met.

For the time being, however, there is little interest in establishing a domestic uranium mine of this size. Instead, the development work has progressed to the point where it is possible to envisage a more complex operation in which not only uranium but also aluminium, vanadium, molybdenum, fertilizer, components such as nitrogen, phosphor and potassium are extracted while the energy content of the organic matters in the shale is utilized by combustion or through other processes. The development work necessary to achieve these goals is in progress.

GEOLOGY OF ORE DEPOSITS

In Sweden there are numerous bituminous shales, but as regards uranium production the most promising area is that situated at Ranstad in the south-west of Sweden. The uranium-bearing shale is a part of a practically horizontal series of sediments belonging to the upper Cambrian Era, Fig 1. The interesting horizon covers an area of 500 sq kilometres. The seam is 2.5 - 4.0 metres thick with a grade of 250 - 325 grams of uranium per metric ton. The total uranium content is about 1 million tons of which at least 0.3 million tons should be recoverable on a purely technical and economical base.

URANIUM EXTRACTION PROCESSES

Since the 50's Atomenergi has both developed and tested the processes for extracting uranium from Swedish black shales. These processes are described below, including the important adjustments which have been made during the last two years in order to keep within the environmental constraints.

Mining was planned on both an open pit and an underground mining basis. The open pit is designed as a strip mining operation with a capacity of 2 million tons per year, the ratio of overburden to ore being approximately 4 to 1.

The plant includes facilities for sorting, percolation leaching, solvent extraction and precipitation of sodium or ammonium uranate. The flow sheet of the proposed process is shown in Fig 2 and is described below.

After primary crushing in a gyratory crusher located underground the ore is transported by belt conveyors to a storage bin. From there the ore is conveyed to the heavy-media separation plant where limestone inclusions are removed from the shale ore.

The coarse float product is crushed in hammer crushers and reunited with the fine float before final crushing is performed in impactors. The crushed material is passed over vibrating resonance screens with a 2 mm square mesh opening. The minus 2 mm grade material is brought into contact with sulphuric acid in curing drums.

The uranium is extracted from the ore by counter-current percolation using sulphuric acid as the leaching agent. With a leaching time of 6 days at a temperature of about 60°C the uranium recovery attains 79 percent (the maximum yield applying extreme conditions and using sulphuric acid is 85 percent). Acid consumption is expected to be 6 percent of the shale weight.

As projected, the leaching plant comprises seven leaching vats. The vats are lined with acid resistent material. The bottom is provided with a gravel filter. After filtration of the solutions the uranium is separated by solvent extraction. Upon addition of sodium carbonate to the organic solution the uranium is stripped and a yellow cake is precipitated by the addition of sodium hydroxide. Pilot plant tests have demonstrated a yield of over 99.8 percent for the solvent extraction stage.

The barren solution is neutralized with finely ground limestone in two steps. After filtration, about 50 percent of the barren solution is recirculated to the leaching vats and 50 percent of the solution is evaporated. The evaporator residues, containing mainly potassium and magnesium sulphates, are dried and used for manufacturing fertilizer. The cleaned filter cakes are slurried in water and pumped to a tailings pond.

The solid residue from the leaching process is mixed with 5 percent finely powdered limestone and will be deposited in the open pit area. Since pyrite still remains in the residue great care must be taken to prevent weathering. The deposit will therefore be covered with limestone and at least three metres of moraine. Finally, the area used for deposition will be cultivated to fit into the surrounding landscape.

ENVIRONMENTAL CONSIDERATIONS

During the last few years work on the project has concentrated on tackling the main environmental constraints decided upon by the Swedish Environmental Authority. This work has resulted in a process which recirculates the process water and permits extraction of fertilizer components.

The ore body is located in a densely populated and richly cultivated district. Mining, processing and tailings disposal could therefore constitute a disturbance to the environment. Accordingly the Swedish Environmental Authority and the various local authorities have the power to influence the overall project and may propose alterations in mining and process specifications. Some of the more important environmental problems are listed below.

- Open pit mining and tailing heaps will change the landscape. It is therefore essential that the depleted open pit area together with the tailing heaps and ponds be arranged to fit the surrounding areas. It will be necessary to recultivate the final ground surface.

- Mining will lower the ground water table over a number of years.

- Water seepage from mining operations and tailings disposal might pollute the ground water. Appropriate measures will therefore be taken.

- A close watch must be maintained on emissions of dust and of sulphur dioxide both from the sulphuric acid plant and from the evaporating plant. The plant will be equipped with efficient means for cleaning exhaust air and stack gases.

- Treatment of the barren solution must be efficient as it contains readily soluble salts which may influence the ground water. These salts will be eliminated through the step-by-step neutralisation and evaporation described earlier. In this way a closed system for process water can be realized while avoiding a contaminated outlet to the recipient.

- The radio toxicity of the tailings has been carefully studied. Radon emission is reduced to low values by covering the tailings with densely packed soil. No great difficulties are foreseen. However, a large and detailed testing and sampling survey is in progress.

SWEDISH MINE LEGISLATION

The right to mine uranium bearing minerals is subject to the issue of a special concession by the Government. Before such a concession is granted the authorities must decide whether state interests are served by the issue of such a concession.

Apart from the Government concession for uranium mining the project must be scrutinized in accordance with the following legislation:

- the Swedish Building Act, paragraph 136a, which includes a veto right for the relevant communities. This means that, independent of the interests of the country as a whole, these communities can stop the project even in the face of government approval
- the Mining Act (minerals other than uranium)
- the Atomic Energy Act
- the Environmental Protection Laws

In addition to these permits, there is a requirement for master planning in accordance with general building legislation. Such planning is formulated at a local level and the plan is formally approved by the Government.

EFFORT TO UTILIZE OTHER MINERALS

In view of the possible world shortage of raw materials and the progressive interest attached to independence within the energy and mineral sectors the alum shale can be regarded as a valuable mineral reserve. It is at the same time the most significant mineral deposit as yet unexploited in Sweden. Mining of the shale should therefore increase the future security of supply within essential industrial sectors such as energy, fertilizer raw materials and raw materials for both the aluminium and steel industries (Table I).

In order to find a technical solution to utilize these interesting minerals, a study is being carried out consisting of three process steps that follow upon mining.

Step 1: Development of the process so that the energy content in the organic matter of the shale becomes available through combustion or gasification.

Step 2: Development of an acid leaching process to recover the aluminium content of the shale.

Step 3: Improvement and adaptation of existing methods to recover various elements, such as uranium, vanadium, molybdenum, fertilizer components (nitrogen, potassium, phosphorous) etc.

This concept, which aims at obtaining the maximum of useful products from a complex ore, calls for a considerable amount of research and development. The solid foundation laid by the extensive work already performed to put the existing uranium extraction process on a firm footing together with new developments in the related areas of chemical engineering justifies the proposals.

CONCLUSIONS

Finally, considering today's world market price, we are convinced that large scale mining of our low grade uranium ores will be profitable.

We are also of the opinion that it is possible to develop processes through which other interesting products can be extracted from the shale. This may be feasible even within the next ten years.

Table I. Main elements available in the Billingen ore

	Content in 1 M ton shale ton	Consumption in Sweden for 1973 ton/year	Import into Sweden 1973
Aluminium	65 000	160 000	160 000
Potassium	35 000	120 000	120 000
Magnesium	4 000	8 000	8 000
Phosphorus	700	250 000	250 000
Sulphur	65 000	450 000	190 000
Uranium	270	-	-
Vanadium	650	1 000	1 000
Molybden	300	4 000	4 000
Nickel	200	30 000	30 000

Heat content 1.8×10^6 Gcal/1 M ton

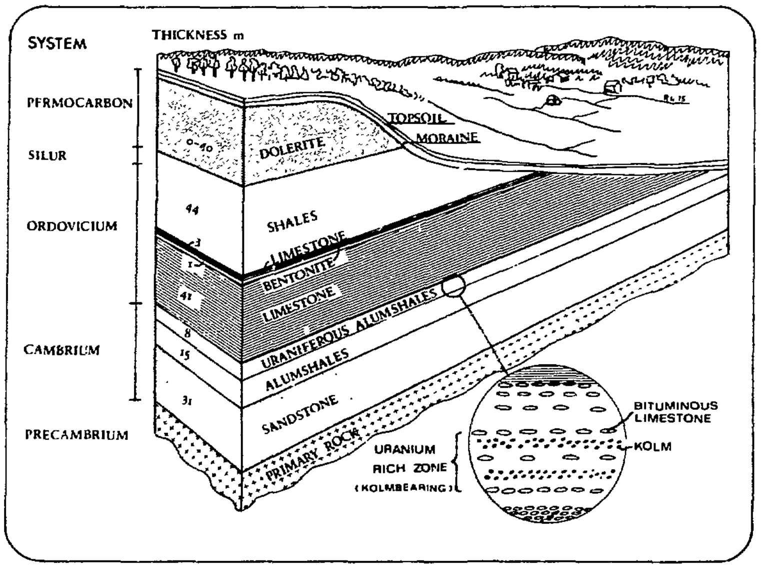

Fig 1. Section of the Billingen mountain.

Fig 2. Flow sheet Ranstad.