generation of ore). Uranium deposits considered by working groups IV and V offer hope for the future, when the minable grade of U_3O_8 decreases. The charges of working groups I and VI transcend individual deposits or types of deposit to help answer the more fundamental problems that ultimately lead to uranium mineralization. Findings in these areas of study are necessary to provide a sound basis for fruitful future exploration.

Although the book was published by photo-offset from manuscript, the quality is very good to excellent. The discussions that follow each paper and reports from the working groups add significantly to the volume.

The symposium was held for uranium exploration geologists and the papers reflect this professionalism. Scientists and engineers with some background or a strong interest in geology will find these papers generally informative, but if you wonder "what geologists do when they dig dirt?," you should pass on this one. This volume should be more digestible if taken after "Short Course in Uranium Deposits: Their Mineralogy and Origin."

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Status and Prospects of Thermal Breeders and Their Effect on Fuel Utilization

(International Atomic Energy Agency Technical Report Series No. 195)

Publisher	Unipub
Pages	143
Price	$18.25
Reviewer	Kazys K. Almenas

For the public at large there is still an aura of the exotic about nuclear engineering, but in fact, this over a third of a century old branch of engineering is in danger of becoming one of its most standardized ones. For these days after pressurized water reactors and boiling water reactors, what else is there? Especially in the U.S. This book is a timely reminder that it was not always thus. Far from it. A mere 10 to 15 years ago literally dozens of reactor types were at various stages of development. Many additional applications (like powering rockets and melting steel) were envisioned for nuclear power. The abbreviations of the reactor types around could have filled a few pages. Most of this is passing into history now and unfortunately it is not a very well-recorded history. Much of the information that the various programs generated appeared only in scattered journal articles and in reports having limited distribution. There is a definite need to summarize and preserve this information in a more accessible format. Though this is not the purpose of the book being reviewed, it does an admirable job of discussing four reactor types, for three of which, the molten-salt breeder reactor (MSBR), heavy water suspension reactor (HWSR), and light water breeder reactor (LWBR), information is not generally available. This should broaden the appeal of this book and make it useful as a general reference.

The primary purpose, as the title states, is to review the prospects of thermal breeders. It is the product of a cooperative International Atomic Energy Agency study edited by J. A. Lane, who probably should get more credit than he has received (a line in the Foreword) for the readability and organization of the text. The book does have some weaknesses (these will be noted), which generally accompany group efforts, but readability is not one of them. In an economical 140 pages, the thermal breeder concept is reviewed, compared with liquid-metal fast breeder reactor (LMFBR) performance and four reactor types [the three already noted plus the thorium cycle Canadian deuterium uranium (CANDU) reactor], and summarized. The text is sufficiently clear that the book can be recommended as a supplementary source for courses dealing with fuel cycle analysis. The distinction between thermal breeders and the much more familiar fast breeders is especially well presented. It is appropriately emphasized that the breeding ratio is not an end in itself but merely the means to an end. The goal, after all, is economical utilization of fissile resources. In order to achieve this not only the breeding ratio but also the specific fissile inventory (kg fissile/MW) must be considered. In terms of the breeding ratio alone, thermal breeders cannot compete with fast breeder reactors (FBRs). A glance at a graph displaying neutron energy-dependent η values illustrates this fact convincingly. However, thermal breeders do have significantly lower fissile inventory requirements. For expanding nuclear power programs, this can lead to a situation where a combination of light water reactors (LWRs) plus thermal breeders can have lower cumulative and yearly fissile requirements than a corresponding combination of LWRs and LMFBRs. It must be emphasized that this is dependent on the specific growth scenarios and is quite sensitive to the assumptions regarding out-of-core fissile inventory requirements. The assumptions used in the studies are consistent and reasonable. They are stated clearly and the results of the analysis are displayed in well chosen, informative graphs. In general, studies that deal with fissile resources utilization using LMFBR-LWR scenarios tend to slight the out-of-core inventory problem. This study had to focus on this important aspect and the results are presented in a sufficiently general manner that they are of interest even disregarding the problem of thermal breeders.

As noted, an equally valuable contribution is the presentation of four reactor types in a manner that allows quantitative comparisons between them and comparisons with the more familiar LWRs and FBRs.

The MSBR and HWSR are homogeneous reactors. The word should be qualified somewhat since for the suspension reactor the fuel consists of 5-μm UO_2 fuel particles held in suspension by proper adjustment of flow rates. However, the particles are sufficiently small that the bulk of the fission products escape from the fuel particle and thus can be removed by appropriate chemical processing. This is an important feature since one of the main advantages of homogeneous systems is the ability to reduce neutron absorption in fission products. The other is the possibility to use continuous fuel reprocessing schemes. These features enable homogeneous thermal breeders to achieve breeding ratios of ~1.05 and thus become breeders in the true sense of the word. The other two types are at best near breeders, since their breeding ratios are very close to 1.0.

The reactor types considered differ widely with respect to their level of development. Thus at one extreme, the CANDU-HWSR can draw on experience that includes 16-GW(electric) capacity in operation or under construction, while the HWSR was operated only as a 1-MW(thermal) experimental facility. The authors thus were faced with a formidable task in trying to compare the reactor types on an equivalent basis. In a sense they met this task somewhat too successfully. By this I mean that the allocation of space information and emphasis is almost identical for each reactor type. This is probably a good way to maintain amity among four different contributing groups, but it does lead to an unwitting distortion. The impression is left that all of the four reactor types have a similar viability. This impression is reinforced by a careful avoidance of preference for any reactor type in the introductory or conclusion sections. It is in this respect that the cooperative effort, which naturally has to balance the views of the contributing parties, shows its influence. A more definite comparison between the reactor types would have been welcome.

However, as noted the information is available. Each reactor type is described in some detail in a separate appendix. The descriptions include diagrams, process flow sheets, and an especially welcome section reviewing the history of the reactor and potential scale-up problems. Since the appendixes were contributed by the separate groups in question, it is quite understandable that they do stress the positive features of each type. However, there is one aspect of this emphasis of the positive that should be strongly critized. The descriptions of both the HWSR and the MSBR contain phrases that state that the reactors are "inherently safe." What is meant is that they do have a prompt negative temperature coefficient of reactivity. In one case it is even stated that "the dilute heat source makes the 'China Syndrome' less of a concern" (p. 94). This is inexcusable. Safety is a too comprehensive, too complex, and too emotional and political a problem to be dealt with on the basis of single features. A prompt negative temperature coefficient should certainly be noted and if possible quantified (this is not done) but the question of "inherent safety" can only be addressed in a more responsible manner.

The above points had to be made because the issue (though minor from the point of view of the subject analyzed in the book) is important. It therefore bears repeating. The reviewed book is indeed well written and organized. It achieves its purpose of comparing thermal breeders in a wider context. In addition, it summarizes information about four reactor types, for three of which information is not easy to find. For 140 pages of text, this is no small achievement.

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Short Course in Uranium Deposits: Their Mineralogy and Origin

Editor M. M. Kimberley

Publisher University of Toronto Press, Toronto (1978)

Pages 521

Price $8.00

Reviewer Arthur L. Reesman

This volume was published by photo-offset *just* prior to the three-day course and the quality of the manuscripts is not as good as *Formation of Uranium Ore Deposits*. The course, which was attended by over 200, is yours for less than 5% of the registration fee. The background of course participants was varied (ranging from students to university faculty and specialists who had been in uranium exploration for years). This book should serve a wider readership than did *Formation of Uranium Ore Deposits*, because it was designed to be a teaching tool. A glossary at the end of the book covers most of the less commonly used geological terms, but it is assumed that the reader is a geologist.

The course was designed to take the average geologist and provided an intensive introduction to the specialized study of uranium mineralization. Even though the bulk of the deposits covered in detail are Canadian, reflecting the experiences of the authors and the interests of the course participants, the principles of ore deposition and the applicability to other deposits make this book valuable to the "professionals" from other geographic regions.

The 21 lectures (papers) are divided into five sections. Section A, Uranium Geochemistry, emphasizes the low-temperature geochemistry and mobility of uranium in the near-surface environment. Section B, Uranium Mineralogy, covers the complex group of uranium-bearing minerals. Identification of most of the 150 or so minerals is so difficult that a mineralogist is needed; however, the more common uranium minerals can be identified in the field with some certainty (if they are large enough). This section is helpful in the broader sense of re-emphasizing the significance of understanding the uranium-bearing minerals, but it will not transform the reader into a specialist in uranium mineralogy.

After quick lessons in uranium geochemistry and mineralogy, Section C covers the Classification and Description of Selected Deposits (five papers). There is no single or universal system for classifying uranium deposits. Most classifications place an emphasis on the genesis of the deposit (when possible) but descriptive features are also used. Classification of deposits is an important step in exploration of similar deposits. Examples of deposits come from a variety of locations, but they favor the Canadian deposits.

Roll-Type and Stratiform Deposits are covered in Section D (five papers). This group of deposits is given special treatment because it accounts for most uranium production, reserves, and potential future reserves. Section E focuses in depth on the Uranium Deposits in Northern Saskatchewan (six papers).