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URANIUM — AND THORIUM-BEARING PEGMATITES OF THE UNITED STATES

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Golden, Colorado 80401

April 1980

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TABLE OF CONTENTS

PART I

	<u>Page</u>
ABSTRACT	i
CHAPTER I - INTRODUCTION -----	1
CHAPTER II - GEOLOGY OF PEGMATITES -----	9
INTRODUCTION -----	9
DEFINITION -----	9
CLASSIFICATION -----	9
INTERNAL STRUCTURE -----	11
DISTRIBUTION AND SPATIAL RELATIONS -----	17
GENESIS -----	19
TECTONIC SETTING -----	25
Introduction -----	25
Appalachian Fold Belt -----	27
Central and Southern Rocky Mountains -----	36
Discussion -----	39
CHAPTER III - GEOCHEMISTRY OF URANIUM AND THORIUM -----	43
CHAPTER IV - URANIUM-AND THORIUM-BEARING PEGMATITES -----	49
MINERALOGY -----	49
Essential Minerals -----	49
Common Accessory Minerals -----	50
Radioactive Minerals -----	53
Effects of Natural Irradiation -----	58
ELEMENTAL AND MINERALOGICAL ASSOCIATIONS -----	63
Introduction -----	63
Maine and New Hampshire -----	65
North Carolina -----	69
Colorado -----	74
New Mexico -----	76
South Dakota -----	81
Summary -----	82
Discussion -----	86
URANIUM AND THORIUM IN UNZONED PEGMATITES -----	88
URANIUM AND THORIUM IN ZONED PEGMATITES -----	90
HOST ROCK RELATIONS -----	104
AGE RELATIONS -----	107
DISTRIBUTION -----	109

TABLE OF CONTENTS (continued)

	<u>Page</u>
CHAPTER V - SUMMARY -----	111
GEOLOGY OF PEGMATITES -----	111
GEOCHEMISTRY OF URANIUM AND THORIUM -----	111
URANIUM- AND THORIUM-BEARING PEGMATITES -----	112
CHAPTER VI - DISCUSSION -----	115
CONCEPTUAL MODEL -----	115
FAVORABILITY CRITERIA -----	116
Radioactivity -----	117
Tectonic Setting -----	117
Host Rock Relations -----	118
Mineralogy -----	118
Internal Structure -----	119
Alteration -----	120
Geochemistry -----	120
Prospecting Guides -----	120
FAVORABLE ENVIRONMENTS -----	122
Pegmatites Associated with Syenite and Grenville-Age Rocks -----	122
Pegmatites Associated with Iron-Rich Rocks of Grenville Age -----	122
Pegmatites Associated with Alkaline Intrusives -----	123
Multiple-Oxide Pegmatites -----	123
Pegmatites Associated with Migmatites -----	123
CHAPTER VII - RESOURCE POTENTIAL AND CONCLUSIONS -----	125
RESOURCE POTENTIAL -----	125
CONCLUDING REMARKS -----	127
REFERENCES CITED -----follows page-	127
APPENDIX - SAMPLE DESCRIPTIONS AND ANALYSES	

ILLUSTRATIONS

PLATES

Page

1. URANIUM- AND THORIUM-BEARING PEGMATITES OF
THE UNITED STATES -----in pocket
2. MAJOR TECTONIC PROVINCES AND PEGMATITE
DISTRICTS IN THE UNITED STATES -----in pocket

FIGURES

1. Diagram showing relationships of pegmatite
units. ----- 13
2. Diagram showing position of various zones
within pegmatites. ----- 14
3. Flow chart outlining crystallization of granitic
magma, pegmatite, and related rocks. ----- 23
4. Sequence of crystallization for granitic
pegmatites. ----- 26
5. Ionic radii of elements. ----- 45
6. Frequency distribution of radioactive minerals
by pegmatite zones and secondary units. ----- 92
7. Frequency distribution of radioactive pegmatites
by host rock. ----- 105
8. Frequency distribution of radioactive pegmatites
by age. ----- 108

TABLES

	<u>Page</u>
1. Summary of known uranium production from pegmatites in the United States. -----	2
2. List of pegmatites visited in both Canada and the United States. -----	5
3. Mineral compositions commonly associated with pegmatite zones. -----	16
4. Summary of tectonic setting for various tectonic provinces containing pegmatites. -----	28
5. Average abundances of uranium and thorium. -----	44
6. Radioactive minerals appearing in text. -----	54
7. Selected radioactive pegmatites of Maine. -----	67
8. Selected radioactive pegmatites of New Hampshire. ---	68
9. Selected non-radioactive pegmatites of Maine. -----	70
10. Selected non-radioactive pegmatites of New Hampshire.	71
11. Selected radioactive pegmatites of North Carolina. --	72
12. Selected radioactive pegmatites (allanite) of North Carolina. -----	73
13. Elemental associations of Colorado pegmatite provinces.	75
14. Selected radioactive pegmatites of Colorado. -----	77
15. Selected non-radioactive pegmatites of Colorado. ----	78
16. Selected radioactive pegmatites of New Mexico. -----	79
17. Selected radioactive pegmatites of South Dakota. ----	83
18. Selected non-radioactive pegmatites of South Dakota. -	84
19. Distribution of radioactive minerals with zoned pegmatites. -----	91
20. Summary of the mineralogy of zoned pegmatites. -----	95

PART II

INDEX TO URANIUM- AND THORIUM-BEARING PEGMATITES IN THE UNITED
STATES LOCATION MAPS - 1 THROUGH 89

PART III

SELECTED ANNOTATED BIBLIOGRAPHY OF PEGMATITES

INTRODUCTION

BIBLIOGRAPHY

SUBJECT INDEX

URANIUM- AND THORIUM-BEARING
PEGMATITES OF THE UNITED STATES

PART I

ABSTRACT

This report is part of the National Uranium Resource Evaluation (NURE) Program designed to identify criteria favorable for the occurrence of the world's significant uranium deposits. This project deals specifically with uranium- and thorium-bearing pegmatites in the United States and, in particular, their distribution and origin.

From an extensive literature survey and field examination of 44 pegmatite localities in the United States and Canada, the authors have compiled an index to approximately 300 uranium- and thorium-bearing pegmatites in the United States, maps giving location of these deposits, and an annotated bibliography to some of the most pertinent literature on the geology of pegmatites.

Pegmatites form from late-stage magma differentiates rich in volatile constituents with an attendant aqueous vapor phase. It is the presence of an aqueous phase which results in the development of the variable grain size which characterizes pegmatites. All pegmatites occur in areas of tectonic mobility involving crustal material usually along plate margins. Those pegmatites containing radioactive mineral species show, essentially, a similar distribution to those without radioactive minerals.

Because of their unique geochemical properties, uranium and thorium are frequently transported with the volatile fraction in the magmatic environment and, therefore, are a common, but not abundant, constituent of pegmatites. As the composition of source rocks for pegmatitic magma varies, so too does the resultant mineral assemblage, particularly the accessory minerals.

Various pegmatite districts which contain radioactive pegmatites may have mineralogical or elemental associations which serve as indicators for the presence of radioactive elements. Nb-Ta, F and the rare-earth elements are examples of indicator elements, although these are strongly district specific. Although no universal pathfinder elements have been defined, it is axiomatic that the more complex the chemistry of a pegmatite, the more likely that it will contain radio-elements. The radioactive minerals may occur disseminated within an unzoned pegmatite, in specific zones within a zoned pegmatite, or associated with secondary units crosscutting a pegmatite body. Radioactive pegmatites are characteristically Precambrian or Devonian-Carboniferous in age and are hosted principally by high grade metamorphic rocks such as gneisses and schists as well as granitic intrusives. The preponderance of radioactive pegmatites and pegmatites in general occur in crustal mobile belts as illustrated by their abundant distribution along the Appalachian and Cordilleran Fold Belts in the United States.

Criteria such as tectonic setting, magma composition, host rock, and elemental indicators among others, all serve to help delineate areas more favorable for uranium- and thorium-bearing pegmatites. The most useful guide remains the radioactivity exhibited by uranium- and thorium-bearing pegmatites. Although pegmatites are frequently noted as favorable hosts for radioactive minerals, the general paucity and sporadic distribution of these minerals and inherent mining and milling difficulties negate the resource potential of pegmatites for uranium or thorium.

CHAPTER I

INTRODUCTION

This study of uranium- and thorium-bearing pegmatites was conducted by Derry, Michener & Booth, Inc. (DMB) under sub-contract to Bendix Field Engineering Cooperation (BFEC) for the National Uranium Resource Evaluation (NURE) program managed by the Grand Junction Office of the U. S. Department of Energy (DOE). The NURE program was formulated "to develop and compile geologic, geophysical and other information which will contribute to assessing the distribution and magnitude of uranium resources and to determine areas favorable for the occurrence of uranium in the United States" (BFEC, 1979, p. 6). One phase of this program was directed towards topical geologic studies to identify the criteria that best explain the occurrences of the world's significant uranium deposits.

Deposits considered to be pegmatites are mined for uranium in the Bancroft area in Ontario, and the large uranium deposit at the Rössing property in Namibia is, in part, in pegmatite. About one hundred tons of uranium-rich minerals have been recovered from pegmatites in the Malagasy Republic and reportedly several hundred pounds of uraninite were obtained from Norwegian pegmatites after World War II (Heinrich, 1958). In the United States, radioactive minerals have been recovered from a few pegmatites which have yielded some test shipments, but no sustained production (see Table 1).

Subcontract #78-252-S of the BFEC commissioned DMB to study uranium- and thorium-bearing pegmatites in the United States. The study was to be restricted to those pegmatites formed, for the most part, from magmatic fluids.

Criteria which distinguish pegmatites of magmatic origin have been discussed by Tan (1966) and include:

1. Sharp and discordant contacts with the wall rock.
2. Extreme variation in grain size.

Name	Location	Mineral Mined	Production	Comments
Rare Metals Mine	Mohave Co., Ariz. Map 3, Loc. 4	Yttrotantalite	7-8 tons ore	Produced on footwall side of quartz core in zoned Precambrian pegmatite.
Hudson Tunnel	Idaho Springs, Colo. Map 17, Loc. 8	Uraninite	51.5 tcns at 0.24% U_3O_8 yielding approx. 250 lbs. uranium	Unzoned Precambrian pegmatite.
Spinelli Prospect	Hartford Co., Conn. Map 23, Loc. 16	Samarskite	50 lbs.	Mined in 1933; zoned pegmatite.
Cranberry Lake, Charlotte Mine	Sussex Co., N.J. Map 50, Loc. 3	Fergusonite, Thorite, Allanite,	95 tons ore	Deposit produced from semibasic Precambrian pegmatite and contact zones.
La Paloma Pegmatite	Rio Arriba Co., N.M. Map 52, Loc. 8	Samarskite	4 tons	Mined 1954; zoned Precambrian pegmatite.
Spruce Pine District	Mitchell & Yancy Cos. N. Carolina Map 62, Loc's. 1-7	Uraninite	100 lbs.	Sporadic production attempted from Fanny Gouge.
Spar Bed Hill Quarry	Essex Co., N.Y. Map 60, Loc. 11	Allanite	200 lbs.	Reverse zoning.

Table 1: Summary of known uranium production from pegmatites in the United States.
Map and location numbers are keyed to the Index to Uranium- and Thorium-Bearing
Pegmatites in the United States (Part II of this report).

Name	Location	Mineral Mined	Production	Comments
Baringer Hill	Llano Co., Texas	Gadolinite	800-1200 lbs.	Zoned Precambrian pegmatite mined prior to 1907.
Kaniksu	Pend Orielle Co., Washington Map 83, Loc. 5	Uraninite	300 lbs.	Produced from a poorly zoned Cretaceous pegmatite.
Platt	Carbon Co., Wy. Map 84, Loc. 4	Euxenite	+10,000 lbs.	Production was from 1956-1958.
Sparks-Stone	San Miguel Co., New Mexico	Autunite	10.5 tons at .13% U_3O_8	Produced in 1956

Table 1 continued

3. Chilled margins.
4. Systematic variation in the composition of minerals such as plagioclase, garnet, and biotite within the pegmatite.
5. High temperature of formation.

Pegmatites such as those at Rössing which formed through anatexis or remobilization of elements with the host rock and with little or no addition of magmatic material were to be excluded from the study. The objectives of the research were to develop criteria favorable for the occurrence of uranium- and thorium-bearing pegmatites and to apply these criteria to select areas within the United States where such deposits might be found.

For the purposes of this study, uranium- and thorium-bearing pegmatites are defined as "holocrystalline rocks that are at least, in part, very coarse grained, whose major constituents include minerals typically found in ordinary igneous rocks, and in which extreme textural variations especially in grain size are characteristic" (Jahns, 1955, p. 1030), and which contain identifiable uranium or thorium minerals as more than extremely rare constituents.

The study began in October, 1978, and the final report was submitted in April of 1980. A total of 1.75 man years was devoted to the project by the authors and others of the DMB professional staff. In the course of the research, 44 pegmatites were visited. Table 2 is a list of those deposits examined. In most cases the pegmatite was given only cursory examination, many were sampled and a few were mapped in detail. Radiometric readings were taken at each site and more detailed surveys were made over the more important radioactive occurrences.

Bancroft Area, Ontario, Canada

Madawaska Mine

Rd. Cuts

Arizona

Buckeye Pegmatites, Maricopa Co.

White Picacho area, Maricopa and Yavapai Cos.

Rare Metals Mine area, Mohave Co.

California

Campo Pegmatite, San Diego Co.

Colorado

Mica Basin, Routt Co.

Idaho Springs area, Clear Creek Co.

Roscoe Pegmatite, Jefferson Co.

Seerie Pegmatite, Jefferson Co.

South Platte area, Jefferson Co.

Burroughs Mine, Jefferson Co.

Lake George area, Park Co.

Black Cloud Pegmatite, Teller Co.

St. Peter's Dome area, El Paso Co.

Connecticut

Feldspar Co. Quarry, Middlesex Co.

Strickland Quarry, Middlesex Co.

Branchville Pegmatite, Fairfield Co.

Ridgefield Pegmatite, Fairfield Co.

Maine

Black Mtn. Mine, Oxford Co.

Consolidated Feldspar Quarry No. 1, Sagadahoc Co.

Russell Bros. Quarry, Sagadahoc Co.

Standpipe Hill Quarry, Sagadahoc Co.

Tamminen Pits, Oxford Co.

Newry Hill area, Oxford Co.

Mount Mica Mine, Oxford Co.

Table 2: List of pegmatites visited in both Canada and the U. S.
The list includes 44 localities in 12 states and one Canadian province.

New Hampshire

Beryl Mtn. Quarry, Sullivan Co.

Palermo Quarry, Grafton Co.

New Jersey

Cranberry Lake, Sussex Co.

New Mexico

Harding Mine, Taos Co.

Petaca District

Queen Mine, Rio Arriba Co.

Sunnyside Mine, Rio Arriba Co.

New York

Baylis Quarry, Westchester Co.

McLear Pegmatite, St. Lawrence Co.

North Carolina

Spruce Pine District

Deer Park Mine, Mitchell Co.

McKinney Mine, Mitchell Co.

Wiseman Mine, Mitchell Co.

Pink Mine, Mitchell Co.

Carolina No. 20 Mine, Yancey Co.

Ray Mica Mine, Yancey Co.

Pennsylvania

Rohrbach Prospect, Berks Co.

Virginia

Rutherford Mine, Amelia Co.

Morefield Mine, Amelia Co.

Wyoming

Platt Pegmatite, Carbon Co.

Table 2 continued.

Many of the pegmatites, particularly those in the eastern United States, in which radioactive minerals have been found have not been mined for many years and are now water-filled, overgrown by vegetation, or made inaccessible by urban development. In some it is still possible to recover specimens of radioactive minerals from old dumps, but information as to their original zonal position or abundance in the pegmatite cannot be ascertained.

Samples taken from the pegmatites were examined under the binocular or petrographic microscope. Approximately 54 samples were submitted for emission spectrographic analysis and fluorometric uranium determinations. The Appendix tabulates the results of these investigations.

The main text and conclusions of this report are based on a comprehensive search of the literature and our own investigations and field examinations. The intensive literature search has yielded two side products which are included within this report. One is an indexed annotated bibliography, containing nearly 300 of some of the most pertinent and noteworthy studies on the geology of pegmatites. The second is an index to approximately 300 uranium- and thorium-bearing pegmatites in the United States. The Index gives location, summarizes the principal geologic features, and offers a literature reference wherever possible. Accompanying the Index are 89 location maps to each of the listed pegmatites. Many of the pegmatites discussed throughout the text are listed in the Index and are shown on the location maps to which the reader is referred.

The authors would like to express their appreciation to all of those whose assistance and knowledge we drew upon during this project. In particular, to Dr. R. H. Jahns of Stanford University,

Dr. M. H. Staatz and Dr. W. R. Griffitts of the U. S. Geological Survey, various state geologists who have kindly answered our letters and calls, the staff of the U. S. Geological Survey Library in Golden, Colorado for their assistance in tracking down obscure references, and to Carole Harris for typing and retyping the tables and manuscript of this report.

CHAPTER II

GEOLOGY OF PEGMATITES

INTRODUCTION

The term "pegmatite" has been in use since the early nineteenth century originally in a textural sense and subsequently expanded to embrace compositional aspects. The geology of pegmatites is a varied and complex subject upon which a wealth of material has been published. The interested reader is referred to the accompanying annotated bibliography for a guide to the literature and to Jahns (1955) for an excellent comprehensive review of pegmatite geology.

DEFINITION

Inherent in most definitions of pegmatites are the coarse grain size, the intrusive nature and the association with plutonic rocks (Anderson, 1931; Landes, 1933; Jahns, 1953a, Jahns, 1955; Turner and Verhoogen, 1960; and Hewitt, 1967a). In this report we concur with Jahns (1955, p. 1030) and use his definition of pegmatites as "holocrystalline rocks that are at least in part very coarse grained, whose major constituents include minerals typically found in ordinary igneous rocks, and in which extreme textural variations, especially in grain size, are characteristic." With this definition, pegmatites are not composition specific and may range from granitic to syenitic to gabbroic, although the latter are extremely rare. The textural aspects of pegmatites are important, particularly the variability in grain size.

CLASSIFICATION

Numerous classifications of pegmatites have been presented during the past 50-60 years. Most of these classifications have utilized various combinations of parameters such as form,

size, composition, texture, internal structure, genetic aspects, and country rock relations. One of the earlier classifications (Ginsburg, 1928) suggested a composite scheme based on such varying parameters as external and internal structure, primary and secondary mineral compositions, and alteration.

The first widely accepted classification was that of Fersman (1931) who presented an elaborate scheme based on elements and minerals represented on a decreasing temperature gradient. This scheme is still popular among many European geologists, although Jahns (1955) has pointed out drawbacks of this classification, particularly the restriction of various minerals to specific temperature ranges.

Hess (1933) proposed a genetic classification for pegmatites which included dikes, veins and metamorphic pegmatites. In another popular scheme Landes (1933) focused on the compositional aspects of pegmatites indentifying them as acid, intermediate or basic and then dividing them into simple and complex types depending upon the presence or absence of hydrothermal replacement.

The need for strategic minerals during and immediately after World War II resulted in extensive research into pegmatite deposits and their included rare elements. These studies brought about a fundamental change from earlier descriptive studies to more detailed analyses of economic, mineralogic, structural and genetic aspects. Emphasis on internal structure provided the basis for several classifications. Cameron et al (1949) established the currently accepted definitions of the internal units of pegmatites such as zones, fracture fillings, and replacement units. Similarly, Heinrich (1958) defined unzoned, zoned and complex pegmatites, the latter marked by the presence of secondary units such as the replacement and fracture-filling units of Cameron.

The importance of the mineable uraniferous pegmatites in the Haliburton-Bancroft area of Ontario prompted several geologists to forge classifications unique to this area. Among these classifications is that of Satterly (1957) whose pegmatite classification is part of a scheme encompassing all the radioactive deposits of the area. The pegmatites are divided into simple and complex in the same sense as Landes (1933); however, the simple bodies are subdivided into unzoned and zoned, whereas, the complex bodies are divided compositionally. This classification also includes metasomatic and hydrothermal deposits. More recently, Little (1970) included pegmatites as part of an overall classification of Canadian uranium deposits of igneous affinity, wherein, pegmatites are divided into unzoned and zoned, and the unzoned are further divided into red and white pegmatites.

Hewitt (1967a) proposed a classification which incorporated mineral composition, structure and spatial distribution. The mineral composition groups included granite, syenite, nepheline-syenite, and basic types. His structural classification included unzoned, zoned, complex replacement and xenoblastic pegmatites (replacement pegmatites produced by recrystallization and mobilization in a gneissic environment). Where pegmatites appear to be spatially or genetically related to plutons, Hewett classes them as interior, marginal or exterior.

INTERNAL STRUCTURE

Among the most complex and intensely studied aspects of pegmatites is their internal organization. Two of the more important studies dealing with the internal structure of pegmatites are Cameron et al (1949) and Jahns (1955). The following brief summary is drawn from these works.

Cameron et al (1949) described three lithologic and structural units found in many pegmatites. These include:

- (1) Zones: Successive shells, complete or incomplete, that reflect to varying degrees the shape or gross structure of the pegmatite body. Where ideally developed they are concentric about an innermost zone or core. Some units, however, are not zones, but belong in the categories below.
- (2) Fracture Fillings: Units, generally tabular, that fill fractures in previously consolidated pegmatite.
- (3) Replacement Bodies: Units formed primarily by replacement of pre-existing pegmatite, with or without obvious structural control.

The general relationship of these features are shown in Figure 1 taken from Cameron et al (1949).

Contacts between various units and zones may be either abrupt or else gradational over several feet. Similarly, although concentric, zones are not necessarily symmetric about a central core. Zones may be discontinuous, pinch and swell, taper or telescope along the length of a pegmatite.

Zones have been divided in the following manner from the margin to the center:

- (1) Border Zone
- (2) Wall Zone
- (3) Intermediate Zone (or Zones)
- (4) Core

The relations between the zones are shown diagrammatically in Figure 2.

The border zone is characterized by its marginal position. It is fine-grained, commonly aplitic and ranges from a few

LEGEND

Border Zone		Core
Wall Zone		Replacement
Intermediate Zone		Fracture Fill

Figure 1 Diagram showing relationships of pegmatite units
(Modified after Cameron et al, 1949).

LEGEND

Border Zone

Wall Zone

Intermediate Zone

Core

Figure 2 Diagram showing position of various zones within pegmatites.

(Modified after Cameron et al, 1949).

inches to several feet in thickness. Contacts with the country rock may be either abrupt or else gradational, depending upon the host rock and amount of replacement. The essential minerals of the border zone include plagioclase, quartz, and muscovite with accessory tourmaline, beryl, apatite, garnet, magnetite, and microcline. Additional material may be introduced to the border zone by complete or partial digestion of country rock.

The wall zone is thicker and coarser grained than the border zone. Contacts with adjacent border and intermediate zones are often gradational in composition and texture. It is in this zone where concentrations of economically important minerals such as mica commonly occur. Minerals in the wall zone usually include plagioclase, quartz, perthite, microcline, muscovite, and biotite, and less commonly tourmaline, garnet, beryl, columbite-tantalite, apatite, and other phosphates.

Intermediate zones are absent in many pegmatites and are the least common of the zonal types. Where present, they may form complete shells between wall zone and core, or may be present in only parts of the body. In grain size they are usually as coarse or coarser than the wall zone, and compositionally may be simple or complex. Several intermediate zones of contrasting mineralogy may be present. That part of an intermediate zone adjacent to the core is commonly referred to as the core margin.

The core, or innermost zone of a pegmatite, most commonly consists of massive quartz, however, massive perthite or combinations of quartz, perthite and plagioclase may occur. The size of the core zone depends on the size of the pegmatite and thickness of the wall and intermediate zones.

Table 3 summarizes the mineral associations in the various pegmatite zones.

Zone	Essential minerals	Accessory Minerals
Border Zone	Plagioclase, quartz, <u>+</u> muscovite	Tourmaline, garnet, beryl, apatite, magnetite, microcline
Wall Zone	Quartz, plagioclase, perthite, microcline, <u>+</u> muscovite, <u>+</u> biotite	Tourmaline, garnet, beryl, apatite, and other phosphates, columbite-tantalite
Intermediate Zone	Microcline, quartz, perthite, sodic plagioclase, <u>+</u> muscovite, <u>+</u> biotite	Sodic plagioclase, muscovite
Core	Quartz, perthite, <u>+</u> plagioclase	

Table 3: Mineral compositions commonly associated with pegmatite zones (Modified after Heinrich, 1958).

Heinrich (1958) noted that secondary units, which presumably include fracture filling and replacement bodies, most commonly occur in zoned pegmatites. These units develop from volatile-rich magma fluids and/or hydrothermal solutions which evolve from late differentiate magmatic fluids. In essence, the secondary units represent part of a continuum with granitic magmas and hydrothermal solutions as end members.

DISTRIBUTION AND SPATIAL RELATIONS

The pegmatites of the United States occur in metamorphic and plutonic rocks of various ages. The metamorphic rocks consist typically of gneiss, schist and quartzite and the plutonic rocks are primarily granitic to granodioritic in composition. Genetic relations between pegmatites and intrusives are often ambiguous. This is especially true in areas where several intrusives of varying composition and age occur, as for example, in New Hampshire where pegmatites are associated with several intrusive phases of the New Hampshire magma series as well as those of other older magma series. Conversely, some pegmatites occur in areas where no large granitic intrusives have been observed such as the Tinton District of South Dakota and the Thomaston-Barnesville District of Georgia (Cameron et al, 1949).

In a study of zonal distribution within pegmatite districts Heinrich (1953) points out the relationships between such features of pegmatites as size, shape, internal and external structures, textures and mineralogy with distance from parent magmas and nature of the host rock. He concluded that complex pegmatites were emplaced further from their source than simple pegmatites owing to their low viscosity and, being late differentiates, were frequently rich in rare-element minerals.

Hutchinson (1955) concluded that a change in the pressure-temperature gradient away from a parent granite was the con-

trolling factor for the observed regional zonation in size, attitude, mineralogy, and alteration of pegmatites in the Northwest Territories, Canada. He noted that beryllium pegmatites are closer to the granite, whereas, niobium-tantalum pegmatites and lithium pegmatites are progressively more distant.

In a more recent study, Varlamoff (1972) concluded that the spatial distribution of the pegmatites of central and west Africa was dependent upon the depth of crystallization of the parent intrusive. Where shallow depths are involved the pegmatites are small and are emplaced within the granite. Pegmatites derived from a magma crystallizing at greater depths are characterized by their greater dimensions and emplacement further from the granite. Pegmatites emplaced at greater depths (6-7 kms) are more likely to contain muscovite; those at moderate depths (4-6 kms) may contain cassiterite, columbite-tantalite, microlite, beryl, petalite and other lithium minerals; and in those at shallow depths (2-4 kms) calcite and fluorite are expectable.

Compositional and textural variations may also define zonal distributions. For example, Carboniferous pegmatites of the Blue Ridge and Piedmont provinces of Virginia, North Carolina, and Georgia show a zonal arrangement of mica colors (Olson, 1944; Griffitts and Olson, 1953; Griffitts et al, 1953; Lesure, 1968); green muscovite is proximal to the granite, whereas, brown muscovite occurs further out. A prominent compositional variation in pegmatites associated with intrusives of different ages is seen in the tin- and spodumene-bearing pegmatites of North Carolina which contain mineral assemblages different from nearby younger mica-bearing pegmatites (Griffitts and Olson, 1953).

GENESIS

The evolution of ideas concerning the classification of pegmatites, discussed earlier, is similarly found in the growth of theories regarding pegmatite genesis. Some of the more important studies dealing with genesis are summarized below. It should be noted that because this study is primarily concerned with non-anatectic radioactive pegmatites, deposits such as the Rössing in Namibia (South West Africa) will not be dealt with in as great detail as those pegmatites of undoubted magmatic origin.

In a discussion concerning the origin of zones in pegmatites, Cameron et al (1949) suggested three possible processes:

- (1) In situ fractional crystallization of pegmatitic magma following injection into open fissures. This is a restricted system in the sense that no new magma material is introduced, however, material may migrate out during crystallization or reactions between country rock and pegmatite may take place. Compositional zoning results from successive fractionation of the crystallizing liquid from the wall rock inward toward the core.
- (2) Successive crystallization in an open system along a plumbing network through which pegmatite fluids migrate. Zoning results from progressive changes in temperature, pressure, and composition of the migrating pegmatitic solutions.
- (3) Two stage development involving magma injection and crystallization of massive pegmatite in a closed system followed by replacement by hydrothermal solutions in an open system. The number and arrangement of zones reflects the path or paths along which the solutions migrated.

It is inferred that all three processes are essentially of magmatic origin predicated upon injection of a pegmatitic fluid. In the first two cases zoning develops from primary processes, whereas, in the third category zoning results from secondary processes involving post-crystallization replacement.

A summary of literature on the origin of pegmatites was provided by Jahns (1955). He outlined the principal theories which included:

- A) Aqueous theories:
 - 1. Lateral secretion
 - 2. Selective solution ("aqueous anatexis")
- B) Igneous theories:
 - 1. Viscous magma, segregated or injected.
 - 2. Highly fluid magma, segregated or injected.
 - 3. Injected magma formed by anatexis or palingenesis.
 - 4. Aqueous solutions derived from magmas.
- C) Metamorphic theories:
 - 1. Recrystallization
 - 2. Anatexis or palingenesis
 - 3. Replacement or secretion by non-magmatic fluids.
 - 4. Replacement or secretion through particle diffusion (Metamorphic differentiation).

Both of the aqueous theories enjoyed a degree of popularity in their time, however, they have since been dismissed as being untenable. Selective solution is considered a reasonable hypothesis for lit-par-lit pegmatites by some workers, although, this theory is more akin to metamorphic processes.

The metamorphic theories involve recrystallization or the transfer of material by diffusion of non-magmatic solutions resulting in pegmatite formation via metasomatism, porphyro-

blasis or open-space filling (Jahns, 1955). Many of the more important radioactive pegmatite occurrences are thought to be, in part, of metamorphic origin. For example, the radioactive pegmatites in the Bancroft area are thought to have developed from both intrusive and replacement processes. Hewitt (1967a) envisioned injection of granitic and syenitic magmas with "widespread assimilation and reaction" with wall rocks as well as "extensive hydrothermal replacement of the pegmatite by solutions". Satterly (1957) presented similar views classifying the pegmatites as complex bodies formed via intrusion and replacement, plus assimilation of the country rock. These complex pegmatites include the presently producing Madawaska Mine as well as such important past producers as the Bicroft, Halo, Greyhawk, and Canadian Dyno Mines. Of the magmatically derived, unaltered, simple pegmatites the only radioactive occurrence is at the zoned pegmatite at MacDonald Feldspar Mine (Hewitt, 1954, in Hewitt, 1967a; Satterly, 1957).

The Rössing deposit of Namibia (South West Africa) is likewise thought to be of metamorphic origin. The alaskite pegmatites are interpreted as having developed from an anatectic melt (Smith, 1965; Berning et al, 1976; Nishimori et al, 1977) and were subsequently intruded into gneiss, migmatite, amphibolite, and limestone. Similarities between this deposit and an occurrence in the Wheeler Basin area, Grand County, Colorado, have been noted (Young and Hauff, 1975). To date, this is the only occurrence of this type known in the United States.

Igneous theories requiring a magmatic derivation for pegmatites are based largely on the field relationships of pegmatites with plutons. Such relations include pegmatites with close compositional affinities occurring within plutons; pegmatites which can be traced from host plutons into nearby country rock; systematic zonal distribution in relation to

plutons for pegmatites occurring entirely within country rock; as well as the spatial relations and similarities in composition between pegmatites and granites (Jahns, 1955). Of particular interest are the studies summarized by Jahns which attribute the rare element concentrations in pegmatites to by-products of magmatic differentiation of fluids enriched in those elements.

In an excellent study Jahns and Burnham (1969) pointed out the importance of the role of water in granitic magmas as an integral factor in the development of pegmatites. A highly simplified flow-chart outlining the main processes and end-products for pegmatites and related rocks is shown in Figure 3. This chart is modified from a more comprehensive diagram in Jahns and Burnham (1969) and the reader is referred to their paper for a more detailed description.

Initially, the parent magma is either emplaced or developed in situ by separation from another magma or melting of crustal material. The magma contains water and other volatiles in amounts ranging from less than one percent up to saturation within existing pressure-temperature conditions. Water content increases with a decrease in temperature and subsequent crystallization of anhydrous minerals and may lead to saturation of the rest-liquid. Saturation is also reached by reduction in confining pressure or migration of water from the country rock into the magma. Conversely, an escape of water into country rock results in metasomatic alteration.

The process of pegmatite formation is largely dependent upon the development of an aqueous liquid from the crystallizing melt. This liquid, being less dense, migrates upwards reacting with the crystal-bearing silicate melt. The migrating aqueous liquid enhances crystal growth by facilitating transfer of

Figure 3: Flow chart outlining crystallization of granitic magma, pegmatite, and related rocks (Modified from Jahns and Burnham, 1969).

material from the silicate melt resulting in coarse grain size, whereas, crystals of finer grain size develop from the more viscous silicate melt. The continued segregation and migration of the aqueous phase results in compositional variations within the pegmatite. For example, potash minerals tend to develop in the presence of the aqueous phase and soda minerals with the silicate melt. Because of the migration capacity of the aqueous phase, potash minerals such as muscovite, microcline and perthite commonly occur along the outer margins or as aggregates in the upper parts of pegmatites. Quartz tends to crystallize from both fluids, thus accounting for its ubiquitous occurrence ranging from massive cores to interstitial and graphic intergrowths. Outward migration of the aqueous phase into the country rock often results in compositional alteration and the presence of exotic mineralogic assemblages in the fine-grained border zones. The fine grain size results from a loss of water into the country rock during crystallization. It is probable that beryl occurring in country rock as at the Harding pegmatite, and the beryl, fluorite, and topaz in schists at the Sunnyside deposit in the Petaca District are the result of aqueous fluids migrating into the country rock. The association of uraninite with biotite in both the border zones and wall rocks of pegmatites in the Lac La Ronge area of northern Saskatchewan may be another example of this process.

Reactions between crystal and silicate melt, and crystals and aqueous phase are continuous throughout the crystallizing process. Replacement and reaction between crystals and the aqueous phase is more widespread. Owing to the transporting ability of the aqueous phase, replacement and reaction may commence long before complete crystallization of the melt. Ostensibly, replacement may occur in early formed zones while later zones are crystallizing.

The sequence of crystallization outlined by Jahns and Burnham (1969) is summarized in Figure 4. Crystallization from an initial magmatic stage increases the volatile content in the original melt and produces granites with a normal phaneritic texture. Continued differentiation results in a two-fluid stage of silicate melt and aqueous fluid as well as crystals. It is the development of the aqueous phase which produces textural and compositional features characteristic of pegmatites.

From the foregoing discussion, it may be concluded that pegmatites develop from a parent magma via differentiation into an aqueous phase. This observation is important when considering pegmatites of uncertain or complex origin. Nishimori et al, (1977) aptly noted that if pegmatites develop from aqueous liquids exsolved from a silicate melt then the question of magmatic as opposed to metasomatic origin for deposits such as those in the Bancroft area is more a problem in semantics rather than a fundamental difference in genesis.

TECTONIC SETTING

Introduction

The propensity for pegmatites to occur in districts and provinces has long been recognized (Landes, 1935; Cameron et al, 1949; Heinrich, 1953; Jahns, 1955; Heinrich and Bever, 1957) as has the relation of such districts to certain structural elements. Very few studies, however, have considered pegmatites or pegmatite districts in the context of modern plate tectonics. Similarly, although there have been many papers on the origin and the relation of pegmatites and granites, very few authors have explained the genesis of pegmatites within the tectonic framework. The following pages describe pegmatites in the United States in terms of their tectonic setting.

Figure 4: Sequence of crystallization for granite pegmatites (Nishimori et al, 1977, from Jahns and Burnham, 1969).

Because of the preponderance of pegmatites and especially radioactive pegmatites in the Appalachian Fold Belt and in the central and southern Rocky Mountains these areas will be described in detail (Plates 1 & 2). Where known, the tectonic setting for the remaining occurrences are summarized in table form (Table 4).

It is important to note that, whereas, radioactive pegmatites are found as clusters or groups within districts of the Appalachian Fold Belt and central and southern Rocky Mountains those elsewhere are, for the most part, isolated individual occurrences (Plate 1). Moreover, many major pegmatite districts are virtually devoid of radioactive pegmatites. Examples of districts with very few or no radioactive pegmatites are the Black Hills of South Dakota and the western Arizona Belt from Kingman to White Picacho. The major pegmatite districts of the United States and the tectonic provinces in which they are found are shown in Plate 2 to which the reader is referred.

Appalachian Fold Belt

Pegmatites in the Appalachian Fold Belt are present in two main areas. In the northern Appalachians, concentrations of pegmatites occur in the New England Highlands of Maine (West Paris, Bethel and Rumford areas), New Hampshire, and in the eastern Highlands of Connecticut. Also, in the northern Appalachians are pegmatites which occur in Precambrian crystalline terrane of the northern Piedmont of western Connecticut, New York, New Jersey, Pennsylvania and Maryland. In the southern Appalachians the most notable concentration of pegmatites is in the Spruce Pine District of North Carolina, although other districts occur from Virginia through to Alabama.

Tectonic Province	Age Relations	Tectonic Setting
Appalachian Fold Belt	Pegmatites mainly of Devonian-Carboniferous age intrude highly metamorphosed meta-sediments and metavolcanics ranging from Upper Precambrian to Lower Devonian as well as consanguinous granitic plutons. Late or post-tectonic Permian igneous activity is indicated.	Several phases of deformation and intrusion are associated with opening and closing of the proto-Atlantic. Orogeny commenced in Devonian times in the northern Appalachians with collision of the African Plate. This may have been followed by a collision with the South American Plate in Carboniferous-Permian times in the southern Appalachians.
Precambrian Terrane in the Appalachian Fold Belt	Upper Precambrian (Hadrynian) pegmatites intrude orthogneisses and paragneisses of Grenville series.	Terrane is part of Grenvillian Structural Province which was uplifted and exposed during plate collision in the Taconic Orogeny.
Adirondack Highlands	Upper Proterozoic pegmatites intrude orthogneisses, paragneisses, amphibolite and marble of the Grenville series.	Crustal thickening due to middle Proterozoic continental collision and continental underthrusting. Possible suture exists along Alabama-New York geophysical lineament (King and Zeitz, 1978).
Central and Southern Rocky Mountains	Proterozoic pegmatites intrude highly metamorphosed Precambrian schists, gneisses, amphibolites and migmatites as well as various plutonic rocks ranging from 1000 m.y. to 1800 m.y. Several occurrences in Wyoming are Archean in age.	Collision of a Proterozoic island arc complex and Archean continent resulted in intense deformation and metamorphism. Crustal remobilization and subsequent rifting produced the Silver Plume and Pike's Peak plutons.

Table 4: Summary of tectonic setting for various tectonic provinces containing pegmatites.

Tectonic Province	Age Relations	Tectonic Setting
Black Hills, South Dakota	Proterozoic pegmatites (1667 m.y.) intrude mica and staurolite schist, amphibolite and less commonly, the Harney Peak Granite.	A Middle Precambrian sequence of sediments was deformed and intruded by granitic plutons approximately 1700 m.y. ago. This tectonism may be related to the Penokean Orogeny of Minnesota and Michigan.
Basin and Range of the Cordilleran Fold Belt	Pegmatites, mainly Precambrian in age, intrude schists, gneisses, amphibolites and granitic plutons.	Precambrian tectonics are uncertain. Pre-Beltian cratonic units are truncated by the Beltian Series. These sediments were deposited along a western margin extending from Canada to southwest United States. Most intense deformation is associated with Mesozoic and Cenozoic plate collisions. Pre-Beltian rifting is possible.
Mesozoic Batholiths of Washington, Idaho, and Montana	Cretaceous pegmatites occur in schists, gneisses and migmatites ranging from Precambrian to Mesozoic in age as well as various granitic rocks of the Boulder, Idaho, Colville, Chelan and other batholiths.	Mesozoic tectonics dominated by uplift, folding, faulting and extensive emplacement of granitic plutons. Several episodes of plate motion, either convergent or transcurrent, produced the Sonoran and Nevadan Orogenies and likely the earlier Antler Orogeny.
Mesozoic Batholiths of California	Mesozoic pegmatites intrude Precambrian schists and gneisses as well as granitic and basic intrusives associated with the Southern California and Sierra Nevada batholiths.	Mesozoic plate margin involved downwarping or accretion of the continental crust along a converging plate margin which resulted in deformation and plutonic intrusion principally during the Nevadan Orogeny.

Table 4 continued.

Northern Appalachians. The New England Highlands include igneous and metamorphic rocks of the northern Appalachian Mountains. The metamorphic rocks range in age from Cambrian to Devonian and include sedimentary and volcanic units deposited along the ancient eastern North American continental margin. These units were subsequently metamorphosed by several phases of folding and intrusion. Intrusives include the Jurassic White Mountain magma series and two earlier series, the Oliverian and Highlandcroft.

Most of the pegmatites in the West Paris area of Maine occur in migmatitic gneiss, biotite schist and calc-silicate granulite of the Silurian Patch Mountain and Noyes Mountain Formations. These units were originally deposited as immature sandstones with some interbedded carbonate units (Guidotti, 1965). In the Bethel area of western Maine, as well as in New Hampshire, the host rocks are gneiss, migmatite, granulite and mica schist of the Lower Devonian Littleton Formation. Guidotti (1965) interpreted the Littleton as a sedimentary sequence consisting of fine-grained sediments and immature sandstones.

In the Rumford area of Maine most pegmatites are found in Silurian and Devonian migmatitic gneisses, mica schists and various calc-silicate units originally deposited as fine-grained sediments and immature sandstones (Moench and Hildreth, 1976). Whether any of the Devonian units in the Rumford area are correlative with the Littleton Formation in adjacent areas in Maine and in New Hampshire is uncertain. Ostensibly, the Upper Silurian-Lower Devonian sedimentary sequence in this area represents debris shed from highlands developed in the early stages of the Acadian Orogeny. Age dates suggest that

the pegmatites are of Devonian-Carboniferous age and closely associated with the New Hampshire magma series. Although there is no positive genetic relation with any specific granitic pluton, the spatial distribution strongly suggests an affinity between the New Hampshire series and the pegmatites. Guidotti (1965) stated that the pegmatites in the Bryant Pond quadrangle, near Rumford, Maine, are late differentiates of the Songo Granodiorite of the New Hampshire magma series. The plutons were emplaced in the Middle Devonian during deformation associated with the Acadian Orogeny.

It has been suggested that the Acadian Orogeny, in the northern Appalachians, commenced about 410 m.y. ago during the Silurian and Early Devonian (Naylor, 1971). Folding, intrusion and intense metamorphism continued through to, at least, Middle to Late Devonian times. Intrusion of the New Hampshire series was episodic throughout the orogeny beginning about 410 m.y. ago (Spooner and Fairbairn, 1970), and based on age dating, continued for about 50 m.y. tapering off at the end of the Acadian Orogeny (Lyons and Livingston, 1977). Age dates of 380 m.y. and 369 m.y. have been obtained from granitic stocks in southwest Maine, suggesting that in places Acadian plutonism continued on into the Mississippian. Granitic intrusives in the New England Highlands are both syn- and post-tectonic.

Most pegmatites of the eastern Highlands of Connecticut occur in the Ordovician Bolton Schist or the Devonian Monson Granite Gneiss.

The Bolton Schist is primarily a quartz-mica schist with mica gneiss, amphibole schist, quartzite and marble. These units are intruded by the Monson Granite Gneiss and the Ordovician Hebron Gneiss, which consists of quartz gneiss,

granite gneiss and granite. Cameron et al (1949) have noted that the most productive mica- and beryl-bearing pegmatites occur in the Bolton Schist and Monson Gneiss.

Cameron et al (1949) suggested that at least some of the pegmatites in the Middletown area were emplaced during the Late Devonian as suggested by some of the age dates. However, Zartman et al (1970) noted the anomalously young ages for many of the Middletown pegmatites, ranging from Early to Middle Permian. He concluded that the ages resulted from a Permian igneous event. This Permian igneous activity has been noted elsewhere as, for example, the Permian Narragansett Pier Granite in nearby Rhode Island.

Pegmatites in the Precambrian units of the northern Piedmont are found in western Connecticut, southeastern New York, northern New Jersey and eastern Pennsylvania. These pegmatites occur, for the most part, in highly metamorphosed gneisses and schists of the Grenville Province and are interpreted as being either Late Ordovician to Devonian or Precambrian in age. The latter, which make up the bulk of the occurrences in the Precambrian units, are attributed to the Grenville event.

Radioactive pegmatites in the Philadelphia area occur in the Wissahickon Gneiss. The age of this unit is given variously as Late Precambrian to Lower Ordovician. Proponents of the Precambrian age maintain that the Wissahickon is related to units of similar age in the Piedmont of Maryland (Hopson, 1964). It has also been suggested that the Wissahickon Formation is correlative with the Ordovician Martinsburg shales on the basis of stratigraphic correlation with metamorphic equivalents. In either case, the Wissahickon

consists of a flysch sequence of turbidites, shales and quartzites with interbedded mafic to intermediate volcanics. The age of the pegmatites in the Wissahickon is not established owing to uncertainties in the host rock age. There does not appear to be any genetic relation between the pegmatites and granitic intrusives.

Southern Appalachians. Pegmatites of the southern part of the Appalachian Fold Belt occur, for the most part, in crystalline rocks of the Piedmont and Blue Ridge provinces. Much work has been carried out on these deposits, primarily to recover mica and to a lesser extent, feldspar during and before the second World War. The regional and local geology has been studied by the U. S. Geological Survey among others, and has been presented in various reports over the years (Jahns et al, 1952; Lemke et al, 1952; Griffitts et al, 1953; Griffitts and Olson, 1953; and others). Our study is limited principally to the Spruce Pine District, which contains the largest concentration of radioactive pegmatites in the southern Appalachians. The general relationship between pegmatites and tectonics is similar here to pegmatite districts elsewhere in the Piedmont and Blue Ridge provinces.

The main host rocks for the Spruce Pine pegmatites are Precambrian metamorphic rocks as well as granitic intrusives of probable Paleozoic age. The former include muscovite-biotite gneiss, biotite gneiss and schist, mica schist, quartz-mica schist, quartzite and kyanite mica gneiss and schist, all of which are interpreted as sedimentary in origin. Elsewhere in the southern Appalachians, the metamorphic rocks include mainly mica and hornblende gneiss and schists, with kyanite gneiss, garnet gneiss and schist and graphitic muscovite schist, interpreted as highly metamorphosed igneous and

sedimentary rocks. The metamorphic rocks have been intruded by various granitic plutons including the Redoak Granite in Virginia, several plutons including the Cherryville Quartz Monzonite in the Shelby-Hickory District of North Carolina, the Leatherwood Granite of Virginia and North Carolina, and the Whiteside Granite of western North Carolina. An alaskite intrusive occurring as irregular masses is found in the Spruce Pine area. This unit has also been described as granodiorite and muscovite granodiorite by various authors (Lesure, 1968). Many of the pegmatites in the Spruce Pine District occur within the alaskite. Olson (1944) stated that the pegmatites are genetically related to the alaskite, based on structural relations and compositional similarities.

Age dating suggests that the pegmatites in the Spruce Pine District were emplaced during the Late Devonian or Early Carboniferous and, therefore, are slightly younger than pegmatites of the New England Highlands of Maine and New Hampshire.

Tectonic History. Most pegmatites of the Appalachian Fold Belt are found either within Precambrian crystalline terrane of the Grenville structural province, associated with units emplaced or altered during the Acadian Orogeny, or related to Permian igneous activity.

The Precambrian units mark the eastern limit of basement rocks in North America and occur, for the most part, on the eastern side of the Appalachian Fold Belt in a narrow zone less than 100 miles wide and extending discontinuously from Newfoundland to Georgia. The largest massifs are structurally controlled and are exposed in uplifted horsts or anticlines and are fault

bounded on the west by east dipping thrusts (Williams and Stevens, 1974). These structural elements developed in response to compressive forces of the Taconic Orogeny during closing of the proto-Atlantic which may also have produced the Ordovician-Lower Devonian pegmatites of western Connecticut and southeast New York.

Most of the pegmatites and granitic plutons along the Appalachian Belt are associated with tectonic episodes generated during the Acadian Orogeny. Williams and Stevens, (1974) argued that the Acadian Orogeny represents shortening via compressive forces exerted during final closing of the proto-Atlantic when Africa collided with North America. This closing was not uniform throughout the margin. As noted above, the proto-Atlantic began closing during Taconian times in the northern Appalachians, however, to the south it did not fully close until Permo-Carboniferous times. Correspondingly, progressively younger ages are found in pegmatites and granitic plutons from Canada through Georgia. Presumably, this reflects the differential closing of the proto-Atlantic, but does not account for Permian dates in Connecticut and Rhode Island.

A different sequence of events was proposed by Dewey and Kidd (1974). They maintain that the Acadian Orogeny was produced by collision of South America with North America, followed by rifting, separation and collision with Africa in Late Carboniferous-Early Permian time, thus producing Alleghanian deformation. The final closing of the Atlantic did not occur until Early Permian times in the southern Appalachians, when the collision with Africa produced the Brevard Zone. The authors argue that because of irregularity along the plate margins, variations occur in structural, igneous, and metamorphic style. Collision would first be initiated at projections where compressive forces would result

in thickening and partial melting of the continental crust producing granitic melts emplaced as either synkinematic or postkinematic plutons. The sites of these collisions would be marked by intense deformation, high grade metamorphism and granitic plutons. It was suggested that the New England Highlands represent such an area. The Early Permian activity would adequately explain Permian age dates noted in Middletown, Connecticut pegmatites and elsewhere in New England. Presumably, Carboniferous dates from North Carolina would be in response to early Alleghanian deformation which occurred well before the final closing of the proto-Atlantic.

Central and Southern Rocky Mountains

Many of the pegmatites along the central and southern Rocky Mountains of Wyoming, Colorado and New Mexico occur in Precambrian granitic plutons and metamorphic rocks. Most are of Precambrian age and, in some cases, are genetically related to specific plutons. A Precambrian age is indicated by the lack of metamorphism in Paleozoic or younger rocks and in some areas by an erosional unconformity that separates pegmatites from overlying Paleozoic rocks (Jahns, 1946). Although younger pegmatites are found in the Rocky Mountain region, they are few and economically unimportant as regards mica, feldspar, uranium or thorium. Data is most complete on pegmatites from the Petaca District of New Mexico and the Front Range in Colorado, so these areas will be summarized for descriptive purposes.

Southern Rocky Mountains. Pegmatites of the Petaca District are found in quartzite and quartz-mica schist. Pure, massively-bedded quartzites are restricted in occurrence. The more widespread micaceous quartzite and quartz-mica schist contain feldspathic layers as well as conglomeratic units.

An amphibole schist interlayered with the quartz and mica schists is composed of hornblende, plagioclase, epidote and magnetite and is interpreted as being derived from mafic to intermediate volcanic flows. Bands of meta-rhyolites are also present. The Precambrian units represent a thick sequence of metamorphosed arenaceous and pelitic sediments interbedded with volcanics ranging from rhyolite to basalt in composition.

The pegmatites of the Petaca District are considered to be genetically related to the Tusas Granite based on spatial relationships, e.g. the pegmatites decrease in frequency away from the granite. Compositional similarities between the granite and pegmatites also suggest a genetic relation. The Tusas Granite is part of a large intrusive and consists mainly of quartz and microcline with plagioclase, biotite and minor magnetite.

Conversely, the Harding pegmatite bears no meaningful spatial or compositional relationships to nearby granitic intrusives, thus precluding any genetic relation (Jahns and Ewing, 1977). Both the Harding and Petaca pegmatites were emplaced at mesozonal depths of greater than 7 miles (11 km) and developed long after other igneous rocks were emplaced at shallower depth.

Central Rocky Mountains. Plates 1 and 2 show the distribution of pegmatites along the Front Range of Colorado. Most of the pegmatites occur within or marginal to a granitic pluton such as the Pikes Peak batholith (1000 m.y.), or older granitic rocks including the Silver Plume, Sherman, Cripple Creek (1400 m.y.) and Boulder Creek (1700 m.y.) plutons. The granitic plutons vary in composition and include such

varities as alaskite, leucogranite, quartz monzonite, grandediorite, and in the Mt. Rosa area of Colorado, a riebeckite granite. The Silver Plume and Boulder Creek plutons have been interpreted as mesozonal, whereas, the Pikes Peak has been interpreted as either mesozonal or epizonal (Badgley, 1960).

Metamorphic rocks of the Front Range are, for the most part, included within the Early Proterozoic Idaho Springs Formation. This formation is composed chiefly of inter-layered biotite gneiss, granite gneiss and microcline gneiss, with subordinate quartz gneiss, amphibolite, calc-silicate gneiss and garnet-hornblende gneiss.

Carpenter (1979) interpreted the Idaho Springs Formation as a volcanic sequence of calc-alkalic to alkalic pyroclastic units with some spilites and gabbro dykes. This sequence is interlayered with shallow marine shales, impure carbonates, greywacke and sandstone.

Pegmatites in the Rocky Mountains of Wyoming are very similar to those from Colorado in that they also occur within Precambrian terrane. The Platt and Albany-Fox Park area pegmatites occur in units very similar to the Idaho Springs Formation. The Tie Siding pegmatites occur in granitic rocks of the Sherman pluton which is similar in age to the Silver Plume and Cripple Creek plutons in Colorado. However, three other areas in Wyoming occur in Archean crystalline terrane composed of orthogneiss and paragneiss which are interpreted as being a southern extension of the Superior Province of the Canadian Shield.

Tectonic History. The Idaho Springs Formation is thought to have been deposited in a volcanic island arc setting. A northward moving Early Proterozoic island arc volcanic complex collided with an Archean continental land mass represented by the Wyoming Basement Complex (Carpenter, 1979). This collision resulted in intense deformation and syntectonic intrusion of the Boulder Creek and related plutons. The development of the Silver Plume and related plutons was largely post-tectonic. The younger Pikes Peak Granite is interpreted as being emplaced at shallow depths during crustal mobilization associated with cratonic rifting. The association of pegmatites with the various granitic plutons suggests that pegmatite emplacement begins early in the tectonic history of colliding plate margins, essentially with the earliest granitic intrusive activity.

Discussion

Several generalizations can be made regarding pegmatites and their tectonic environment. First, pegmatites occur either in granitic or high grade metamorphic rocks, such as gneiss, schist and amphibolite. Second, pegmatite districts are intimately associated with tectonic mobile belts, or more specifically, with granitic plutons near plate margins. Third, granitic plutons from which pegmatites are ultimately derived, are emplaced at mesozonal to epizonal depths and are syn-or post-tectonic. These generalizations are mutually related. During plate collision, various zones of intense deformation develop as subduction zones. Thus, sialic rocks are brought into a high thermal regime and depending on their composition may be subject to partial melting or high grade metamorphism. As

a granitic partial melt rises it cools, transferring its thermal energy into the surrounding country rocks resulting in an aureole of high grade metamorphic units. During the cooling stage, the granitic melt differentiates giving rise to pegmatitic fluids which may be injected into the surrounding country rock or may be trapped within the granitic crystal mush.

Final composition of a granitic pluton is dependent upon the composition of the original constituents. Dewey and Kidd (1974) in their discussion of collisions involving irregular plate margins noted that where plate projections collide, the resulting zone of intense deformation, subsequent down-warping and partial melting involves sialic continental crust material and the resulting plutons are potassic granites. Where plate embayments occur they are underlain by oceanic crust, and upon collision become infilled with thick sedimentary sequences. The mixture of oceanic crustal material and sedimentary rocks yields dioritic to granodioritic plutons upon melting, and later crystallization. They cite, as an example, the salient of Newfoundland which, where thought to be underlain by oceanic crust, is dominantly granodioritic with some diorite and adamellite, whereas those areas postulated as originally being continental crust and quartzo-feldspathic metasediments are now chiefly adamellite and granite.

An alternative interpretation regarding the interrelation between plate tectonics and magma generation was given by Brown (1973). He noted that change in chemical composition of plutons along continental margins is dependent upon depth of subduction. Magmas generated at great depth involve mantle material resulting in basaltic and andesitic rocks. Melts derived at intermediate depths involve digestion of both

mantle material, as well as more sialic material resulting in tonalitic to granodioritic plutonic rocks. Magmas generated at shallow depths result in plutons of granitic to monzonitic compositions. In general, Brown postulates a decrease in K_2O and quartz with depth. Similar geochemical trends have been noted in the Sierra Nevada batholith and the Coastal batholiths of North Chile and Peru. Brown's thesis is that acid plutonic rocks are derived from crustal melting. Plutons of tonalitic-dioritic-granodioritic composition involved both crustal material and injection of mantle-derived mafic volcanics, whereas, those plutons of granite-adamellite-monzonite composition are primarily crustal melts.

A mantle source for granitic magmas has been suggested by other studies (Dickinson, 1970; Matsumoto, 1968). Dickinson's interpretation based on initial strontium isotope ratios, favors a mantle-derived granitic magma with subsequent contamination from crustal material, or alternatively, a continental underplating source for the granitic melt.

Regardless of the specific mechanisms involved in magma generation at plate margins certain generalizations are evident. The composition of granitic plutons is dependent upon composition of the original melt material and its differentiation which in turn is dependent upon pressure-temperature relations at depth. Also, systematic geochemical trends exist in granitic plutons along continental margins. These trends can best be explained by plate tectonics and fusing of geochemically distinct units such as oceanic or continental crusts or the mantle.

In summary, most pegmatites are a late-stage differentiate of granites which in turn are derived from melting of continental

crustal material along plate margins in subduction zones. The composition of the pegmatites reflects that of the granites and that of the now-fused crustal material.

CHAPTER III

GEOCHEMISTRY OF URANIUM AND THORIUM

An in-depth discussion of the geochemistry of uranium and thorium is beyond the scope of this study. Nonetheless, a brief review is warranted as an aid to understanding the occurrence of radio-elements in pegmatites.

The following table gives the pertinent chemical parameters for both uranium and thorium. Table 5 gives the average abundances in various geologic units. Two features are notable. First, in most environments thorium is about three times as abundant as uranium, although the reverse may also be found for reasons discussed below. Secondly, both elements are far more abundant in crustal acid rock than in basic or mantle units.

Chemical Parameters for Uranium and Thorium

	Symbol	Atomic No.	Atomic Weight	Valence(s)	Ionic Radius
Uranium	U	92	238.03	6,5,3,4	1.06
Thorium	Th	90	232.04	4	1.08

The preference for the crustal acid rocks is a function of the relatively large ionic radii which characterize both uranium and thorium. Figure 5 adopted from Levinson (1974) illustrates the ionic radii of the naturally occurring elements. Except for yttrium and the lanthanides, only sodium, calcium, cadmium, mercury and bismuth approximate the radii of uranium and thorium. The nearest approximation is calcium with an ionic radius of 1.08Å. The large size of the uranium and thorium ions prevent their incorporation into the structures of most alumino-silicate minerals. The low concentration of the two radio-elements precludes their being sufficiently abundant as to form discrete minerals except in rare instances. These two factors, meager abundance and large

Unit	Uranium ppm	Thorium ppm
Core (1)	0.006	0.001
Lower Mantle (1)	0.015	0.02
Upper Mantle (1)	0.05	0.36
Crust (2)	2.7	10.0
Ultramafic Rocks (2)	0.001	0.003
Basalt (2)	0.6	2.2
Granodiorite (2)	3.0	10.0
Granite (2)	4.8	17.0
Sandstone (1)	1.4	3.8
Shale (2)	4.0	12.0
Limestone (2)	2.0	2.0
Soil (2)	1.0	13.0
River Water (2)	0.4 ppb	0.1 ppb

Table 5: Average abundances of uranium and thorium.

1. Gabelman, 1977
2. Swaine, 1955, in Berkman, 1976

IA		IIA												IIIA IVA VA VIA VIIA						He
H		Li	Be											B	C	N	O	F	Ne	
		0.82	0.35											0.20			1.32	1.25		
Na			Mg											Al	Si	P	S	Cl	Ar	
		1.10	0.80											0.61	0.34	0.28	1.72	1.72		
K			Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
		1.39	1.08	0.83	0.69	0.72	0.70	0.75	0.69	0.73	0.77	0.61	0.63	0.70	0.46	0.58	1.58	1.60		
Rb			Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
		1.61	1.33	0.98	0.80	0.72	0.73		0.70	0.71	0.70	1.23	1.03	0.68	0.77	0.68	2.21	2.13		
Cs			Ba	RARE EARTH		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
		1.96	1.50			0.79	0.72	0.73	0.71	0.71	0.71	0.71	1.37	1.40	1.68	1.37	1.40			
Fr			Ra	ACTINIDES																
		1.96																		

Rare Earth or Lanthanide Group												
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm
1.13	1.09	1.08	1.06		1.04	1.03	1.02	1.00	0.99	0.98	0.97	0.96

Actinide Group			
Ac	Th	Pa	U
	1.08		1.06

Figure 5: Ionic radii of elements. From Levinson, 1974.

ionic radii, combined to exclude uranium and thorium during the differentiation of the primordial core and mantle, and tended to concentrate the two elements with the lighter and volatile elements of the crustal zone. Within the crust, the same features inhibit inclusion of uranium and thorium in basic rocks. It is only in the late-forming acidic suites that the differentiated and, hence, concentrated radio-elements reach abundance levels that allow for the formation of discrete minerals to any marked degree or allow substitution in rare-earth or calcium minerals. Uranium frequently replaces calcium in species such as apatite or sphene. However, uranium and thorium do not substitute for calcium in plagioclase because of a lack of coordination requirements (Larsen and Phair, in Faul, 1954).

The presence of uranium and thorium in pegmatites reflects the same differentiation process. During crystallization of acid magmas, the final fluids are relatively enriched in the normally less abundant elements and those whose chemical parameters inhibit their inclusion in the common rock forming minerals. Uranium, thorium, the rare earths, lithium, beryllium, and other rare metals all are to be found in pegmatite fluids due to exclusion and differentiation during crystallization. Those pegmatites derived from mantle material presumably would have less of the radio-elements because of the low concentration of such elements in the mantle, whereas, those pegmatites derived from digested sialic material are more likely to contain significant quantities of uranium or thorium.

As noted earlier, thorium is in most environments about three times as abundant as uranium, and in soils thorium is thirteen times as abundant, whereas, in limestone uranium and thorium are about equally abundant, and in river waters uranium is four times as prevalent as thorium. These relations

are a direct function of the solubility of the two elements and the solubility in turn is a function of their respective valence states.

Thorium is always quadrivalent, forming essentially insoluble minerals under normal atmospheric conditions. Thorium minerals are resistates and as such are concentrated in soils and may be economically recovered as placer accumulations. Uranium is, for the most part, quadrivalent in the primary state, but oxidizes to a soluble hexavalent state in the atmosphere. The uranyl ion is very soluble which accounts for the prevalence of uranium over thorium in river waters. During the formation of pegmatites, both uranium and thorium are present in the primary quadrivalent state. As such, they are relatively insoluble in water so that as crystallization continues and the fluid becomes increasingly aqueous, the radio-elements are forced from the fluid and precipitated either as discrete minerals or as proxy ions replacing calcium or rare-earth elements.

As noted previously, the role of geochemical differentiation through geologic time is paramount in the migration of uranium and thorium to the crust.

The infrequency of uranium deposits in the early Archean and their appearance in the Proterozoic marks a fundamental geologic change. Archean magmatism was dominated by mafic volcanics tapped from the mantle, whereas, Proterozoic and early Phanerozoic magmatism involved previously existing sialic crustal material. This reworking allowed for concentration of uranium so that the Archean-Proterozoic sedimentary horizon became the locus of many important uranium deposits (Derry, 1961). Nishimori et al, (1977) noted that many "pegmatite-alaskite-gneiss" uranium occurrences formed during Proterozoic - Early Phanerozoic crustal evolution involved remobilization and reworking of crustal materials. Repeated

remobilization and attendant geochemical differentiation led to concentration of uranium and thorium in environments favorable to their deposition.

These earlier formed deposits may have been the ultimate source for later vein, igneous, or sedimentary uranium deposits (Nishimori et al, 1977). The uranium in Tertiary veins of the Colorado Front Range is thought to have originated in Tertiary intrusives which, in turn, derived their uranium from the Precambrian Idaho Springs Formation. Carpenter, (1979) stated that uranium associated with hood zones in the Pike's Peak and Silver Plume intrusives was ultimately derived from cratonic source rocks.

Uranium, thorium and the rare-earth elements associated with the "pegmatite" veins and nearby parent plutons in the Bancroft area of Canada are thought to have been ultimately derived from an extensive sedimentary sequence via "sweating out" (Robinson, 1960) or melting (Evans, 1964; Cunningham-Dunlop, 1967). Similarly, uraniferous migmatites, pegmatites and parent granites in the Grenville crystalline terrane of Quebec, Canada are thought to have been derived from sediments enriched in uranium (Hauseux, 1977; Nishimori et al, 1977). The Rössing uranium deposit is thought to have been derived from anatexis of crustal material enriched in uranium. This material has been involved in several orogenic episodes, each of which tended to concentrate uranium via successive differentiation (Nishimori et al, 1977).

CHAPTER IV

URANIUM- AND THORIUM-BEARING PEGMATITES

MINERALOGY

Essential Minerals

The pegmatites considered in this study are largely of the granitic type and their dominant minerals are the feldspars and quartz, commonly accompanied by the micas (see Internal Structure Section).

The most abundant feldspar in most pegmatites is potash feldspar, usually perthitic microcline, which may occur in giant crystals. Mining of pegmatites has been largely for the recovery of this feldspar.

The plagioclase feldspars are also present in most pegmatites. They are chiefly albite to oligoclase in composition, most being nearer to albite. A platy form of albite, called cleavelandite may be present, especially in replacement units. Although not reported from any domestic radioactive pegmatites, an unusual variety of albite, peristerite, is common in the pegmatites of the Bancroft area in Ontario.

Quartz is most abundant in the cores of zoned pegmatites where it may form masses comprising hundreds of tons. Although these may be completely anhedral, there is evidence in some deposits that the mass is made up of a few very large intergrown crystals. Quartz is subject to discoloration by radiation and may be locally darkened in the vicinity of radioactive minerals. The effects of natural irradiation on minerals will be discussed later in this chapter.

Muscovite is the dominant mica in the pegmatites of most districts and is an important economic mineral. The demand

for sheet mica resulted in the exploration and mining of many pegmatites and in their intensive study by Federal geologists during and immediately after World War II.

The black mica, biotite, is an iron-bearing mica that may occur in pegmatites in association with muscovite, or may be essentially the only mica present. In some pegmatites, biotite may occur in broad lath-like crystals a meter or more in length that will wholly or partially enclose radioactive minerals such as cyrtolite, thorite, or uraninite which apparently began their growth on the biotite and developed simultaneously.

Lithium-bearing micas, chiefly lepidolite, are found in some of the radioactive pegmatites in the United States. Lepidolite can be very abundant in the cores of large zoned pegmatites and in some deposits is the host for microlite that may be uranium-bearing.

Common Accessory Minerals

Hundreds of other mineral species are found as accessory minerals in pegmatites, some rarely, while others may be present in practically all of the pegmatites of any one district. Probably the most ubiquitous accessories are garnet, tourmaline, and apatite.

The garnets include several sub-species of different composition that are isomorphous with each other so that any particular garnet may be intermediate to the various end-members of the group. Garnets that are compositionally near spessartite, the manganese-aluminum member, appear to be most common in granitic pegmatites, but as a definitive classification is difficult, the exact type of garnet present in a deposit is rarely stated.

Tourmaline, a complex boro-silicate mineral, is abundant in many pegmatite provinces particularly as the black, iron-rich variety called schorl. Colored varieties, which may be of gem value, are found in some deposits notably those in which lithium minerals are present. Some pegmatite provinces, such as the Petaca District in New Mexico may be almost devoid of tourmaline, indicating a deficiency of boron in the pegmatite fluids. There does not appear to be any particular significance in the presence or absence of tourmaline with respect to the radioactive elements.

Fluorapatite, the most common member of the apatite group, is another accessory mineral in pegmatites, but may be much more abundant in some districts than others. It may be colorless, gray, pink, purple, green, or blue. Apatite may contain trace amounts of various elements, including the rare earths, thorium, and uranium in substitution for calcium. The uranium content may be as much as 120 ppm (Altschuler, et al, 1958) in primary igneous apatite and even greater for thorium. Our sample of the blue manganoan-apatite that forms large anhedral masses in the wall zone of the Harding pegmatite in New Mexico contained 22 ppm uranium (See Appendix, Sample #13-NM-11).

Where only a very small amount of uranium is present in a pegmatite it could be largely camouflaged in the structures of fluorapatite and a few other hosts to the extent that no discrete uranium minerals are formed.

Minerals of some rare metals such as beryllium, niobium, tantalum, the rare earths, and lithium are found as accessories in many radioactive pegmatites.

Beryl is the most common beryllium mineral in pegmatites. Beryl may occur in crystals or anhedral masses of great size

and has been an important product from pegmatites in many parts of the world. Another beryllium mineral, gadolinite ($\text{Be}_2\text{FeY}_2\text{Si}_2\text{O}_{10}$), is much less abundant, but is noteworthy inasmuch as it may be quite radioactive due to contained thorium.

Columbite and tantalite form an isomorphous series of the general composition $(\text{Fe}, \text{Mn}) (\text{Nb}, \text{Ta})_2\text{O}_6$. The mineral found in most pegmatites is apt to be richer in niobium than tantalum and, hence, is columbite. Some columbite may be radioactive because of uranium and possibly thorium in its structure, or from inclusions, veinlets, or coatings of strongly radioactive minerals (Heinrich, 1962). The significance of niobium, and to a lesser extent tantalum, will be considered in the section on Elemental and Mineralogical Associations.

Lithium minerals, such as spodumene, amblygonite, lepidolite, and zinnwaldite, are found in pegmatites of some districts. Lepidolite is notable as in some pegmatites it is closely associated with the calcium-tantalate mineral microlite which may be uranium-bearing. Microlite will be discussed in further detail under the radioactive minerals.

Fluorite is very abundant in some pegmatite districts and rare in others. In the South Platte pegmatites in Colorado it is found in perthite-quartz-fluorite intermediate zones as green anhedral crystals several inches across. In the same pegmatites a late stage of fluorine metasomatism has deposited euhedral pale purple fluorite crystals on corroded quartz and feldspar. Rough crystals of fluorite as much as seven feet in diameter are described by Jahns (1953a) from the pegmatites of the Petaca District, New Mexico. Where fluorite is absent in pegmatites, initially available fluorine may be

entirely combined with phosphorous in fluorapatite or held in the structures of other minerals such as lepidolite or topaz.

Radioactive Minerals

In Table 6 we have listed the radioactive minerals that are mentioned in the text of this report. This list includes only about one-third of the known species that contain uranium or thorium as an essential constituent and only a few of the species that may contain small amounts of these elements by diadochic substitution. Some of the radioactive minerals that are most commonly found in pegmatites, or otherwise seem significant, are described below.

Oxides. Uraninite is the only simple oxide of uranium found in pegmatites, with the possible exception of some hydrated oxides such as bequerelite that may be present as alteration products collectively called "gummite". The mineral is cubic and is found as cubes, cubo-octahedral, or dodecahedral crystals or as black anhedral nodular masses that may be enclosed by haloes of colorful secondary minerals. Dendritic forms may be present as at the Ruggles pegmatite in New Hampshire (Shaub, 1938).

Pegmatitic uraninite as compared to the pitchblende variety of hydrothermal or sandstone deposits is apt to contain a higher percentage of rare-earth elements and thorium and will generally show a larger unit cell; such variations are discussed in detail by Frondel (1958).

The thorium oxide, thorianite, may occur in domestic pegmatites but is reported only from the unusual deposits at Easton, Pennsylvania (Frondel, 1958). The occurrence here may be questionable, however, as thorianite is not listed by Smith (1978) as being found in Pennsylvania. Thorianite has

	Name	Formula
Oxides & hydrated oxides	Clarkeite	$(\text{Nb,Ca,Pb})_2\text{U}_2(\text{O,OH})_7$
	Thorianite	ThO_2
	Uraninite	UO_2
Multiple Oxides	Betafite	$(\text{Ca,Na,U})_2(\text{Nb,Ta})_2\text{O}_6(\text{OH})$
	Brannerite	$(\text{U,Ca,Ce})(\text{Ti,Fe})_2\text{O}_6$
	Djalmaite	Synonym of microlite
	Euxenite	$(\text{Y,Ca,Ce,U,Th})(\text{Nb,Ta,Ti})_2\text{O}_6$
	Fergusonite	YNbO_4
	Microlite	$(\text{Na,Ca})_2\text{Ta}_2\text{O}_6(\text{O,OH,F})$
	Polycrase	$(\text{Y,Ca,Ce,U,Th})(\text{Ti,Nb,Ta})_2\text{O}_6$
	Pyrochlore	$(\text{Na,Ca})_2\text{Nb}_2\text{O}_6(\text{OH,F})$
	Samarskite	$(\text{Y,Ce,U,Ca,Pb})(\text{Nb,Ta,Ti,Sn})_2\text{O}_6$
	Uranmicrolite	Uranoan Microlite
	Yttrocrasite	$(\text{Y,Th,U,Ca})_2\text{Ti}_4\text{O}_{11}(?)$
	Yttrotantalite	$(\text{Y,U,Fe})(\text{Ta,Nb})\text{O}_4$
Silicates	Allanite	$(\text{Ce,Ca,Y})_2(\text{Al,Fe})_3(\text{SiO}_4)_3(\text{OH})$
	Beta-Uranophane	$\text{Ca}(\text{UO}_2)_2\text{SiO}_7 \cdot 6\text{H}_2\text{O}$
	Boltwoodite	$\text{K}_2(\text{UO}_2)_2(\text{SiO}_3)_2(\text{OH})_2 \cdot 5\text{H}_2\text{O}$
	Chevkinite	$(\text{Ca,Ce,Th})_4(\text{Fe,Mg})_2(\text{Ti,Fe})_3\text{Si}_4\text{O}_{22}$
	Cyrtolite	Var. of zircon with U,Th, and REE's
	Gadolinite	$\text{Be}_2\text{Fe Y}_2\text{Si}_2\text{O}_{10}$
	Soddyite	$(\text{UO}_2)_5\text{Si}_2\text{O}_9 \cdot 6\text{H}_2\text{O}$
	Thorite	ThSiO_4
	Thorogummite	$\text{Th}(\text{SiO}_4)_{1-x}(\text{OH})_{4x}$
	Uranophane	$\text{Ca}(\text{UO}_2)_2\text{Si}_2\text{O}_7 \cdot 6\text{H}_2\text{O}$
	Uranothorite	Uranoan thorite
	Zircon	ZrSiO_4 (may contain U)
Phosphates	Autunite	$\text{Ca}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 10-12\text{H}_2\text{O}$
	Meta-autunite	$\text{Ca}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 2-6\text{H}_2\text{O}$
	Meta-torbernite	$\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$
	Monazite	$(\text{La,Ce,Nd,Th})\text{PO}_4$
	Phosphuranylite	$\text{Ca}(\text{UO}_2)_4(\text{PO}_4)_2(\text{OH})_4 \cdot 7\text{H}_2\text{O}$
	Torbernite	$\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8-12\text{H}_2\text{O}$
	Xenotime	YPO_4 (may contain U)
Sulfates	Uranopilite	$(\text{UO}_2)_6(\text{SO}_4)(\text{OH})_{10} \cdot 12\text{H}_2\text{O}$

Table 6: Radioactive minerals appearing in text.

Phosphates	Autunite	$\text{Ca}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 10-12\text{H}_2\text{O}$
	Meta-autunite	$\text{Ca}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 2-6\text{H}_2\text{O}$
	Meta-torbernite	$\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$
	Monazite	$(\text{La,Ce,Nd,Th})\text{PO}_4$
	Phosphuranylite	$\text{Ca}(\text{UO}_2)_4(\text{PO}_4)_2(\text{OH})_4 \cdot 7\text{H}_2\text{O}$
	Torbernite	$\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8-12\text{H}_2\text{O}$
	Xenotime	YPO_4 (may contain U)
Sulfates	Uranopilite	$(\text{UO}_2)_6(\text{SO}_4)(\text{OH})_{10} \cdot 12\text{H}_2\text{O}$

Table 6: Radioactive minerals appearing in text.

been found in pegmatites in Saskatchewan (Lang, 1952) where it is associated with uraninite.

Multiple oxides. A large number of uranium minerals may be classed as multiple oxides and include species that have been referred to as niobates, tantalates and titanates inasmuch as Nb, Ta, and Ti are commonly essential elements in their structures. The compositions as given in the formulas shown in Table 6 are generalized and do not take into account the complex ionic substitutions that may greatly influence the composition of individual samples.

The distinction between many of the species is impossible without the use of laboratory techniques, such as X-ray diffraction, but even this method may be difficult as the minerals are commonly in a metamict state as a result of the destruction or partial destruction of the crystal structure of the mineral by internal radiation. Due to the difficulties in their identification, incorrect names have often been applied to these species in the literature.

Samarskite and euxenite are the most commonly found multiple oxides in pegmatites, the former being dominant in the Spruce Pine District in North Carolina, and the latter in the pegmatites of Colorado. Both require niobium and the rare-earth elements for their development so will not be found where these elements were not available in the pegmatitic fluids.

Although uranium does not appear in the formula of micro-lite this important ore mineral of tantalum may be uranium-bearing through the substitution of uranium for calcium. Micro-lite occurs almost exclusively in lithium-rich pegmatites where it occurs as octahedral or dodecahedral crystals that range from pale yellowish-white to nearly black. At the Harding pegmatite in New Mexico the mineral is particularly abundant

and has been recovered by a combination of hand sorting and milling. Analyses showed a very low uranium content in the light colored variety, but over eight percent UO_3 in a very dark reddish-brown variety and over seven percent in nearly black microlite (Jahns and Ewing, 1977).

Silicates. The thorium silicate, thorite, is found in some pegmatites, but is more abundant in vein deposits associated with alkalic rock complexes.

Thorite, in most occurrences, is brick-red in color, highly radioactive, and may contain uranium and the rare earths in substitution for thorium. Uranoan thorite is sometimes referred to as uranothorite.

The most notable occurrences of thorite in domestic pegmatites are in Colorado where it is found in the St. Peter's Dome and South Platte Districts. At the Seerie pegmatite in the western part of the South Platte District it occurs in several different color varieties that contain from 3.44 to 14.96 percent UO_3 , the highest value being found in a greenish black thorite that contains inclusions of uraninite (Staatz et al, 1976). In other pegmatites of the district, intergrowths of thorite and cyrtolite form large masses in the biotite of wall zones.

Cyrtolite, a variety of zircon containing uranium, thorium and the rare earths, is found in pegmatites of many districts. It is characterized by its curved crystal faces that probably result from deformation of the zircon structure. Although referred to as an "altered zircon", cyrtolite appears to be a primary mineral in the pegmatites.

Normal zircon, not showing the deformation in crystal habit may be uraniferous. A study of zircons from alkalic

pegmatites in the Wichita Mountains, Oklahoma by Al-Shaieb (1978) show that non-metamict crystals contain about 50 ppm uranium while as much as 1500 ppm is found in metamict varieties.

Allanite, sometimes called orthite, is a silicate mineral related to epidote, but containing rare-earth elements, chiefly those of the cerium group. It is a very common accessory mineral in the pegmatites of some districts and is probably the most widely distributed radioactive mineral in these deposits. Allanite is primarily a host for thorium which may be present to the extent of a few percent. The uranium content is apt to be negligible.

The mineral occurs as black elongate bladed crystals or anhedral masses that are dull reddish-brown when altered. Most allanite is wholly or partly metamict.

Phosphates. Monazite is essentially a phosphate of the cerium group of rare earths and almost always contains thorium, but very little uranium. Samples from the Deer Park mine in the Spruce Pine District in North Carolina, for example, contain an average of 5.51 percent ThO_2 , but only 0.02 percent U_3O_8 (Overstreet, 1967). Higher thorium contents are not uncommon, however.

Monazite from pegmatites is generally found as small euhedral crystals or large subhedral masses. The color is yellowish-brown to brick red.

Although widespread in its distribution, monazite is particularly abundant in the pegmatites of the Petaca District, New Mexico where it is largely concentrated in albite-rich parts of the deposits (Jahns, 1946).

Xenotime, the phosphate of the yttrium-group rare earths, is far less abundant than monazite in domestic pegmatites. Not always radioactive, it may, however, contain as much as 3.5 percent UO_3 and 2.2 percent ThO_2 (Heinrich, 1958). Xenotime forms tetragonal crystals resembling zircon.

Several hydrated phosphate minerals such as autunite and torbernite are found in pegmatites. They appear to be largely secondary, occurring chiefly as yellow or yellow-green platy crystals that have developed on fracture surfaces and cleavage planes. Autunite and the less-hydrated species meta-autunite are fluorescent. Torbernite and meta-torbernite do not show this effect.

The term "gummite" has been applied to the fine-grained assemblage of secondary uranium minerals that are found as partial or complete replacements of uraninite. Typically, they form red, yellow, or orange zones around a core of residual uraninite, but in some instances all the uraninite may be replaced. The secondary minerals may include the uranium silicate uranophane as well as many rare species (Fronzel, 1958). In "gummite" these minerals are microcrystalline so that their identification requires X-ray methods.

Effects of Natural Irradiation

Changes in the natural color of minerals associated with radioactive species range from the minute pleochroic haloes observed in thin-sections of various rock types to the very extensive effects found in pegmatites, including the darkening of quartz and micas, the reddening of feldspars, and presence of golden-colored beryl. Although these effects have been cited as criteria that may indicate the presence of radioactive

minerals (Page, 1950) they cannot, per se, be considered as strong evidence that uranium or thorium minerals will be found.

Smoky quartz is common in pegmatites in which no discrete radioactive minerals occur, although the cause of the darkening is still attributable to irradiation derived either from the total environment or to radio-elements incorporated in the structure of the quartz (Holden, 1925). In a study of the darkening of quartz, Ritter and Dennin (1966) found that natural quartz of different geologic origin is blackened to different degrees by gamma irradiation, and that pegmatite quartz appears to be highly susceptible to such darkening.

The time required to produce an appreciable darkening of pegmatite quartz by natural irradiation has been estimated by Kohn and Benjamin (1961). Based on high energy gamma radiation experiments on smoky quartz from a pegmatite in the Spruce Pine District of North Carolina, they conclude that darkening could have been effected by its close association with torbernite in the deposit in about one million years.

Descriptions of the red coloration of feldspar in radioactive deposits while numerous, commonly leave doubt as to whether the coloration is actually an internal feature of the feldspar or is due to pervasive ferruginous staining. Actually, both situations may be present due to abnormal concentrations of ferric iron as hematite inclusions in the feldspar and "limonitic" stains and coatings on fractures.

A possible mechanism for the aureoles of ferric oxides and hydroxides around radioactive minerals is discussed by Walker and Adams (1963) for vein deposits, but may be applicable to pegmatites, particularly those in which euxenite or other commonly metamict radioactive species occur.

In these pegmatites the masses of metamict minerals are often centers for radial shatter cracks that may extend for a meter or more into the enclosing rock. These cracks, which are most probably produced by the volume change of the minerals during metamictization, provide paths for the migration of radioactive daughter products and, thus, establish local radiation sites at some distance from the parent mineral.

When the pegmatite becomes accessible to ground water, some oxidation of iron minerals, notably biotite, will take place with a release of ferrous iron which may then be carried by the water into the shatter zones surrounding the radioactive minerals and, thus, into areas of anomalously high radiation.

If further oxidation of the iron to the ferric state is promoted by irradiation as indicated by the experimental work cited by Lovering (1955), then a concentration of ferric oxides and hydroxides would develop preferentially in roughly spherical zones surrounding the radioactive minerals.

This mechanism does not explain the internal coloration of feldspar which, if present, undoubtedly represents a higher than normal content of hematite "dust" or micro-inclusions. One might speculate, however, that the radiation environment has promoted the oxidation of what ferrous iron may be present in solid solution in the feldspar.

The association of golden-colored beryl with radioactive minerals has been mentioned by Page (1950) and Heinrich (1958) and has been observed by us at the Beryl Mountain pegmatite in New Hampshire. At this locality, a large crystal of yellow-brown beryl intergrown with cyrtolite was in sharp contrast with neighboring crystals of normal blue-green color. The

yellow color of beryl has been ascribed to ferric iron, but whether the coloration is always related to irradiation is doubtful.

Fluorite may be colored violet, purple, or nearly black by natural irradiation, but the mineral is uncommon in most domestic pegmatites so the effect of its association with radioactive minerals in these deposits has not been widely reported.

Purple fluorite is mentioned by Heinrich (1948) as occurring in radioactive pegmatites in the Trout Creek and Cotopaxi Districts in Colorado and has been seen by us in the South Platte District also in Colorado. In this district, green fluorite is a primary mineral in the intermediate zone adjacent to the quartz core. A purple to violet type is also present, but is of a later stage and was deposited on partly replaced earlier minerals throughout the pegmatite. The coloration of the late fluorite we believe to be due to radioelements derived from the radioactive minerals in the pegmatite and incorporated in the fluorite itself.

Large masses of fluorite, some so dark as to be nearly opaque, were noted by Hess (1908) in the famous radioactive pegmatite of Baringer Hill, Texas. He observed that the dark fluorite was associated with dark minerals and that lighter colored fluorite occurred in quartz; unfortunately, the identity of the "dark minerals" was not stated, but they probably included some of the numerous radioactive species found in the deposit.

Radiation-produced effects that have been utilized in recent years as a method of age determination are the minute tracks that are developed in minerals by the spontaneous

fission of contained uranium atoms. The tracks are made visible by optical microscopy after suitable etching and from their population density and the uranium content of the sample an age determination may be made. The fission tracks found in apatite and zircon are commonly used for dating, but a technique in which the tracks produced in quartz by adjacent uraninite has been described (Weiland, et al, 1979) which may be of value in age determination of pegmatites.

Although the effects of radiation on the various minerals in pegmatites are of scientific interest, their value in the recognition of pegmatites that may contain concentrations of radioactive minerals is slight.

ELEMENTAL AND MINERALOGICAL ASSOCIATIONS

Introduction

Pegmatites have long been known as hosts for a wide variety of mineral species many of which contain rare elements. Where these minerals occurred in crystals or masses large enough to be recovered by simple hand-sorting, pegmatites were an attractive source for many valuable elements, a by-product of mining for feldspar or mica. Beryllium, lithium, tantalum, niobium, tin, the rare-earth elements, scandium, zirconium, cesium, uranium, and thorium have all been recovered from pegmatites in the past, but alternative sources for many of these together with a great reduction in the number of pegmatites mined for feldspar and mica have greatly reduced the interest in these deposits.

In our study of pegmatites containing uranium and thorium, we have attempted to ascertain if any significant association could be noted between the radioactive elements and other minor elements. Such associations may be of value as criteria in the occurrence of radioactive deposits, and may be a guide as to the favorability or unfavorability of certain pegmatite districts.

In preparing the Index of Geologic Features it became apparent that there was a marked difference in the mineral assemblages found in radioactive pegmatites throughout the United States. These differences reflect the elemental suite present in the pegmatite fluids, which in turn, can be attributed to the source rocks from which the fluids were derived. The nature of the pegmatite fluids may also be controlled by the spatial relations of the pegmatites to the parent intrusive (Heinrich, 1953), the stage of crystallization achieved by the magma at the time the fluids were withdrawn (Jahns and Burnham,

1969), the depth at which the magma crystallized (Varlamoff, 1972), or the possible gain or loss of elements by reaction of the fluids with the wall rocks during emplacement.

Fairly detailed mineralogical data is available to some, but by no means all, of the pegmatites containing uranium and thorium minerals that are known in the United States. Data on pegmatites from various districts in Maine and New Hampshire, North Carolina, Colorado, New Mexico, and South Dakota are shown in Tables 7 - 18. These are largely radioactive pegmatites, but some not known to contain radioactive minerals are included for comparative purposes. For each pegmatite the table lists certain accessory minerals reported to occur, as well as the presence or absence of muscovite and biotite. Quartz and feldspars have been omitted inasmuch as they are common to all the pegmatites; the possible significance of the feldspars will be discussed later under Favorability Criteria.

Minerals that are included in the table are primarily intended to show elemental rather than mineralogical features. No quantitative evaluation is attempted.

Following the list of minerals are headings for various elements present in the pegmatite as indicated by the mineralogy. Phosphorus, for example, will be shown in the appropriate column when apatite or other phosphate minerals are reported. Fluorine, however, is shown only for deposits in which fluorite is found even though fluorine may be present in apatite, topaz, and other minerals. This restriction is an attempt to indicate deposits in which fluorine may be in excess. Trace elements that may be incorporated in the structures of certain minerals are not considered.

Some accessory minerals pertinent to this study have undoubtedly been overlooked or not reported from some deposits, but the completeness of the listed assemblages, although questionable, is considered adequate for its intended use.

To study elemental and mineralogical associations, the pegmatites ideally should be listed in such a way as to emphasize genetic relationships such as a common intrusive source. Such a classification, however, is generally impractical due to the rarity of undoubted correlation between the pegmatites and specific intrusives, so the deposits are grouped by States with mention of their geologic age where known.

It must be emphasized that the pegmatites in which appreciable amounts of uranium and thorium minerals are found generally represent a very small percentage of the pegmatite population in most areas. The vast majority are of simple feldspar-quartz-mica composition with garnet and tourmaline as common accessories. Those that are listed in the Tables are, for the most part, the large complex pegmatites that have been prospected or mined because of concentrations of feldspar, mica or beryl. These are the deposits which are apt to contain a wider variety of accessory minerals and which also have been the subject of more intensive study.

The following paragraphs discuss the more important elemental and mineralogical associations noted in the pegmatites from the various States.

Maine and New Hampshire

A relatively large number of pegmatites in Maine and New Hampshire contain radioactive minerals and as the pegmatites are largely of Devonian age they are discussed together. Data

for 26 selected radioactive deposits are shown in Tables 7 and 8.

Both muscovite and biotite are present in almost all of the pegmatites, although muscovite is undoubtedly the more abundant. Tourmaline and garnet are also common. Apatite has been noted in 13 of the pegmatites and some, notably the Palermo in New Hampshire, contain many less-common phosphate minerals.

Beryl has been found in 25 of the 26 deposits, some of which have produced considerable tonnages of this mineral. Lithium minerals occur in 10, columbite-tantalite is reported from 15, and microlite from 4. Zircon, usually the radioactive variety cyrtolite, has been noted in six of the pegmatites. Fluorite is uncommon, only four occurrences being reported.

Minerals of yttrium and the lanthanide elements are conspicuously lacking in most of the pegmatites of this area although these elements are undoubtedly present to some extent in the structures of such species as apatite, zircon, and uraninite. One exceptional occurrence is the pegmatite quarried at Standpipe Hill at Topsham, Maine. Here samarskite and monazite occur in microcline with biotite (Yedlin, 1942) and allanite has also been reported (Morrill, 1958). A highly radioactive mineral (Sample #13-ME-7) collected by us from the nearby Russell Brothers quarry at Topsham was identified by X-ray diffraction as samarskite. Samarskite has also been found at the Weeks mine in New Hampshire where it occurs in large masses intergrown with columbite. A rare-earth-bearing fluorite ("Yttrocerite") has been mentioned in early accounts of the mineral assemblage found at Mt. Mica in Paris, Maine (Bastin, 1911).

In Maine and New Hampshire it appears that where uranium is present in pegmatites it will be found predominantly as

Lord Hill	Fisher Quarry	Red Hill	Cons. Feldspar	Standpipe Hill	Russell Bros.	Singlepole	Bennett	Mt. Mica	Harvard	Tamminen	Sterns	Guy Johnson	Wardwell	Bumpus	Dunton	Black Mtn.	
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Uraninite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Sec. U-Mins.
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Mult. Oxides
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Uranothorite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Thorite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Monazite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Pyrochlore- Microlite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Cyrtolite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Allanite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Other REE Mins.
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Muscovite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Biotite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Be-minerals
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Columbite-tantalite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Li-minerals
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Tourmaline
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Garnet
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Zircon
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Apatite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Rare Phos. Mins.
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Fluorite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Fe oxides
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Bi-minerals
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Topaz
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Th
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Nb-Ta
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Be
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Zr
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	REE
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Li
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Mo
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	F
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	P
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Bi

Table 7: Selected radioactive pegmatites of Maine.

• Present at locality

1. "Yttrocerite" (Cerian fluorite) reported.

Parker Mtn.	Weeks	Palermo	E. E. Smith	Danbury Mica	Carpenter	Globe	Ruggles	Beryl Mtn.	
•		•	•	•	•	•	•	•	Uraninite
•		•	•	•	•	•	•	•	Sec. U-Mins.
•	•	•	•	•	•	•	•	•	Mult. Oxides
•	•	•	•	•	•	•	•	•	Uranothorite
•	•	•	•	•	•	•	•	•	Thorite
•	•	•	•	•	•	•	•	•	Monazite
•	•	•	•	•	•	•	•	•	Pyrochlore- Microlite
•	•	•	•	•	•	•	•	•	Cyrtolite
•	•	•	•	•	•	•	•	•	Allanite
•	•	•	•	•	•	•	•	•	Other REE Mins.
•	•	•	•	•	•	•	•	•	Muscovite
•	•	•	•	•	•	•	•	•	Biotite
•	•	•	•	•	•	•	•	•	Be-minerals
•	•	•	•	•	•	•	•	•	Columbite-tantalite
•	•	•	•	•	•	•	•	•	Li-minerals
•	•	•	•	•	•	•	•	•	Tourmaline
•	•	•	•	•	•	•	•	•	Garnet
•	•	•	•	•	•	•	•	•	Zircon
•	•	•	•	•	•	•	•	•	Apatite
•	•	•	•	•	•	•	•	•	Rare Phos. Mins.
•	•	•	•	•	•	•	•	•	Fluorite
•	•	•	•	•	•	•	•	•	Fe oxides
•	•	•	•	•	•	•	•	•	Bi-minerals
•	•	•	•	•	•	•	•	•	Topaz
•	•	•	•	•	•	•	•	•	Th
•	•	•	•	•	•	•	•	•	Nb-Ta
•	•	•	•	•	•	•	•	•	Be
•	•	•	•	•	•	•	•	•	Zr
•	•	•	•	•	•	•	•	•	REE
•	•	•	•	•	•	•	•	•	Li
•	•	•	•	•	•	•	•	•	Mo
•	•	•	•	•	•	•	•	•	F
•	•	•	•	•	•	•	•	•	P
•	•	•	•	•	•	•	•	•	Bi

Table 8: Selected radioactive pegmatites of New Hampshire.

• Present at locality

either uraninite or as secondary uranium minerals. It would also appear that uranium-bearing pegmatites of this region are characterized by the presence of beryllium, niobium-tantalum, phosphorus, and lithium and a general lack of fluorine and rare-earth elements.

Essentially, the same elemental pattern, however, is found in many of the non-uraniferous pegmatites of the area ten of which are shown in Tables 9 and 10.

Most significant is the infrequent occurrence of the rare-earth elements without which the uranium-bearing multiple oxide minerals such as samarskite or euxenite cannot form. The rarity of fluorite in these deposits is also noteworthy as there is a close geochemical affinity between fluorine and the rare-earths in many pegmatite districts (Heinrich, 1948).

North Carolina

Pegmatites in North Carolina have been known for many years as a source of specimens of radioactive minerals including uraninite, samarskite, monazite, allanite, and secondary uranium minerals. These minerals are largely found in the pegmatites of the Spruce Pine District, a major mica and feldspar producing area. This district is well suited for a consideration of elemental and mineralogic associations inasmuch as it has been intensively studied by the U. S. Geological Survey so that mineralogical data on some 625 pegmatites are available. These data are summarized by Lesure (1968), the source for much of the material shown in Tables 11 and 12.

According to Lesure (op. cit.) the mineral assemblage of the pegmatites is generally simple consisting of plagioclase, quartz, perthitic microcline, and muscovite. Accessory minerals,

	Coombs	Plumbago Mtn.	Peabody Mtn.	Lobkis Mica	George Elliot	
						Uraninite
						Sec. U-Mins.
						Mult. Oxides
						Uranothorite
						Thorite
						Monazite
						Pyrochlore- Microcline
						Cyrtolite
						Allanite
						Other REE Mins.
						Muscovite
						Biotite
						Be-minerals
						Columbite-tantalite
						Li-minerals
						Tourmaline
						Garnet
						Zircon
						Apatite
						Rare Phos. Mins.
						Fluorite
						Fe oxides
						Bi-minerals
						Topaz
						Th
						Nb-Ta
						Be
						Zr
						REE
						Li
						Mo
						F
						P
						Bi

Table 9: Selected non-radioactive pegmatites of Maine.

● Present at locality

	Vatcher	Corson	Chickering	McGall	Chandler	
						Uraninite
						Sec. U-Mins.
						Mult. Oxides
						Uranothorite
						Thorite
						Monazite
						Pyrochlore- Microlite
						Cyrtolite
						Allanite
						Other REE Mins.
						Muscovite
						Biotite
						Be-minerals
						Columbite-tantalite
						Li-minerals
						Tourmaline
						Garnet
						Zircon
						Apatite
						Rare Phos. Mins.
						Fluorite
						Fe oxides
						Bi-minerals
						Topaz
						Th
						Nb-Ta
						Be
						Zr
						REE
						Li
						Mo
						F
						P
						Bi

Table 10: Selected non-radioactive pegmatites of New Hampshire.

● Present at locality

S. W. Hoppus	Hickey	Horse Ridge	Polly Randolph	Salley Knob	Field	Fanny Gouge	Ray	Deake	Pink	Wiseman	Pine Mt.	Flat Rock	English Knob	Deer Park	#20	McKinney	
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Uraninite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Sec. U-Mins.
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Mult. Oxides
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Uranothorite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Thorite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Monazite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Pyrochlore- Microlite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Cyrtolite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Allanite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Other REE Mins.
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Muscovite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Diotite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Be-minerals
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Columbite-tantalite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Li-minerals
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Tourmaline
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Garnet
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Zircon
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Apatite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Rare Phos. Mins.
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Fluorite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Fe oxides
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Bi-minerals
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Topaz
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Th
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Nb-Ta
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Be
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Zr
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	REE
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Li
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Mo
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	F
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	P
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Bi

Table 11: Selected radioactive pegmatites of North Carolina.

• Present at locality

Champion	Trolley Bent	Tantrough	Francis Ogle	Grassy Knob	Elkins	Fox	Abernathy	Little Bear Ck.	Jeff Cut	Lick Ridge	Branch	Slippery Elm	Powdermill	Meadow	Lincoln Rock	Johnson	Franklyn	Doublehead	Uraninite
.....																			Sec. U-Mins.
.....																			Mult. Oxides
.....																			Uranothorite
.....																			Thorite
.....																			Monazite
.....																			Pyrochlore-
.....																			Microlite
.....																			Cyrtolite
.....																			Allanite
.....																			Other REE Mins.
.....																			Muscovite
.....																			Biollite
.....																			Be-minerals
.....																			Columbite-tantalite
.....																			Li-minerals
.....																			Tourmaline
.....																			Garnet
.....																			Zircon
.....																			Apatite
.....																			Rare Phos. Mins.
.....																			Fluorite
.....																			Fe oxides
.....																			Bi-minerals
.....																			Topaz
.....																			Th
.....																			Nb-Ta
.....																			Be
.....																			Zr
.....																			REE
.....																			Li
.....																			Mo
.....																			F
.....																			P
.....																			Bi

Table 12: Selected radioactive pegmatites (allanite) of North Carolina.

● Present at locality

of which garnet and biotite are the most abundant, make up less than five percent of the pegmatite. Beryl has been found in only 28 of the 625 deposits, and columbite in only 10.

Uranium-bearing minerals are known in only a few known deposits most of which are shown on Table 11. Thorium is present largely in monazite and allanite, the latter probably is the most common radioactive mineral in the district occurring in six percent of the 625 pegmatites that were investigated (Lesure, op. cit.).

Table 12 lists many of the known allanite-bearing pegmatites of the Spruce Pine District with their reported accessory minerals and in which the radioactivity is largely due to thorium.

The most obvious feature shown by the Tables is the complex suite of radioactive minerals generally present in the uraniferous type as compared to the thorium or allanite type. The uraniferous type may also contain beryl, columbite, cyrtolite, and monazite, species which appear to be lacking in the allanite pegmatites.

Colorado

Pegmatites are very numerous in Colorado, and with the notable exception of the Tertiary pegmatites of the Mount Antero area most are presumed to be of Precambrian age. They are widely distributed throughout the central part of the state, but tend to be chiefly in some nineteen major provinces which have been defined by Heinrich and Bever (1957) on the basis of the structural and mineralogical characteristics of their pegmatites.

Using their mineralogical data we have prepared a list (Table 13) which shows the elemental associations present in the pegmatites of each province. We have omitted the Jamestown province as the deposits containing the uranium and rare-earth

	Nb-Ta	Be	Zr	REE	Li	Mo	F	P	Bi	B	Fe	Th	Pegmatite Provinces
Provinces in which uranium or thorium minerals are not reported.	..●					●	●	●		●	●		Mount Antero
	●	●								●			Left-Hand Creek
						●	●			●			Ward-Nederland
	..●									●			Granby
	●	●						●					Cripple Creek
	..●					●							Alma
	●	●						●		●			Canon City
	●	●						●		●			Turret
													Climax
	..●									●			Gunnison River
Provinces in which uranium or thorium minerals are reported.	..●	●	●							●	●		Georgetown-Montezuma ¹
	●	●								●			Larimer County
	●	●											Clear Creek
	●												South Platte
	●	●											Pikes Peak-Florissant
	●	●											Guffey-Micanite
	●	●											Quartz Creek
	●	●											Cotopaxi-Trout Creek

Table 13: Elemental associations of Colorado pegmatite provinces
(modified from Heinrich & Bever, 1957).

● Present at locality

1. Alllanite only.

minerals there are aplite dikes rather than pegmatites as defined in this report.

From the Table it will be seen that the provinces in which uranium or thorium minerals are found are chiefly those in which rare-earth elements, niobium-tantalum, and fluorine are all constituents of the mineral assemblage. Much less significance can be placed on the presence of beryllium which, although commonly present in radioactive pegmatite provinces, is also found in these provinces in which uranium or thorium minerals have not been reported.

Elemental and mineralogical associations for some individual radioactive pegmatites in Colorado are shown on Table 14. Other pegmatites of complex mineralogy, but in which no uranium- or thorium-bearing species have been reported, are listed on Table 15. In Colorado pegmatites, the multiple oxide minerals are more common than uraninite, a result of the general availability of both niobium-tantalum and the rare earths. Thorium is usually present as monazite, but thorite is dominant in pegmatites of the St. Peter's Dome and South Platte areas.

New Mexico

Most of the radioactive pegmatites in New Mexico are Precambrian in age and occur in the Petaca District in Rio Arriba County. These are almost universally muscovite pegmatites and contain a very characteristic suite of accessory minerals including beryl, columbite-tantalite, fluorite, and bismuth minerals. Apatite and tourmaline are rare (Table 16).

In a detailed study of the district, Jahns (1946) found that in sixty-nine pegmatites examined, monazite occurred in 57, samarskite in 40 and uraninite in 2.

Hudson Tunnel	Wheeler Basin	Red Head	Hyatt	Quartz Creek 6	Quartz Creek 4	Roscoe	Burroughs	Teller	Guffy Area 3	St. Peters Dome	Black Cloud	So. Platte	Seerie	Cotopaxi	Clara May	Crystal #8	Yard	
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Uraninite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Sec. U-Mins.
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Mult. Oxides
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Uranothorite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Thorite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Monazite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Pyrochlore-Microlite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Cyrtolite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Allanite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Other REE Mins.
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Muscovite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Biotite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Be-minerals
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Columbite-tantalite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Li-minerals
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Tourmaline
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Garnet
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Zircon
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Apatite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Rare Phos. Mins.
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Fluorite
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Fe oxides
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Bi-minerals
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Topaz
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Th
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Nb-Ta
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Be
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Zr
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	REE
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Li
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Mo
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	F
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	P
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	Bi

Table 14: Selected radioactive pegmatites of Colorado.

1. Be in gadolinite
2. Be in bertrandite and genthelvite
3. Composite of Guffey area pegmatites
4. Brown Derby No. 1 pegmatite
5. In alteration products of spodumene
6. Beryl and Rare Minerals Lode
- Present at locality

Buckhorn	Devils Hole	School Section	Myers'	Rock King	Johnny	Mica Lode	Chief	
•	•	•	•	•	•	•	•	Uraninite
•	•	•	•	•	•	•	•	Sec. U-Mins.
•	•	•	•	•	•	•	•	Mult. Oxides
•	•	•	•	•	•	•	•	Uranothorite
•	•	•	•	•	•	•	•	Thorite
•	•	•	•	•	•	•	•	Monazite
•	•	•	•	•	•	•	•	Pyrochlore-Microlite
•	•	•	•	•	•	•	•	Cyrtolite
•	•	•	•	•	•	•	•	Allanite
•	•	•	•	•	•	•	•	Other REE Mins.
•	•	•	•	•	•	•	•	Muscovite
•	•	•	•	•	•	•	•	Biotite
•	•	•	•	•	•	•	•	Be-minerals
•	•	•	•	•	•	•	•	Columbite-tantalite
•	•	•	•	•	•	•	•	Li-minerals
•	•	•	•	•	•	•	•	Tourmaline
•	•	•	•	•	•	•	•	Garnet
•	•	•	•	•	•	•	•	Zircon
•	•	•	•	•	•	•	•	Apatite
•	•	•	•	•	•	•	•	Rare Phos. Mins.
•	•	•	•	•	•	•	•	Fluorite
•	•	•	•	•	•	•	•	Fe oxides
•	•	•	•	•	•	•	•	Bi-minerals
•	•	•	•	•	•	•	•	Topaz
•	•	•	•	•	•	•	•	Th
•	•	•	•	•	•	•	•	Nb-Ta
•	•	•	•	•	•	•	•	Be
•	•	•	•	•	•	•	•	Zr
•	•	•	•	•	•	•	•	REE
•	•	•	•	•	•	•	•	Li
•	•	•	•	•	•	•	•	Mo
•	•	•	•	•	•	•	•	F
•	•	•	•	•	•	•	•	P
•	•	•	•	•	•	•	•	Bi

Table 15: Selected non-radioactive pegmatites of Colorado.

● Present at locality

	Gold Hill	Elk Mtn. ²	Pidlite	Harding	Globe	Cribbenville	Ojo Caliente	La Paloma	Pino Verde	Fridlund	Eureka	Kiawa	
.....	●								●	●			Uraninite
.....													Sec. U-Mins.
.....													Mult. Oxides
.....													Uranothorite
.....													Thorite
.....													Monazite
.....													Pyrochlore- Microlite
.....													Cyrtolite
.....													Allanite
.....													Other REE Mins.
.....													Muscovite
.....													Biotite
.....													Be-minerals
.....													Columbite-tantalite
.....													Li-minerals
.....													Tourmaline
.....													Garnet
.....													Zircon
.....													Apatite
.....													Rare Phos. Mins.
.....													Fluorite
.....													Fe oxides
.....													Bi-minerals
.....													Topaz
.....													Th
.....													Nb-Ta
.....													Be
.....													Zr
.....													REE
.....													Li
.....													Mo
.....													F
.....													P
.....													Bi

Table 16: Selected radioactive pegmatites of New Mexico.

1. Very Rare

2. Guy No. 1 deposit

● Present at locality

A quite different mineral assemblage is found at the famous Harding pegmatite about 20 miles (30 km) southeast of the Petaca District. Here uranium occurs almost entirely in microlite although in widely varying amounts; metamict microlite from the deposit may contain nearly five percent uranium (Brookings, et al, 1979). Other radioactive minerals such as thorite, monazite, and allanite have been reported (Jahns and Ewing, 1977), but are very rare, as are tourmaline, zircon, and fluorite. Beryl, Ta-rich columbite, tantalite, spodumene, Li-muscovite, lepidolite, and apatite are abundant. The Harding pegmatite is, therefore, characterized by minerals of beryllium, lithium, tantalum-niobium, and phosphorous. It contrasts markedly with the pegmatites of the Petaca District in the virtual absence of the rare-earth elements and the abundance of lithium. Although fluorite is very rare at the Harding as opposed to the Petaca pegmatites, fluorine is present in apatite and to a lesser extent, in lepidolite and topaz. Boron is essentially absent in both areas.

A very complex mineral assemblage is found at the Pidlite mine in Mora County (Jahns, 1953b). In this pegmatite the radioactive elements occur in betafite, monazite, uraniferous microlite, and cyrtolite. Its minor element suite is quite similar to that at the Harding except for the appearance of the rare-earth elements.

At the Guy No. 1 mine in the Elk Mountain District, uraninite as well as multiple oxides, and monazite are found. The deposit is remarkably different from the Pidlite and Harding pegmatites in that both beryllium and lithium appear to be absent.

It is of interest to note that bismuth minerals are found in all of the radioactive pegmatites in northern New Mexico for which we have detailed mineralogy. Although bismuth minerals are found in granitic pegmatites of other areas, they are most consistently present in this area.

A few radioactive pegmatites are found in the southwestern part of New Mexico notably at Gold Hill where multiple oxide minerals, allanite, and cyrtolite reportedly occur (Gillerman, 1964). Associated minerals are muscovite and biotite, garnet, fluorite, and abundant magnetite. The mineral assemblage of these pegmatites is quite similar to that found in the pegmatites of the Trout Creek Pass area in Colorado (Yard, Crystal No. 8, and Clora May pegmatites).

South Dakota

Radioactive minerals are found in only a few of the thousands of Precambrian pegmatites of the Black Hills, and are rare in these. We have included the area for discussion, however, as it offers an opportunity to examine the elemental associations found in a well-studied province.

Uraninite has been reported from three of the large, mineralogically complex pegmatites near Keystone (Table 17) and is characteristically surrounded by red, orange, and yellow alteration products that in aggregate are called "gummite". The uranium phosphates, autunite and torbernite, are occasionally found in Black Hills' pegmatites, chiefly as coatings on fracture surfaces.

Two pegmatites, the Bob Ingersoll and the Tin Mountain, contain microlite, a calcium tantalate mineral that may contain several percent uranium as a vicarious constituent. We have no information on the uranium content of the microlite from these pegmatites, but are classifying the Tin Mountain deposit as a radioactive pegmatite inasmuch as the microlite there is described as being dark-brownish to black (Staatz, et al, 1963), characteristic of uraniferous microlite.

In an early report, Connolly and O'Harra (1929) list a large number of minerals reportedly found in Black Hills pegma-

tites. These include monazite, fluorite, zircon, bismuthinite, and molybdenite, all of which are significant to our study. More recent investigations, however, fail to note the occurrence of these minerals so they may be very rare or absent at least in the pegmatites studied during and after World War II.

Although fluorite may not occur in the pegmatites, fluorine is present in apatite, the micas, and other minerals such as amblygonite.

With the exception of monazite, there are no other minerals of thorium or the rare earths reported from the pegmatites, but these elements may be present in trace amounts in other minerals.

From Tables 17 and 18, it will be seen that in the Black Hills' pegmatites muscovite is the dominant mica, and that tourmaline and apatite are common accessories. The pegmatites may contain beryllium and lithium, niobium and tantalum, phosphorus, and sometimes tin, but very little uranium, and essentially no zirconium, thorium, or rare-earth elements.

Summary

In a review of various types of uranium deposits, Klepper and Wyant (1957) expressed the opinion that no particular mineral assemblage is known that can be used to predict successfully which pegmatite is likely to be radioactive and which is not.

From our study we have found nothing that will completely refute their conclusion, but there are, however, some mineralogic and hence, elemental characteristics that may influence the favorability of certain districts or of pegmatites within a

	Etta	Dan Patch	Bob Ingersoll	Tin Mtn.	
●	●	●	●	●	Uraninite
●	●	●	●	●	Sec. U-Mins.
●	●	●	●	●	Mult. Oxides
●	●	●	●	●	Uranothorite
●	●	●	●	●	Thorite
●	●	●	●	●	Monazite
●	●	●	●	●	Pyrochlore-Microlite
●	●	●	●	●	Cyrtolite
●	●	●	●	●	Allanite
●	●	●	●	●	Other REE Mins.
●	●	●	●	●	Muscovite
●	●	●	●	●	Biotite
●	●	●	●	●	Be-minerals
●	●	●	●	●	Columbite-tantalite
●	●	●	●	●	Li-minerals
●	●	●	●	●	Tourmaline
●	●	●	●	●	Garnet
●	●	●	●	●	Zircon
●	●	●	●	●	Apatite
●	●	●	●	●	Rare Phos. Mins.
●	●	●	●	●	Fluorite
●	●	●	●	●	Fe oxides
●	●	●	●	●	Bi-minerals
●	●	●	●	●	Topaz
●	●	●	●	●	Th
●	●	●	●	●	Nb-Ta
●	●	●	●	●	Be
●	●	●	●	●	Zr
●	●	●	●	●	REE
●	●	●	●	●	Li
●	●	●	●	●	Mo
●	●	●	●	●	F
●	●	●	●	●	P
●	●	●	●	●	Bi

Table 17: Selected radioactive pegmatites of South Dakota.

● Present at locality

High Climb	Earl Lode	Old Mike	Custer Mtn.	John Ross	Sitting Bull	Monte Carlo	Gayle (Dubuque) and Royal Flush	Helen Beryl	Hugo	Peerless	
.....											Uraninite
.....											Sec. U-Mins.
.....											Mult. Oxides
.....											Uranothorite
.....											Thorite
.....											Monazite
.....											Pyrochlore- Microcline
.....											Cyrtolite
.....											Allanite
.....											Other REE Mins.
.....											Muscovite
.....											Biotite
.....											Be-minerals
.....											Columbite-tantalite
.....											Li-minerals
.....											Tourmaline
.....											Garnet
.....											Zircon
.....											Apatite
.....											Rare Phos. Mins.
.....											Fluorite
.....											Fe oxides
.....											Bi-minerals
.....											Topaz
.....											Th
.....											Nb-Ta
.....											Be
.....											Zr
.....											REE
.....											Li
.....											Mu
.....											F
.....											P
.....											Bi

Table 18: Selected non-radioactive pegmatites of South Dakota.

● Present at locality

district. These characteristics can best be discussed by a review of the same major pegmatite areas described earlier in this section.

Although pegmatites are very numerous in Maine and New Hampshire, the great majority are of simple mineralogy and do not contain uranium or other rare metals.

Where uranium occurs, it is apt to be in pegmatites of complex mineralogy and in elemental association with beryllium, niobium and tantalum, lithium, and less commonly zirconium. As may be noted from Tables 9 and 10, these same elements are found in complex pegmatites without associated uranium. Nevertheless, such complex pegmatites are the most favorable for the occurrence of uranium.

Beryllium alone does not appear to indicate the favorability of a deposit. Olson (1950), has noted that of the 207 New Hampshire pegmatites studied 101 contained beryl. Of the 207 only about 10 are known to contain uranium. Where beryllium is found together with niobium and tantalum, lithium, or zirconium the probability of associated uranium appears to be higher.

A very similar elemental association is noted in the pegmatites of the Black Hills of South Dakota where uraninite is found only in the mineralogically complex pegmatites although much less commonly than in New England.

In the Spruce Pine district where most of the radioactive pegmatites of North Carolina are concentrated, the elemental assemblage associated with uraniferous pegmatites is again complex, but with some different elements involved. Beryllium, which is common in the pegmatites of Maine, New Hampshire, and

South Dakota, is very minor and lithium is essentially absent. The rare earths, niobium, and tantalum are ubiquitous and commonly combine with uranium to form the multiple oxide minerals, such as samarskite which is found in several Spruce Pine pegmatites.

The correlation between uranium and the rare elements, notably niobium, is particularly evident in this district inasmuch as the uraniferous deposits include all or nearly all of the pegmatites in which niobium minerals have been reported.

The numerous allanite pegmatites of the district do not appear to contain rare elements other than thorium and the rare earths.

Several types of radioactive pegmatites are found in Colorado and nearly all are characterized by niobium and tantalum, the rare earths, and fluorine. Beryllium is common to a large number of pegmatites, whereas lithium is restricted to a very few. Both uranium and thorium are present in most of the deposits; thorium is dominant in some, notably those of the St. Peters Dome area.

Radioactive pegmatites in New Mexico show a very similar group of rare elements as well as abundant fluorine. Lithium is rare except in two of the deposits. Bismuth is present in all of the radioactive pegmatites of northern New Mexico.

Discussion

Although we have presented elemental and mineralogical association data for only some of the pegmatite areas of the United States, the relationships shown can be considered applicable to other areas inasmuch as a wide variety of pegmatites are included.

Probably the most significant factor influencing the general favorability for the occurrence of uranium minerals in pegmatites is the complexity of the elemental assemblage present in the deposit.

We have found that the elements that are apt to be associated with uranium may differ from district to district, but most commonly are niobium and tantalum, the rare earths, beryllium, zirconium, lithium and fluorine. Pegmatites containing various combinations of these elements appear to be much more favorable than those in which one rare element such as beryllium or niobium is found alone and are far more favorable than those in which none of these rare elements are present.

No particular significance can be placed on some of the other elements such as boron or phosphorus which, in tourmaline and apatite, may be ubiquitous in a district. A distinct favorability of biotite over muscovite in radioactive pegmatites in some Canadian areas has been noted (Fratta, 1970), but no clear examples of this were noted in our study of domestic pegmatites, and indeed, muscovite may be the dominant or only mica in some radioactive pegmatites.

It can be concluded then that a district in which pegmatites are known to contain certain rare elements will be more likely to contain uraniferous pegmatites than districts where these elements are lacking, and that in the favorable district those pegmatites containing a diversity of these elements may be considered to be the most likely hosts for uranium.

URANIUM AND THORIUM IN UNZONED PEGMATITES

Information on zoning is available for 121 of the radioactive pegmatites listed in the Index of Geologic Features. Of these, 20 are unzoned and the remainder are zoned. Although unzoned radioactive pegmatites are far less abundant they are by no means unimportant. Heinrich (1958, p. 192) noted that unzoned pegmatites "represent the most economically significant kind of radioactive pegmatite". Many of the important deposits in the Bancroft area of Canada are unzoned pegmatites as are many of the pegmatites in the Grenville Province of southern Quebec. Similarly, many radioactive unzoned pegmatites occur in northern Saskatchewan (Mawdsley, 1955).

Unzoned pegmatites are distinguished by a lack of segregation of mineralogic assemblages. There does not appear to be any spatial control on the distribution of radioactive minerals within unzoned pegmatites. For example, radioactive minerals are not concentrated in margins or near the center of the pegmatite bodies. However, in some cases there appears to be a mineralogic control. For example in the Bancroft deposits many of the radioactive minerals are associated with mafic constituents such as hornblende, biotite, magnetite, pyroxene and country rock xenoliths.

The only known unzoned radioactive pegmatites of interest in the conterminous United States occur in the Wheeler Basin in Grand County, Colorado (Young and Hauff, 1975) and near Idaho Springs in Clear Creek County, Colorado. The latter, a minor former producer (Table 1), consists of a small three-foot wide microcline-plagioclase-quartz-biotite pegmatite. Uraninite is associated primarily with biotite, but also occurs as small cubes in feldspar surrounded by a red alteration halo.

Because of their homogeneous mineralogic composition, unzoned pegmatites lend themselves more readily to economic bulk mining and are more amenable to milling than are zoned pegmatites. Although the overall tenor of a radioactive unzoned pegmatite may be no greater than that which may be found in zoned pegmatites, the unzoned body is a more attractive exploration target.

URANIUM AND THORIUM IN ZONED PEGMATITES

An earlier section on the internal structure of pegmatites described the typical concentric zonation of pegmatites into border, wall, intermediate and core zones. The mineral suites that characteristically are found within each zone were presented in Table 3. The present section will examine the distribution of uranium and thorium minerals within the various zones and/crosscutting replacement units or fracture fillings.

Table 19 and Figure 6 summarize the zonal position of radioactive minerals of pegmatites for which specific data is available. A small number of pegmatites from outside the United States have been included to illustrate universality of the distribution patterns.

From Table 20 it is apparent that the essential mineralogy of each zone is nearly identical with that expected of pegmatites in general as described earlier. Some differences do exist and these are discussed in the section on Elemental and Mineralogical Associations.

The border zone contains the least number of occurrences reflecting, in part, the unfavorability of this zone and, in part, that this zone is not developed in many zoned pegmatites. The wall zone is the most frequently quoted host for the radio-elements with progressively fewer occurrences noted in the intermediate and core zones. Secondary units, including both replacement bodies and fracture fillings, are more apt to contain radioactive minerals than any of the zones; however, the number of occurrences in zonal units is considerably greater.

Figure 6 is based on the frequency of occurrences and does not reflect relative abundances. For example, at the Seerie

Group	Mineral	Border	Wall	Inter- mediate	Core	Secondary Units
Oxide	Uraninite	56,59	7,14,15,31,41 47,58,60,63	5,33,52,53 59	33,53	7,10,18,25 49,50,64
	Betafite		29	61	57	3,64
Multiple Oxides	Euxenite		2,63	4,30,61	4,6,9	62,64
	Fergusonite			33,53,61	53,54	17,28,54, 64,66
	Microlite		14,55	51,52	29,51	62,64
	Pyrochlore		55			
	Polycrase					65
	Samarskite		13,22,47	8,30,48 53,61	23,24	25,26,27, 28,64
	Yttrocrasite			53	53	
	Yttrotantalite					2,64,66
Silicates	Allanite		1,31,35,36,37, 38,42,43,44,57	30,32,33 53,61	9,33,53	50,54,64,66
	Cyrtolite	29	8,14,53	30	10,53,54, 57	3,18,64,66
	Gadolinite			53	53,54	2,62,64,66
	Sphene					64
	Thorite		8			7,64
	Uranophane		15,45			18,50
	Uranothorite				58	
Phosphates	Autunite		15,35,41,47	16,21,34	12,19,20	18,49,50
	Monazite		2,29,39,55	4,33,54,59	4,6,11, 24,25	23,25,26,27 28,62,64,65
	Torbernite		15,35,47	34	12	18
	Xenotime			4	4	64,66
Others	"Gummite"		47	16		18
	Secondary Uranium Mins.		14,15,36,39, 40,46	5,52		50
	"Thorogummite"			61		62

Table 19: Distribution of radioactive minerals within zoned pegmatites.
Location numbers are keyed to Table 20.

Figure 6 .Frequency distribution of radioactive minerals by pegmatite zones and secondary units.

pegmatite in Colorado uraninite occurs as a primary mineral in the wall zone, however, thorite in fracture filling units is far more abundant.

These observations differ somewhat from those of Page (1950) who noted that although radioactive minerals may occur in all zones and secondary units, they are most likely to occur in intermediate zones and cores. This apparent difference reflects a problem in definitions because some investigators may label a particular zone a wall zone while others may interpret the same as an intermediate zone. A similar problem occurs with the position of the core-margin. Some investigators include it with the intermediate zone while others include it with the core. We concur with the former.

The zonal position of radioactive minerals appears to differ between districts. For example in the Petaca District albite-rich replacement units are the most common host. Similarly, in North Carolina the vast majority of the occurrences are within the wall zone, and in New York in intermediate zones. An implication from this observation is that, although processes of pegmatite formation are similar in a general sense, the crystallization sequence, extent of differentiation of the aqueous phase, or the nature of replacement units may vary and, hence, may affect the zonal position of radioactive minerals.

Pegmatites are most likely formed by in situ fractional crystallization within a closed system progressing from the wall rock toward the core. If so, precipitation of the various radioactive minerals most frequently commences after crystallization of the border zone and continues through to crystallization of the core. Radioactive minerals associated with replacement

units may develop during or after crystallization of the various zones. Whether the uranium and thorium are scavenged en route or are primary to the replacement fluids is difficult to ascertain. Theoretically, if the replacement fluids are the final volatile phases of the pegmatitic fluid, then they would expectably be enriched in fluorine complexes, which are frequent carriers of uranium and thorium.

Table 20 describes the zonal position of uranium and thorium minerals in pegmatites. The zones are described from outermost to innermost and, where information was complete, labeled border, wall, intermediate and core. The composition for the most part is listed in order of decreasing mineralogic abundance within a particular zone. Abbreviations used include:

Q = quartz
M = microcline
Pl = plagioclase
P = perthite
Al = albite
F = feldspar
Ol = oligoclase
Cl = cleavelandite
Mv = muscovite
B = biotite
Fl = fluorite
Br = beryl
T = tourmaline
H = hornblende
Sp = spodumene
Am = amblygonite
Ca = calcite
Ap = apatite
GG = graphic granite

LOCATICN	ZONAL MINERALOGIC ASSEMBLAGE	RADIOACTIVE MINERAL OCCURRENCE
<u>Arizona</u>		
1) Kingman Feldspar Mine	Q-F border zone, Q-F-B-Mv Wall Zone, M-Q core	<u>Allanite</u> in wall zone.
2) Rare Metals Mine	Q-M-Pl-Mv wall zone, M-Mv core margin, Q core, Ab-Mv 'line rock'	<u>Monazite</u> in unaltered wall zone, <u>euxenite</u> in albitized, <u>gadolinite</u> and <u>yttrotantalite</u> in aplitic 'line rock'.
<u>California</u>		
3) Cady Mountains	Q-F zone, granitic wall zone Al replacement of K-Spar	<u>Cyrtoelite</u> and <u>betafite</u> associated with biotite and albitized K-Spar.
4) Winchester and S. P. Silica Quarry	Graphic granite zone, core margin, Q core	<u>Monazite</u> , <u>xenotime</u> and <u>euxenite</u> in core margin and core.
<u>Colorado</u>		
5) Hyatt Beryl Mine	Pl-Q-Mv core margin, P core	<u>Uraninite</u> and secondaries in core-margin only.
6) Burroughs Mine	Q-M-B wall zone, Q-M core	<u>Monazite</u> and <u>euxenite</u> from outer edge of core. <u>Allanite</u> and <u>gadolinite</u> (?) also occur in pegmatite.
7) Seerie Pegmatite	P-Q-Pl wall zone, Q-P intermediate zone, Q core, P-Q-Pl replacement unit in intermediate zone, Fl fracture fill	<u>Thorite</u> occurs in fracture fill in the wall zone. <u>Uraninite</u> occurs as inclusions in thorite as well as discrete grains in the wall zone.

TABLE 20: Summary of the mineralogy of zoned pegmatites. Data for several occurrences is incomplete. Location numbers are used in Table 19.

LOCATION	ZONAL MINERALOGIC ASSEMBLAGE	RADIOACTIVE MINERAL OCCURRENCE
<u>Colorado</u>		
8) South Platte Area	P-B wall zone, P-Q intermediate zone, P-Q-F1 replacement in core margin, Q core	<u>Cyrtolite</u> and <u>thorite</u> occur in the wall zone and <u>samaraskite</u> in the intermediate zone.
9) Crystal No. 8 and Clora May Mine	Q-M-Pl-garnet border zone, Q-M-Pl core	<u>Euxenite</u> and <u>allanite</u> occur in the core only.
<u>Connecticut</u>		
10) Branchville	Q-Ol border, Mv-Q wall zone, C core, cleavelandite-quartz, cleavelandite, and cleavelandite-spodumene replacement units.	<u>Uraninite</u> occurs in the cleavelandite-spodumene replacement unit and <u>cyrtolite</u> in the core
11) Hale Quarry	Q-Pl-T border zone, Q-P core	<u>Morazite</u> occurs in the core, but is rare.
12) Toll Gate Quarry	Q-Mv-Pl border zone, Q-Pl-Mv-P wall zone, Q-P (core?) zone	<u>Autunite</u> and <u>torbernite</u> occur in the quartz-perthite (core?) zone.
13) Spinelli Prospect	Q-F-Mv border zone, Q-P-Pl wall zone, Q-core	<u>Samaraskite</u> occurs in the wall zone.
<u>Maine</u>		
14) Black Mtn. Mine	Q-Pl-Mv border zone, Pl-Cl-Q-Mv wall zone, Q-P core	<u>Microlite</u> occurs within lepidolite which, together with uranium minerals, occurs in cleavelandite-rich zones.
15) Wardwell Quarry	Q-P-B wall zone, Q-F intermediate zone, Q core	Uranium minerals occur in the wall zone.
16) Consolidated Feldspar Quarry	Q-Pl-P-Mv wall zone, GG-P-Q intermediate zone, Q-P core	<u>Autunite</u> and " <u>gummite</u> " occur with beryl in the intermediate zone.

Table 20 continued

LOCATION	ZONAL MINERALOGIC ASSEMBLAGE	RADIOACTIVE MINERAL OCCURRENCE
<u>Montana</u>		
17) Sappington Area	Unknown	<u>Fergusonite</u> is associated with microcline and plagioclase in a replacement unit.
<u>New Hampshire</u>		
18) Ruggles Mine	10 zones and 3 secondary units recognized	Uranium minerals are associated with late veins and quartz near the perthite core.
19) Globe Mica Mine	Q-Pl-Mv border zone, Q-P-Pl wall zone, Al-Mv in intermediate zone, Q core	<u>Autunite</u> occurs in the quartz core.
20) Danbury Mica Mine	Q-Pl-Mv border zone, Pl-Q-Mv wall zone, P-Q intermediate zone, Q core	<u>Autunite</u> occurs in the quartz core.
21) E. E. Smith Mica Mine	Q-Mv border zone, Pl-Q-Mv wall zone, Pl-Q-P intermediate zone, Pl-Mv-Q-Br intermediate zone, P-Q intermediate zone, Q core	<u>Autunite</u> is associated with columbite-tantalite in the Pl-Mv-Q-Br intermediate zone.
22) Weeks Mine	Q-Pl border zone, Al-Q-Mv-P wall zone, Q core	<u>Samarskite</u> occurs intergrown with columbite in albite-rich parts of the wall zone.
<u>New Mexico</u>		
23) Kiawa	Pl-Q-M border zone, M-Q wall zone, M-Q-GG outer intermediate zone, M-Q inner intermediate zone, Q core, Al-Cl replacement	<u>Samarskite</u> occurs along fractures in massive quartz. <u>Monazite</u> occurs in albite-rich areas.
24) Fridlund	M-Q-Al-Pl border zone, M-Q core, Al replacement	<u>Monazite</u> , <u>samarskite</u> , and columbite occur on the hanging-wall side of the quartz core.

Table 20 continued

LOCATION	ZONAL MINERALOGIC ASSEMBLAGE	RADIOACTIVE MINERAL OCCURRENCE
<u>New Mexico</u>		
25) Pino Verde	M-Q wall zone, M-Q-GG intermediate zone, Q core, Al replacement	<u>Samarskite</u> , <u>monazite</u> , and <u>uraninite</u> occur in albite-rich replacement. <u>Monazite</u> and columbite occur in albite-rich portions of microcline within the core.
26) Cribbenville	M-Q-Al-Pl border zone, M-Q-GG-Al wall zone, GG intermediate, M intermediate, Q-M intermediate zone, Q core, Al replacement	<u>Monazite</u> and columbite are abundant in albite-rich areas. <u>Samarskite</u> occurs in quartz-albite areas in the interior.
27) Globe	M-Q-Mv border zone, M-Q wall zone, two M-Q intermediate zones, Q core, Al replacement	<u>Monazite</u> is associated with columbite and fluorite in albite-rich replacement areas. <u>Samarskite</u> and bismutite occur in quartz-albite replacement areas.
28) La Paloma	Q-Mv-F border zone, M-Q zone, Q-core, Al replacement	<u>Samarskite</u> , <u>fergusonite</u> (?) and <u>monazite</u> occur with columbite in quartz-albite-rich replacement unit.
29) Pidlite Mine	Al-Q-Mv-F border zone, Q-P intermediate zone, Q core	<u>Cyrtolite</u> occurs in biotite in the border zone. <u>Betafite</u> and <u>monazite</u> occur in the wall zone and <u>microlite</u> in lepidolite in the quartz core.
30) Gold Hill	Al-Q-Mv wall zone, F-Q intermediate, Q-M core	<u>Samarskite</u> , <u>euxenite</u> , <u>allanite</u> and <u>cyrtolite</u> occur in the intermediate zone.
<u>New York</u>		
31) Batchellerville	Mv-F-Q-B wall zone, M-Mv-Q intermediate zone, Q core	<u>Uraninite</u> and <u>allanite</u> occur in the wall zone near the country rock contact.

Table 20 continued

LOCATION	ZONAL MINERALOGIC ASSEMBLAGE	RADIOACTIVE MINERAL OCCURRENCE
<u>New York</u>		
32) Crown Point Spar Co.	B-F-Q border and wall zone, F-B outer intermediate zone, F-B-T-H inner intermediate zone, Q core	<u>Allanite</u> occurs as a massive cluster in the inner intermediate zone.
33) Spar Bed Hill Quarry	M-Pl-Q outer zone, Pl-T outer intermediate zone, F-B-Q-H inner intermediate zone, B-Q-F innermost zone	<u>Uraninite</u> and <u>allanite</u> occur in the core and intermediate zones. <u>Monazite</u> and <u>allanite</u> occur in the inner intermediate zone and <u>fergusonite</u> in the outer intermediate zone.
34) Corinth Feldspar	Pl-B border zone, M-Mv wall zone, Pl-M-Mv outer intermediate zone, M-Mv inner intermediate zone, Q core	<u>Autunite</u> and <u>torbernite</u> are associated with plagioclase in the outer intermediate zone.
<u>North Carolina</u>		
35) Pine Mountain Mine	P-Pl-Q wall zone, Q core	<u>Allanite</u> , <u>autunite</u> and <u>torbernite</u> occur in the wall zone.
36) Deake Mine	Pl-Q-P-Mv wall zone, Q core	<u>Allanite</u> and <u>uranium minerals</u> occur in the wall zone.
37) Powdermill Mine	Pl-Q-Mv-B wall zone, P-Pl-Q core	<u>Allanite</u> occurs in the wall zone.
38) Branch Mine	Pl-P-Q-Mv-B wall zone, Q core	<u>Allanite</u> occurs in the wall zone.
39) Jake Buchanan Mine	Pl-P-Q-Mv wall zone, Q core	<u>Monazite</u> and <u>uranium minerals</u> occur in the wall zone.
40) Old Susie Phillips Mine	P-Pl-Q-Mv wall zone, Q core	<u>Uranium minerals</u> occur in the wall zone.
41) Polly Randolph Mine	Pl-Q-P-Mv wall zone, Q core	<u>Uraninite</u> and <u>autunite</u> occur in the wall zone.

Table 20 continued

LOCATION	ZONAL MINERALOGIC ASSEMBLAGE	RADIOACTIVE MINERAL OCCURRENCE
<u>North Carolina</u>		
42) Elkins Mine	F-Q-Mv wall zone, Q core	<u>Allanite</u> occurs in the wall zone.
43) Francis Ogle Mine	Pl-Q-Mv wall zone, Q core	<u>Allanite</u> occurs in the wall zone.
44) Tantrough Mine	Pl-Q-Mv wall zone, Q core	<u>Allanite</u> occurs in the wall zone.
45) James Mine	Pl-P-Q-Mv wall zone, Q core	<u>Uranophane</u> occurs in the wall zone.
46) Crabtree No. 1 Mine	P-Pl-Q-Mv wall zone, Q core	<u>Uranium minerals</u> occur in the wall zone.
47) Field Mine	Pl-Q-Mv wall zone, P-Q core	<u>Samarskite</u> , <u>uraninite</u> , <u>autunite</u> , <u>torbernite</u> and "gummite" occur in the wall zone.
48) Sheep Cliff Mine	P-Q-Fl-Mv wall zone, F-Q intermediate zone, Q core	One grain of <u>samarskite</u> was found in the intermediate zone adjacent to the core.
49) A. H. Hoyle Mine	Q-Pl border zone, Pl-Q-Mv-P wall zone, P-Pl-Q-Mv inner zone	<u>Uraninite</u> and <u>autunite</u> occur along fracture surfaces in the wall zone.
50) Knight Mine	Q-Pl border zone, Pl-Q-Mv wall zone P intermediate zone, Q core	<u>Uraninite</u> , <u>autunite</u> , <u>uranophane</u> , <u>allanite</u> , and <u>secondary uranium minerals</u> occur on fracture and cleavage surfaces in the perthite zone.
<u>South Dakota</u>		
51) Tin Mountain	Mv-Al-Q border zone, Al-Q-Mv wall zone, P-Q-Al intermediate, P intermediate, Al-Q-Sp intermediate, Q-Sp-Lp core	<u>Microlite</u> is associated with lepidolite and columbite-tantalite all of which occur intergrown with albite between spodumene and quartz crystals.
52) Bob Ingersoll	Q-Al-Mv border/wall zone, Q-Al intermediate zone, Mv-Al-Q intermediate zone, P-Q intermediate zone, Q-Am-Al-P intermediate zone, Q-Sp core	<u>Uraninite</u> and <u>microlite</u> occur in the muscovite-albite-quartz intermediate zone associated with lepidolite in amblygonite-quartz areas.

Table 20 continued

LOCATION	ZONAL MINERALOGIC ASSEMBLAGE	RADIOACTIVE MINERAL OCCURRENCE
<u>Texas</u>		
53) Clear Creek	GG-B border zone, B-M intermediate zone, P-Q intermediate zone, M-Q intermediate zone, Q core	<u>Cyrtolite</u> occurs in the wall zone. <u>Fergusonite</u> occurs in the outer intermediate zone. <u>Fergusonite</u> , <u>gadolinite</u> , <u>yttrrocrasite</u> , <u>samaraskite</u> , <u>uraninite</u> and <u>allanite</u> occur in the inner intermediate zone. The core zone contains <u>uraninite</u> , <u>gadolinite</u> , <u>fergusonite</u> , <u>allanite</u> , <u>cyrtolite</u> and <u>yttrrocrasite</u> .
54) Rode Ranch	GG outer zone, Q-M-P core, Al replacement	<u>Allanite</u> and <u>fergusonite</u> occur in albite replacement near quartz-albite interfaces. <u>Cyrtolite</u> and <u>fergusonite</u> occur disseminated in perthite and with <u>gadolinite</u> associated with biotite along perthite-quartz contact in the core zone.
<u>Virginia</u>		
55) Champion Mine	Pl-Mv border zone, Al wall zone, Q core	<u>Microcline</u> occurs in albite wall zone. <u>Pyrochlore</u> and <u>monazite</u> are interstitial to quartz and feldspar in the wall zone.
<u>Washington</u>		
56) Electric City	F-Q-B border zone, Q core	<u>Uraninite</u> occurs in the border zone.
<u>Foreign Occurrences*</u>		
57) MacDonald Feldspar Mine Ontario, Canada	GG border zone, Al-M-Q wall zone, Q-P intermediate zone, Q-M core, Ca-sulfide-Pl pod along footwall side of core	<u>Cyrtolite</u> and <u>betafite</u> are associated with calcite pods along the footwall of the core. <u>Allanite</u> occurs in the wall zone

*in Heinrich, E. W., 1958

Table 20 continued

LOCATION	ZONAL MINERALOGIC ASSEMBLAGE	RADIOACTIVE MINERAL OCCURRENCE
<u>Foreign Occurrences *</u>		
58) Richardson Deposit Ontario, Canada	Ol-M border zone, Ol-M-P wall zone, H-F intermediate zone, Ca-Fl-Ap core	<u>Uraninite</u> occurs in the wall zone feldspars and with <u>uraniothorite</u> in the core.
59) Lac La Ronge Area	Ol-Q border zone, M-Q-Ol intermediate zone, M-P-Q core zone	<u>Monazite</u> occurs in the upper part of the intermediate zone. <u>Uraninite</u> occurs in the upper intermediate zone, the border zone and the adjacent biotite-rich wall rock selvage.
60) Northern Karelia, U.S.S.R.	Q-Ol-B wall zone, F intermediate zones, Q ccre, Al replacement	<u>Uraninite</u> occurs in quartz-oligoclase-biotite wall zone.
61) Sui-chung District, China	Q ccre, Al-M replacement in core margin	<u>Euxenite</u> , <u>fergusonite</u> , <u>samaraskite</u> , <u>betafite</u> , <u>allanite</u> , <u>thorogummite</u> , and zircon are associated with albite and biotite laths in the core-margin.
62) Wodgina, Western Australia	Albitized units	<u>Gadolinite</u> , <u>monazite</u> , <u>euxenite</u> , <u>microlite</u> , and <u>thorogummite</u> occur in albitized replacement unit and with quartz and biotite bordering the central (core?) unit.
63) Gordonia District, Cape Province South Africa	B in wall zone, Al replacement	<u>Uraninite</u> and <u>euxenite</u> associated with biotite in the wall zones. Some <u>uraninite</u> occurs in the adjacent wall rock.
64) Iveland, Setesdal, Norway	Q-M core, biotite fracture units, M-Al units	<u>Gadolinite</u> , <u>allanite</u> , <u>cyrtolite</u> , <u>fergusonite</u> , <u>yttrantalite</u> , <u>euxenite</u> , <u>samaraskite</u> , <u>betafite</u> , <u>microlite</u> , <u>uraninite</u> , <u>thorite</u> , <u>monazite</u> , <u>xenotime</u> and <u>sphene</u> are associated with fracture-controlled mica units in the core zone.

*in Heinrich, E. W., 1958
Table 20 continued

LOCATION	ZONAL MINERALOGIC ASSEMBLAGE	RADIOACTIVE MINERAL OCCURRENCE
<u>Foreign Occurrences*</u>		
65) Kragero and Southern Norway	Q-F core, Cl veins, Al replacement(?)	<u>Mcnaizite</u> and <u>polycrase</u> are associated with albitized parts of the core.
66) Ytterby, Sweden	Q core, fracture controlled biotite sheets in core and margins	<u>Fergusonite</u> , <u>yttrotantalite</u> , <u>gadolinite</u> , <u>cyrtolite</u> , <u>allanite</u> , and <u>xenotime</u> are associated with biotite in fracture units.

*in Heinrich, E. W., 1958

Table 20 continued

HOST ROCK RELATIONS

In the discussion of the tectonic setting of pegmatites it was noted that host rocks, for the most part, were either high grade metamorphic or intrusive rocks. Examination of the host rock sub-headings listed in the Index of Geologic Features indicates that radioactive pegmatites conform to this observation. Figure 7 is a plot of the frequency distribution of pegmatites by host rock type. Radioactive pegmatites in metamorphic rocks outnumber those in intrusive rocks by three to one. The most common host rock types in order of prevalence are gneiss, intrusives of various composition, and schist. Other less important host rock types include amphibolite, granite-gneiss, quartzite and migmatite.

Gneiss is a host rock for 104 radioactive pegmatites listed in the Index. The host lithologies include biotite gneiss, mica gneiss, hornblende gneiss, biotite-sillimanite gneiss and feldspathic gneiss. Granite-gneiss has been described from 17 occurrences, however, owing to its uncertain origin, is listed separately.

Intrusive host rocks consist chiefly of granite variously described as alaskite, muscovite granite, biotite granite, and microcline granite. Quartz monzonite and granodiorite hosts are not as prevalent as granite hosts and norite, diorite, syenite and pyroxenite rarely host pegmatites.

Schist is a host rock for 74 occurrences. Lithologies include mica schist, quartz-mica schist, quartz-biotite schist, quartz-muscovite schist, biotite schist, hornblende schist, kyanite schist and staurolite schist. Less common host rocks include amphibolite, micaceous quartzite, migmatite, augen gneiss, charnokitic gneiss, syenitic gneiss, tourmalinized gneiss, serpentized marble and greenstone.

Figure 7 Frequency distribution of radioactive pegmatites by host rock.

It is of interest to note that two of the largest radioactive pegmatite deposits e.g. Bancroft District, Canada, and the Rössing deposit in Namibia are closely associated with rocks which are rarely described as host rocks in the United States. At Bancroft the deposits are genetically related to syenite and nepheline-syenite in Grenville series rocks, and at Rössing the deposit occurs in migmatites.

Many of the intrusives associated with radioactive pegmatites in the United States are acidic and K_2O enriched. Examples include the Pikes Peak Granite, the New Hampshire magma series (quartz monzonite-granodiorite--granite), and the alaskite intrusive bodies in the Spruce Pine District. These intrusives are late differentiates and appear to be favorable for the occurrence of radioactive pegmatites.

AGE RELATIONS

The ages listed for pegmatites in the Index of Geologic Features were obtained from published reports or interpreted from available data. Most of the ages were determined from spatial relationships of the pegmatite to enclosing or nearby rock units. More exact chronology is available for some pegmatites that have been dated by modern isotope ratio methods. A number of pegmatites were not described as to age in the literature, so the present authors have used such data as was available to assign a probable age. Ages arrived at by interpretation were indicated as questionable in the Index. Figure 8 is a frequency distribution plot of the pegmatite ages.

Most of the pegmatites in the Index are of Precambrian age. The oldest are of Archean age and are restricted to the southern extension of the Superior Province in Wyoming. Middle and Late Precambrian pegmatites make up the greatest number of pegmatites and occur in three main areas, the central and southern Rocky Mountains, the Grenville Crystalline Terrane of the Appalachian Fold Belt and the Adirondack Highlands of New York.

Pegmatites from the Paleozoic era are dominantly of Devonian-Carboniferous or Permo-Pennsylvanian age. The older group is found primarily in the Appalachian Fold Belt. Those in New Hampshire and Maine are of Devonian-Carboniferous age, whereas, those found further south as in North Carolina are of Carboniferous age. Permo-Pennsylvanian age pegmatites are principally in Connecticut.

Mesozoic pegmatites are represented by Cretaceous deposits associated with batholiths in Washington, Idaho, Montana and California. The youngest uranium- and thorium-bearing pegmatites in the United States occur in Tertiary intrusives in Nevada.

Figure 8 . Frequency distribution of radioactive pegmatites by age.

DISTRIBUTION

The intrinsic relation between pegmatite districts and crustal mobile belts is well documented. Non-radioactive pegmatites occur in numerous areas throughout the United States (Plate 2) but, are particularly abundant in several regions. Pegmatites are most common in the Appalachian Mountains and the central and southern Rocky Mountains, however, other important areas include the Black Hills, South Dakota; the Adirondack Highlands, New York; the Llano area, Texas; White Picacho and Kingman areas, Arizona; Pala and other districts in Southern California, and several other areas west of the Rocky Mountains.

The radioactive pegmatites plotted in Plate 1 show a very similar distribution. They occur as clusters within the major areas described above as well as non-clustered, isolated occurrences such as west of the Rocky Mountains. The main difference in distribution between radioactive and non-radioactive pegmatites is the paucity of the latter in areas such as the Black Hills, South Dakota, the White Picacho belt, Arizona, and the various districts in Southern California. Presumably, this is a result of a lack of uranium- or thorium-rich source rocks.

The more important geologic aspects associated with the distribution of non-radioactive pegmatites are discussed in the section on Distribution and Spatial Relations.

Our study suggests that there may be some correlations between the distribution of radioactive pegmatites and such factors as their distance from the parent pluton and the pluton's depth of emplacement. Such correlations relate to the influence that these factors may have on the elemental and mineralogical composition of the pegmatites. Complex, thus more favorable, deposits tend to occur further from the parent pluton than simple pegmatites

(Heinrich, 1953; Hutchinson, 1955). Varlamoff (1972) has observed that pegmatites related to plutons emplaced at moderate depths are apt to host the elemental and mineralogical associations that our investigations have shown to be indicative of pegmatites likely to contain uranium.

CHAPTER V

SUMMARY

GEOLOGY OF PEGMATITES

Pegmatites are characterized by their coarse grain size and extreme textural variation. Numerous classification schemes have been suggested focusing chiefly on composition, genesis and internal form. Pegmatites can be unzoned or zoned, and may contain structural units such as fracture filling and replacement bodies. Pegmatite zones can be divided into border, wall, intermediate, and core according to their position in the pegmatite and attendant mineralogy.

It is generally accepted that pegmatites form from differentiation of a parent magma. The same process of differentiation leads to pegmatites being enriched in volatiles, REE's, U, Th and other rare metals. The development of an aqueous phase promotes the formation of those textural and compositional variations characteristic of pegmatites.

Pegmatites in general are formed in crustal mobile belts, particularly along plate margins where melting of crustal material results in the formation of granitic magmas. In the United States these areas include the Appalachian and Cordilleran Fold Belts.

GEOCHEMISTRY OF URANIUM AND THORIUM

Uranium and thorium are more abundant in crustal rocks of acidic or felsic composition as opposed to basic or mantle derived units. The large ionic radii of the radio-elements prevents their incorporation into the structures of aluminosilicate minerals, and, therefore, during differentiation of the primordial core and mantle, uranium and thorium were

segregated into the lighter volatile fractions which migrated toward the crust. Once in the crust these elements undergo concentration by differentiation in magmatic environments or by sedimentary processes in surface environments.

The lack of uranium deposits in Archean units and their appearance in the Proterozoic may reflect the change from mantle derived magmas and volcanics to reworked sialic crustal material.

URANIUM-AND THORIUM-BEARING PEGMATITES

Granitic pegmatites consist essentially of feldspar, quartz and mica with garnet, tourmaline and apatite as common accessories. A large number of other minerals including those of uranium and thorium, beryllium, niobium and tantalum, lithium and the rare-earth elements may also be present.

The most common primary uranium minerals found in domestic pegmatites are the oxide, uraninite, and the multiple oxides euxenite and samarskite. Where secondary uranium minerals occur they are usually the phosphates, namely autunite or torbernite.

Significant amounts of uranium may be present in the structures of some pegmatite minerals notably zircon and microlite.

Thorium is found in only a few mineral species in pegmatites, the most important of which is the rare-earth phosphate, monazite. Thorite, a thorium silicate, occurs chiefly in alkalic pegmatites. A few percent of thorium is generally present in allanite, one of the most widespread radioactive minerals found in pegmatites.

Effects attributable to irradiation are exhibited in some radioactive pegmatites. These include the darkening of quartz and micas, the reddening of feldspars, the golden coloration of beryl, purple coloration of fluorite, and haloes of ferruginous staining. Although these may also result from other causes, they should be considered as possible indicators of the presence of radioactive minerals in a deposit.

Exclusive of the radioactive minerals themselves, no specific mineral or assemblage of minerals can be said to characterize a pegmatite to the extent that it is distinguishable from one in which no radioactive minerals will be found. There is evidence, however, that in any particular pegmatite district those pegmatites of complex mineralogy in which several rare metals and fluorine are present will be more favorable for uranium or thorium than will be those of simple mineralogy.

In zoned pegmatites uranium- and thorium-bearing minerals are more likely to occur in secondary units, and the wall, intermediate and core zones and least likely to occur in the border zone. In unzoned pegmatites, radioactive minerals do not show any particular spatial distribution although they do tend to be associated with the mafic constituents.

Pegmatites are almost exclusively associated with high grade metamorphic or intrusive host rocks. Most radioactive pegmatites occur in gneiss or intrusives followed in abundance by schist. Less frequent host rocks include amphibolite, quartzite and migmatite. The intrusive host rocks consist chiefly of alaskite, muscovite granite, biotite granite, microcline granite, quartz monzonite and granodiorite.

The majority of both radioactive and non-radioactive pegmatites in the United States are of Precambrian or Devonian-Carboniferous age and occur mainly along the Appalachian Mountains and the central and southern Rocky Mountains.

CHAPTER VI

DISCUSSION

CONCEPTUAL MODEL

The development of a pegmatite is initiated by the intrusion of its parent magma which is commonly granitic, but which may range to syenitic in composition. The magmas are generated along tectonically active areas such as plate margins and may be either synkinematic or postkinematic. The magmas crystallize at mesozonal depths at temperatures below 1300°C.

On cooling, an aqueous phase develops from inherent water and the crystallization of anhydrous minerals. This crystallization enriches the still fluid parts of the pluton in water and other volatiles. This fluid phase becomes enriched in uranium, thorium and several other rare elements not accommodated in the structures of the earlier formed minerals. Pegmatite fluid is of lower density and viscosity than the bulk of the pluton and migrates upward to crystallize in the parent pluton or be expelled into the enclosing host rock. The more complex pegmatites are emplaced at some distance from their source. The temperature range of the injected pegmatite fluid is 550°C - 700°C.

The host rocks are generally high-grade metamorphic rocks such as gneiss or schist and mainly of sedimentary or of mixed sedimentary and volcanic origin. Volcanic host rocks are rare.

The pegmatites themselves may be zoned or unzoned. If zoned, the radioactive minerals may be found in any zone or in fracture controlled units that may transect the zones. Most occurrences are in the fracture controlled units, but larger concentrations are apt to occur in inner zones. In unzoned pegmatites the minerals are dispersed throughout the deposit.

FAVORABILITY CRITERIA

This study of uranium- and thorium-bearing pegmatites was, in part, initiated to establish criteria by which an area or an environment could be deemed favorable for the occurrence of uranium- or thorium-bearing pegmatites. There have been many previous discussions concerning various aspects of pegmatite favorability some of which are included in the accompanying Annotated Bibliography. For the most part, however, these studies restrict themselves to one or another geologic feature or geographic area and, therefore, the criteria suggested by different authors are applicable only to particular occurrences, or at best, to individual districts.

Two noteworthy publications that considered features of pegmatites that were favorable for uranium and thorium on a broader scale are Page (1950) and Mickle and Mathews (1979).

We believe it necessary to stress that, as Mickle and Matthews (1979, p. 137) state, "Uraniferous pegmatites do not differ greatly from nonuraniferous pegmatites; the genesis of the two kinds is virtually identical".

Those geologic features which are indicative of an environment favorable for pegmatites are essentially the same as those favorable for uranium- and thorium-bearing pegmatites. The following paragraphs describe many of the common features associated with pegmatites and discuss their possible application as criteria of favorability.

Radioactivity

The single most valid criteria marking a pegmatite as being uranium- or thorium-rich is the presence of anomalous radioactivity; however, zoned pegmatites containing uranium or thorium minerals may not exhibit radioactivity on outcrop because these minerals may be concentrated in unexposed parts of the deposit. Where these minerals occur in unzoned deposits, radioactivity may be anomalously high throughout the body although local concentrations may be present.

Pegmatites barren of uranium and thorium minerals may exhibit a higher than background level of radioactivity due to their potassium content.

Tectonic Setting

Pegmatites occur in areas of extreme crustal mobility. There does not appear to be any tectonic framework that is more favorable for the occurrence of radioactive pegmatites as opposed to other pegmatites. Dewey and Kidd's (1974) concept of magma generation would suggest, however, that continental salients which would supply sialic crustal material for melting and remobilization may be more likely to yield a uranium enriched parent magma than oceanic crustal or mantle derived material.

As noted by Mickle and Mathews (1979) uraniferous pegmatites are generally associated with mesozonal or catazonal rather than epizonal plutons. There appears to be a greater association with mesozonal plutons.

Most pegmatites and all of those of magmatic origin reviewed in this paper are of syn- or post-orogenic origin.

Host Rock Relations

For the most part, as pointed out by both Page (1950) and Mickle and Mathews (1979), uraniferous pegmatites are associated with granitic intrusives and particularly with those intrusives high in K_2O . It is pertinent to point out, however, that the economically important pegmatite deposits of Bancroft, Ontario are associated with intrusives of syenitic and nepheline syenitic composition. It is also important to note that alkalic intrusives are more likely to have associated occurrences of thorium-rich pegmatites than are granitic rocks.

Our research has indicated that host rocks or related intrusives need not be anomalously high in uranium or thorium, although this may be the case in some areas. Radio-element content of associated rocks is not a reliable criteria.

Mickle and Mathews (1979, p. 137) proposed that "the size, number and complexity of pegmatites decrease with increasing distance from the parent pluton". However, in regard to the complexity of pegmatites Heinrich (1953) and Hutchinson (1955) noted that pegmatites of complex mineralogy are generally more distant from the parent plutons and as noted earlier, we regard complex pegmatites as being more favorable for the occurrence of uranium and thorium. We cannot agree with Mickle and Mathews (1979, p. 139) statement that "uraniferous pegmatites may grade laterally into hydrothermal deposits". We know of no occurrence where this relationship is demonstrated.

Mineralogy

Uraniferous pegmatites are normally granitic although those at Bancroft are, in part, syenitic, those at Camp Smith, New York are dioritic, and the Cranberry Lake deposit in New Jersey is described as "semi-basic" (Williams, 1967).

In general, however, uranium- and thorium-bearing pegmatites are rich in quartz and potash feldspar. Mica is almost always present. We do not fully concur with Page (1950) who postulates that muscovite is a criteria indicative of uranium-rich pegmatites. Although this may be true, it is also true that biotite is prevalent in many radioactive pegmatites. It is of interest to note that in studies of pegmatites of the Grenville Province of Ontario and Quebec, muscovite-bearing pegmatites are essentially barren of radioactivity as compared with those containing abnormal concentrations of biotite (Fratta, 1970). We do not believe that the presence or absence of any particular mica is a universal criteria of favorability.

Mickle and Mathews (1979) suggested that fluorite, hematite, topaz, zircon, garnet and apatite are favorable indicator minerals, This is no doubt true in many instances, but perusal of the Index of Uranium- and Thorium-Bearing Pegmatites in the United States, Part II of this report, indicates these mineral guides are of only very restricted value.

Page (1950) refers to golden beryl, reddish-brown stained feldspar or muscovite, iron staining and darkened quartz as criteria indicative of uranium or thorium. As discussed earlier under mineralogy, these effects may be the result of radiation damage, but they should be considered as guides rather than favorability criteria.

Internal Structure

Although uranium- and thorium-bearing pegmatites may be zoned or unzoned, potentially economic pegmatite deposits are more likely to be of the unzoned type with the radioactive minerals disseminated throughout the deposit. This conclusion is based on the greater amenability of unzoned pegmatites to the recovery of radioactive minerals through milling.

Alteration

Mickle and Mathews (1979) state that argillic alteration, albitization, and tourmalinization are common effects in and around uraniferous pegmatites. Exogenic effects such as the development of micas, feldspars, and tourmaline in the host rocks of pegmatites are expectable and are, indeed, common; argillic alteration is rarely observed. Such effects may be found around any pegmatite and their presence is not indicative of radioactive minerals.

Geochemistry

Our study of pathfinder elements has not indicated any direct relation between uranium and thorium and any other particular element. It is true, however, that the presence of rare-earth elements, niobium and tantalum will very often be associated with the radio-elements. Seemingly, the more complex the chemistry of a pegmatite, the more likely that it will be uranium- and thorium-bearing.

Mickle and Mathews (1979) suggest that uraniferous pegmatites are low in Fe, Mg and Ca. This again, is true in many cases, but is not universal and is particularly not the case with the economically important deposits of Bancroft where mafic minerals and anhydrite are present, at Cranberry Lake where magnetite is abundant, or at the South Platte District in Colorado where radioactive minerals occur in a biotite-rich environment. Therefore, low Fe, Mg and Ca contents are not in themselves indicative of uraniferous pegmatites.

Prospecting Guides

If then, there are so few geologic criteria which are considered favorable for the occurrence of uranium and thorium in pegmatites, what guides are available to aid in prospecting and evaluating pegmatites for uranium and thorium?

The most useful and most easily sought guide is anomalous radioactivity. Pegmatites with abnormal uranium or thorium content may be discovered by both airborne and ground radiometric surveys. A skilled prospector can quickly traverse a pegmatite dike and evaluate its surface radioactivity.

Other guides are discolorations of minerals such as darkened quartz, fluorite or beryl and abundance of hematite staining. Although as noted earlier, these features may not indicate radioactive minerals in the deposit, their presence calls for investigation by the prospector.

One point we wish to stress is the difficulty in sampling a pegmatite. It is essential that the sample be a large bulk sample in order to make it representative. Channel samples of unzoned pegmatites may be useful in determining overall grade; in zoned pegmatites, however, representative samples are difficult to obtain, but a grade estimate might be made by a radiometric study, grain counting, or preferably the analyses of large bulk samples.

From our study of the zoned Platt pegmatite in Wyoming, we have found that analyses of gangue minerals such as feldspars and micas do not afford any indication of the presence of radioactive minerals in the deposit, which has been mined for euxenite (see Appendix). In contrast, however, chip-channel samples from the unzoned Hudson Tunnel pegmatite at Idaho Springs, Colorado yielded anomalously high uranium contents that reflected the grade of the ore mined at the deposit.

The anomalously high uranium content of water from a hot spring in Rio Arriba County, New Mexico has been considered as being possibly related to the radioactive minerals of nearby pegmatites (Wenrich-Verbeek, 1977).

In closing this section on Prospecting Guides, it is perhaps pertinent to point out for the prospector that although potash-rich granites are deemed the most likely parent of uraniferous pegmatites, the economically important deposits at Bancroft and Rössing are associated with syenite and migmatite, respectively. It may then be advantageous to seek pegmatites associated with these rocks in preference to those associated with granites.

FAVORABLE ENVIRONMENTS

Application of the foregoing criteria allow one to define areas in the United States favorable for radioactive pegmatites. These areas are described below and are loosely classified according to pegmatite host rock associations.

Pegmatites Associated with Syenite and Grenville-Age Rocks

This type of deposit is associated with syenite plutons within gneisses, schists and migmatites of sedimentary origin. At Bancroft, these units are Upper Proterozoic and associated with the Grenville structural province. Likely areas in the U. S. include the Adirondack Highlands, Grenville age units of the Appalachian Fold Belt, and mid-to upper Proterozoic units of the Cordilleran Fold Belt.

Pegmatites Associated with Iron-Rich Rocks of Grenville Age

An interesting occurrence of radioactive pegmatite is found at the Bemco Prospect near Cranberry Lake in northeast New Jersey. Here the pegmatite is intruded into a band of magnetite-pyroxenite, with uranium minerals occurring along the pegmatite-pyroxenite contact. Accessory minerals include magnetite, hornblende and pyrite. At the nearby Scrub Oaks iron mine rare-earth minerals are associated with magnetite. A similar occurrence is found at Camp Smith in southeastern New York. Radioactivity is associated with a pegmatite of composition close to diorite and containing magnetite, pyrrhotite, pyrite, augite and hornblende as accessory minerals. Magnetite and some copper mineralization is found in

nearby country rock. Both of these deposits occur in Grenville age basement rocks rich in mafic constituents. Other deposits may occur associated within similar units in this horizon along the northern part of the Appalachian Fold Belt.

Pegmatites Associated with Alkaline Intrusives

This type of deposit includes the thorium-rich pegmatites of the St. Peter's Dome area, Colorado, which are related to the Mt. Rosa riebeckite granite. Other areas of possible interest would include the Conway Granite of New Hampshire, the alkaline granites of Massachusetts and Rhode Island, and the aegirine-riebeckite Quanah Granite in the Wichita Mountains, Oklahoma. The Bokan Mountain deposit in Alaska may be classified with this type of occurrence.

Multiple-Oxide Pegmatites

Zoned pegmatites enriched in multiple-oxide minerals such as euxenite and samarskite are associated with several granitic plutons including the aforementioned Silver Plume Granite in Colorado as well as the Sherman Pluton in Wyoming. This type of occurrence is particularly abundant in the Trout Creek Pass area of Colorado. Similar pegmatites may occur associated with these and other intrusives along the central and southern Rocky Mountains.

Pegmatites Associated with Migmatite

Although the pegmatite-migmatite association is commonly considered to be of anatectic origin, as at Rössing, and related to partial melting at catazonal depths, we include it here for the sake of completeness. Radioactive pegmatites and gneissic-migmatite of the Idaho Springs Formation occur in the Wheeler Basin area of Colorado. The pegmatites appear to be related to

the Silver Plume Granite. Radioactive pegmatites may well occur with other intrusives in the migmatized Idaho Springs Formation in Colorado and southeastern Wyoming. Radioactive pegmatites occur associated with migmatites, gneisses and granites in northeastern Washington and migmatitic terrain in the Grandfather Mountain area of North Carolina.

CHAPTER VII

RESOURCE POTENTIAL AND CONCLUSIONS

RESOURCE POTENTIAL

About 300 pegmatites bearing uranium or thorium minerals have been recognized in the conterminous United States, and undoubtedly as many or more remain unreported or undiscovered.

Only a few of the deposits have produced more than a few hundred pounds of radioactive minerals (Table 1) and none have seen sustained production.

The uranium and thorium minerals so far produced domestically have come largely from zoned pegmatites in which radioactive materials commonly occur in localized concentrations of relatively high grade that are easily recognizable and are amenable to hand-sorting during the mining of other products. The bulk of the pegmatite, however, is apt to be completely barren so that the total grade of the deposit may be little more than that of an average granite. Such deposits offer only small lots of radioactive minerals, and in view of the decline of pegmatite mining in the United States, future by-product production from zoned pegmatites is unlikely.

Unzoned radioactive pegmatites, such as have been exploited in Canada have been found in only a few places in the United States, offer somewhat more promise as a source of uranium or thorium than the zoned type. Here the minerals may expectably be more or less uniformly distributed and, hence, more amenable to recovery by milling. Although unzoned pegmatites may be the dominant type in some districts, they have not received the attention given to the generally coarser-grained zoned type from which valuable minerals are more readily obtained by bulk mining. Notable exceptions are the large homogeneous Li-pegmatites at

King's Mountain, North Carolina from which spodumene is recovered by milling.

The possibility exists that undiscovered uranium-bearing unzoned pegmatites of economic significance are present in the United States. However, the possibility of the discovery of rich deposits analogous to those at Bancroft, Ontario is remote as the Canadian deposits occur in a restricted and possibly unique geologic environment in which favorable Grenville host rocks are intruded by syenitic plutons.

From our study we must conclude that there are no known pegmatites in the conterminous United States capable of sustained production of uranium or thorium minerals. At best, their uranium or thorium resource potential must be considered trivial in relation to the potential of other types of deposits.

We concur with Gabelman's (1977, p. 90) opinion that "... although pegmatites have been long reputed as favorable uranium environments, they are equally reputed as poor mining targets".

CONCLUDING REMARKS

Over the eighteen-month period extending from October, 1978 through March 1980, we have studied the occurrence and distribution of uranium- and thorium-bearing pegmatites. As a result of our studies we have compiled an Annotated Bibliography including nearly 300 of the most important publications on pegmatite geology. We have also compiled an Index giving the salient geologic and geographic features of radioactive pegmatites in the United States. Accompanying the Index are 89 maps showing the location of these occurrences and a 1 to 3.1 million scale map of the United States illustrating their nationwide distribution.

Our study has reinforced the realization that, whereas, there are criteria to indicate pegmatites favorable for the occurrence of uranium within a specific district, the only universal guide to uranium- or thorium-bearing pegmatites is the presence of anomalous radioactivity.

There does not appear to be any genetic peculiarity that results in the formation of uranium- or thorium-bearing pegmatites.

Lastly, although several areas in the United States are more favorable than others for the occurrence of radioactive pegmatites, the potential for economic deposits is poor.

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APPENDIX

The following pages list all of the samples collected during our study of Uranium- and Thorium-Bearing Pegmatites. The lists include sample number, location and a brief field description of the sample and/or the sample locality. Interspersed with the sample list are tables giving the analytical results.

All analyses were made by Skyline Labs Inc. of Golden, Colorado.

Detection limit in ppm of elements are shown below:

Fe	500	Bi	10	Mn	10	Sr	100
Ca	200	Cd	50	Mo	2	Ti	20
Mg	200	Co	5	Nb	20	V	10
Ag	1	Cr	10	Ni	5	W	50
As	500	Cu	2	Pb	10	Y	10
B	10	Ga	10	Sb	100	Zn	200
Ba	10	Ge	20	Sc	10	Zr	20
Be	2	La	20	Sn	10	U	2

Analyzed elements occurring below detection limit appear as "-2".

SAMPLE #	DESCRIPTION
13-CAN-1	Near Bancroft, Ontario: Radioactive mineral (zircon?) with quartz and K-spar.
13-CAN-2	Near Bancroft, Ontario: Fe stained garnet (?), unidentified radioactive minerals.
13-CAN-3	Near Bancroft, Ontario: Biotite, plagioclase and unidentified radioactive mineral(s).
13-CAN-4	Madawaska Mine, Bancroft, Ontario: Aggregate of pink anhydrite, hornblende and unidentified radioactive mineral.
13-CAN-5	Madawaska Mine, Bancroft, Ontario: Pale purple anhydrite.
13-CAN-6	Madawaska Mine, Bancroft, Ontario: Fine-grained biotite rich rock in contact with brick-red radioactive "pegmatite".
13-CAN-7	Madawaska Mine, Bancroft, Ontario: Highly radioactive sample of "pegmatite"; contains abundant hornblende(?), plagioclase (including peristerite), zircon, unidentified radioactive black minerals and rare sulfides.
13-CAN-8	Madawaska Mine, Bancroft, Ontario: Anhydrite with fine-grained quartz-biotite rock.
13-CAN-9	Madawaska Mine, Bancroft, Ontario: Highly radioactive rocks containing abundant ferromagnesian minerals, unidentified radioactive mineral, zircon, chlorite, some sulphides.
13-AZ-1	Buckeye, Arizona: Several euhedral allanite crystals 1-2 cm; quartz (clear-white), perthitic K-spar; minor magnetite and biotite.
13-CO-1	Seerie Pegmatite, Jefferson County, Colorado: Pikes Peak Granite.

SAMPLE #	DESCRIPTION
13-CO-2	Seerie Pegmatite, Jefferson County, Colorado: Fine grained wall zone. Collected on the west side side of the pegmatite, 4 ft. from the contact with granite. Biotite laths $\pm$ 1" long. Small red-brown translucent grains.
13-CO-3	Seerie Pegmatite, Jefferson County, Colorado: K-spar and quartz from intermediate zone, west side of the pegmatite.
13-CO-4	Seerie Pegmatite, Jefferson County, Colorado: Chiefly microcline, minor CaF_2 , from vuggy replacement unit, east side of open cut.
13-CO-5	Seerie Pegmatite, Jefferson County, Colorado: Quartz and K-spar from perthite-quartz zone.
13-CO-6	Seerie Pegmatite, Jefferson County, Colorado: Chip sample of wall zone north of thorite zone.
13-CO-7	St. Peter's Dome Area, El Paso County, Colorado: White feldspar (K-spar), white quartz, riebeckite and astrophyllite crystals.
13-CO-8	St. Peter's Dome Area, El Paso County, Colorado: Salmon to brick red K-spar, white to smoky quartz, bertrandite, muscovite, biotite and thorite. Thorite is brick red vitreous and associated with biotite.
13-CO-9	St. Peter's Dome Area, El Paso County, Colorado: Brick red bertrandite, light gray quartz, micas, mainly muscovite. Dense fine-grained matted aegirine(?).
13-CO-10	St. Peter's Dome Area, El Paso County, Colorado: White quartz, plagioclase and biotite; felted, fine-grained astrophyllite, riebeckite(?), and zircon (brown, euhedral).

SAMPLE #	DESCRIPTION
13-CO-11	St. Peter's Dome Area, El Paso County, Colorado: Quartz, feldspar, riebeckite and astrophyllite in fine-grained groundmass of quartz, feldspar and zircon. Zircon crystals common. Several patches of brick red thorite.
13-CO-12	St. Peter's Dome Area, El Paso County, Colorado: Fine-grained equigranular granite (Pikes Peak) with quartz, plagioclase, zircon and biotite. Large euhedral zircon crystals up to 1.5cm.
13-CO-13	Black Cloud Pegmatite, Teller County, Colorado: Massive salmon to brick red perthite, biotite, and crystals or laths of brown, vitreous fergusonite up to 6 cm.
13-CO-14 a,b,c	Russell Gulch, Gilpin County, Colorado: 3 samples of medium-grained pegmatite, all consist of K-spar (fresh and kaolinized), quartz and minor biotite.
13-CO-15	Hudson Tunnel, Clear Creek County, Colorado: Feldspar, quartz vein in Idaho Springs Formation near Virginia Canyon. Numerous hematite stained, altered spots and yellow uranophane.
13-CO-16	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: Hornblende, plagioclase, quartz-amphibolite country rock. Also contains rust-brown mica (muscovite?) and a blue secondary mineral which occurs as a coating in several patches and specks, possibly a phosphate.
13-CO-17	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: Fine-to medium-grained pink granite-gneiss with quartz, feldspar, and biotite.

SAMPLE #	DESCRIPTION
13-CO-18	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: Gneissic unit composed of biotite, plagioclase, quartz, and K-spar. Large granular red-brown garnet aggregates = 4 x 3 cm.
13-CO-19	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: Very coarse-grained white quartz and white-pink perthite.
13-CO-20 a,b,c	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: Biotite book with quartz, plagioclase, and red hexagonal (?) crystals which are somewhat radioactive.
13-CO-21	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: White plagioclase and K-spar with minor quartz and biotite. 1 cm patch of magnetite.
13-CO-22	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: Quartz - biotite - perthite pegmatite sample.
13-CO-23	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: Three small pieces of unidentified uranium mineral. Mineral is black, glassy, with a conchoidal fracture and abundant Fe_2O_3 stain and reaction rims.
13-CO-24	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: White perthite from pegmatite.

SAMPLE ANALYSES

ELEMENT	13-CO-01	13-CO-02	13-CO-03	13-CO-04	13-CO-06	13-CO-14	13-CO-17	13-CO-18	13-CO-20	13-CO-24
Fe	30,000	10,000	1,000	500	10,000	7,000	15,000	100,000	150,000	5,000
Ca	10,000	10,000	1,000	200	3,000	10,000	7,000	7,000	5,000	2,000
Mg	3,000	1,500	300	200	700	2,000	5,000	20,000	50,000	300
Ag	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
As	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
B	-2	10	-2	-2	10	-2	-2	10	20	-2
Ba	1,000	-2	200	-2	-2	2,000	1,000	100	300	200
Be	2	5	3	2	5	-2	-2	2	-2	-2
Bi	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Cd	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Co	-2	-2	-2	-2	-2	-2	-2	5	50	-2
Cr	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Cu	2	10	-2	-2	-2	30	-2	10	50	2
Ga	20	50	50	200	50	20	20	150	200	50
Ge	-2	-2	-2	-2	-2	-2	-2	-2	-2	20
La	200	-2	-2	-2	-2	100	70	100	1,000	-2
Mn	1,500	200	30	10	100	500	1,000	2,000	2,000	100
Mo	-2	-2	-2	-2	-2	100	-2	-2	10	-2
Nb	50	500	-2	-2	70	-2	20	150	100	-2
Ni	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Pb	2,000	300	500	500	100	200	100	150	200	100
Sb	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Sc	10	-2	-2	-2	-2	-2	10	200	300	-2
Sn	-2	-2	-2	-2	-2	-2	-2	30	50	-2
Sr	100	100	-2	-2	-2	500	100	-2	-2	100
Ti	3,000	500	-2	-2	700	1,000	2,000	5,000	10,000	200
V	-2	-2	-2	-2	-2	10	15	50	70	-2
W	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Y	200	300	-2	-2	30	15	10	700	1,000	-2
Zn	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Zr	500	100	-2	-2	100	-2	100	1,000	20	-2
U	2	150	-2	-2	12	18	-2	80	190	-2

SAMPLE #	DESCRIPTION
13-CO-25	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: White quartz from pegmatite.
13-CO-26 a,b,c	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: Magnetite with minor quartz and mica from pegmatite.
13-CO-27	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: K-spar (pink and white), quartz, magnetite and minor biotite.
13-CO-28	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: Pink-white K-spar (perthite), quartz, magnetite and small patches of biotite with green sericite.
13-CO-29	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: Cream plagioclase, quartz, magnetite, and a brown-black glassy radioactive mineral with small hairline veins of quartz.
13-CO-30	Mica Basin, Mt. Zirkel Wilderness Area, Routt County, Colorado: Radioactive mineral; black-brown glassy, conchoidal fracture, tabular crystals. Brown feldspar with reaction rim.
13-CO-31 a,b,c	Raleigh Peak Pegmatite, Jefferson County, Colorado: Pike's Peak granite composed of K-spar (salmon), quartz-biotite and minor purple fluorite associated with biotite.
13-CO-32	Raleigh Peak Pegmatite, Jefferson County, Colorado: Brown-brick red K-spar, red-brown cyrtolite, "thorite" black-red as veinlets and interstitial to cyrtolite, yellow secondary mineral on thorite.
13-CO-33	Raleigh Peak Pegmatite, Jefferson County, Colorado: Biotite book.
13-CO-34	Raleigh Peak Pegmatite, Jefferson County, Colorado: Brown cyrtolite, biotite and yellow secondary mineral or altered cyrtolite.

SAMPLE #	DESCRIPTION
13-CO-35	Raleigh Peak Pegmatite, Jefferson County, Colorado: Red-brown, well weathered cyrtolite and possible thorite from the wall zone.
13-CO-36	Raleigh Peak Pegmatite, Jefferson County, Colorado: Samarskite occurring as elongate black and brown, glassy crystals in salmon colored perthite.
13-CO-37	Raleigh Peak Pegmatite, Jefferson County, Colorado: Red-brown to dark brown cyrtolite with some inter- stitial brick red K-spar. Collected from the wall zone.
13-CO-38	Raleigh Peak Pegmatite, Jefferson County, Colorado: Primary and secondary fluorite. Former occurs as white to pale green crystals with prominent cleavage. Later as purple crystalline aggregates and replace- ment around rims of primary fluorite.
13-CO-39	Seerie Pegmatite, Jefferson County, Colorado: Various biotite samples.
13-CO-40	Seerie Pegmatite, Jefferson County, Colorado: Pike's Peak Granite composed of pink K-spar, quartz, biotite and rare pink-purple-clear fluorite associated with biotite.
13-CO-41	Seerie Pegmatite, Jefferson County, Colorado: Samples of Pike's Peak Granite composed of pink K-spar, quartz, biotite and rare allanite with yellow-white bastnaesite alteration rim. Very rare purple fluorite associated with biotite.
13-CO-42	Seerie Pegmatite, Jefferson County, Colorado: Samples of Pike's Peak Granite composed of K-spar, quartz, biotite, rare purple-pink fluorite with biotite and very rare altered allanite.
13-CO-43	Seerie Pegmatite, Jefferson County, Colorado: Wall zone composed of brick red-salmon K-spar, quartz and elongate biotite laths.

SAMPLE #	DESCRIPTION
13-CO-44	Seerie Pegmatite, Jefferson County, Colorado: Pike's Peak Granite consisting of salmon K-spar, quartz, biotite and rare altered allanite.
13-CO-45	Seerie Pegmatite, Jefferson County, Colorado: Pike's Peak Granite similar to other granite samples.
13-CO-46	Seerie Pegmatite, Jefferson County, Colorado: Pike's Peak Granite country rock.
13-CO-47	Burroughs Mine, Jefferson County, Colorado: Euxenite(?) masses about 1/2 inch maximum size, in buff feldspar, probably largely K-spar. Muscovite in individuals not over 1/8 inch are sparsely disseminated through feldspar. Very minor quartz.

SAMPLE ANALYSES

Element	13-CO-26	13-CO-31	13-CO-33	13-CO-39	13-CO-41	13-CO-42	13-CO-43	13-CO-44	13-CO-45	13-CO-46
Fe	> 200,000	30,000	200,000	200,000	30,000	30,000	3,000	30,000	20,000	20,000
Ca	200	7,000	-2	200	15,000	10,000	5,000	10,000	2,000	7,000
Mg	3,000	2,000	1,000	1,000	3,000	3,000	500	3,000	2,000	3,000
Ag	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
As	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
B	100	-2	20	30	-2	-2	-2	-2	-2	-2
Ba	100	700	50	50	1,000	300	-2	1,000	500	700
Be	-2	2	-2	-2	2	5	5	-2	2	-2
Bi	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Cd	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Co	50	-2	-2	-2	-2	-2	-2	-2	-2	-2
Cr	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Cu	5	-2	-2	2	5	2	5	-2	-2	-2
Ga	150	30	200	200	30	20	30	20	20	20
Ge	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
La	-2	200	-2	-2	200	200	-2	200	200	100
Mn	200	1,000	5,000	5,000	1,500	1,000	100	1,500	1,000	200
Mo	50	-2	10	10	-2	2	-2	-2	-2	-2
Nb	20	50	200	200	70	70	100	50	50	-2
Ni	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Pb	-2	50	10	10	50	50	50	70	50	100
Sb	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Sc	10	10	100	30	10	10	-2	-2	-2	-2
Sn	100	-2	200	200	-2	-2	-2	-2	-2	-2
Sr	-2	100	-2	-2	200	100	-2	200	100	200
Ti	1,000	2,000	1,500	1,000	3,000	3,000	100	3,000	2,000	2,000
V	500	10	-2	-2	10	10	-2	-2	-2	20
W	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Y	10	200	-2	100	200	200	70	100	100	50
Zn	500	-2	1,500	2,000	-2	-2	-2	-2	-2	-2
Zr	-2	300	-2	-2	200	200	50	200	150	100
U	-2	-2	-2	-2	2	11	55	-2	-2	4

SAMPLE #	DESCRIPTION
13-CO-48	Burroughs Mine, Jefferson County, Colorado: Nearly pure perthite, pale buff.
13-CO-49	Burroughs Mine, Jefferson County, Colorado: Quartz, nearly pure.
13-CO-50	Burroughs Mine, Jefferson County, Colorado: Biotite from very large book in wall zone. Minor quartz, albite(?) intergrowths.
13-CO-51	Burroughs Mine, Jefferson County, Colorado: Brown radioactive mineral (monazite?). Three small fragments. One shows a few crystal faces.
13-CO-52	Burroughs Mine, Jefferson County, Colorado: Medium to fine-grained rock chiefly plagioclase, with quartz, perthite and minor biotite. From the rim of a schist inclusion in the wall of the pit.
13-CO-53	Burroughs Mine, Jefferson County, Colorado: Fine grained rock containing quartz, hornblende and biotite. Spots of yellow-green alteration may be clays or leucoxene.
13-CO-55	Hudson Tunnel, Clear Creek County, Colorado: Several samples of unzoned K-spar, biotite, quartz pegmatite. Small cubic uraninite grains in K-spar and biotite often with red reaction rims. Abundant sulfide specks (pyrite), and rare molyb- denite. Uraninite is frequently altered.
13-CO-56	Hudson Tunnel, Clear Creek County, Colorado: Three samples of quartz, biotite, feldspar schist with minor, small brown garnets.
13-CO-57	Clear Creek County, Colorado: Medium to coarse- grained pegmatite. Chiefly buff to white K-spar, quartz and clots of biotite; minor albite. A few very small crystals of beryl noted. Biotite clots show weak radioactivity.

SAMPLE #	DESCRIPTION
13-CO-58	Clear Creek County, Colorado: Lighter colored phase of same pegmatite as CO-58. Chiefly plagioclase, quartz, small biotite clots (1"). Small (0.5mm) cubic molds with yellow brown fillings - possible former uraninite sites.
13-CO-59	Clear Creek County, Colorado: Plagioclase, quartz hornblende, amphibolite.
13-CO-60	Clear Creek County, Colorado: Microcline, quartz, biotite pegmatite medium-grained. Biotite clots and possibly some albite.

SAMPLE ANALYSES

Element	13-CO-48	13-CO-49	13-CO-50	13-CO-53	13-CO-54	13-CO-55	13-CO-56	13-CO-57	13-CO-58	13-CO-59	13-CO-60
Fe	2,000	-2	100,000	100,000	30,000	10,000	100,000	5,000	7,000	150,000	5,000
Ca	300	-2	200	200,000	10,000	10,000	20,000	10,000	30,000	50,000	2,000
Mg	-2	-2	5,000	70,000	3,000	7,000	10,000	3,000	3,000	20,000	2,000
Ag	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
As	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
B	-2	-2	30	15	-2	-2	10	-2	-2	10	-2
Ba	10	-2	200	50	1,500	500	500	1,000	100	200	1,000
Be	-2	-2	2	-2	-2	-2	-2	2	3	-2	-2
Bi	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Cd	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Co	-2	-2	20	70	-2	-2	5	-2	-2	50	-2
Cr	15	-2	-2	200	-2	-2	-2	-2	-2	-2	-2
Cu	2	2	10	100	2	30	100	-2	5	50	2
Ga	50	-2	100	20	30	30	50	20	30	30	15
Ge	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
La	-2	-2	-2	-2	200	100	20	-2	-2	-2	-2
Mn	50	20	5,000	2,000	1,000	500	3,000	200	300	2,000	300
Mo	2	-2	3	2	-2	500	3	-2	-2	2	-2
Nb	-2	-2	50	-2	50	-2	20	-2	-2	20	-2
Ni	-2	-2	-2	50	-2	-2	-2	-2	-2	-2	-2
Pb	150	-2	10	10	50	500	30	100	200	10	50
Sb	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Sc	-2	-2	100	50	10	-2	30	-2	-2	50	-2
Sn	-2	-2	300	-2	-2	-2	-2	-2	-2	-2	-2
Sr	-2	-2	-2	200	200	500	300	500	500	200	200
Ti	20	-2	3,000	5,000	3,000	1,000	3,000	500	500	7,000	500
V	-2	-2	70	200	10	30	30	-2	-2	70	10
W	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Y	-2	-2	-2	10	200	500	100	20	50	50	-2
Zn	-2	-2	500	-2	-2	-2	-2	-2	-2	-2	-2
Zr	-2	-2	-2	50	200	20	100	50	100	70	20
U	-2	-2	-2	-2	-2	900	3	22	28	-2	-2

SAMPLE #	DESCRIPTION
13-CO-61	Hudson Tunnel Area, Idaho Springs, Colorado: Microcline-quartz pegmatite, medium-grained light tan K-spar with interstitial quartz. Quartz highly shattered and resembles a quartzite. No micas noted. Few grains of limonite after pyrite. Hematite streaks may represent earlier biotite.
13-CO-62	Hudson Tunnel Area, Idaho Springs, Colorado: Microcline-quartz pegmatite similar to 13-CO-61, but contains some vein quartz containing limonite pseudomorphs after pyrite. Minute quartz crystals in open parts of veinlets. Few wisps of muscovite and/or sericite.
13-CO-63	Hudson Tunnel Area, Idaho Springs, Colorado: Several small samples of unzoned pegmatites. Secondary uranium minerals coat many surfaces. White plagioclase, white granular quartz, fine-grained biotite, and abundant sulfide specks and veinlets.
13-CO-64	Hudson Tunnel Area, Idaho Springs, Colorado: Country rock amphibolite 6" below pegmatite. Fine-grained with abundant sulfide specks. Biotite, quartz, and feldspar.
13-CO-65	Hudson Tunnel Area, Idaho Springs, Colorado: Small exposure of unzoned pegmatite. Pink and white plagioclase, biotite, white granular quartz, rare radioactive mineral (uraninite?) occurs as small cubes in feldspar with red radiation halo around uranium mineral.
13-CO-66	Hudson Tunnel Area, Idaho Springs, Colorado: Two inch wide medium-grained unzoned pegmatite. Pink and white plagioclase, biotite, white granular quartz, rare small cubes of radioactive mineral in feldspar (uraninite?) with red haloes, minor sulfide specks, pyrolusite and rare molybdenite.

SAMPLE #	DESCRIPTION
13-CO-67	Hudson Tunnel Area, Idaho Springs, Colorado: White plagioclase, white quartz, biotite clots (layered), sulfide specks, and rare small uranium mineral with a red halo in white plagioclase, all of which occur in pegmatite debris from a raise.
13-CO-68	Hudson Tunnel Area, Idaho Springs, Colorado: White - slightly pink feldspar, white quartz, biotite, specks and veinlets of sulfides and small radioactive mineral grains with red radiation halo in feldspar from a large pegmatite.
13-CO-69	Hudson Tunnel Area, Idaho Springs, Colorado: Same as 13-CO-68.
13-CO-70	Hudson Tunnel Area, Idaho Springs, Colorado: Same as 13-CO-68 & 69. White plagioclase, white quartz, biotite and sulphide specks and veinlets.
13-CO-71	Portal of Hudson Tunnel, Idaho Springs, Colorado: White plagioclase, white granular quartz, biotite, sericitized mica, minor sulfide specks including pyrolusite and a brown, slightly resinous mineral with biotite.

SAMPLE ANALYSES

Element 13-CO-61 13-CO-62

Fe	2,000	5,000
Ca	2,000	2,000
Mg	500	3,000
Ag	-2	-2
As	-2	-2
B	-2	-2
Ba	300	200
Be	-2	2
Bi	-2	-2
Cd	-2	-2
Co	-2	-2
Cr	-2	-2
Cu	2	2
Ga	20	20
Ge	-2	-2
La	70	20
Mn	300	500
Mo	-2	5
Nb	-2	-2
Ni	-2	-2
Pb	100	100
Sb	-2	-2
Sc	-2	-2
Sn	-2	-2
Sr	100	100
Ti	200	200
V	-2	-2
W	-2	-2
Y	200	20
Zn	-2	-2
Zr	-2	20
U	15	20

SAMPLE #	DESCRIPTION
13-CT-1	Branchville Pegmatite, Branchville, Connecticut: Pegmatite sample consisting of buff plagioclase, muscovite, and uraninite with a green fluorescent secondary mineral, probably autunite.
13-CT-2	Branchville Pegmatite, Branchville, Connecticut: Uraninite and a brown anhedral mineral (monazite?) with muscovite.
13-CT-3	Branchville Pegmatite, Branchville, Connecticut: Red-brown feldspar with black euhedral crystals of unidentified radioactive mineral.

SAMPLE ANALYSES

Element	13-CO-63	13-CO-64	13-CO-65	13-CO-66	13-CO-67	13-CO-68	13-CO-69	13-CO-70	13-CO-71
Fe	15,000	30,000	10,000	30,000	2,000	5,000	10,000	10,000	5,000
Ca	15,000	20,000	7,000	10,000	3,000	700	1,000	3,000	5,000
Mg	10,000	20,000	3,000	20,000	700	500	5,000	2,000	1,000
Ag	-2	-2	2	-2	-2	-2	-2	-2	-2
As	-2	-2	-2	-2	-2	-2	-2	-2	-2
B	-2	-2	-2	-2	-2	-2	-2	-2	-2
Ba	70	100	500	200	100	-2	20	100	200
Be	-2	2	-2	-2	-2	-2	-2	2	2
Bi	-2	-2	-2	-2	-2	-2	-2	-2	-2
Cd	-2	-2	-2	-2	-2	-2	-2	-2	-2
Co	5	-2	-2	5	-2	-2	-2	-2	-2
Cr	50	30	30	10	20	50	50	30	20
Cu	50	100	10	15	2	10	50	20	3
Ga	20	30	20	20	10	15	-2	15	20
Ge	-2	-2	-2	-2	-2	-2	-2	-2	-2
La	20	20	20	70	-2	-2	30	100	-2
Mn	1,000	2,000	300	1,000	200	100	500	300	200
Mo	3	2	2	700	10	-2	-2	15	-2
Nb	20	20	-2	30	-2	-2	30	20	-2
Ni	10	5	5	5	5	5	5	5	5
Pb	150	30	100	300	50	30	50	100	100
Sb	-2	-2	-2	-2	-2	-2	-2	-2	-2
Sc	-2	20	-2	20	-2	-2	10	-2	-2
Sn	-2	-2	-2	-2	-2	-2	-2	-2	-2
Sr	200	200	200	200	100	100	100	100	100
Ti	1,000	2,000	700	2,000	200	200	1,000	700	500
V	50	20	15	70	-2	-2	30	10	-2
W	-2	-2	-2	-2	-2	-2	-2	-2	-2
Y	100	50	300	200	100	-2	50	500	30
Zn	200	200	-2	-2	-2	-2	-2	-2	-2
Zr	50	100	-2	-2	-2	-2	-2	-2	-2
U	115	85	200	1,800	140	15	340	90	8

SAMPLE #	DESCRIPTION
13-ME-1	Black Mountain Mine, Andover, Maine: White-pale gray quartz with white euhedral beryl crystals of varying size. Black, 8mm anhedral columbite crystal.
13-ME-2	Black Mountain Mine, Andover, Maine: White cleavelandite, smoky quartz, and 5 cm, black, elongate laths of columbite. Leached uranium mineral occurs in feldspar with brown reaction rim and secondary uranium mineral (yellow) which fluoresces bright lime green.
13-ME-3	Black Mountain Mine, Andover, Maine: White cleavelandite with black elongate, 2mm thick x 8 cm long columbite crystals and rare green tourmaline.
13-ME-4	Black Mountain Mine, Andover, Maine: Fine-grained aggregate of lepidolite, dark pinkish-purple with limonite stain on weathered surface. Contains 1 mm dark amber-brown glassy microlite crystals with conchoidal fracture. Bright lime-green fluorescent mineral also present.
13-ME-5	Black Mountain Mine, Andover, Maine: Fine-grained aggregate of gray lepidolite with numerous 1-2 mm crystals of dark amber-brown-black microlite often with a brown-rust reaction rim. Minor white feldspar, red and green tourmaline and schorl. Bright lime-green fluorescent mineral
13-ME-6	Consolidated Feldspar Quarry No. 1, Topsham, Maine: White-cream plagioclase, microcline, smoky and clear quartz some with sulfide coating, and biotite enclosing euhedral red garnet. The garnet contains a .5 mm euhedral cube of a leached mineral.
13-ME-7	Russell Bros. Quarry, Topsham, Maine: Two small pieces of samarskite. Black, glassy luster with some red feldspar.

SAMPLE #	DESCRIPTION
13-ME-8	Tamminen Pits, near West Paris, Maine: Sample contains large, cream colored, broken spodumene crystals. Crystal borders contain mica, schorl and blue tourmaline. White cleavelandite; clear to slightly gray quartz; garnet and biotite also present.
13-ME-9	Standpipe Hill, Topsham, Maine: Samarskite; salmon K-spar with smoky quartz and biotite.
13-ME-10	Standpipe Hill, Topsham, Maine: Samarskite with pink K-spar and books of biotite.
13-ME-11	Standpipe Hill, Topsham, Maine: Pink-salmon K-spar with muscovite, biotite and smoky quartz. Samarskite is interstitial to K-spar and mica and is within K-spar.
13-ME-12	Mt. Mica, Paris, Maine: Coarse pegmatite chiefly garnet, black tourmaline, platy albite, minor smoky quartz. A few dark brown grains or imperfect crystals of zircon or microlite. Very sparse 1-2 mm platy black crystals of columbite(?).
13-ME-12A	Mt. Mica, Paris, Maine: Impure garnet.

SAMPLE ANALYSES

Elements 13-ME-12 13-ME-12A

Fe	100,000	200,000
Ca	1,000	10,000
Mg	5,000	5,000
Ag	-2	-2
As	-2	-2
B	> 10,000	1,000
Ba	10	10
Be	10	100
Bi	-2	-2
Cd	-2	-2
Co	-2	-2
Cr	-2	-2
Cu	-2	-2
Ga	30	10
Ge	-2	50
La	-2	-2
Mn	> 10,000	> 10,000
Mo	2	20
Nb	-2	20
Ni	-2	-2
Pb	50	-2
Sb	-2	-2
Sc	20	50
Sn	500	30
Sr	-2	-2
Ti	500	200
V	10	20
W	-2	-2
Y	50	200
Zn	300	200
Zr	200	100
U	300	120

SAMPLE #	DESCRIPTION
13-NH-1	Palermo Mine, North Groton, New Hampshire: Coarse-grained, white-tan-brown plagioclase, blue-black tourmaline, euhedral dark brown-black columbite laths and uraninite with yellow secondary mineral which fluoresces bright lime green.
13-NH-2	Palermo Mine, North Groton, New Hampshire: Massive triphylite with small white quartz veins. Minor sulfide specks, streaks and coatings (pyrite or pyrrhotite).
13-NH-3	Palermo Mine, North Groton, New Hampshire: Well weathered, white-buff K-spar, muscovite, smoky quartz vein, and abundant uranophane and associated hematite stained K-spar, some crystal casts up to 2 mm (after uraninite?).
13-NH-4	Palermo Mine, North Groton, New Hampshire: Numerous anhedral-euhedral 1 mm uraninite crystals scattered throughout fine-to medium-grained brown-red feldspar with muscovite. Uraninite occurs in several stages of alteration; some is completely altered to secondary uranium minerals.
13-NH-5	Palermo Mine, North Groton, New Hampshire: Gray-pale blue triphylite with dark blue scorzalite(?), pale green apatite, and sulphide veinlets and specks (pyrite-chalcopyrite?).
13-NH-6	Palermo Mine, North Groton, New Hampshire: Brick red feldspar, medium-grained, bronze-clear muscovite with hematite stained fractures and cleavage planes. 1 mm, black to yellow altered uraninite.
13-NH-7	Palermo Mine, North Groton, New Hampshire: Massive, pale blue-steel gray triphylite with secondary dark blue scorzalite-lazulite along cleavage planes and fractures.

SAMPLE #	DESCRIPTION
13-NJ-1	Bemco Prospect, Cranberry Lake, New Jersey: Composed mainly of magnetite with some pyroxene(?), small specks of quartz, slightly radioactive due to fergusonite, spencite(?), and allanite.
13-NJ-2	Bemco Prospect, Cranberry Lake, New Jersey: Orthoclase, magnetite, quartz, uraninite (and secondary uranium minerals) and spencite.

SAMPLE #	DESCRIPTION
13-NM-1	Harding Mine, Taos County, New Mexico: Microlite in "spotted rock". Microlite grains up to 3 mm and dark brown in color. Rock is largely microcline with pink areas containing lepidolite and purple muscovite.
13-NM-2	Harding Mine, Taos County, New Mexico: Microlite with smoky quartz and albite. Microlite in yellow-brown grains, 2-3 mm, are concentrated in a pod in smoky quartz. Minor albite; quartz, feldspar, and mica appear to be interstitial to microlite.
13-NM-3	Harding Mine, Taos County, New Mexico: Dense fine-grained rock containing quartz, purple micas and minor albite(?).
13-NM-4	Harding Mine, Taos County, New Mexico: Quartz, purple micas, albite, and apatite (green).
13-NM-5	Harding Mine, Taos County, New Mexico: Patch of green Bi-carbonate on white quartz.
13-NM-6	Harding Mine, Taos County, New Mexico: Dense pale-lavender rock that is probably microcline largely replaced by very fine-grained lithium micas. "Spotted rock" zone.
13-NM-7	Harding Mine, Taos County, New Mexico: Green apatite with quartz and a gray mica, probably lepidolite.
13-NM-8	Harding Mine, Taos County, New Mexico: Beryl (white) with fine-grained micas. Minor pale brown garnet(?) and very small black bladed crystals of columbite-tantalite embedded in beryl.
13-NM-9	Harding Mine, Taos County, New Mexico: Beryl, pale greenish white.

SAMPLE #	DESCRIPTION
13-NM-10	Harding Mine, Taos County, New Mexico: Beryl (pale yellow), albite, quartz, and Li-micas. One grain of microlite occurs in albite.
13-NM-11	Harding Mine, Taos County, New Mexico: Rock largely gray Li-micas with green apatite, anhedral white beryl, and a single crystal of columbite-tantalite about 10 mm across.
13-NM-12	Harding Mine, Taos County, New Mexico: Quartz, pale bluish-white microcline, and microcline partly replaced by lavender Li-minerals. A few small microlite grains occur in the Li-rich part of the sample.
13-NM-13	Harding Mine, Taos County, New Mexico: Anhedral white beryl and green apatite make up much of the sample. Gray Li-micas, albite, and quartz are present.
13-NM-14	Harding Mine, Taos County, New Mexico: Spodumene (flat crystal surface) with albite and quartz. Albite probably interstitial to spodumene laths.
13-NM-15	Petaca District, New Mexico: Sample largely albite with minor muscovite and quartz. Two areas contain small grains of samarskite(?) surrounded by much larger zone of brown-stained albite. Small columbite grain noted.

SAMPLE ANALYSES

Element 13-NM-11

Fe	5,000
Ca	> 200,000
Mg	2,000
Ag	-2
As	-2
B	30
Ba	-2
Be	2
Bi	2
Cd	-2
Co	-2
Cr	-2
Cu	30
Ga	-2
Ge	-2
La	-2
Mn	> 10,000
Mo	-2
Nb	-2
Ni	-2
Pb	150
Sb	-2
Sc	-2
Sn	-2
Sr	500
Ti	200
V	20
W	-2
Y	300
Zn	-2
Zr	-2
U	22

SAMPLE #	DESCRIPTION
13-NC-1	Deer Park Mine, Spruce Pine, North Carolina: White feldspars, plagioclase, smoky quartz, muscovite (lt. green), reddish brown garnet (almandite?), and small uraninite cubes along garnet-quartz interfaces.
13-NC-2	Deer Park Mine, Spruce Pine, North Carolina: Chiefly pale smoky quartz, white plagioclase, and muscovite. Contains one canary yellow waxy "gummite" pseudomorph 2 x 5 mm. in quartz and muscovite and other yellow to orange "gummite" pseudomorphs in muscovite.
13-NC-3	Deer Park Mine, Spruce Pine, North Carolina: Chiefly light smoky quartz, white perthite(?). Minor muscovite and garnet, Small patches of yellow secondary U-minerals, possibly uranophane, on surface of rock.
13-NC-4	McKinney Mine, Spruce Pine, North Carolina: Largely pale smoky quartz. Sphalerite (very dark) with muscovite and plagioclase abundant on one surface. No detectable radioactivity.
13-NC-5	McKinney Mine, Spruce Pine, North Carolina: Largely white K-spar with subordinate muscovite, quartz, plagioclase and rare garnet. Irregular 3 x 20 mm patch black glassy samarskite in quartz. Quartz within a few mm of samarskite is reddened (not smoky) possibly from iron oxide concentration.
13-NC-6	McKinney Mine, Spruce Pine, North Carolina: Aggregate of feldspars including some pale amazonite, plagioclase, minor quartz, muscovite and some needles of green tourmaline.
13-NC 7	Wiseman Mine, Spruce Pine, North Carolina: Several bladed crystals of samarskite up to 6 cm long, $\pm$ 1 cm wide in rock composed dominantly of white feldspar (cleavelandite?) with minor quartz and muscovite.

SAMPLE #	DESCRIPTION
13-NC-8	Wiseman Quarry, Spruce Pine, North Carolina: Mass of uraninite with garnet, feldspar (plagioclase stained yellow-orange occasionally with radiating texture), muscovite, quartz (white-clear-smoky). Secondary uranium minerals.
13-NC-9	Ray Mica Mine, Spruce Pine, North Carolina: Medium grained with quartz (clear-white), feldspar (plagioclase-cleavelandite) white-buff, minor garnet, and two small euhedral crystals of columbite in feldspar and at feldspar-quartz interface.
13-NC-10	Ray Mica Mine, Spruce Pine, North Carolina: White cleavelandite and plagioclase with clear to slightly smoky quartz, black tourmaline, rare muscovite, and allanite with brownish-yellow reaction rim on quartz.
13-NC-11	Ray Mica Mine, Spruce Pine, North Carolina: Fine- to medium-grained white feldspar (plagioclase; some cleavelandite), quartz (clear-white) garnet (red, anhedral-euhedral), muscovite, tourmaline and a euhedral beryl crystal.
13-NC-12	Ray Mica Mine, Spruce Pine, North Carolina: Coarse crystalline white K-spar and gray quartz, minor muscovite, garnet and samarskite with brown Fe_2O_3 stain on quartz and feldspar. Green fluorescent mineral as coating on quartz and feldspar (autunite?).
13-NC-13	Ray Mica Mine, Spruce Pine, North Carolina: White K-spar, medium-grained, smoky quartz, muscovite, garnet, and a 1 cm green euhedral beryl crystal with a grain of uraninite. The beryl is golden and highly fractured near the uraninite.

SAMPLE ANALYSES

Element 13-NC-12

Fe	5.000
Ca	1.000
Mg	-2
Ag	-2
As	-2
B	-2
Ba	-2
Be	-2
Bi	-2
Cd	-2
Co	-2
Cr	-2
Cu	10
Ga	30
Ge	-2
La	-2
Mn	3,000
Mo	-2
Nb	-2
Ni	-2
Pb	500
Sb	-2
Sc	-2
Sn	-2
Sr	-2
Ti	-2
V	-2
W	-2
Y	-2
Zn	-2
Zr	-2
U	2

SAMPLE #	DESCRIPTION
13-WY-1	Platt Pegmatite, Carbon County, Wyoming: Red K-spar, with 1 cm clots of muscovite and quartz.
13-WY-2	Platt Pegmatite, Carbon County, Wyoming: Pink K-spar with well developed cleavage.
13-WY-3	Platt Pegmatite, Carbon County, Wyoming: White K-spar with well developed cleavage.
13-WY-4	Platt Pegmatite, Carbon County, Wyoming: Granite-gneiss country rock, fine-grained, equigranular, with plagioclase, hornblende, quartz, and very minor sulphides.
13-WY-5	Platt Pegmatite, Carbon County, Wyoming: Aplite dike, fine-grained, equigranular with plagioclase, quartz, hornblende, and biotite.
13-WY-6	Platt Pegmatite, Carbon County, Wyoming: Hornblende-plagioclase-quartz schist with some epidote alteration.
13-WY-7	Platt Pegmatite, Carbon County, Wyoming: White quartz and black tourmaline crystals up to 1 cm.
13-WY-8	Platt Pegmatite, Carbon County, Wyoming: Pink and white K-spar, granular garnet, muscovite, minor tourmaline and sericite alteration.
13-WY-9	Platt Pegmatite, Carbon County, Wyoming: Tourmaline crystals up to 2.5 cm with white-gray quartz, white K-spar, muscovite, and 2-3 mm speck of black, glassy radioactive mineral with brown oxidation rim, possibly euxenite.
13-WY-10	Platt Pegmatite, Carbon County, Wyoming: Red K-spar with minor muscovite, sericite, and a 2x1 mm crystal of euxenite.

SAMPLE #	DESCRIPTION
13-WY-11	Platt Pegmatite, Carbon County, Wyoming: 1.5x3 cm allanite crystal in red and white K-spar with some gray quartz. Two brick red K-spars with intense reaction rims from euxenite.
13-WY-12	Platt Pegmatite, Carbon County, Wyoming: Allanite (10mm x 3mm) in quartz-K-spar rock with some muscovite.
13-WY-13	Platt Pegmatite, Carbon County, Wyoming: 1x2.5 cm allanite crystal in quartz with some muscovite and a very slight reaction rim.
13-WY-14	Platt Pegmatite, Carbon County, Wyoming: Three samples of cleavelandite (from same rock). White, with well developed cleavage, minor white quartz; muscovite and sericite are rare.
13-WY-15	Platt Pegmatite, Carbon County, Wyoming: Muscovite.

SAMPLE ANALYSES

Element	13-WY-01	13-WY-02	13-WY-03	13-WY-04	13-WY-05	13-WY-06	13-WY-14	13-WY-15
Fe	1,500	-2	-2	70,000	20,000	100,000	1,000	50,000
Ca	500	1,000	700	150,000	10,000	200,000	10,000	15,000
Mg	-2	-2	-2	70,000	15,000	70,000	500	10,000
Ag	-2	-2	-2	-2	-2	-2	-2	-2
As	-2	-2	-2	-2	-2	-2	-2	-2
B	-2	-2	-2	10	10	10	10	20
Ba	500	500	500	100	1,000	200	-2	100
Be	-2	-2	-2	-2	-2	7	5	3
Bi	-2	-2	-2	-2	-2	-2	-2	-2
Cd	-2	-2	-2	-2	-2	-2	-2	-2
Co	-2	-2	-2	20	-2	30	-2	5
Cr	-2	-2	-2	-2	-2	500	-2	-2
Cu	-2	2	-2	10	5	20	5	30
Ga	30	30	30	20	20	20	50	300
Ge	-2	-2	-2	-2	-2	-2	-2	-2
La	-2	-2	-2	-2	20	-2	20	-2
Mn	100	50	10	700	500	1,500	50	1,500
Mo	-2	-2	-2	-2	-2	-2	-2	-2
Nb	-2	-2	-2	20	20	-2	-2	200
Ni	-2	-2	-2	15	-2	150	-2	5
Pb	200	200	300	10	10	10	100	20
Sb	-2	-2	-2	-2	-2	-2	-2	-2
Sc	-2	-2	-2	50	10	30	-2	200
Sn	-2	-2	-2	-2	-2	-2	-2	200
Sr	200	200	100	1,000	300	700	200	100
Ti	-2	-2	-2	5,000	1,500	3,000	20	3,000
V	-2	-2	-2	150	20	200	-2	70
W	-2	-2	-2	-2	-2	-2	-2	-2
Y	-2	-2	-2	15	20	10	-2	-2
Zn	-2	-2	-2	-2	-2	-2	-2	-2
Zr	-2	-2	-2	70	150	30	-2	-2
U	-2	2	-2	-2	-2	-2	-2	-2

SAMPLE #	DESCRIPTION
13-WY-16	Platt Pegmatite, Carbon County, Wyoming: Biotite and muscovite on light gray quartz and pink and white K-spar.
13-WY-17	Platt Pegmatite, Carbon County, Wyoming: Muscovite with some white quartz and pink K-spar.
13-WY-18	Platt Pegmatite, Carbon County, Wyoming: Allanite crystal with slight brown reaction rim. Crystal is along border of pink K-spar and light gray quartz.
13-WY-19	Platt Pegmatite, Carbon County, Wyoming: White, buff and brick red K-spar with muscovite and allanite crystal in quartz and muscovite.
13-WY-20	Platt Pegmatite, Carbon County, Wyoming: Light gray quartz with several allanite crystals; the largest is 6 mm and has a slight brown reaction rim.

URANIUM- AND THORIUM-BEARING
PEGMATITES OF THE UNITED STATES

PART II

INDEX TO URANIUM- AND THORIUM-
BEARING PEGMATITES IN THE
UNITED STATES

INDEX TO
URANIUM- AND THORIUM BEARING PEGMATITES
IN THE
UNITED STATES

The Index to Uranium- and Thorium-Bearing pegmatites in the United States provides data on the locations and principal geologic features of approximately 300 known radioactive pegmatites.

Selection of pegmatites to be included is based primarily on the parameters discussed in Part I. Thus, we are restricting our study to pegmatites known to contain identifiable uranium or thorium minerals and which were presumably derived from fluid or gaseous late-stage segregations from a magmatic source rather than those of anatectic origin. In many cases, it has been impossible to determine from the published data the extent of the mineralization. We have, none the less, elected to include such deposits in the index. In other cases where radioactivity has been reported, but no mineralogic identification made, we have excluded such deposits as probably having such minor concentrations of uranium and thorium as to be outside the scope of this study.

The index is constructed alphabetically by State. Within each State the localities are in an arbitrary numerical sequence. There are three distinct sections to the State index: the first describes the geographic location, the second is a tabulation of the principal geologic features and the third is a map showing each location.

The geographic index lists the locality and map numbers of the deposits; the name of the deposit; the county in which it is found; the U. S. Geological Survey Topographic (1:250,000) sheet including the deposit; the 7½ or 15 minute map; and the references used to locate and evaluate the deposit.

We have used many references to construct the index. The full title for each reference will be found either in our Selected Annotated Bibliography (Part III), or in the References Cited in Part I. It should be noted that geographic data is principally drawn from Olson and Adams, 1962 and Grauch and Zarinski, 1976. In some cases, we have drawn upon our own experience to provide data not available in the literature.

The next portion of the index is a tabulation of the principal geologic features for each deposit. The data are principally from the literature, but have been augmented by personal observations by the authors or by communications from other professional geologists.

The principal geologic features we have elected to tabulate are: zoning, radioactivity, mineralogy, age and host rock. A column has been provided for comments upon tectonic setting, alteration, structure, etc. In cases where no data is available, a blank space is left in the table.

Under the zoning column will be noted the presence, absence, or characteristics of zoning within the pegmatite.

Under R/A is noted the radioactivity that might be expectably found in the deposit. The distribution of uranium and thorium minerals in most pegmatites is such that the radiation level may range from background to very high depending on the proximity to what are generally isolated concentrations of these minerals, so that no average radiation level for the deposit is meaningful. We are, therefore, arbitrarily listing as "A" those deposits in which uraninite, thorite, or the radioactive multiple oxides such as euxenite, or samarskite have been observed by us or reported in the literature as being relatively abundant. Under "B", we include pegmatites in which these minerals have been reported, but with no data as to abundance. Also, under "B" are deposits containing significant amounts of uranium-bearing microlite such as is found at the Harding mine in New Mexico.

Classed as "C" are those deposits believed to contain only minerals of low radioactivity such as allanite, or in which only secondary uranium minerals are reported. No quantitative evaluation of the deposit is implied by this classification.

Where radiation data are available, we have shown it as presented in the literature.

In the mineralogy column we have listed and underlined the principal uranium and thorium minerals noted in the literature relevant to that deposit. The listing is not meant to be a catalog of every radioactive mineral present, further, the list includes many field identifications which may or may not be substantiated by detailed laboratory study. In many cases black radioactive grains have been called "uraninite". Similarly secondary coatings are often described as "autunite" or the non-specific "gummite". We have not tried to interpret the true identity of these minerals, but have simply listed them for purposes of general descriptions.

The radioactive minerals are followed by minerals other than quartz, feldspar and mica. Although, if specific mention is made of the variety of mica or of cleavelandite we have elected to list such information. In general, this column lists accessories such as garnet, beryl, non-radioactive zircon, magnetite, etc.

The age of the pegmatite is given where known. In most cases, only the titular geologic era or age is available. Where isotopic age determinations are available they have been listed.

The host rock enclosing the pegmatite is shown for those deposits where such data is available. If the pegmatite intrudes more than one rock type, we have listed each intruded host.

As noted earlier, the "Comments" column will include miscellaneous pertinent data.

An integral part of the index is the location map section. The maps are all on the scale of 1 to 250,000 and have been taken from the U. S. Geological Survey National Map Series. We have attempted with each map to include geographic sites or coordinates to allow for ease of referring back to the original U.S.G.S. map sheet. Pegmatite deposits on each map are shown as stars and are listed for easy reference.

In constructing this index, we have attempted to include all significantly radioactive pegmatites in the conterminous United States. To this end we have thoroughly researched the literature and contacted the various State geological surveys as well as numerous federal and university geologists. We believe the index to be complete, but if there are any omissions we regret the oversight. We would appreciate receiving notice of such oversights, complete with the descriptive data needed to enter such omissions in a possible future revised index.

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

ARIZONA

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or-15 Minute series	References
1	1	Kingman Feldspar Mine	Mohave	Kingman	Kingman	Heinrich, 1960
2	1	Mineral X Claim	Mohave	Kingman	Kingman SE	Olson & Adams, 1962; U.S.A.E.C., 1970a
3	2	Hillside Group and Quartz Mtn.	Mohave	Williams	Quartermaster Canyon SW	Olson & Adams, 1962; U.S.A.E.C., 1970a
4	3	Rare Metals Mine	Mohave	Prescott	Tule Wash	Heinrich, 1960
5	3	Signal District	Mohave	Prescott	Greenwood Peak	Olson & Adams, 1962
6	3	White Owl & Gray Boy Mtns.	Mohave	Prescott	Artillery Peak (15')	U.S.A.E.C., 1970a
7	4	White Picacho District	Maricopa & Yavapai	Phoenix	Red Picacho	Jahns, 1952
8	5	Buckeye	Maricopa	Phoenix	Buckeye	Olson & Adams, 1962
9	6	Papago Wells	Pima	Ajo	O'Neill Hills (15')	Olson & Adams, 1962; U.S.A.E.C., 1970b

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

ARIZONA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	1	Kingman Feldspar Mine	Zoned	C	<u>Allanite</u> , biotite, muscovite, garnet	Precambrian	Precambrian granite, biotite gneiss	Allanite in wall zone.
2	1	Mineral X Claim		B	<u>Fergusonite</u> , <u>allanite</u> , zircon, fluorite, epidote, thalenite	Precambrian	Precambrian biotite schist	Granitic plug 500' from pegmatites
3	2	Hillside Group		B	<u>Euxenite</u> , <u>polycrase</u> , <u>monazite</u> , <u>allanite</u>		Precambrian gneiss	
4	3	Rare Metals Mine	Zoned	A	<u>Yttrotantalite</u> , <u>euxenite</u> , bismutite, muscovite	Precambrian	Precambrian granite	Produced from footwall side of quartz core.
5	3	Signal District		B	<u>Samarskite</u> , <u>euxenite</u> , <u>allanite</u>		Precambrian gneiss	
6	3	White Owl and Gray Boy Mtns.		C	Uranium minerals reported		Precambrian gneiss	
7	4	White Picacho District	Zoned	C	<u>Allanite</u> , <u>monazite</u> , <u>microlite</u> , <u>pyrochlore</u> , biotite, muscovite, fluorite, Li-minerals (eucryptite) beryl	Precambrian	Precambrian schist, gneiss, amphibolite	Diverse mineralogy includes many Li-minerals
8	5	Buckeye	Unzoned	A	<u>Euxenite</u> , <u>allanite</u> , magnetite, xenotime		Precambrian gneiss	

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

ARIZONA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
9	6	Papago Wells		C	<u>Monazite</u> ,		Precambrian gneiss	Uranium minerals as fracture coating.

LAKE MOHAVE
LAKE MEAD NATIONAL
RECREATION AREA

INDEX MAP #1 - ARIZONA

1. Kingman Feldspar Mine
2. Mineral X Claim

INDEX MAP #2 - ARIZONA

3. Hillside Group and Quartz Mountain

N

INDEX MAP #3 - ARIZONA

- 4. Rare Metals Mine
- 5. Signal District
- 6. White Owl & Gray
Boy Mountains

N

INDEX MAP #4 - ARIZONA
7. White Picacho District

N

LINE

ATIRON MOUNTAIN

GLENDALE

INDEX MAP #5 - ARIZONA
8. Buckeye

30,000 FEET
(ARIZ. WEST)

INDEX MAP #6 - ARIZONA

9. Papago Wells

CABEZA PRIETA GAME RANGE

ORGAN PIPE CACTUS NATIONAL MONUMENT

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

CALIFORNIA

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	7	Pacoima Canyon	Los Angeles	Los Angeles	Sunland	Neuerburg, 1954
2	8	Pomona Tile Quarry (Rock Corral Area)	San Bernardino	San Bernardino	Bighorn Canyon	Hewett & Glass, 1953
3	8	Alger Creek	San Bernardino	San Bernardino	Forest Falls	Hewett & Stone, 1957
4	9	Hoerner-Ross (Cady Mtns.)	San Bernardino	San Bernardino	Cady Mtns. (15')	Hewett & Glass, 1953
5	10	Winchester	Riverside	Santa Ana	Perris	Murdoch & Webb, 1966; Olson & Adams, 1962
6	10	S. P. Silica Quarry	Riverside	Santa Ana	Winchester	Patchick, 1960
7	11	Himalaya Dike Mesa Grande	San Diego	Santa Ana	Mesa Grande	Foord, 1977
8	11	Banner Area	San Diego	Santa Ana	Earthquake Valley	Foord, 1977
9	12	Rainbow Group	San Bernardino	Kingman	Old Dad Mtn. (15')	Olson & Adams, 1962; Walker, et al, 1956

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

CALIFORNIA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	7	Pacoima Canyon	Unzoned	B	<u>Uranothorite</u> , <u>allanite</u> , biotite	pre-Cre- taceous	Precambrian monite	Uranium minerals in red perthite. Adjacent to San Andreas fault system.
2	8	Pomona Tile Quarry (Rock Corral Area)	Unzoned	B	<u>Euxenite</u> , <u>cyrtolite</u> , <u>monazite</u> , <u>allanite</u> , <u>unknown uranium mineral</u> , biotite, ilmenite, epidote hematite, magnetite, rutile, sphene	Jurassic 150+ 5 m.y.	Precambrian(?) hornblende and biotite schists	Uranium minerals associated with ilmenite; cyrtolite in country rock; adjacent to San Andreas fault system; nearby quartz-monzonite
3	8	Alger Creek	Unzoned	B	<u>Uranothorite</u> , <u>allanite</u> , biotite, magnetite, zircon		Precambrian granite- greiss	Uranium minerals associated with magnetite
4	9	Hoerner-Ross (Cady Mtns.)	Zoned	B	<u>Betafite</u> , <u>cyrtolite</u> , biotite, muscovite, green mica, magnetite, niobian anatase	Jurassic 155+ 3 m.y.	Mesozoic quartz monzonite	Uranium minerals associated with magnetite and biotite; niobian anatase associated with muscovite and green mica; adjacent to San Andreas fault system
5	10	Winchester	Zoned	C	<u>Monazite</u> , xenotime	Cretaceous	Cretaceous granite	
6	10	S. P. Silica Quarry	Zoned	B	<u>Euxenite</u>	Cretaceous (?)	Cretaceous granite	

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

CALIFORNIA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
7	11	Himalaya Dike, Mesa Grande	Zoned	C	<u>Uranomicrolite-microlite</u> , <u>uraniferous zircon</u> , <u>monazite</u> , <u>djalmaite</u> (all rare), muscovite, lepidolite, minor biotite, tourmaline	Cretaceous	Hornblende norite Cretaceous 100+ m.y.	Uranium minerals found only in pocket zones. Uranomicro- lite in quartz and tourmaline; within the southern Cali- fornia batholith
8	11	Banner Area	Zoned	C	<u>Uranomicrolite-microlite</u> , <u>monazite</u> , <u>uraniferous zircon</u> , <u>djalmaite</u> (all rare)	Cretaceous(?)	Cretaceous(?)	
9	12	Rainbow Group	Unzoned	B	<u>Uraninite</u> , <u>thorite</u> , <u>monazite</u> , hematite, magnetite		Jurassic granodiorite	Within San Andreas fault system; U-Th minerals associ- ated with hematite and mag- netite

INDEX MAP #9 - CALIFORNIA
4. Hoerner-Ross (Cady Mtns.)

INDEX MAP #11 - CALIFORNIA

7. Himalaya Dike Mesa

Grande

8. Banner Area

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

COLORADO						
Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or-15 Minute Series	References
1	13	Mt. Zirkel (Mica Basin)	Routt	Craig	Mt. Zirkel	Olson & Adams, 1962
2	14	Yard Mine	Chaffee	Montrose	Buena Vista (15')	Hanley, et al, 1950
3	14	Quartz Creek Area	Gunnison	Montrose	Pitkin	Staatz & Trites, 1955
4	15	Red Head Claim	Larimer	Greeley	Cherokee Park	Olson & Adams, 1962
5	16	Hyatt Beryl Mine	Larimer	Greeley	Drake	Hanley, et al, 1950; Thurston, 1955
6	16	Wheeler Basin	Grand	Greeley	Monarch Lake	Young & Hauff, 1975
7	17	Waterloo Mine	Gilpin	Denver	Central City	Sims & Gable, 1964
8	17	Idaho Springs District	Clear Creek	Denver	Central City	Elevatorski, 1979; Sims, et al, 1963
9	17	Ralston Creek Area	Jefferson	Denver	Ralston Buttes	Olson & Adams, 1962
10	17	Roscoe Pegmatite	Jefferson	Denver	Evergreen	Eckel, 1961; Hanley, et al, 1950; Olson & Adams, 1962
11	17	Burroughs Mine	Jefferson	Denver	Evergreen	Boos, 1954; Olson & Adams, 1962
12	18	Seerie Pegmatite	Jefferson	Denver	Platte Canyon	Staatz, et al, 1976
13	18	South Platte Area	Jefferson	Denver	Platte Canyon	Haynes, 1965
14	19	Crystal No. 8	Chaffee	Pueblo	Antero Reservoir (15')	Hanley, et al, 1950
15	19	Clora May Mine	Chaffee	Pueblo	Antero Reservoir (15')	Hanley, et al, 1950
16	19	Badger Creek	Park	Pueblo	Antero Reservoir (15')	Haynes, 1960
17	19	Guffey Area	Park	Pueblo	Florissant (15')	Heinrich & Bever, 1957; Olson & Adams, 1962

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

COLORADO

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
18	19	Teller Mine	Fark	Pueblo	Lake George	Glass, Rose & Over, 1958; Olson & Adams, 1962
19	20	Cotopaxi Area	Fremont	Pueblo	Cotopaxi (15')	Heinrich & Bever, 1957; Olson & Adams, 1962
20	20	Villa Grove Area	Saguache	Pueblo	Howard (15')	Brown & Malan, 1954
21	20	Crestone Area	Saguache	Pueblo	Electric Peak (15')	Brown & Malan, 1954
22	21	Black Cloud	Teller	Pueblo	Divide	Heinrich & Gross, 1960
23	21	St. Peter's Dome	El Paso	Pueblo	Mount Big Chief	Gross & Heinrich, 1966

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

COLORADO

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	13	Mt Zirkel (Mica Basin)	Zoned	B	<u>Uraninite</u> , <u>cyrtolite</u> , <u>monazite</u> , magnetite, garnet, biotite, tourma- line, hornblende, muscovite	Precambrian	Precambrian granite- gneiss and amphibolite	Abundant magnetite, some very slightly radioactive; garnet also slightly radioactive, but less common
2	14	Yard Mine	Zoned	A	<u>Euxenite</u> , <u>monazite</u> , biotite, muscovite	Precambrian	Precambrian granite	Pegmatite is genetically related to the coarse-grained host rock
3	14	Quartz Creek Area	Zoned & Unzoned	B	<u>Monazite</u> , <u>microlite</u> - <u>pyrochlore</u> , <u>allanite</u> , <u>unidentified Nb-Ta-U</u> <u>mineral</u> , biotite, muscovite, cleavelandite, lepidolite	Precambrian 1320-1560 m.y.	Precambrian granite, quartz monzonite, hornblende gneiss	Pyrochlore-microlite associa- ted with cleavelandite and lepidolite
4	15	Red Head Claim		C	<u>Monazite</u> , <u>cyrtolite</u> , beryl, columbite- tantalite, topaz		Precambrian granite and metamorphics	Monazite and cyrtolite associ- ated with beryl, Nb-Ta and topaz
5	16	Hyatt Beryl Mine	Zoned	B	<u>Uraninite</u> , <u>torbernite</u> , <u>autunite</u> , " <u>gummite</u> ", cleavelandite, muscovite, beryl, lithiophilite- triphyllite, bismuthinite, tourmaline, garnet, apatite	Precambrian	Precambrian Idaho Springs Formation schist and gneiss	Uranium minerals associated with albite in intermediate zone near the contact with the core. Related to Mt. Olympus Granite.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

COLORADO

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
6	16	Wheeler Basin	Unzoned	A	<u>Uraninite</u> , <u>monazite</u> , biotite, muscovite,	Precambrian 1450 [±] m.y.	Precambrian Idaho Springs Formation gneiss.	Uraninite in migmatites and pegmatites. Metamor- phics are correlative with Idaho Springs Formation. Uraninite associated with biotite, locally in contact with hematite. Proximal to Silver Plume Granite.
7	17	Waterloo Mine	Unzoned	B	<u>Uraninite</u> , biotite, zircon	Precambrian 1210-1360 m.y.	Precambrian Idaho Springs Formation biotite gneiss	Uraninite associated with Idaho Springs biotite.
8	17	Idaho Springs	Unzoned	A	<u>Uraninite</u> , <u>monazite</u> , biotite, xenotime	Precambrian 1200-1350 m.y.	Precambrian Idaho Springs Formation biotite gneiss	Uraninite associated with Idaho Springs biotite. Molybdenite, pyrite, galena, chalcopyrite and hematite in fractures.
9	17	Ralston Creek Area		C	Rare-earth minerals			

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

COLORADO

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
10	17	Roscoe Pegmatite	Unzoned	B	<u>Uraninite</u> , <u>fergusonite</u> , <u>gadolinite</u> , <u>monazite</u> , biotite, muscovite, magnetite, garnet, beryl, xenotime	Precambrian	Precambrian Idaho Springs Formation biotite gneiss	Uraninite associated with magnetite
11	17	Burroughs Mine	Zoned	B	<u>Euxenite</u> , <u>allanite</u> , <u>monazite</u> , <u>gadolinite</u> (?) biotite, beryl, columbite, tantalite, xenotime, tourmaline, garnet	Precambrian	Precambrian Idaho Springs Formation biotite gneiss	
12	18	Seerie Pegmatite	Zoned	A	<u>Uraninite</u> , <u>thorite</u> , <u>uranothorite</u> , <u>thoro-</u> <u>gummite</u> , biotite, fluorite, yttrifluorite, topaz, muscovite	Precambrian	Precambrian Pike's Peak Granite	Radioactivity associated with replacement unit and wall zone.
13	18	South Platte Area	Zoned	A	<u>Samarskite</u> , <u>thorite</u> , <u>cyrtolite</u> , <u>allanite</u> , <u>fergusonite</u> , <u>gadolinite</u> , biotite, fluorite, yttrifluorite, fluocerite, thalenite.	Precambrian	Precambrian Pike's Peak Granite	Radioactive minerals found in wall zone, and perthite- quartz zone.
14	19	Crystal No. 8	Zoned	A	<u>Euxenite</u> , <u>allanite</u> , garnet, biotite	Precambrian	Precambrian granite porphyry	Pegmatite is genetically related to granite.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

COLORADO

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
15	19	Clora May Mine	Zoned	A	<u>Euxenite</u> , <u>allanite</u> , garnet, biotite, bismuth minerals	Precambrian	Precambrian	
16	19	Badger Creek	Unzoned	B	<u>Euxenite</u>	Precambrian		
17	19	Guffey Area	Zoned	B	<u>Euxenite</u> , <u>monazite</u> , <u>allanite</u> , <u>urano-</u> <u>thorite(?)</u> , biotite, magnetite, ilmenite.	Precambrian	Precambrian biotite gneiss, granite	Lenses of Boulder Creek Granite nearby
18	19	Teller Mine	Unzoned	C	<u>Gadolinite</u> , <u>xenotime</u> , <u>monazite</u> , <u>allanite</u> , <u>samarskite(?)</u> , <u>euxenite(?)</u> , <u>thorite(?)</u> flucrite	Precambrian	Precambrian Pikes Peak Granite	Rare-earth minerals are associated with fluorite as hydrothermal replacement of feldspar.
19	20	Cotopaxi Area	Zoned	A	<u>Uraninite</u> , <u>samarskite</u> , <u>euxenite</u> , <u>allanite</u> <u>cyrtolite</u> , biotite, magnetite, garnet, fluorite, hornblende, doverite, cenosite, xenotime.	Precambrian	Precambrian fine-grained granite	Muscovite poor, but abundant biotite and magnetite. One pegmatite contained 75 lbs. of uraninite.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

COLORADO

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
20	20	Villa Grove Area		A	<u>Euxenite</u> , <u>xenotime</u> , <u>cyrtolite</u>		Precambrian gneiss	
21	20	Crestone Area		B	<u>Euxenite</u> , <u>cyrtolite</u> , <u>monazite</u>		Precambrian gneiss	
22	21	Black Cloud	Zoned	A	<u>Fergusonite</u> , <u>samarskite</u> , <u>thorite</u> , <u>monazite</u> , <u>allanite</u> , <u>yttrioantalite</u> , <u>gadolinite</u> , <u>biotite</u>	Precambrian	Precambrian Pikes Peak Granite	Rare-earth and radioactive minerals occur in fluorite and albite replacement units.
23	21	St. Peter's Dome	Zoned	A	<u>Thorite</u> , rare earths <u>cyrtolite</u> , <u>pyrochlore</u> many rare accessory minerals	Precambrian	Precambrian Pikes Peak Granite	Numerous pegmatites. Some of alkalic type may be derived from Mt. Rosa Granite; others from Pikes Peak Granite.

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4. Red Head Claim

INDEX MAP #16 - COLORADO

- 5. Hyatt Beryl Mine
- 6. Wheeler Basin

INDEX MAP #17 - COLORADO

- 7. Waterloo Mine
- 8. Idaho Springs District
- 9. Ralston Creek Area
- 10. Roscoe Pegmatite
- 11. Burroughs Mine

INDEX MAP #18 - COLORADO

12. Seerie Pegmatite

13. South Platte Area

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INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

CONNECTICUT

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	22	Bethel	Fairfield	Hartford	Bethel	Grauch & Zarinski, 1976; Januzzi, 1959
2	22	Branchville	Fairfield	Hartford	Bethel	Cameron, et al, 1954; Grauch & Zarinski, 1976; Januzzi, 1959
3	22	East Village	Fairfield	Hartford	Botsford	Grauch & Zarinski, 1976; Schairer, 1931
4	22	Ridgefield	Fairfield	Hartford	Peach Lake	Grauch & Zarinski, 1976; Januzzi, 1959
5	22	Southford	New Haven	Hartford	Southbury	Grauch & Zarinski, 1976; Januzzi, 1959
6	22	Upper Merryall (Roebeling)	Litchfield	Hartford	New Milford	Cameron, et al, 1954; Grauch & Zarinski, 1976; Januzzi, 1959
7	22	Woodbury	Litchfield	Hartford	Woodbury	Grauch & Zarinski, 1976
8	23	Andrews and Hale Quarries	Middlesex	Hartford	Middle Haddam	Cameron, et al, 1954; Grauch & Zarinski, 1976; Schairer, 1931; Stugard, 1958
8	23	Strickland Quarry	Middlesex	Hartford	Middle Haddam	Cameron, et al, 1954; Grauch & Zarinski, 1976; Schairer, 1931; Stugard, 1958
9	23	Hazen Property	Middlesex	Hartford	Haddam	Grauch & Zarinski, 1976
9	23	Long (Turkey) Hill	Middlesex	Hartford	Haddam	Barton & Goldsmith, 1968; Grauch & Zarinski, 1976; Schairer, 1931
10	23	Pelton's Quarry	Middlesex	Hartford	Middletown	Grauch & Zarinski, 1976; Schairer, 1931

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

CONNECTICUT

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
11	23	Rock Landing Quarry	Middlesex	Hartford	Haddam	Grauch & Zarinski, 1976; Ingerson 1938; Stugard, 1958
12	23	Toll Gate Quarry	Middlesex	Hartford	Middletown	Cameron, et al, 1954; Grauch & Zarinski, 1976
13	23	White Rocks	Middlesex	Hartford	Middle Haddam	Grauch & Zarinski, 1976
14	23	Husband Quarries	Hartford	Hartford	Glastonbury	Grauch & Zarinski, 1976
15	23	Willimantic	Windham	Hartford	Willimantic	Grauch & Zarinski, 1976
16	23	Spinelli Prospect	Hartford	Hartford	Glastonbury	Cameron, et al, 1954; Stugard, 1958
17	23	Walden Gem Mine	Middlesex	Hartford	Middletown	Barton & Goldsmith, 1968

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

CONNECTICUT

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	22	Bethel		B	<u>Uraninite</u> , <u>fergusonite</u> , <u>cyrtolite</u> , <u>uranophane</u> , <u>autunite</u> , "gummite"	Devonian	Cambro-Ordovician gneisses and schists	
2	22	Branchville	Zoned	B	<u>Uraninite</u> , <u>cyrtolite</u> , <u>autunite</u> , <u>torbernite</u> , <u>phosphuranylite</u> , "gummite" muscovite, cleavelandite, spodumene, tourmaline, garnet, apatite, manganese-phosphates, Nb-Ta mins.	Devonian 368 m.y.	Ordovician(?) sphene and ilmenite-bearing amphibolite	Pegmatite is genetically related to the Thomaston Granite. Uraninite found in cleavelandite-spodumene replacement unit.
3	22	East Village		B	<u>Torbernite</u>	Devonian	Middle to Upper Ordovician biotite gneiss	
4	22	Ridgefield		B	<u>Uraninite</u> , <u>cyrtolite</u> , <u>autunite</u> , <u>torbernite</u> , "gummite"	Late Ordovician(?)	Precambrian (Grenville) Fordham Gneiss	
5	22	Southford	Zoned	B	<u>Uraninite</u> , <u>autunite</u> , <u>torbernite</u> , muscovite, garnet, tourmaline, bismuth minerals, chalcopryrite, galena	Carboniferous 334 m.y.	Cambro-Ordovician biotite-hornblend gneiss and schist	Emplacement of the pegmatites is related to the Acadian Orogeny. Those intruded early are slightly foliated.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

CONNECTICUT

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
6	22	Upper Merryall (Roebling)	Zoned	B	<u>Uraninite</u> , <u>cyrtolite</u> , <u>autunite</u> , <u>torbernite</u> , "gummite", muscovite, biotite, tourmaline, garnet, beryl		Precambrian (Grenville) quartz-mica schist	
7	22	Woodbury		B	<u>Uraninite</u> , <u>autunite</u> , <u>torbernite</u>		Middle to Upper Ordovi- cian granitic gneiss and metasediments of the Hart- land Formation	Pegmatites are related to the Nonewang Granite.
8	23	Andrews and Hale Quarries	Zoned	B	<u>Uraninite</u> , <u>monazite</u> , muscovite, tourmaline, beryl, columbite- tantalite	Pennsylva- nian-Permian (270-300 m.y.)	Middle Ordo- vician Monson Granite and gneiss 472+ 15 m.y.	Age of uraninite is 270-290 m. y. and that of monazite is 300 m.y.
8	23	Strickland Quarry	Zoned	B	<u>Uraninite</u> , muscovite, biotite, tourmaline, spodumene, garnet, apatite, beryl, rare lepidolite, fluorite, columbite-tantalite	Pennsylvanian 280-320 m.y. 293 m.y.	Silurian- Devonian Bolton schist	Columbite-tantalite occurs in plagioclase-quartz core. Anomalously young age date (245 [±] 7 m.y.) for muscovite also reported.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

CONNECTICUT

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
9	23	Hazen Property		C	<u>Autunite</u>	Permian 265 m.y.	Silurian- Devonian Bolton Schist	
9	23	Long (Turkey) Hill	Zoned	C	<u>Autunite</u> , <u>torbernite</u>	Permian 265 m.y.	Silurian- Devonian Bolton Schist	
10	23	Pelton's Quarry		B	<u>Uraninite</u> , <u>samarskite</u>	Pennsylvanian	Devonian Monson Gneiss	
11	23	Rock Landing Quarry		B	<u>Uraninite</u> , <u>autunite</u> , <u>torbernite</u> , "gummite"	Pennsylvanian Permian 280 m.y.; 269 m.y.		Younger age date is from uraninite.
12	23	Toll Gate Quarry	Zoned	C	<u>Autunite</u> , <u>torbernite</u> , muscovite, biotite, some cleavelandite, garnet, tourmaline, columbite-tantalite	Pennsylvanian	Silurian- Devonian quartz-mica schist (Bolton Schist)	Secondary uranium minerals occur in the quartz-perthite zone.
13	23	White Rocks		B	<u>Uraninite</u> , <u>microlite</u> , muscovite, biotite, garnet, tourmaline, beryl	Pennsylvanian	Silurian- Devonian feldspathic gneiss, quartz- mica schist (Bolton Schist)	

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

CONNECTICUT

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
14	23	Husband Quarries		C	<u>Torbernite</u>	Pennsylvanian	Silurian- Devonian Bolton Schist	
15	23	Willimantic		B	<u>Uraninite</u>		Precambrian granite and Gneiss (Willimantic Gneiss)	
16	23	Spinelli Prospect	Zoned	A	<u>Samaraskite</u> , very minor muscovite, garnet, tourmaline	Permian 260 m.y.; 280 m.y.	Middle Ordovi- cian Monson Gneiss	50 lbs. of samarskite mined in 1933. Samarskite occurs in quartz-perthite-plagioclase zone. Age date from samarskite: K-Ar age date from biotite in gneiss = 233 ± 7 m.y.
17	23	Walden Gem Mine	Zoned	B	<u>Uraninite</u> , <u>autunite</u> , pyrochlore, almandite garnet, lepidolite, beryl, spodumene, pollucite, rubellite, apatite, manganotantalite, black tourmaline, columbite, muscovite, amblygonite, biotite	Pennsylvanian (?)	Silurian - Devonian Bolton Schist	Uranium minerals are rare.

INDEX MAP #22 - CONNECTICUT

1. Bethel
2. Branchville
3. East Village
4. Ridgefield
5. Southford
6. Upper Merryall
(Roebling)
7. Woodbury

INDEX MAP #23 - CONNECTICUT

- 8. Andrews Quarry
(Hale Quarry)
- 8. Strickland Quarry
- 9. Hazen Property
- 9. Long (Turkey) Hill
- 10. Pelton's Quarry
- 11. Rock Landing Quarry
- 12. Toll Gate Quarry
- 13. White Rocks
- 14. Husband Quarries
- 15. Willimantic
- 16. Spinelli Prospect
- 17. Walden Gem Mine

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

GEORGIA

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	24	Amphlett Mine	Cherokee	Rome	Ball Ground East	Grauch & Zarinski, 1976; Heinrich, et al, 1953
2	25	Stone Mountain	DeKalb	Atlanta	Stone Mtn.	Grauch & Zarinski, 1976; S.I.N.B., 1969
3	25	A. H. Moye Mica Mine	Lamar	Phenix City	Strouds	Grauch & Zarinski, 1976; S.I.N.B., 1969
4	26	W. E. Adams Mica Mine	Upson	Phenix City	Yatesville	Grauch & Zarinski, 1976; S.I.N.B., 1969
5	27	U. M. Poss Feldspar Mine	Greene	Athens	Woodville	Grauch & Zarinski, 1976; S.I.N.B., 1969
6	28	J. R. Parker	Jasper	Athens	Hillsboro	Grauch & Zarinski, 1976; S.I.N.B., 1969

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

GEORGIA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	24	Amphlett Mine		C	<u>Autunite</u> , " <u>gammite</u> "		Mica schist, gneiss	Blue Ridge and Piedmont crystalline rocks.
2	25	Stone Mountain		C	<u>Uranophane</u>	Permian	Permian Stone Mtn. Granite (quartz monzonite)	Pegmatites associated with the Stone Mountain granite. Uranium minerals as fracture surface coatings.
3	26	A. H. Moye Mica Mine		C	<u>Meta-autunite</u> , <u>meta-torbernite</u> , <u>beta-uranophane</u> , <u>soddyite</u>		Granite gneiss	Blue Ridge and Piedmont crystalline rocks. Uranium minerals as fracture surface coatings.
4	26	W. E. Adams Mica Mine		C	<u>Secondary uranium minerals</u>		Granite gneiss	Blue Ridge and Piedmont crystalline rocks. Uranium minerals on fracture surfaces.
5	27	U. M. Poss Feldspar Mine		C	<u>Secondary uranium minerals</u>		Granitic gneiss, hornblende gneiss	Blue Ridge and Piedmont crystalline rocks. Uranium minerals as coatings, veinlets and segregations.
6	28	J. R. Parker		C	<u>Secondary uranium minerals</u>		Hornblende gneiss and amphibolite	Blue Ridge and Piedmont crystalline rocks. Uranium minerals as coatings.

INDEX MAP #24 - GEORGIA
1. Amphlett Mine

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INDEX MAP #25 - GEORGIA

2. Stone Mountain

N

INDEX MAP #26 - GEORGIA

3. A. H. Moyer Mica Mine

4. W. E. Adams Mica Mine

N

INDEX MAP #27 - GEORGIA
5. U. M. Poss Feldspar
Mine

INDEX MAP #28 - GEORGIA
6. J. R. Parker

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

IDAHO

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	29	Big Jureano Creek	Lemhi	Elk City	Leesburg (15')	Bennett, 1977; Olson & Adams, 1962; Shockey, 1957
2	29	Mineral Hill District	Lemhi	Elk City	Ulysses Mtn. (15')	Kaiser, 1956; Olson & Adams, 1962
3	30	Columbite Group	Boise	Challis	Garden Valley (15')	Olson & Adams, 1962

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

IDAHO

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	29	Big Jureano Creek		C	<u>Allanite</u> , biotite		Precambrian gneiss	Gneiss is poorly foliated and resembles rapakivi granite.
2	29	Mineral Hill District	Unzoned	C	<u>Allanite</u> , <u>monazite</u>		Precambrian gneiss, amphibolite	Allanite and monazite are very rare constituents.
3	30	Columbite Group		E	<u>Samarskite</u> , <u>monazite</u> , columbite	Cretaceous(?)	Cretaceous Idaho batho- lith	Granitic rocks.

INDEX MAP #29 - IDAHO

1. Big Jureano Creek
2. Mineral Hill District

INDEX MAP #30 - IDAHO
3. Columbite Group

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MAINE						
Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	31	Black Mountain Mine	Oxford	Lewiston	Rumford	Grauch & Zarinski, 1976; Wintringham, 1955
2	31	Dunton Pegmatite (Newry Mines)	Oxford	Lewiston	East Andover	Cameron, et al, 1954; Grauch & Zarinski, 1976; Shainin & Dellwig, 1954; Wintringham, 1955
3	31	Nevel Quarry	Oxford	Lewiston	East Andover	Grauch & Zarinski, 1976; Wintringham, 1955
3	31	Scotty Mine (Newry Mines)	Oxford	Lewiston	East Andover	Grauch & Zarinski, 1976; Wintringham, 1955
4	31	Red Hill	Oxford	Lewiston	Rumford	Grauch & Zarinski, 1976; Morrill, 1958
5	31	Cole Mine	Oxford	Lewiston	Center Lovell	Morrill, 1958
6	31	Harndon Hill	Oxford	Lewiston	Center Lovell	Morrill, 1958
7	31	Lord Hill	Oxford	Lewiston	Center Lovell	Grauch & Zarinski, 1976; Morrill, 1958
8	31	Sugarloaf Mtn. (Melrose Prospect)	Oxford	Lewiston	East Stoneham	Grauch & Zarinski, 1976; Morrill 1958
9	31	Oak Hill	Oxford	Lewiston	North Waterford	Grauch & Zarinski, 1976; Morrill, 1958
10	31	Bumpus Quarry	Oxford	Lewiston	East Stoneham	Cameron, et al, 1954; Wintringham, 1955
11	31	Wardell Quarry	Oxford	Lewiston	East Stoneham	Grauch & Zarinski, 1976; Wintringham, 1955

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MAINE

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
12	31	Guy Johnson Mine	Oxford	Lewiston	Greenwood	Grauch & Zarinski, 1976; Wintringham, 1955
13	31	Stearns Mine	Oxford	Lewiston	Greenwood	Cameron, et al, 1954; Grauch & Zarinski, 1976; Morrill, 1958; Wintringham, 1955
14	31	Tamminen Pits	Oxford	Lewiston	Greenwood	Grauch & Zarinski, 1976; Wintringham, 1955
15	31	Harvard Quarry	Oxford	Lewiston	West Paris	Grauch & Zarinski, 1976; Wintringham, 1955
16	31	Beryllium Corp. Mine	Oxford	Lewiston	West Paris	Grauch & Zarinski, 1976; Morrill, 1958
17	31	Witt Hill	Oxford	Lewiston	West Paris	Grauch & Zarinski, 1976; Morrill, 1958
18	31	Mount Mica Mine	Oxford	Lewiston	West Sumner	Grauch & Zarinski, 1976; Morrill, 1958; Wintringham, 1955
19	31	Bennett Quarry	Oxford	Lewiston	West Sumner	Cameron, et al, 1954; Grauch & Zarinski, 1976; Wintringham, 1955
20	31	Haper's Ledge Feldspar Quarry	Oxford	Lewiston	Poland (15')	Grauch & Zarinski, 1976; Morrill, 1958
21	31	Singlepole Mine	Oxford	Lewiston	Poland (15')	Grauch & Zarinski, 1976; Morrill, 1958; Wintringham, 1955
22	32	LaFlamme Quarry	Androscoggin	Lewiston	Poland (15')	Grauch & Zarinski, 1976; Morrill, 1958

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MAINE

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
23	32	Fisher Quarry	Androscoggin	Lewiston	Poland (15')	Grauch & Zarinski, 1976; Morrill, 1958
23	32	Mount Apatite	Androscoggin	Lewiston	Poland (15')	Grauch & Zarinski, 1976; Morrill, 1958
24	32	Russell Brothers Quarry	Sagadahoc	Lewiston	Lewiston (15')	Cameron, et al, 1954; Grauch & Zarinski, 1976; Morrill, 1958
25	33	Brown Hill	Cumberland	Portland	Gray (15')	Grauch & Zarinski, 1976; Morrill, 1958
26	33	Freeport Village	Cumberland	Portland	Freeport	Grauch & Zarinski, 1976; Morrill, 1958
27	34	Dr. Brasso Mine	Sagadahoc	Bangor	Gardiner (15')	Grauch & Zarinski, 1976; Morrill, 1958
28	34	H. G. Starret	Knox	Bangor	Waldoboro	Grauch & Zarinski, 1976; Morrill, 1958
29	35	Standpipe Hill Quarry	Sagadahoc	Bath	Bath (15')	Olson & Adams, 1962
30	35	North Topsham Spar Quarry	Sagadahoc	Bath	Bath (15')	Grauch & Zarinski, 1976; Morrill, 1958
31	35	Fisher Quarry	Sagadahoc	Bath	Bath (15')	Grauch & Zarinski, 1976; Morrill, 1958
32	35	Consolidated Mine No. 1	Sagadahoc	Bath	Bath (15')	Grauch & Zarinski, 1976; Morrill, 1958
33	35	E. P. Thomas Quarry	Sagadahoc	Bath	Small Point	Grauch & Zarinski, 1976; Morrill, 1958

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MAINE

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
34	35	Consolidated Feldspar Quarry	Sagadahoc	Bath	Small Point	Cameron, et al, 1954; Grauch & Zarinski, 1976; Morrill, 1958

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MAINE

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	31	Black Mountain Mine	Zoned	B	<u>Uraninite</u> , <u>cyrtolite</u> , <u>microlite</u> , <u>autunite</u> , <u>uranophane</u> , <u>uranopilite</u> , "gummite", muscovite, cleavelandite, tourma- line, garnet, spodumene, lepidolite, columbite- tantalite, cassiterite, beryl	Devonian	Silurian quartz-mica schist, quartzite	Quartz monzonite encountered in drill holes. Gem tourmaline.
2	31	Dunton Pegmatite (Newry Mines)	Zoned	B	<u>Uraninite</u> , <u>autunite</u> , <u>torbernite</u> , <u>uranophane</u> , "gummite", muscovite, cleavelandite, tourma- line, columbite- tantalite, beryl, Li- minerals, rare phos- phates, pollucite	Carboniferous 300 m.y.	Silurian quartz-mica schist, quartzite	Gem mine, extremely diverse accessory minerals. Age determination from Sr/Rb in lepidolite.
3	31	Nevel Quarry		C	<u>Autunite</u> , beryl, columbite, apatite, Li-minerals, rare phosphates, sphalerite	Devonian	Silurian quartz-mica schist, quartzite	

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MAINE

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
3	31	Scotty Mine	Zoned	B	<u>Uraninite</u> , <u>autunite</u> , <u>uranophane</u> , <u>gummite</u> , beryl, apatite, tourma- line, sulfides, rare phosphates, magnetite, spodumene	Devonian	Silurian gabbro, quartz- mica schist	
4	31	Red Hill		B	<u>Uraninite</u> , beryl, apatite, rare phosphates, sulfides, columbite	Devonian	Siluran granite (quartz monzonite?)	Several pegmatites represented.
5	31	Cole Mine		C	<u>Autunite</u> , beryl, columbite, apatite, Li-minerals	Upper Devonian	Lower Devonian Littleton Formation bio- tite-sillimanite gneiss	
6	31	Harndon Hill		C	<u>Autunite</u>	Upper Devonian	Lower Devonian Littleton Formation bio- tite-sillimanite gneiss	

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MAINE

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
7	31	Lord Hill		C	<u>Autunite</u> , <u>torbernite</u> , <u>uranophane</u> , " <u>gummite</u> ", <u>cyrtolite</u> , topaz, fluorite, amblygonite, beryl, columbite, apatite, rare phos- phates, muscovite, biotite	Upper Devonian	Lower Devonian Littleton Formation biotite- sillimanite gneiss	
8	31	Sugarloaf Mtn. (Melrose Prospect)		C	<u>Autunite</u>	Upper Devonian	Upper Devonian Sango Grano- diorite	
9	31	Oak Hill		C	<u>Autunite</u> , <u>uranophane</u>	Upper Devonian	Devonian granite	
10	31	Bumpus Quarry	Zoned	C	<u>Autunite</u> , cleavelandite, biotite, garnet, apatite, tourmaline, beryl	Upper Devonian	Upper Devonian Well zoned gneissic bio- tite granite to granodiorite	
11	31	Wardell Quarry	Zoned	B	<u>Uraninite</u> , <u>autunite</u> , <u>torbernite</u> , <u>uranophane</u> , biotite, muscovite, tourmaline, garnet, beryl	Upper Devonian	Upper Devonian Uranium minerals occur in a quartz biotite quartz-perthite-biotite wall schist and zone; beryl is found in a granite quartz-perthite zone.	

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MAINE

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
12	31	Guy Johnson Mine	Zoned	C	<u>Asturite</u> , <u>torbernite</u> , muscovite, biotite, tourmaline, beryl, garnet, apatite	Middle to Upper Devonian	Middle to Upper Devo- nian biotite gneiss and quartz monzo- nite	Uranium minerals occur in a plagioclase-quartz unit, beryl and tourmaline occur in several units.
13	31	Stearns Mine	Zoned	B	<u>Uraninite</u> , biotite, tourmaline, beryl	Middle to Upper Devonian	Devonian biotite gneiss and granite	
14	31	Tamminen Pits		B	<u>Uraninite</u> , Li-minerals, beryl, apatite, columbite-tantalite, tourmaline, fluorite, topaz	Middle to Upper Devonian	Silurian biotite gneiss and granite	
15	31	Harvard Quarry	Zoned	C	<u>Autunite</u> , cleavelandite, muscovite, garnet, tourmaline, apatite, beryl, spodumene, lepidolite and numerous other accessories	Middle to Upper Devonian	Silurian biotite schist, migmatite	Two post-magmatic hydrothermal phases recognized.
16	31	Beryllium Corp. Mine		C	<u>Torbernite</u>	Middle to Upper Devonian	Silurian biotite schist, migmatite	

GEOLGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MAINE

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
17	31	Witt Hill		C	<u>Autunite</u> , <u>uranophane</u>	Middle to Upper Devonian	Silurian biotite schist, migmatite	
18	31	Mount Mica Mine		B	<u>Uraninite</u> , <u>autunite</u> , muscovite, tourmaline, garnet, lepidolite, beryl	Middle to Upper Devonian 250 m.y. (?)	Silurian quartz-mica schist and gneiss	Radioactivity associated with garnets. Age date based on Sr/Rb in lepidolite.
19	31	Bennett Quarry	Zoned	C	<u>Autunite</u> , biotite, garnet, tourmaline, apatite, beryl, lepidolite, topaz and numerous other accessory minerals	Middle to Upper Devonian	Silurian gneiss	Four hydrothermal stages recognized.
20	31	Haper's Ledge Feldspar Quarry		C	<u>Autunite</u>	Middle to Upper Devonian 280 m.y. (?)	Silurian schist and gneiss	
21	31	Singlepole Mine	Unzoned	C	<u>Autunite</u> , <u>torbernite</u> , muscovite, biotite tourmaline, beryl, apatite, garnet, columbite	Middle to Upper Devonian 280 m.y. (?)	Silurian mica schist	Pegmatite cut by basic dike.

GEOLGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MAINE

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
22	32	La Flamme		B	<u>Uraninite</u> , <u>autunite</u>	Middle to Upper Devonian 280 m.y. (?)	Silurian- Devonian granite and schists	Includes nearby Phillips and Sturtevant occurrences.
23	32	Fisher Quarry		C	<u>Torbernite</u>	Middle to Upper Devonian 280 m.y. (?)	Ordovician biotite- granite and schist	
23	32	Mount Apatite		C	<u>Autunite</u>	Middle to Upper Devonian 280 m.y. (?)	Ordovician biotite- granite and schist	
24	32	Russell Brothers Quarry	Zoned	B	<u>Uraninite?</u> , <u>samarskite</u> , muscovite, biotite, garnet, tourmaline, beryl, columbite- tantalite	Devonian	Silurian feldspathic biotite gneiss and amphi- bolite	
25	33	Brown Hill		C	<u>Autunite</u>	Devonian	Devonian biotite granite	

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MAINE

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
26	33	Freeport Village		C	<u>Autunite</u>	Devonian(?)	Precambrian gneiss and amphibolite	
27	34	Dr. Brasso Mine		C	<u>Torbernite</u>	Devonian(?)	Precambrian biotite gneiss and amphibolite	
28	34	H. G. Starret		B	<u>Uraninite</u> , <u>cyrtolite</u> , <u>autunite</u> , <u>torbernite</u>	Middle to Upper Devonian	Devonian granite	
29	35	Standpipe Hill Quarry	Zoned	B	<u>Samarskite</u> , <u>monazite</u> , <u>autunite</u> , <u>microcline</u> , <u>allanite</u> , garnet, biotite, beryl, magnetite, hematite, cleavelandite	Devonian- Carboniferous	Precambrian (Hadrynian) quartz-mica schist	Samarskite and monazite occur in feldspar and biotite. Beryl is honey-yellow.
30	35	North Topsham Spar Quarry		B	<u>Uraninite</u>	Triassic 200 m.y. and 220 m.y.	Precambrian (Hadrynian) quartz-mica schist	Ages considered too young. Age date determination on samarskite (220 m.y.) and Sr/Rb in lepidolite (200 m.y.)
31	35	Fisher Quarry		C	<u>Cyrtolite</u> , <u>torbernite</u> lepidolite, beryl, apatite, microcline, columbite, topaz, tourmaline, gahnite, garnet	Devonian- Carboniferous	Precambrian (Hadrynian) quartz-mica schist	

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MAINE

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
32	35	Consolidated Mine No. 1		B	<u>Uraninite</u>	Devonian-Carboniferous	Precambrian (Hadrynian) quartz-mica schist, quartzite	Pegmatites and granite consanguineous and intrusive into Precambrian metamorphics. Probable age is Upper Devonian.
33	35	E. P. Thomas Quarry	Zoned	C	<u>Uranophane</u>	Devonian-Carboniferous	Devonian granite	
34	35	Consolidated Feldspar Quarry	Zoned	C	<u>Autunite</u> , " <u>gummite</u> ", yellowish-green beryl, black tourmaline, garnet, minor sulphides	Devonian-Carboniferous	Ordovician quartz-mica schist, quartzite	U-minerals associated with beryl in quartz of quartz-perthite core.

INDEX MAP #31 - MAINE

1. Black Mountain Mine
2. Dunton Pegmatite (Newry Mines)
3. Nevel Quarry
3. Scotty Mine (Newry Mines)
4. Red Hill
5. Cole Mine
6. Harndon Hill
7. Lord Hill
8. Sugarloaf Mtn. (Melrose Prospect)
9. Oak Hill
10. Bumpus Quarry
11. Wardell Quarry
12. Guy Johnson Mine
13. Stearns Mine
14. Tamminen Pits
15. Harvard Quarry
16. Beryllium Corp. Mine
17. Witt Hill
18. Mount Mica Mine
19. Bennett Quarry
20. Haper's Ledge Feldspar Quarry
21. Singlepole Mine

Index Map #31

INDEX MAP #33 - MAINE

25. Brown Hill

26. Freeport Village

INDEX MAP #34 - MAINE

27. Dr. Brasso Mine

28. H. G. Starret

N

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MARYLAND

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	36	Baltimore County Area	Baltimore	Baltimore	Baltimore East	Grauch & Zarinski, 1976
2	36	Orange Grove	Baltimore	Baltimore	Ellicot City	Grauch & Zarinski, 1976
3	36	Kensington Mica Mine	Montgomery	Baltimore	Kensington	Grauch & Zarinski, 1976; Shannon, 1926

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MARYLAND

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	36	Baltimore County Area		B	<u>Samarskite</u> , <u>autunite</u> , <u>torbernite</u>	Precambrian(?)	Precambrian Baltimore Gneiss, horn- blende gneiss	
2	36	Orange Grove		C	<u>Autunite</u>	Precambrian(?)	Precambrian gneiss	
3	36	Kensington Mica Mine		C	<u>Microlite</u> , <u>autunite</u> , <u>betafite</u> , <u>cleavelandite</u> , garnet, tourmaline, beryl, apatite	Precambrian(?)	Precambrian(?) mica gneiss	Identification of microlite, betafite uncertain.

INDEX MAP #36 - MARYLAND

1. Baltimore County Area
2. Orange Grove
3. Kensington Mica Mine

INDEX OF LOCALITIES OF URANIUM-AND THORIUM BEARING-PEGMATITES

MASSACHUSETTS

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	37	West Chesterfield	Worcester	Albany	Goshen	Grauch & Zarinski, 1976
2	38	Rollstone Hill (McCauliff Quarries)	Worcester	Boston	Fitchburg	Billings, 1941; Grauch & Zarinski, 1976; Hitchen, 1935
3	38	Leominster	Worcester	Boston	Fitchburg	Billings & Wolfe, 1944; Grauch & Zarinski, 1976
4	39	Blueberry Mtn.	Middlesex	Boston	Lexington	Billings, 1941; Grauch & Zarinski, 1976
5	39	Cape Ann Area	Essex	Boston	Gloucester	Grauch & Zarinski, 1976; Olson & Adams, 1962

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MASSACHUSETTS

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	37	West Chesterfield		C	<u>Cyrtolite</u> , <u>microlite</u> , <u>autunite</u> , <u>torbernite</u> , muscovite, biotite, beryl, spodumene, zircon, columbite, cleavelandite, tourma- line, garnet, cassiterite, lepidolite, apatite, triphyllite, cookeite		Ordovician(?) felsic intrusive	Autunite appears to be an alteration product of zircon.
2	38	Rollstone Hill (McCauliff Quarries)		C	<u>Uraninite</u> , <u>allanite</u> , <u>autunite</u> , muscovite, biotite, spodumene, beryl, tourmaline, garnet, apatite, fluorite, columbite, sphene, cassiterite, pollucite, phosphate minerals, pyrite, chalc- pyrite, molybdenite		Devonian muscovite- biotite- microcline granite	Five types of pegmatites recognized based on acces- sories: biotite, tourmaline, beryl, cassiterite, allanite, in decreasing age.
3	38	Leominster		C	<u>Autunite</u> , muscovite, spodumene, columbite, tourmaline, pollucite, phosphate minerals		Devonian schist, gneissic granite	

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MASSACHUSETTS

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
4	39	Blueberry Mtn.		B	<u>Thorite</u> , <u>cyrtolite</u> , <u>allanite</u> , cleavelandite, biotite, hornblende, magnetite, sphene, zircon, tourmaline, garnet, stilbite, pyrite, chalcopyrite, molybdenite, sphalerite	Silurian 400-430 m.y.	Granodiorite	Hornblende and magnetite in host granodiorite
5	39	Cape Ann Area		B	<u>Thorite</u> , <u>fergusonite</u> , <u>gadolinite</u> , <u>cyrtolite</u> , <u>allanite</u> , lepidomelane, hornblende, fayalite, fluorite, yttrocerite, tantalite, calcite, pyrite, pyrrhotite, galena, sphalerite, molybdenite, Fe-oxides, danalite	Carboniferous	Silurian Quincy Granite, Cape Ann Syenite	Some pegmatites are alkalic type. Possible older age of 450+ 25 m.y. with younger thermal event.

INDEX MAP #37 - MASSACHUSETTS

1. West Chesterfield

INDEX MAP #38 - MASSACHUSETTS

2. Rollstone Hill
(McCauliff Quarries)
3. Leominster

N

INDEX MAP #39 - MASSACHUSETTS

- 4. Blueberry Mountain
- 5. Cape Ann Area

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MONTANA

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	40	Darby Area	Ravalli	Elk City	Medicine Hot Springs	Olson & Adams, 1962
2	41	Janney Pegmatites	Silver Bow	Dillon	Butte South (15')	Heinrich, 1949; Olson & Adams, 1962
3	42	Divide No. 1, Lookout No. 1	Beaverhead	Dubois	Garfield Canyon	Trites & Tooker, 1953
4	42	Gray Goose	Beaverhead	Dubois	Garfield Canyon	Trites & Tooker, 1953
5	43	Sappington Area	Madison	Bozeman	Jefferson Island (15')	Heinrich, 1949; Olson & Adams, 1962

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

MONTANA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	40	Darby Area		B	<u>Samarskite</u>	Proterozoic(?)	Precambrian Belt series	
2	41	Janney Pegmatites	Unzoned	C	<u>Allanite</u> , biotite, epidote, tourmaline, garnet, pyrite	Mesozoic	Late Creta- ceus Boulder batholith	
3	42	Divide No. 1, Lookout No. 1		C	<u>Monazite</u>	Proterozoic(?)	Precambrian quartz-bio- tite schist, hornblende gneiss	Pre-Beltian series host rock.
4	42	Gray Goose		C	<u>Monazite</u>	Proterozoic(?)	Precambrian quartz-bio- tite schist, hornblende gneiss	Pre-Beltian series host rock.
5	43	Sappington Area	Zoned	B	<u>Euxenite</u> , muscovite, magnetite, tourmaline	Proterozoic	Precambrian hornblende gneiss and biotite gneiss	Pre-Beltian series host rock; euxenite is associated with microcline and plagio- clase in a replacement unit.

INDEX MAP #40 - MONTANA
1. Darby Area

INDEX MAP #41 - MONTANA

2. Janney Pegmatites

INDEX MAP #42 - MONTANA

- 3. Divide No. 1,
Lookout No. 1
- 4. Gray Goose

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEVADA

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	44	Red Rock Road	Storey	Reno	Dogskin Mtn. (15')	Olson & Adams, 1962; Olson & Hinrichs, 1960
2	44	Deer Lodge Claims	Storey	Reno	Dogskin Mtn. (15')	Davis, 1954
3	45	Dawley Canyon	Elko	Elko	Franklin Lake NW	Olson & Hinrichs, 1960; Willden & Kistler, 1969
4	45	Hankins Canyon	Elko	Elko	Franklin Lake SW	Olson & Hinrichs, 1960; Willden & Kistler, 1969
5	45	Gilbert Canyon	Elko	Elko	Jiggs (15')	Olson & Hinrichs, 1960; Willden & Kistler, 1969
6	46	Gold Butte Pegmatite District	Clark	Las Vegas	Gold Butte (15')	Longwell, et al, 1965; Olson & Hinrichs, 1960; Volborth, 1963

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEVADA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	44	Red Rock Road		C	<u>Allanite</u>	Tertiary(?)	Tertiary biotite granite	
2	44	Deer Lodge Claims		C	<u>Allanite</u> , <u>chevkinite</u>	Tertiary(?)	Tertiary granite and diorite	
3	45	Dawley Canyon	Zoned	C	<u>Autunite</u> , columbite- tantalite		Middle Jurassic- Tertiary felsic intrusives	Pegmatites occur in several intrusive bodies of varying ages.
4	45	Hankins Canyon	Zoned	C	<u>Autunite</u> , columbite- tantalite		Middle Jurassic- Tertiary felsic intrusives	Pegmatites occur in several intrusive bodies of varying ages.
5	45	Gilbert Canyon	Zoned	B	<u>Uraninite</u> , <u>autunite</u> , columbite-tantalite, beryl		Middle Jurassic- Tertiary felsic intrusives	Pegmatites occur in several intrusive bodies of varying ages.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEVADA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
6	46	Gold Butte Pegmatite District	Zoned	B	<u>Samarskite</u> , <u>euxerite</u> , <u>gadolinite</u> , <u>allanite</u> , muscovite, biotite, columbite, zircon	Precambrian 1700 m.y. and 1060 m.y.	Precambrian gneisses and schists	Three generations of pegmatites; oldest occurs as lenses in gneiss, younger two occur in both the granite and meta- morphics. Granite is rapakivi type and contains allanite. Aplites grade into pegmatites. Age of granite is 1060 m.y.

INDEX MAP #44 - NEVADA

1. Red Rock Road
2. Deer Lodge Claims

N

INDEX MAP #45 - NEVADA

- 3. Dawley Canyon
- 4. Hankins Canyon
- 5. Gilbert Canyon

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW HAMPSHIRE

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	47	Beryl Mtn.	Sullivan	Glens Falls	Bellows Falls (15')	Olson, 1950
2	47	Golding-Keere Mine	Cheshire	Glens Falls	Bellows Falls (15')	Grauch & Zarinski, 1976; Meyers, 1941
3	47	New Hampshire Mica and Mining Co. Quarry	Cheshire	Glens Falls	Bellows Falls (15')	Grauch & Zarinski, 1976; Meyers, 1941
4	48	Ruggles Mine	Grafton	Portland	Cardigan (15')	Cameron, et al, 1954; Grauch & Zarinski, 1976; Meyers, 1941; Shaub, 1938
5	48	Globe Mica Mine	Sullivan	Portland	Mt. Kearsarge (15')	Cameron, et al, 1954; Grauch & Zarinski, 1976
6	48	Carpenter Mica Mine	Grafton	Portland	Cardigan (15')	Cameron, et al, 1954; Grauch & Zarinski, 1976
7	48	Danbury Mica Mine	Merrimack	Portland	Cardigan (15')	Cameron, et al, 1954; Grauch & Zarinski, 1976
8	48	E. E. Smith Mica Mine	Grafton	Portland	Cardigan (15')	Cameron, et al, 1954; Grauch & Zarinski, 1976; Page & Larrabee, 1962
9	48	Palermo Mine	Grafton	Portland	Cardigan (15')	Cameron, et al, 1954; Grauch & Zarinski, 1976; Verrow, 1941
10	49	Weeks Mine	Carroll	Portland	Newfield (15')	Cameron, et al, 1954; Olson, 1950
11	49	Parker Mtn. Mica Mine	Strafford	Portland	Alton (15')	Cameron, et al, 1954; Grauch & Zarinski, 1976; Meyers, 1941; Page & Larrabee, 1962

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW HAMPSHIRE

Loc. #	Map #	Name	Zoning	R.A.	Mineralogy	Age	Host Rock	Comments
1	47	Beryl Mtn.	Zoned	B	<u>Uraninite</u> , <u>cyrtolite</u> , <u>secondary uranium</u> <u>minerals</u> , beryl, muscovite, biotite, tourmaline	Devonian Carboniferous 328± 10 m.y.	Devonian(?) gneiss and schist	Golden beryl associated with cyrtolite. Age date from muscovite.
2	47	Golding-Keene Mine	Zoned	B	<u>Uraninite</u> , <u>uranophane</u>		Devonian Littleton Formation schist, gneiss and amphibolite	
3	47	New Hampshire Mica and Mining Co. Quarry		C	<u>Autunite</u>		Devonian Littleton Formation schist, gneiss and amphibolite	
4	48	Ruggles Mine	Zoned	A	<u>Uraninite</u> , <u>autunite</u> , <u>torbernite</u> , <u>uranophane</u> , "gummite", <u>cyrtolite</u> , muscovite, cleaveland- ite, biotite, tourmaline, apatite, beryl	Carboniferous 310 m.y.	Devonian Littleton Formation quartz-mica schist, bio- tite gneiss, amphibolite	Uranium minerals associated with late veins and irregular bodies of quartz. Age determination from uraninite.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW HAMPSHIRE

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
9	48	Palermo Mine	Zoned	B	Uraninite, <u>cyrtolite</u> , <u>autunite</u> , <u>uranophane</u> , "gummite", muscovite, biotite, columbite, tourmaline, garnet, beryl, triphylite, graftonite, apatite, and numerous other accessories	Devonian 264 [±] 8 m.y. 337 [±] 15 m.y.	Devonian quartz-mica schist, quartzite, amphibolite	Associated minerals include pyrite, chalcopyrite, sphalerite. Numerous pegma- tites occur in the area. Stratigraphic age accepted as Devonian. Pegmatite age dates from muscovite K/Ar
10	49	Weeks Mine	Zoned	B	<u>Samarskite</u> , muscovite, cleavelandite, garnet, beryl, molybdenite, columbite	Devonian	Devonian	Pegmatite probably related to a granite, both of which are cut by a basic dike. Up to 60 lb. masses of intergrown columbite and samarskite occur in albite. Molybdenite occurs as scattered flakes in wall zone.
11	49	Parker Mtn. Mica Mine	Zoned	C	<u>Autunite</u> , muscovite, cleavelandite, apatite, tourmaline, beryl, triphylite as well as numerous other accessory minerals	Devonian 269 [±] 8 m.y.	Devonian gneissic aplite, quartz-mica schist	Many of the accessories are associated with replacement units. Stratigraphic age older than age determination for muscovite.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW HAMPSHIRE

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
5	48	Globe Mica Mine	Zoned	C	<u>Autunite</u> , muscovite, biotite, garnet, tourmaline, apatite, beryl, loellingite	Devonian-Carboniferous	Devonian quartz-mica schist	Autunite occurs in the quartz core.
6	48	Carpenter Mica Mine	Unzoned	C	<u>Autunite</u> , <u>torbernite</u> , muscovite, biotite, apatite	Devonian-Carboniferous	Devonian schist	
7	48	Danbury Mica Mine	Zoned	C	<u>Autunite</u> , muscovite, garnet, beryl	Devonian-Carboniferous	Devonian gneissic quartz monzonite	Autunite occurs in a perthite-quartz intermediate zone.
8	48	E. E. Smith Mica Mine	Zoned	C	<u>Autunite</u> , muscovite, garnet, tourmaline, beryl, triphylite, columbite-tantalite	Devonian-Carboniferous	Devonian gneissic quartz monzonite, quartz-mica schist	Autunite associated with columbite-tantalite in plagioclase-muscovite-quartz-beryl intermediate zone.

INDEX MAP #48 - NEW HAMPSHIRE

4. Ruggles Mine
5. Globe Mica Mine
6. Carpenter Mica Mine
7. Danbury Mica Mine
8. E. E. Smith Mica Mine
9. Palermo Mine

N

INDEX MAP #49 - NEW HAMPSHIRE

10. Weeks Mine

11. Parker Mtn. Mica Mine

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW JERSEY

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	50	Bowling Green Mtn.	Morris	Newark	Dover	Grauch & Zarinski, 1976
2	50	Gross (Stanhope)	Sussex	Newark	Stanhope	Grauch & Zarinski, 1976
3	50	Cranberry Lake, Charlotte Mine	Sussex	Newark	Stanhope	Grauch & Zarinski, 1976; Haji- Vassiliou, et al, 1974; Williams, 1967
4	50	Scrub Oaks Mine	Morris	Newark	Dover	Grauch & Zarinski, 1976; Klemic, et al, 1959
5	50	Drake Claim	Warren	Newark	Blairstown	Grauch & Zarinski, 1976

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW JERSEY

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	50	Bowling Green Mtn.		B	<u>Uraninite</u>		Precambrian Byran Granite	
2	50	Gross (Stanhope)		B	<u>Uraninite</u> , magnetite	Precambrian	Precambrian hornblende gneiss	
3	50	Cranberry Lake, Charlotte Mine		A	<u>Uraninite</u> , <u>thorite</u> , <u>uranothorite</u> , <u>allanite</u> <u>fergusonite</u> , <u>spencite</u> , pyrite, hornblende, zircon, fluorite, apatite, magnetite	Precambrian	Precambrian granite gneiss, pyroxenite, amphibolite	Uranium zone occurs along pegmatite-pyroxenite contact. Uranium precipitated from hydrothermal solutions associated with pegmatite.
4	50	Scrub Oaks Mine		C	<u>Chevkinite</u> , <u>monazite</u> , magnetite, apatite, doberite, bastnaesite, xenotime, zircon	Precambrian	Precambrian granite gneiss, horn- blende gneiss	Rare-earth minerals occur in magnetite ore and pegmatite adjacent to magnetite ore.
5	50	Drake Claim		B	<u>Uraninite</u>	Precambrian	Precambrian granite	

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW MEXICO

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	51	High Noon No. 1	Grant	Silver City	Burro Peak	Olson & Adams, 1962
2	51	Gold Hill Area	Hidalgo	Silver City	Gold Hill	Gillerman, 1964
3	52	Kiawa	Rio Arriba	Aztec	Las Tablas	Jahns, 1946
4	52	Eureka	Rio Arriba	Aztec	Las Tablas	Jahns, 1946
5	52	Fridlund	Rio Arriba	Aztec	Las Tablas	Jahns, 1946
6	52	Pino Verde	Rio Arriba	Aztec	La Madera	Jahns, 1946
7	52	Cribbenville	Rio Arriba	Aztec	La Madera	Jahns, 1946
8	52	Sunnyside	Rio Arriba	Aztec	La Madera	Jahns, 1946
8	52	Globe	Rio Arriba	Aztec	La Madera	Wright, 1948
8	52	La Paloma	Rio Arriba	Aztec	La Madera	Elevatorski, 1979; Jahns, 1946
9	52	Ojo Caliente District	Rio Arriba	Aztec	Ojo Caliente	Jahns, 1946
10	53	Harding Mine	Taos	Raton	Trampas	Jahns & Ewing, 1977
11	54	Pidlite Mine	Mora	Santa Fe	Pecos Falls	Jahns, 1953b
12	54	Elk Mtn. District	San Miguel	Santa Fe	El Porvenir	Jahns, 1946
13	54	Sparks-Stone Property	San Miguel	Santa Fe	El Porvenir	Olson & Adams, 1962

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW MEXICO

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	51	High Noon No. 1		B	<u>Euxenite</u>	Precambrian	Precambrian granite 1700 - 1800 m.y.	
2	51	Gold Hill Area		B	<u>Samarskite</u> , <u>euxenite</u> , <u>allanite</u> , beryl	Precambrian	Precambrian granite 1700- 1800 m.y.	
3	52	Kiawa	Zoned	B	<u>Samarskite</u> , <u>monazite</u> , muscovite, cleaveland- ite, garnet, columbite, fluorite, beryl, magnetite, bismutite, pyrite, chalcopyrite, chalcocite	Precambrian	Precambrian Micaceous quartzite, schist	Samarskite, magnetite and bismutite occur along fractures in massive quartz. Columbite, monazite and purple fluorite are associated with albite- rich zones.
4	52	Eureka	Zoned	C	<u>Monazite</u> , fluorite, garnet, columbite, bismutite, ilmenite	Precambrian	Precambrian quartzite, mica schist	
5	52	Fridlund	Zoned	A	<u>Samarskite</u> , <u>monazite</u> , muscovite, columbite, bismutite, bismuthinite, garnet, fluorite, beryl, Cu-sulfides	Precambrian	Precambrian micaceous quartzite	Monazite, samarskite and columbite are abundant, parti- cularly near the quartz core. Masses of columbite and samarskite up to 14".

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW MEXICO

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
6	52	Pino Verde	Zoned	B	<u>Uraninite</u> , <u>samarskite</u> , <u>monazite</u> , garnet, columbite, fluorite, bismutite	Precambrian	Precambrian micaceous quartzite	A few hundred pounds of monazite mined. Samarskite, monazite and uraninite occur in albite-rich pegmatite. Monazite and columbite occur in albite-rich portions of microcline crystals within the ore.
7	52	Crikbenville	Zoned	E	<u>Samarskite</u> , <u>monazite</u> , mica, fluorite, garnet, columbite, magnetite, ilmenite, hematite, bismutite, chalcocite, bornite	Precambrian	Precambrian micaceous quartzite	Monazite and columbite are abundant in albite-rich areas. Samarskite is associated with quartz-albite zones.
8	52	Sunnyside	Zoned	B	<u>Samarskite</u> , <u>monazite</u> , muscovite, cleavelandite, fluorite, columbite, bismutite, beryl, apatite	Precambrian	Precambrian micaceous schist	Monazite and columbite occur in albite-rich portions of the pegmatite, the latter is much more abundant. Samarskite and bismutite occur in quartz- albite pegmatites.
8	52	Globe	Zoned	B	<u>Samarskite</u> , <u>monazite</u> , muscovite, cleavelandite, fluorite, columbite	Precambrian	Precambrian micaceous schist	Monazite associated with columbite and purple fluorite in albite; samarskite in quartz is late stage.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW MEXICO

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
8	52	LaPaloma	Zoned	B	<u>Samarskite</u> , <u>fergusonite</u> , <u>monazite</u> , muscovite, cleavelandite, beryl, garnet, fluorite, columbite, bismutite	Precambrian	Precambrian micaceous quartzite and quartzose schist.	Samarskite, monazite and columbite occur in quartz and albite-rich zones. Four tons averaging .03% U_3O_8 shipped in 1954.
9	52	Ojo Caliente District	Zoned	B	<u>Samarskite</u> , <u>monazite</u> , garnet, fluorite, beryl, columbite, bismutite	Precambrian	Precambrian gneissic granite, schist, quartzite	Monazite and columbite are locally abundant in albite-rich portions of pegmatites. Samarskite, bismutite and sulfides most common in quartz-albite pegmatite.
10	53	Harding Mine	Zoned	B	<u>Microcline</u> , <u>allanite</u> , <u>thorite</u> , pink muscovite, spodumene, lepidolite, apatite, bismutite, beryl, garnet, columbite-tantalite	Precambrian 1366+ 30 m.y.	Precambrian quartz muscovite schist and amphibolite	Microcline occurs in lepidolite and less commonly with albite. Allanite and thorite very rare.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW MEXICO

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
11	54	Pidlite Mine	Zoned	B	<u>Cyrtolite</u> , <u>microlite</u> , <u>betafite</u> , <u>monazite</u> , muscovite, biotite, lepidolite, cleave- landite, apatite, beryl, fluorite, garnet, spodumene, topaz, tourmaline, magnetite, bismuth, bismutite, columbite- tantallite and other accessory minerals	Precambrian	Precambrian gneiss, schist, amphibolite	Cyrtolite occurs in small biotite books, betafite and monazite occur in the wall zone. Microlite occurs in the lepidolite-rich unit.
12	54	Elk Mtn. District	Zoned	B	<u>Uraninite</u> , <u>samarskite</u> , <u>euxenite</u> , <u>fergusonite</u> , <u>gadolinite</u> , <u>monazite</u> , <u>betafite</u> , cleavelandite, muscovite, garnet, fluorite, columbite, tourmaline, beryl bismutite	Precambrian	Precambrian schist and quartzite	Pegmatites generally occur in schist rather than crystalline rocks. Uranium minerals most commonly occur in albite-mica portions of the pegmatites.
13	54	Sparks-Stone Property	Zoned	B	<u>Euxenite</u> , <u>autunite</u>	Precambrian	Precambrian schist	Produced 10.5 tons averaging .13% U ₃ O ₈ in 1956.

INDEX MAP #51 - NEW MEXICO

1. High Noon No. 1
2. Gold Hill Area

INDEX MAP #52 - NEW MEXICO

- 3. Kiawa
 - 4. Eureka
 - 5. Fridlund
 - 6. Pino Verde
 - 7. Cribbenville
 - 8. Sunnyside
 - 8. Globe
 - 8. La Paloma
 - 9. Ojo Caliente
- District

25 MI TO U.S. 285

25 MI TO U.S. 64

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW YORK

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	55	McLear Pegmatite	St. Lawrence	Ogdensburg	Bigelow	Grauch & Zarinski, 1976; Shaub, 1940; Tan, 1966
2	55	Talcville	St. Lawrence	Ogdensburg	Edwards	Grauch & Zarinski, 1976; Narten & McKeown, 1953
3	55	Benson Mines	St. Lawrence	Ogdensburg	Oswegatchie	Gableman, 1968; Grauch & Zarinski, 1976; McKeown & Klemic, 1953; Narten & McKeown, 1952
4	56	Duane Locality	Franklin	Ogdensburg	Lake Titus	Olson & Adams, 1962
5	57	Shaney No. 1	Lewis	Utica	Brantingham	Gableman, 1968; Grauch & Zarinski, 1976; U.S.A.E.C., 1969
6	57	Stennbrickner Farm	Lewis	Utica	Port Leyden	Grauch & Zarinski, 1976; U.S.A.E.C., 1969
7	58	Batchellerville	Saratoga	Utica	Edinburg	Tan, 1966
8	59	Miles Standish Mine	Orange	Scranton	Greenwood	Grauch & Zarinski, 1976
9	59	Bear Mtn. Localities	Orange-Rockland	Scranton	Popolopen	Grauch & Zarinski, 1976
10	60	Crown Point Spar Co.	Essex	Glens Falls	Crown Point	Tan, 1966
11	60	Spar Bed Hill Quarry	Essex	Glens Falls	Eagle Lake	Tan, 1966
12	61	Corinth Feldspar Co.	Saratoga	Glens Falls	Corinth	Tan, 1966
13	62	Phillips Mine- Camp Smith	Putnam	Hartford	Peekskill	Grauch & Zarinski, 1976; Klemic, et al, 1959
14	62	Cattel Estate	Putnam	Hartford	West Point	Grauch & Zarinski, 1976
15	62	Canor No. 1	Westchester	Hartford	Peekskill	U.S.A.E.C., 1969
16	62	Baylis Quarry	Westchester	Hartford	Mount Kisco	Grauch & Zarinski, 1976; Januzzi, 1959; Tan, 1966

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW YORK

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	55	McLear Pegmatite		B	<u>Uraninite</u> , <u>allanite</u> , biotite-phlogopite, diopside, actinolite- tremolite, talc, sphene, calcite, apatite, molybdenite, rutile, pyrrhotite, magnetite, hematite, limonite, serpentine	Precambrian 1094 m.y.	Precambrian Grenville series marble	Metamorphosed pegmatites; uraninite occurs in white quartz.
2	55	Talcville		B	<u>Uraninite</u> , <u>allanite</u> , molybdenite, pyrite	Precambrian	Precambrian Grenville series marble	
3	55	Benson Mines		C	<u>Allanite</u> , <u>torbernite</u> , magnetite	Precambrian	Precambrian (Grenville) granite gneiss	
4	56	Duane Locality		C	<u>Uraniferous zircon</u> , xenotime	Precambrian	Precambrian (Grenville) paragneiss and orthogneiss	
5	57	Shaneeey No. 1		B	<u>Thorite</u> , <u>uraninite</u>	Precambrian	Precambrian (Grenville) felsic intrusive	Hornblende pegmatite.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW YORK

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
6	57	Stennbrickner Farm		B	<u>Uraninite</u> , pyrite, magnetite, fluorite, sphalerite	Precambrian	Precambrian (Grenville) gneiss and amphibolite	
7	58	Batchellerville	Zoned	B	<u>Uraninite</u> , <u>allanite</u> , biotite, muscovite, apatite, beryl, tourmaline, garnet, fluorite, cerite	Precambrian	Precambrian (Grenville) gneiss and amphibolite	Uraninite occurs near pegma- tite-wall rock contacts; allanite occurs in an inter- mediate zone.
8	59	Miles Standish Mine		B	<u>Uraninite</u> , magnetite, pyrite	Precambrian	Precambrian (Grenville) gneiss (Pochuck Formation)	
9	59	Bear Mtn. Localities		B	<u>Uraninite</u> , <u>monazite</u>		Precambrian amphibolite, granite gneiss	Hornblende pegmatite.
10	60	Crown Point Spar Co.	Zoned	C	<u>Allanite</u> , biotite, hornblende, garnet, tourmaline	Precambrian	Precambrian (Grenville) amphibolite	Allanite cluster of several hundred crystals occurs in an inner intermediate zone. Allanite crystals several feet long reported.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW YORK

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
11	60	Spar Bed Hill Quarry	Zoned	A	<u>Uraninite</u> , <u>thorite</u> , <u>fergusonite</u> , <u>cyrtolite</u> , <u>monazite</u> , <u>allanite</u> , <u>uranophane</u> , biotite, hornblende, tourmaline, cleavelandite?, pyrrhotite, magnetite, topaz, spodumene, and numerous other accessory minerals	Precambrian	Precambrian (Grenville) charnockitic gneiss	Reverse zoning. Uraninite cubes up to 3" and allanite were found in the outer and innermost zones, fergusonite in the intermediate zone. 200 lbs. of allanite recovered.
12	61	Corinth Feldspar Company	Zoned	C	<u>Allanite</u> , <u>uranophane</u> , and <u>unidentified U-mineral</u> , biotite, garnet, zircon	Precambrian	Precambrian (Grenville) biotite-hornblende gneiss, syenitic gneiss	Garnet and zircon are abundant.
13	62	Phillips Mine - Camp Smith	Unzoned	B	<u>Uraninite</u> , <u>allanite</u> , magnetite, pyrrhotite, pyrite, augite, hornblende	Precambrian 970 m.y.	Precambrian hornblende gneiss, diorite	Pegmatite composition is diorite (e.g. hornblende pegmatite). Oligoclase-quartz pegmatite also occurs, but does not contain uraninite. Minor uraninite in wall rock.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NEW YORK

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comment
14	62	Cattel Estate		B	<u>Uraninite</u> , <u>allanite</u> pyrite, hornblende		Precambrian (Grenville) Canada Hill Formation granite, gneiss	Similar to Phillips Mine - Camp Smith occurrence. Hornblende pegmatite.
15	62	Canor No. 1		B	<u>Uraninite</u> , <u>secondary</u> <u>uranium minerals</u>	Precambrian	Precambrian (Grenville) paragneiss and orthogneiss	
16	62	Bayliss Quarry	Zoned	B	<u>Uraninite</u> , <u>uranophane</u> , <u>torbernite</u> , <u>autunite</u> , "gummite", <u>cyrtolite</u> , biotite, muscovite, tourmaline, garnet, columbite, beryl, molybdenite, bismuthinite, calcite, epidote, bertrandite	Devonian 350-400 m.y.	Precambrian (Grenville) Bedford Augen Gneiss	Autunite and torbernite are associated with plagioclase in the outer intermediate zone.

INDEX MAP #55 - NEW YORK

1. McLear Pegmatite
2. Talcville
3. Benson Mines

INDEX MAP #59 - NEW YORK

- 8. Miles Standish Mine
- 9. Bear Mtn. Localities

N

INDEX MAP #60 - NEW YORK
10. Crown Point Spar Co.
11. Spar Bed Hill Quarry

INDEX MAP #61 - NEW YORK
12. Corinth Feldspar
Company

INDEX MAP #62 - NEW YORK

- 13. Phillips Mine-Camp
Smith
- 14. Cattel Estate
- 15. Canor No. 1
- 16. Baylis Quarry

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NORTH CAROLINA

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	63	Ray Mica Mine	Yancey	Knoxville	Burnsville	Grauch & Zarinski, 1976; Lesure, 1968
2	63	Fanny Gouge	Yancey	Knoxville	Celo	Brobst, 1962; Lesure, 1968
3	63	McKinney Mine	Mitchell	Knoxville	Celo	Grauch & Zarinski, 1976; Lesure, 1968
3	63	Carolina Mineral Co. No. 20 Mine	Yancey	Knoxville	Celo	Grauch & Zarinski, 1976; Lesure, 1968
4	63	English Knob Mine	Mitchell	Knoxville	Spruce Pine	Grauch & Zarinski, 1976; Lesure, 1968
4	63	Pink Mine	Mitchell	Knoxville	Spruce Pine	Lesure, 1968
4	63	Wiseman Mine	Mitchell	Knoxville	Spruce Pine	Lesure, 1968
5	63	Flat Rock	Mitchell	Knoxville	Spruce Pine	Grauch & Zarinski, 1976; Lesure, 1968
5	63	Deer Park	Mitchell	Knoxville	Spruce Pine	Grauch & Zarinski, 1976; Lesure, 1968
6	63	Pine Mountain Mine	Mitchell	Knoxville	Spruce Pine	Grauch & Zarinski, 1976; Lesure, 1968
7	63	Deake Mine	Mitchell	Knoxville	Spruce Pine	Grauch & Zarinski, 1976; Lesure, 1968
8	64	Jones Mine	Henderson	Knoxville	Zirconia	Olson, 1952
8	64	Freeman Mine	Henderson	Knoxville	Zirconia	Olson, 1952
9	64	Sheep Cliff Mine	Jackson	Knoxville	Cashiers	Olson, 1952; Wilson & McKenzie, 1978

*Additional pegmatites of the Spruce Pine area are shown on the North Carolina addendum.

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NORTH CAROLINA

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
10	64	Wolf Creek	Jackson	Knoxville	Lake Toxaway	Olson, 1952
11	64	L. M. McCall	Jackson	Knoxville	Sam Knob	Conley, 1958; Wilson & McKenzie, 1978
12	65	Farmington Area	Davie	Winston-Salem	Clemmons	Conley, 1958; Grauch & Zarinski, 1976; S.I.N.B., 1969
13	66	Big Bess Mine	Gaston	Charlotte	Bessemer City	Conley, 1958; Griffitts & Olson, 1953; S.I.N.B., 1969; Wilson & McKenzie, 1978
14	66	A. F. Hoyle Mine	Cleveland	Charlotte	Casar	Griffitts & Olson, 1953
15	67	Knight Mine	Rockingham	Greensboro	Price	Griffitts, et al, 1953

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NORTH CAROLINA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	63	Ray Mica Mine	Unzoned	C	<u>Autunite</u> , <u>monazite</u> , muscovite, biotite, columbite, tourmaline, garnet, beryl, thulite	Carboniferous	Precambrian mica gneiss	Possibly related to nearby muscovite granodiorite.
2	63	Fanny Gouge	Zoned	A	<u>Uraninite</u> , <u>clarkeite</u> , <u>monazite</u> , <u>cyrtolite</u> , <u>uranophane</u> , <u>autunite</u> , <u>torbernite</u> , " <u>gummite</u> " muscovite, biotite, epidote, calcite, thulite, garnet, apatite	Carboniferous	Precambrian mica gneiss	Mining of the deposit for uranium in 1950 was unsuccessful.
3	63	McKinney Mine	Zoned	A	<u>Uraninite</u> , <u>samaraskite</u> , <u>autunite</u> , <u>torbernite</u> , <u>allanite</u> , muscovite, columbite, garnet, beryl, apatite, thulite, epidote, spha- lerite, pyrite, chalcop- pyrite, covellite	Devonian- Carboniferous 300-350 m.y.	Precambrian mica gneiss	Age date on samarskite varies from 300 [±] 40 to 400 [±] 80 m.y.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NORTH CAROLINA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
3	63	Carolina Mineral Co. No. 20 Mine	Zoned	B	<u>Uraninite</u> , <u>samarskite</u> , <u>allanite</u> , <u>cyrtolite</u> , <u>autunite</u> , <u>torbernite</u> , "gummite", muscovite, biotite, garnet, siderite, Cu-sulfides	Carboniferous	Precambrian mica gneiss	Pegmatite is cut by aplite dikes.
4	63	English Knob Mine	Zoned	B	<u>Uraninite</u> , <u>samarskite</u> , <u>monazite</u> , <u>cyrtolite</u> , <u>autunite</u> , <u>torbernite</u> , "gummite", muscovite, garnet, columbite-tantalite, thulite	Carboniferous	Precambrian granite hornblende gneiss	Nearby muscovite granodiorite and pegmatites are intrusive into Precambrian gneiss and schist basement complex.
4	63	Pink Mine	Unzoned	E	<u>Samarskite</u> , <u>allanite</u> , muscovite, garnet, columbite-tantalite, thulite, sulfides	Carboniferous	Paleozoic granite	
4	63	Wiseman Mine	Zoned	B	<u>Samarskite</u> , <u>uranium minerals</u> , muscovite, cleavelandite, garnet, epidote, zoisite, thulite	Carboniferous 300 m.y. (?)	Paleozoic granite	Age dates range from 205 ⁺ 50 to 380- 80 m.y.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NORTH CAROLINA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
5	63	Flat Rock Mine	Zoned	B	<u>Uraninite</u> , <u>cyrtolite</u> , <u>autunite</u> , <u>uranophane</u> , "gummite", muscovite, biotite, garnet, apatite, beryl, thulite	Devonian Carboniferous 340-370 m.y.	Paleozoic muscovite granodiorite, mica gneiss	Pegmatite consanguineous with granodiorite
5	63	Deer Park Mine	Zoned	B	<u>Uraninite</u> , <u>monazite</u> , <u>uranophane</u> , "gummite", muscovite, sulfides	Carboniferous 340 m.y. 580 m.y.	Paleozoic (alaskite) granite Precambrian hornblende- biotite gneiss	Two age dates of 340 m.y. and 580 m.y.
6	63	Pire Mountain Mine	Zoned	C	<u>Allanite</u> , <u>autunite</u> , <u>torbernite</u> , muscovite	Paleozoic	Paleozoic gra- nite, Precam- brian interlay- ered biotite and hornblende gneiss	
7	63	Deake Mine	Zoned	B	<u>Allanite</u> , <u>uranium</u> <u>minerals</u> , muscovite, biotite, garnet, columbite, apatite	Carboniferous	Paleozoic gra- nite, Precam- brian inter- layered bio- tite and horn- blende gneiss	Main pegmatite cut by later pegmatite

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NORTH CAROLINA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
8	64	Jones Mine	Zoned	B	<u>Allanite</u> , <u>monazite</u> , <u>cyrtolite</u> , <u>polycrase</u> , xenotime, zircon	Carboniferous	Precambrian gneiss, schist	Pegmatites in district geologically related to Paleozoic Whiteside Granite.
8	64	Freeman Mine	Zoned	B	<u>Allanite</u> , <u>monazite</u> , <u>cyrtolite</u> , <u>polycrase</u> , xenotime, zircon	Carboniferous	Precambrian gneiss, schist	
9	64	Sheep Cliff Mine	Zoned	B	<u>Samarskite</u> (very rare), muscovite, beryl, garnet	Carboniferous	Precambrian biotite gneiss	Samarskite in perthite- quartz unit.
10	64	Wolf Creek Mine	Zoned	B	<u>Uraninite</u> , <u>autunite</u> , <u>uranothorite</u> , muscovite, garnet	Carboniferous	Precambrian biotite gneiss	
11	64	L. M. McCall		B	<u>Uraninite</u> , <u>samarskite</u> , <u>cyrtolite</u> , muscovite, biotite, garnet, pyrrhotite	Carboniferous	Precambrian biotite gneiss	
12	65	Farmington Area		C	<u>Autunite</u> , columbite	Carboniferous (?)	Precambrian metamorphics	

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

NORTH CAROLINA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
13	66	Big Bess Mine	Zoned	B	<u>Uraninite</u> , muscovite, biotite, beryl, apatite, garnet, tourmaline	Carboniferous	Precambrian Carolina Gneiss, quartzose schist	Pegmatite is located near large granitic intrusive of Carboni- ferous age.
14	66	A. F. Hoyle Mine	Zoned	B	<u>Uraninite</u> , <u>autunite</u> , muscovite, biotite, garnet, apatite, sulfide minerals, calcite, zeolites	Carboniferous	Precambrian Carolina Gneiss, biotite gneiss	Carboniferous garnet- bearing quartz monzonite located south of mine. Uranium minerals occur along fracture surfaces in the wall zone.
15	67	Knight Mine	Zoned	B	<u>Uraninite</u> , <u>allanite</u> , <u>autunite</u> , <u>uranophane</u> , muscovite, garnet	Devonian- Carboniferous	Precambrian biotite- quartz schist	Uranium minerals occur on fractures and cleavage cracks in perthite. Pegmatite may be geneti- cally related to Leather- wood Granite.

NORTH CAROLINA ADDENDUM*

NAME	ZONING	R/A	MINERALOGY	AGE	HOST ROCK
Shaffer (Goodmar) Mine	Zoned	B	<u>Uraninite</u> (?), biotite, apatite, garnet, muscovite	Carboniferous (?)	Mica gneiss
Alfred (Vance) Mine		B	<u>Uraninite</u> (?), vermiculite, garnet, muscovite	Carboniferous (?)	Interlayered biotite and hornblende gneiss
Black Mine		C	<u>Allanite</u> , muscovite, biotite, apatite	Carboniferous (?)	Interlayered hornblende and biotite gneiss
Tom Carpenter (Old Hennessey) Mine		C	<u>Allanite</u> , muscovite, biotite, vermiculite	Carboniferous (?)	Mica gneiss
Charles Rock Mine		C	<u>Allanite</u> , muscovite, biotite, sericite, garnet	Carboniferous (?)	Hornblende gneiss
Powdermill Roughs Mine		C	<u>Allanite</u> (?), muscovite, biotite, sericite, tourmaline	Carboniferous (?)	Interlayered hornblende and biotite gneiss
Marie Mine		B	<u>Uraninite</u> , muscovite, biotite, apatite, garnet	Carboniferous (?)	Mica gneiss
Butler Mine		C	<u>Allanite</u> , muscovite, garnet	Carboniferous (?)	Mica gneiss
Southwest		B	<u>Samarskite</u> (?), <u>uranophane</u> (?), sericite, muscovite, beryl, apatite, spessartite, tourmaline, columbite-tantalite, sericite	Carboniferous (?)	Biotite gneiss

*Data from Lesure (1968)

NORTH CAROLINA ADDENDUM

NAME	ZONING	R/A	MINERALOGY	AGE	HOST ROCK
Gouges Creek Mine		B	<u>Uranium minerals</u> , muscovite, garnet, thulite	Carboniferous (?)	Granite
Hickory Flat Mine		B	<u>Uranium minerals</u> , garnet, thulite, muscovite	Carboniferous (?)	Granite and mica gneiss
Jake Buchanan Mine		B	<u>Uranium minerals</u> , muscovite, beryl, apatite, garnet, monazite	Carboniferous (?)	Mica gneiss
Murphy Rock Mine		B	<u>Uranium minerals</u> , muscovite, biotite, garnet	Carboniferous (?)	Biotite gneiss
Old Susie Phillips Mine		B	<u>Uranium minerals</u> (?), beryl, biotite, garnet, pyrite, columbite-tantalite	Carboniferous (?)	Interlayered biotite and hornblende gneiss
Randolph (Randall) Mine		B	<u>Autunite</u> , biotite, garnet, sulfides	Carboniferous (?)	Mica gneiss
Horse Ridge Mine		B	<u>Uraninite</u> ; <u>secondary</u> <u>uranium minerals</u> , muscovite, garnet	Carboniferous (?)	Interlayered hornblende and biotite gneiss
Peterson Mine		B	<u>Samarskite</u> , <u>uranium minerals</u> , columbite, muscovite	Carboniferous (?)	Mica gneiss

NORTH CAROLINA ADDENDUM

NAME	ZONING	R/A	MINERALOGY	AGE	HOST ROCK
Charles Robinson Mine		B	<u>Uranium minerals</u> , <u>allanite</u> , beryl, garnet, apatite, muscovite	Carboniferous (?)	Mica gneiss
Black Dixie Mine		B	<u>Allanite</u> , muscovite, biotite, vermiculite, garnet, epidote, sericite	Carboniferous (?)	Mica gneiss
Sally Knob Mine		B	<u>Samarskite</u> , <u>allanite</u> , garnet, thulite	Carboniferous (?)	Mica gneiss
Speck Mine		B	<u>Allanite</u> , biotite, muscovite, vermiculite, garnet, epidote	Carboniferous (?)	Mica gneiss
Spider Mine		B	<u>Allanite</u> , epidote, garnet, muscovite	Carboniferous (?)	Biotite gneiss
Charlie Young Mine		B	<u>Allanite</u> , vermiculite, garnet, epidote, thulite, muscovite	Carboniferous (?)	Mica gneiss
James Mine	Zoned	B	<u>Uranophane</u> , garnet, thulite, muscovite	Carboniferous (?)	Granite, mica gneiss
Crabtree No. 1 (Wildcat) Mine	Zoned	B	<u>Uranium minerals</u> (?), muscovite, garnet, copper sulfides	Carboniferous (?)	Granite, biotite gneiss

INDEX MAP #63 - NCRTH CAROLINA

1. Ray Mica Mine
2. Fanny Gouge
3. McKinney Mine
3. Carolina Mineral
Co. No. 20 Mine
4. English Knob Mine
4. Pink Mine
4. Wiseman Mine
5. Flat Rock
5. Deer Park
6. Pine Mountain Mine
7. Deake Mine

INDEX MAP #64 - NORTH CAROLINA

- 8. Jones Mine
- 8. Freeman Mine
- 9. Sheep Cliff Mine
- 10. Wolf Creek
- 11. L. M. McCall

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INDEX MAP #66 - NORTH CAROLINA

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13. Big Bess Mine

14. A. F. Hoyle Mine

INDEX MAP #67 - NORTH CAROLINA

15. Knight Mine

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INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

OKLAHOMA

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	68	Charors Garden	Comanche	Lawton	Odetta	Al-Shaieb, 1978
2	68	Hale Spring Pegmatites	Comanche	Lawton	Saddle Mtn.	Al-Shaieb, 1978

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

OKLAHOMA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	68	Charons Garden		C	<u>Allanite, urariferous zircon</u>		Cambrian granite	Uranium in metamict zircons. The uranium is derived from late stage hydrothermal fluids.
2	68	Hale Spring Pegmatites		C	<u>Allanite, urariferous zircon</u> , aegirine, riebeckite		Cambrian granite	Aegirine-riebeckite pegmatites. Uranium is associated with aegirine, riebeckite, allanite and zircon. The uranium is derived from late stage hydrothermal fluids.

INDEX MAP #68 - OKLAHOMA

1. Charons Gardens
2. Hale Spring Pegmatites

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

PENNSYLVANIA

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	69	Rohrbach Prospect	Berks	Newark	Manatawny	Buckwalter, 1959; Grauch & Zarinski, 1976
2	69	Vera Cruz	Lehigh	Newark	Allentown East	Grauch & Zarinski, 1976
3	69	Williams Quarry	Northampton	Newark	Easton	Grauch & Zarinski, 1976
4	70	McCrea's Quarry	Philadelphia	Wilmington	Germantown	Grauch & Zarinski, 1976; McKinstry, 1949
5	70	Steidler	Chester	Wilmington	Coatesville	Smith, 1978
6	70	Fairmont Water Works	Philadelphia	Wilmington	Philadelphia	Grauch & Zarinski, 1976; McKinstry, 1949
7	70	Dickinson's Mill	Delaware	Wilmington	Philadelphia	Grauch & Zarinski, 1976
8	70	Leiper's Quarry	Delaware	Wilmington	Lansdowne	Grauch & Zarinski, 1976; Smith, 1978; Ward, 1959
9	70	Deshong's Quarry	Delaware	Wilmington	Lansdowne	Grauch & Zarinski, 1976; Ward, 1959
10	70	Glendale Quarry	Delaware	Wilmington	Lansdowne	Smith, 1978; Ward, 1959
11	70	Crozer's Quarry	Delaware	Wilmington	Bridgeport	Grauch & Zarinski, 1976
12	70	Peter Green's Farm	Delaware	Wilmington	Marcus Hook	Grauch & Zarinski, 1976

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

PENNSYLVANIA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	69	Rohrbach Prospect		B	<u>Uraninite</u> , magnetite, ilmenite	Precambrian	Precambrian hornblende gneiss	Associated with ilmenite- magnetite ore.
2	69	Vera Cruz		B	<u>Uraninite</u> , molybdenite		Granite gneiss	
3	69	Williams Quarry		B	<u>Uraninite</u> , <u>thorite</u> , <u>thorianite</u> , <u>autunite</u> , <u>uranophane</u> , <u>boltwoodite</u> ,	Precambrian	Precambrian serpentinized marble	Uranium and thorium minerals occur in pegmatite and host rock.
4	70	McCrea's Quarry		C	<u>Autunite</u> , <u>torbernite</u> , "gummite", <u>uranophane</u> , <u>allanite</u> , pyrite, bornite		Upper Pre- cambrian- Lower Paleo- zoic Wissahi- ckon Greiss	Host rock is argillaceous metasediments.
5	70	Steidler		B	<u>Uraninite</u> , <u>clarkeite</u> , <u>uranophane</u> , <u>meta-</u> <u>torbernite</u> , <u>meta-</u> <u>autunite</u> , <u>phosphuranylite</u>		Upper Pre- cambrian- Lower Paleo- zoic Wissahickon Gneiss and chlorite schist	

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

PENNSYLVANIA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
6	70	Fairmont Water Works		B	<u>Uraninite</u> , <u>autunite</u> , <u>torbernite</u> , " <u>gummite</u> ", molybdenite, ilmerite, pyrite, chalcopyrite		Upper Pre-cambrian Lower Paleozoic Wissahickon Gneiss(?)	
7	70	Dickinson's Mill		B	<u>Uraninite</u> , <u>autunite</u> , " <u>gummite</u> "		Upper Pre-cambrian-Lower Paleozoic Wissahickon Gneiss	
8	70	Leiper's Quarry		B	<u>Uraninite</u> , <u>autunite</u> , <u>torbernite</u> , <u>uranophane</u> , " <u>gummite</u> ", molybdenite, magnetite, ilmenite, pyrite, chalcopyrite		Upper Pre-cambrian- Lower Paleozoic granite gneiss Wissahickon(?)	
9	70	Deshong's Quarry		C	<u>Autunite</u> , <u>torbernite</u> , " <u>gummite</u> "		Upper Pre-cambrian- Lower Paleozoic banded gneiss	

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

PENNSYLVANIA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
10	70	Glendale Quarry		B	<u>Uraninite</u> , <u>clarkeite</u> , <u>uranophane</u> , <u>meta-</u> <u>torbernite</u> , <u>meta-</u> <u>autunite</u> , <u>phosphurany-</u> <u>lite</u>		Upper Pre- cambrian-Lower Paleozoic banded gneiss	
11	70	Crozer's Quarry		B	<u>Uraninite</u> , <u>autunite</u> , <u>torbernite</u> , " <u>gummite</u> "		Upper Pre- cambrian-Lower Paleozoic granite gneiss	
12	70	Peter Green's Farm		B	<u>Uraninite</u> , molybdenite, pyrite, chalcopyrite		Upper Pre- cambrian-Lower Paleozoic Wissahickon Gneiss

INDEX MAP #70 - PENNSYLVANIA

4. McCrea's Quarry
5. Steidler
6. Fairmont Water Works
7. Dickinson's Mill
8. Leiper's Quarry
9. Deshong's Quarry
10. Glendale Quarry
11. Crozer's Quarry
12. Peter Green's Farm

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

SOUTH DAKOTA

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	71	Tin Mountain	Custer	Hot Springs	Bernie	Staatz, et al, 1963
2	71	Bob Ingersoll	Pennington	Hot Springs	Mount Rushmore	Landes, 1928; Page, et al, 1953
3	71	Dan Patch Feldspar Mine	Pennington	Hot Springs	Mount Rushmore	Norton, et al, 1964
4	71	Etta Mine	Pennington	Hot Springs	Mount Rushmore	Norton, et al, 1964

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

SOUTH DAKOTA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Hcst Rock	Comments
1	71	Tin Mountain	Zoned	C	<u>Microlite</u> , muscovite, spodumene, lepidolite, tourmaline, cassiterite, apatite, beryl, columbite-tantalite, loellingite, amblygonite	Precambrian	Precambrian quartz-mica schist, amphibolite	Related to Harney Peak Granite. Microlite occurs in core.
2	71	Bob Ingersoll	Zoned	B	<u>Uraninite</u> , <u>microlite</u> , muscovite, cleavelandite, lepidolite, amblygonite, beryl, columbite, tourmaline, cassiterite	Precambrian 1667 m.y.	Precambrian biotite-garnet-staurolite schist	A small mass of uraninite and associated secondary uranium minerals occurred in amblygonite and quartz with lepidolite. Uranium minerals also occur as very rare constituents in other pegmatites in the Keystone area.
3	71	Dan Patch Feldspar Mine	Zoned	B	<u>Uraninite</u> , muscovite, tourmaline, beryl, apatite, columbite, iron-manganese phosphates including triphylite and heterosite, loellingite(?) pyrite, sphalerite	Precambrian	Precambrian micaceous schist	

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

SOUTH DAKOTA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
4	71	Etta Mine	Zoned	B	<u>Uraninite</u> , <u>torbernite</u> , muscovite, apatite, cassiterite, tantalite, tourmaline, spodumene, stannite, beryl, iron- manganese phosphates	Precambrian	Precambrian quartz-mica schist

BLACK HILLS NATIONAL FOREST

PENNINGTON COUNTY

CUSTER COUNTY

PENNINGTON COUNTY

CUSTER COUNTY

CUSTER STATE PARK

BLACK HILLS NATIONAL FOREST

BLACK HILLS NATIONAL FOREST

WIND CAVE NATIONAL PARK

INDEX MAP #71 - SOUTH DAKOTA

1. Tin Mountain
2. Bob Ingersoll
3. Dan Patch Feldspar
4. Etta Mine

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

TENNESSEE

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15 Minute Series	References
1	72	Big Flats Branch	Carter	Johnson City	Iron Mtn. Gap	Grauch & Zarinski, 1976; Maher (written comm.), 1979
2	73	Gladys Roberts	Carter	Winston-Salem	Elk Park	Grauch & Zarinski, 1976; Maher (written comm.), 1979
3	73	Row Branch	Carter	Winston-Salem	Elk Mills	Grauch & Zarinski, 1976; Maher (written comm.), 1979
4	73	Pearson Farm	Johnson	Winston-Salem	Elk Mills	Grauch & Zarinski, 1976; Maher (written comm.), 1979
5	73	Dewey Payne	Carter	Winston-Salem	Elk Mills	Grauch & Zarinski, 1976; Maher (written comm.), 1979

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

TENNESSEE

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	72	Big Flats Branch		B	<u>Uranothorite</u> , <u>samarskite</u> , <u>euxenite</u>	Precambrian	Precambrian Cranberry Granite	Mica-poor. Thorium predominates
2	73	Gladys Roberts		B	<u>Uranothorite</u> , <u>samarskite</u> , <u>euxenite</u>	Precambrian	Precambrian Cranberry Granite	Mica-poor. Thorium predominates
3	73	Row Branch		B	<u>Uranothorite</u> , <u>samarskite</u> , <u>euxenite</u>	Precambrian	Precambrian Cranberry Granite	Mica-poor. Thorium predominates
4	73	Pearson Farm		B	<u>Urancthorite</u> , <u>samarskite</u> , <u>euxenite</u>	Precambrian	Precambrian Cranberry Granite	Mica-poor. Thorium predominates
5	73	Dewey Payne		B	<u>Urancthorite</u> , <u>samarskite</u> , <u>euxenite</u>	Precambrian	Precambrian Cranberry Granite	Mica-poor. Thorium predominates

INDEX MAP #72 - TENNESSEE

1. Big Flats Branch

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NATIONAL
FOREST

CHEROKEE NATIONAL
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CHEROKEE NATIONAL
FOREST

INDEX MAP #73 - TENNESSEE

2. Gladys Roberts
3. Row Branch
4. Pearson Farm
5. Dewey Payne

N

10 1/4 SOUTH

15'

ELIZABETH TON 23 MI

900 000 FEET IN C-1

SPRUCE PINE 18 MI

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

TEXAS

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	74	Duncan-Elmore	El Paso	El Paso	North Franklin Mtn.	Olson & Adams, 1962
2	75	Rode Ranch	Llano	Llano	Oxford	Ehlmann, et al, 1964
3	75	Clear Creek	Burnet	Llano	Council Creek	Crook, 1977

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

TEXAS

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	74	Duncan-Elmore		B	<u>Euxenite</u> , <u>monazite</u>		Precambrian granite(?)	
2	75	Rode Ranch	Zoned	B	<u>Fergusonite</u> , <u>cyrtolite</u> , <u>gadolinite</u> , <u>allanite</u> , "thorogummite", biotite, bastnaesite, magnetite, Fe oxides, garnet, beryllium hydroxide		Precambrian granite in the Valley Springs Gneiss	Radioactivity associated with microcline and biotite in perthite zone. Fergusonite and cyrtolite mainly in microcline.
3	75	Clear Creek	Zoned	B	<u>Uraninite</u> , <u>samarskite</u> , <u>cyrtolite</u> , <u>allanite</u> , <u>gadolinite</u> , <u>fergusonite</u> , <u>yttrocrasite</u> , biotite, magnetite, fluorite, garnet, bastnaesite, zircon, Fe oxides, pyrite, pyrolusite		Precambrian Valley Springs Gneiss	Near margin of the Lone Grove granite pluton.

INDEX MAP #74 - TEXAS
1. Duncan-Elmore

INDEX MAP #75 - TEXAS

2. Rode Ranch
3. Clear Creek

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

UTAH

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	76	Willard Group	Box Elder	Brigham City	Willard	Olson & Adams, 1962
2	77	Sheeprock	Tooele	Delta	Erickson Knoll	Olson & Adams, 1962

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

UTAH

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	76	Willard Group		C	<u>Cyrtolite</u>		Upper Pre-cambrian meta-sediments	
2	77	Sheeprock Area		B	<u>Samarskite</u> , biotite, magnetite		Upper Pre-cambrian metasediments	Thorium-bearing mineral occurs with biotite and magnetite in aplitic pods.

INDEX MAP #76 - UTAH
1. Willard Group

ELEVATION 4195
OCTOBER 1969

INDEX MAP #77 - UTAH
2. Sheeprock Area

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

VERMONT

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	78	Snow Mountain (1)	Bennington	Glens Falls	Manchester	Gableman, 1968; Grauch & Zarinski, 1976; U.S.A.E.C., 1969
2	78	Snow Mountain (2)	Bennington	Glens Falls	Londonderry (15')	Grauch & Zarinski, 1976

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

VERMONT

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	78	Snow Mountain (1)		B	<u>Uraninite</u> , magnetite, pyrite		Precambrian gneiss, amphibolite	
2	78	Snow Mountain (2)		B	<u>Uraninite</u> , <u>allanite</u> , magnetite		Precambrian greenstone	Pegmatite occurs as segregations within the greenstone.

N

1. Snow Mountain (1)
2. Snow Mountain (2)

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

VIRGINIA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
4	80	Champion	Zoned	C	<u>Micro</u> lite, <u>pyrochlore</u> , <u>allanite</u> , <u>monazite</u> , tourmaline, garnet, beryl, calcite, arseno- pyrite, scorodite, tantalite-columbite, zircon, galena, pyrite, chalcopryite, muscovite		Precambrian Wissahickon mica gneiss and horn- blende schist	Microlite occurs in albite; pyrochlore, monazite, zircon and columbite- tantalite occur between quartz and feldspar crystals within the wall zone.
5	80	White Peak No. 1	Zoned	B	<u>Samarskite</u> , muscovite, biotite, beryl, garnet, tourmaline, columbite- tantalite		Precambrian mica-schist	U-rich samarskite.

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

VIRGINIA

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	79	Bedford Area	Bedford	Roanoke	Moneta	Griffitts, et al, 1953
2	80	Rutherford Mine	Amelia	Richmond	Amelia Court House	Lemke, et al, 1952; Sweet, 1974
3	80	Morefield Mine	Amelia	Richmond	Amelia Court House	Lemke, et al, 1952; Sweet, 1974
4	80	Champion Mine	Amelia	Richmond	Chula	Lemke, et al, 1952
5	80	White Peak No. 1	Powhatan	Richmond	Fine Creek	Griffitts, et al, 1953

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

VIRGINIA

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	79	Bedford Area	Zoned	B	<u>Samarskite</u> , <u>fergusonite</u> , muscovite, biotite, garnet, thulite, columbite-tantalite		Precambrian hornblende- biotite schist	Samarskite occurs as large intergrowths with columbite. Area includes Wheatly, Mitchell and Thunder Hill pegmatites. Pegmatites are genetically related to the Leatherwood Granite (quartz diorite).
2	80	Rutherford Mine	Irregularly B Zoned		<u>Fergusonite</u> , <u>allanite</u> , <u>monazite</u> , <u>microlite</u> , muscovite, biotite, cleavelandite, tanta- lite-columbite, cassiterite, beryl, fluorite, topaz, garnet and numerous other accessory minerals		Precambrian Wissahickon biotite gneiss and hornblende gneiss	Microlite and other acces- sories occur between cleavelandite crystals. The pegmatites in the Amelia district may be genetically related to the biotite-quartz monzonite Redoak Granite.
3	80	Morefield Mine	Irregularly C Zoned		<u>Microlite</u> , <u>allanite</u> , <u>monazite</u> , biotite, muscovite, cleavelandite, beryl, cassiterite, columbite, fluorite, tourmaline and numerous other accessory minerals		Precambrian interlayered biotite- hornblende schist	Microlite occurs in cleaveland- ite, monazite is associated with albite. Complex pegmatites in the Amelia district are affected by hydrothermal alteration.

INDEX MAP #79 - VIRGINIA

1. Bedford Area

N

INDEX MAP #80 - VIRGINIA

1. Rutherford Mine
2. Morefield Mine
3. Champion Mine
4. Champion Mine
5. White Peak No. 1

N

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

WASHINGTON

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	81	Sanpoil	Okanogan	Okanogan	Bald Knob (15')	Huntting, 1956; Olson & Adams, 1962
2	81	Colville Area	Ferry	Okanogan	Sherman Peak (15')	Ross, 1969
3	82	Peterson	Grant	Ritzville	Electric City	Huntting, 1956; Olson & Adams, 1962
4	83	Chelan Area	Chelan	Ritzville	Chelan Falls	Ross, 1969
5	84	Kaniksu Area	Pend Oreille	Sandpoint	Timber Mtn.	Ross, 1969
6	85	Spokane Area	Spokane	Spokane	Mt. Spokane (15')	Ross, 1969

GEOLOGIC FEATURES OF URANIUM-AND THORIUM BEARING PEGMATITES

WASHINGTON

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	81	Sanpoil	Zoned	B	<u>Uraninite</u> , <u>samarskite</u> , biotite, muscovite, garnet, violet fluorite	Cretaceous	Mesozoic gneiss, and migma- tite	
2	81	Colville Area	Zoned	B	<u>Uraninite</u> , <u>autunite</u> , muscovite, biotite, garnet	Cretaceous	Cretaceous granite and granite gneiss as well as Paleozoic meta- sediments	Various pegmatites in the area are genetically related to the Colville batholith.
3	82	Peterson	Zoned	B	<u>Uraninite</u> , <u>euxenite</u> , <u>cyrtolite</u> , <u>allanite</u> , <u>brannerite</u> , biotite, chlorite	Cretaceous	Cretaceous(?) biotite granite	Genetically related to the Colville batholith.
4	83	Chelan Area	Zoned	B	<u>Uraninite</u> , muscovite, biotite, garnet	Mesozoic	Mesozoic quartz monzonite	Pegmatites occur in the Chelan batholith. Urani- nite associated with biotite in small pegmatite cutting larger pegmatite.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

WASHINGTON

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
5	84	Kaniksu	Zoned	B	<u>Uraninite</u> , <u>autunite</u> , <u>torbernite</u> , plumose mica, beryl, tourma- line, garnet, bismuthi- nite, columbite	Cretaceous	Cretaceous biotite and muscovite granite	Various pegmatites are genetically related to the Kaniksu batholith. Radio- active minerals occur as replacement or fracture filling. Three hundred pounds of radioactive minerals were produced.
6	85	Spokane Area	Unzoned	B	<u>Uraninite</u> , muscovite, beryl, garnet, tourmaline	Cretaceous	Cretaceous granite and Precambrian gneiss and quartzite	In some cases uraninite is concentrated near pegmatite contact. Pegmatites are genetically related to the Loon Lake batholith.

INDEX MAP #81 - WASHINGTON

1. Sanpoil
2. Colville Area

N

INDEX MAP #82 - WASHINGTON

3. Peterson

INDEX MAP #83 - WASHINGTON
4. Chelan Area

WENATCHEE 30 MI.
900 000 FEET (SOUTH)

WENATCHEE 30 MI.

INDEX MAP #84 - WASHINGTON
5. Kaniksu Area

INDEX MAP #85 - WASHINGTON

6. Spokane Area

N

INDEX OF LOCALITIES OF URANIUM-AND THORIUM-BEARING PEGMATITES

WYOMING

Loc. #	Map #	Name	County	USGS Topo Map 1:250,000 Sheet	7½-or 15- Minute Series	References
1	86	Angie Claims (Beartooth Plateau)	Park	Cody	Deep Lake (15')	Olson & Adams, 1962; Pierce, 1965
2	86	Ralston Area	Park	Cody	Deep Lake (15')	Olson & Adams, 1962; Osterwald & Osterwald, 1966; Pierce, 1965
3	87	Allie Claim Area	Natrona	Arminto	Badwater NE	Olson & Adams, 1962; Osterwald & Osterwald, 1966
4	88	Platt Pegmatite	Carbon	Rawlins	Elkhorn Point	Houston, 1961; Osterwald & Osterwald, 1966
5	88	Albany-Foxpark Area	Albany	Rawlins	Albany, Foxpark	Hanley, et al, 1950; Olson & Adams, 1962
6	89	Tie Siding Area	Laramie	Cheyenne	Sherman Mtns.	Olson & Adams, 1962; Osterwald & Osterwald, 1966

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

WYOMING

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
1	86	Angie Claims		C	<u>Gadolinite</u> and other rare-earth minerals	Precambrian(?)	Archean 2500 m.y. Precam- brian granite gneiss and granite	
2	86	Ralston Area		C	<u>Allanite</u> and other rare-earth minerals	Precambrian(?)	Archean 2500 m.y. Precam- brian granite gneiss and granite	
3	87	Allie Claim Area		C	<u>Allanite</u>	Precambrian(?)	Archean 2500 m.y. Precam- brian gneiss	
4	88	Platt Pegmatite	Zoned	A	<u>Euxenite</u> , <u>allanite</u> , monazite, muscovite, biotite, cleavelandite, tourmaline, garnet	Precambrian	Early Prote- rozoic Pre- cambrian granite gneiss horn- blende schist	⁺ 10,000 lbs. of euxenite produced. Euxenite associated with K-spars.

GEOLOGIC FEATURES OF URANIUM-AND THORIUM-BEARING PEGMATITES

WYOMING

Loc. #	Map #	Name	Zoning	R/A	Mineralogy	Age	Host Rock	Comments
5	88	Albany-Foxpark Area	Unzoned	B	<u>Euxenite</u> , <u>fergusonite</u> , <u>allanite</u> , muscovite, cleavelandite, garnet, tourmaline, beryl, tantalite	Precambrian	Early Proterozoic Precambrian tourmalinized mica schist and gneiss	Tantalite occurs in cleavelandite.
6	89	Tie Siding Area		C	<u>Allanite</u>	Precambrian	Precambrian granitic rocks 1300- 1400 m.y.	Related to Sherman pluton.

45' 1000 FEET EAST CENTRAL

INDEX MAP #86 - WYOMING

1. Angie Claims
(Beartooth Plateau)
2. Ralston Area

INDEX MAP #88 - WYOMING

4. Platt Pegmatite

5. Albany-Foxpark Area

N

200 FEET (EAST)

URANIUM- AND THORIUM-BEARING
PEGMATITES OF THE UNITED STATES

PART III

SELECTED ANNOTATED BIBLIOGRAPHY
OF
PEGMATITES

INTRODUCTION

In the continuing search for uranium and thorium in the United States, relatively little effort has been directed toward the investigation of domestic pegmatites as a possible economic source of radioactive raw materials. The lack of attention given to pegmatite deposits is due, in part, to the negligible amount of uranium and thorium produced from domestic pegmatites and to the relative abundance of these elements available from other ores. Radioactive minerals are, however, not uncommon in pegmatites and have been mined in the past from such deposits in various parts of the world. Ore bodies, considered to be pegmatites by some geologists, are currently being mined for uranium in Canada, also pegmatites comprise at least part of the ore zone at the Rössing deposit in Namibia. The possibility that there are pegmatites in the United States that could be profitably mined for radioactive elements cannot be discounted.

The Selected Annotated Bibliography of Pegmatites was compiled to provide a survey of the literature relating to pegmatite geology and mineralogy that is particularly relevant to uranium- and thorium-bearing pegmatites. Emphasis is on occurrences in the United States, however, foreign deposits are included where pertinent. The Bibliography is part of a general study of Uranium- and Thorium-Bearing Pegmatites conducted by Derry, Michener and Booth, Inc. (DMB) under contract to Bendix Field Engineering Corporation (BFEC) for the National Uranium Resource Evaluation (NURE) program managed by the Grand Junction Office of the U. S. Department of Energy (DOE).

In compiling the Bibliography, we have sought to include much of the material related to the present study. Additional articles, however, are given in the References Cited section in Part I.

The Bibliography is arranged alphabetically by senior author. Bibliographic data closely follows the standard U. S. Geological Survey format. The annotations are meant not to synopsise, but to illustrate the nature of the referred study. There are 283 references each of which has been given an identifying code.

An alphabetical index of subject headings follows the Bibliography. Following each heading is a list of code numbers indicating references with information pertinent to specific subjects.

BIBLIOGRAPHY

- A -

- A- 1. Adams, J. A. S. and Lowder, W. M., eds., 1964; The natural radiation environment: Chicago Univ. Press, 1069 p.

A comprehensive volume on natural (rock, water, air and cosmic) radiation. The first three chapters on granitic rocks and the continental crust are not specific to pegmatites, but are of value in presenting generalized regional data.

- A- 2. Adams, J. W., 1966, Rare earths, in Mineral resources of California: California Div. Mines and Geology Bull. 191, p. 350-355.

Summarizes radioactive pegmatite occurrences in California. Index map and table giving mineralogy and references are provided.

- A- 3. _____ and Iberall, E. R., 1973, Bibliography of the geology and mineralogy of the rare earths and scandium to 1971: U. S. Geol. Survey Bull. 1366, 195 p.

Although compiled for the aid of research in rare earths, this bibliography contains many references pertinent to uranium and thorium in pegmatites.

- A- 4. Al-Shaieb, Zuhair, 1977, Uranium-rich pegmatite dikes in the Wichita Mountains, Oklahoma: NURE Geology Uranium Symposium, Igneous Host Rock Session, Grand Junction, Colo., Dec. 7-8, 1977, 37 p. Also U. S. Geol. Survey Circ. 753, p. 61-63.

Riebeckite-aegirine pegmatite dikes contain 40-100 ppm uranium and up to 10% zircon. The uranium is derived from a late hydrothermal stage which followed an early magmatic phase.

- A- 5. _____, 1978, Uranium-rich pegmatite dikes in Wichita Mountains, Oklahoma (abs): 1977 NURE Uranium Geology Symposium, Abstracts and Visual Presentations, Grand Junction, Colo., p. 165-166.

Aegirine-riebeckite pegmatite dikes in the Hale Spring area,

Oklahoma contain up to 115 ppm U. Uranium is associated with aegerine, riebeckite, allanite and zircon.

Pegmatites in the Charons Garden area, Oklahoma contain metamict zircon with up to 1500 ppm U, whereas only 50 ppm U are present in non-metamict zircons.

- A- 6. Åmli, Reidar, 1977, Internal structure and mineralogy of the Gloserheia granite pegmatite, Froland, southern Norway: Norsk. Geol. Tidsskr., v. 57, no. 3, p. 243-262.

Pegmatite shows a well developed and regular zonation around a quartz core. Eight zones are recognized. Radioactive minerals include allanite, uraninite, thorite, monazite, euxenite and several secondary uranium minerals.

Uraninite was found embedded in plagioclase in intermediate zone III associated with euxenite, zircon and secondary uranium minerals.

- A- 7. Arribas, Antonio, 1967, Mineralogy and metallogeny of Spanish uranium deposits. Sierra Albarana (Cordoba) (in Spanish): Real. Soc. Espana, Hist. Natur., Secc. Geol., Bol., v. 65, no. 2, p. 157-170; abs. in Chem. Abs., v. 68, item 116364e, 1968.

Uranium-bearing pegmatites occur in highly metamorphosed Cambrian sediments. Brannerite (51.7% U_3O_8) is the most abundant radioactive mineral, but uraninite, monazite, becquerelite, autunite and torbernite are also found. Accessory minerals include ilmenite, rutile, magnetite, tourmaline and sulphides. Beryl is absent.

- A- 8. Augustithis, S. S., 1964, Geochemical and ore-microscopic studies of hydrothermal and pegmatitic primary uranium paragenesis: Nova Acta Leopoldina, Leipzig, v. 28, no. 1/0, p. 1-94; abs. in Min. Abs. v. 17, p. 480, 1967.

Uraniferous pegmatites characterized by: U, Th, Y, Zr, Hf, Nb, Ta, Ti, REE's, and the minerals zircon and monazite.

- A -

Th, Y, Zr, Hf and REE's are most indicative of pegmatitic uraninite. Bi, Sb and As characterize hydrothermal type uranium deposits. Ti and Zr are in both pegmatitic and hydrothermal uraninite.

Ruggles mine uraninite is possibly not of pegmatitic origin (low Th). Numerous photomicrographs of uraninite and pitchblende from various deposits are shown.

- A- 9. Augustithis, S. S. and Minatidis, D. G., 1979, The significance of trace elements in solving petrogenetic problems and controversies: Chem. Geol., v. 25, p. 213-218.

A discussion of the advantages and dangers of using trace element geochemistry in solving geologic problems. Trace element studies by themselves are of limited value, but coupled with structural, textural and other geologic data definitely contribute to greater understanding.

Hydrothermal uraninites lack the abundance of Th, Zr, Y and REE's found in uraninite of pegmatitic origin.

- B -

- B- 1. Backström, J. W. von, 1970, The Rössing uranium deposit near Swakopmund, Southwest Africa, in Uranium Exploration Geology: Internat. Atomic Energy Comm., Vienna, p. 143-149.

Mineralized area is irregular in shape and about 700 m in diameter. Ore is in a very coarse-grained leucocratic granite composed almost entirely of quartz, microcline and microcline-perthite; biotite is often a minor constituent, but locally may become major. Uraninite ranges in size from a few microns to 0.3 mm. Betafite and several secondary uranium minerals are present. Associated minerals are zircon and monazite (often with uraninite), minor pyrite, chalcopryite, molybdenite, ilmenite, magnetite and rare fluorite. Pegmatites are of alaskitic composition.

- B- 2. Bain, G. W., 1950, Geology of the fissionable materials: Econ. Geol., v. 45, no. 4, p. 273-323.

Generalized discussion of geology, distribution, and resource potential of known uranium and thorium deposits. Pegmatites are noted as being unfavorable for uranium ore deposits because they generally have only minor amounts of uranium, usually in grades less than 0.01%, and mostly in refractory minerals. Areas with uraniferous pegmatites are unlikely to host other uranium deposits.

- B- 3. Baldwin, A. B., 1970, Uranium and thorium occurrences on the north shore of the Gulf of St. Lawrence: Canadian Mining and Metall. Bull., vol. 63, no. 698, p. 699-707.

Pegmatites and granites are host rocks for disseminated radioactive minerals that include uraninite, uranothorite, uranothorianite, monazite and minor zircon and allanite. At Sept-Iles the pegmatites are chiefly pink K-feldspar, quartz, plagioclase and biotite. Magnetite is associated with the radioactive minerals. In the Baie Johan Beetz area, the greatest concentrations of radioactive minerals occur in white to gray pegmatites containing much plagioclase and are associated with magnetite, biotite, molybdenite and smoky quartz. Intense brown hematitic alteration and the development of uranophane on joint surfaces have been noted in mineralized areas. White pegmatites containing muscovite are always barren of radioactivity.

- B- 4. Bannerman, H. M., Quarrier, S. S. and Schooner, Richard, 1968, Mineral deposits of the central Connecticut pegmatite district: State Geol. and Nat. Hist. Survey of Connecticut, Guidebook No. 2, New England Intercol. Geol. Conf., 60th, New Haven, Sec. F6, p. 1-7.

Describes Hale and Strickland quarries near Middletown, Connecticut. Pegmatites mined for feldspar in these quarries have been a source of specimens of primary and secondary

uranium minerals including oxides, multiple oxides, phosphates and silicates. An index map shows the location of these and other pegmatites in the area.

- B- 5. Barton, W. R. and Goldsmith, C. E., 1968, New England beryllium investigations: U. S. Bur. Mines, Rept. Inv. 7070, 177 p.

Briefly describes various beryl pegmatites in New England with radioactive mineral occurrences mentioned. Location maps for each occurrence are provided.

- B- 6. Bateman, J. D., 1955, Recent uranium developments in Ontario: Econ. Geology, v. 50, p. 361-372.

Uraninite is disseminated in granitic to syenitic granular dikes and is concentrated in zones of biotite or pyroxene crystals near both hangingwall and footwall. The deposits are considered as being late magmatic or deuteric in origin, as the radioactive material is also associated with chalcopryrite and molybdenite.

- B- 7. Berman, R. M., 1957, The role of lead and excess oxygen in uraninite: Am. Mineralogist, v. 42, nos. 11 and 12, p. 705-731.

Discusses variations in properties of uraninite studied by X-ray and analytical methods. Pegmatite uraninite represented by 16 samples for which unit cell and partial analyses are given. Cell size of pegmatite uraninite is, in general, larger than those from vein or sedimentary deposits.

- B- 8. Berning, J., Cook, R., Hiemstra, S. A. and Hoffman, U., 1976, The Rössing uranium deposit, South West Africa: Econ. Geology, v. 71, p. 351-368.

Uranium mineralization is associated with a syenitic alaskite which shows wide textural variations ranging from aplitic to granitic to pegmatitic. The deposits may be concordant, discordant or replacements in the intensely folded gneisses, schists, marbles and limestones of the Khan and Rössing

formations. Uranium-bearing minerals are mainly uraninite and its alteration products with minor betafite. Host rocks are Precambrian. Mineralogy and origin of the ores as well as metallurgical treatment are discussed.

- B- 9. Bever, J. E., 1953, Notes on some mineral occurrences in the Guffey region, Colorado: Am. Mineralogist, v. 38, p. 138-141.

An "unusual concentration" of euxenite was found in the core margin unit of a small zoned pegmatite. The euxenite was associated with abundant coarse biotite and magnetite. Tantalite was also found in the deposit.

- B-10. Billings, M. P., 1941, Pegmatites of Massachusetts: Mass. Dept. Public Works - - U. S. Geol. Survey Cooperative Geologic Project, Bull. 5, 22 p.

The principal pegmatites in Massachusetts are located and described. Areas considered favorable for pegmatites are in a central belt extending from Greenfield to Pittsfield. Most pegmatites are small and of no commercial significance. Uranium minerals are noted near Cape Ann, near Woburn, at Rollstone Hill and at McKinney's north of Norwich.

- B-11. Billings, M. P. and Wolfe, C. W., 1944, Spodumene deposits in the Leominster-Sterling Area, Massachusetts: Mass. Dept. of Public Works Inf. Circ. 3, 9 p.

Spodumene-bearing pegmatites are exposed near Leominster and Sterling, Mass. Average spodumene content is estimated at 10.4 percent. Quartz makes up 25 percent and feldspar 64 percent of the average pegmatite. A location map is provided. Radioactivity, uranium and thorium are not mentioned.

- B-12. Bjørlykke, Harald, 1935, The mineral paragenesis and classification of the granite pegmatites of Iveland, Setesdal, southern Norway: Norsk. Geol. Tidsskr., v. 14, p. 211 - 311.

Pegmatites in southern Norway may be divided into two groups: microcline-quartz dikes of magmatic origin and cleavelandite-quartz dikes formed by later hydrothermal-pneumatolytic activity. Magmatic pegmatites contain more of the rare-earth, uranium and thorium minerals. These are present in a definite order of crystallization reflecting the changing composition of the parent magma.

Cleavelandite-quartz pegmatites are younger than the magmatic type. They do not exhibit distinct sequences of crystallization and contain little rare earths, tungsten, thorium or uranium.

Uraninite, thorite and uranothorite occur only in magmatic pegmatites and only when uranium and thorium are present in the parent magma in excessive amounts. Uraninite is particularly rare, being found in only 4 dikes.

- B-13. _____, 1937, The granite pegmatites of southern Norway: Am. Mineralogist, vol. 22, no. 4, p. 241-255.

Norwegian pegmatites were studied and results illustrate the formation of different uranium-thorium minerals depending upon amounts and proportions of rare-earth elements and P, Si, Ca, Nb, Ti, Ta and Fe. Uraninite forms only when an excess of uranium is present in the original liquor.

Generally, those pegmatites with irregular structure will contain more rare earths and a more varied mineralogy than pegmatites exhibiting simple regular dike-like structure.

- B-14. Boos, M. F., 1954, Genesis of Precambrian granitic pegmatites in the Denver Mountain Parks area, Colorado: Geol. Soc. America Bull., v. 65, no. 2, p. 115-141.

Differences in texture, mineralogy, structure, etc. are used to relate simple pegmatites to one of five granitic intrusives near Denver, Colorado. Uranium minerals are not prominent,

although allanite (orthite) is present in "considerable" quantities in two of the five pegmatite series.

Some of the few complex pegmatites present do contain radioactive material. Complex pegmatites are in contact with more than one granite and may represent mixing of two or more simple pegmatite types.

Pegmatite locations are given on maps and in tables.

- B-15. Borisov, P. A., 1937, Pegmatites of the Chupa Fjord district: Internat. Geol. Cong., 17th, Moscow and Leningrad 1937, Guide to Excursions, The Northern Excursion - The Karelian Autonomous Soviet Socialist Rep., p. 117-128.

Zoned pegmatites show quartz cores, feldspathic intermediate zones and quartz-oligoclase-biotite wall zones. Uraninite is found in wall zones with tourmaline and garnet. Other minerals found include allanite, zircon, xenotime, monazite, supergene U-minerals and thucolite.

- B-16. Bowie, S. H. U., 1978, Global distribution of uranium ores and potential UK deposits, in Duff, P. McL.D. (ed.). Geological aspects of uranium in the environment: Geol. Soc. Misc. Papers, no. 7, p. 12-20.

Rössing, S. W. Africa, is a relatively low grade (350 ppm U_3O_8) deposit that is economic only when worked on a large scale. It has given pegmatites a new importance. At Rössing, uranium occurs mainly in uraninite in alkali-feldspar pegmatites. Betafite and davidite also occur in appreciable amounts and there is an abundance of secondary minerals in near-surface rocks.

Bancroft, where the grade averages 0.1 percent U_3O_8 , is considered to be pegmatitic.

- B-17. Brobst, D. A., 1962, Geology of the Spruce Pine district, Avery, Mitchell, and Yancey Counties, North Carolina: U. S. Geol. Survey

Bull. 1122-A, 26 p.

Deake, Flat Rock, McKinney, Pink and Wiseman are uraniferous pegmatites in Mitchell Co., as are the Carolina Mineral Company No. 20 and Ray mines in Yancey Co. The Fanny Gouge pegmatite was mined unsuccessfully for uranium in 1950. (Mines not shown on maps accompanying report.)

- B-18. Brotzen, Otto, 1959a, Outline of mineralization in zoned granitic pegmatites, a qualitative and comparative study: Geol. Foren., Stockholm Forh., v. 81, no. 2, p. 1-98.

Examples of simple zoned granitic pegmatites from the Stockholm area are described. Radioactive accessory minerals occur sporadically. Deposits are compared with similar pegmatites in Scandinavia, Italy, Japan and Korea. Complex pegmatites, those with muscovite, late albite, lithium minerals and phosphate minerals, are also described in detail. These pegmatites show a modified zonal arrangement.

Observations of both simple and zoned pegmatites serve as the basis for interpretation of paragenetic relations. A synopsis of pegmatite features such as mineralization, crystallization and replacement is presented.

- B-19. _____, 1959b, Mineral-association in granitic pegmatites: Geol. Foren., Stockholm Forh., v. 81, no. 2, p. 231-296.

A descriptive paper which examines the association of various accessory minerals from granitic pegmatites containing feldspars, micas, quartz, petalite and spodumene. The following radioactive accessory minerals were included: allanite, monazite, euxenite and fergusonite. The data are presented in numerous tables.

- B-20. Brown, L. J. and Malan, R. C., 1954, Reconnaissance for uranium in the south central part of Colorado: U. S. Atomic Energy Comm., RME-1044, 17 p.

Euxenite and other radioactive minerals are found in pegmatites on the west side of the Sangre de Cristo Mountains in Colorado. Report describes the Bob Cat and Mocking Bird pegmatites with sketch maps and analytical data from channel samples.

- B-21. Brown, W. R., 1962, Mica and feldspar deposits of Virginia: Virginia Div. of Mineral Resources, Min. Res. Rept. 3, 195 p.

Data on Amelia and Powhatan areas. Radioactive minerals are not discussed, but the article is useful for location and general descriptions.

- B-22. Buntebarth, Gunter, 1976, Distribution of uranium in intrusive bodies due to combined migration and diffusion: Earth and Planetary Sci. Letters, v. 32, p. 84-90: abs. in Min. Abs., v. 28, no. 2, 77-1736.

Uranium enrichment in border zones of magmatic bodies is caused by the migration of uranium-rich hydrous solutions along intergranular paths toward the contact zone with the wall rock. Examples given are Mont Blanc granite (Swiss Alps) and a pluton in the USSR.

- B-23. Butler, A. P., Jr., 1975, Uranium potential of pyrochlore-bearing sanidine-calcite-aegirite-biotite pegmatite and syenite, Bearpaw Mountains, Montana: U. S. Geol. Survey, Open-File Report 75-635, 3 p.

A zoned pegmatite cuts the Rocky Boy syenite complex in the Bearpaw Mountains of Montana.

Upwards of 100,000 tons of rock grading 0.2% U_3O_8 and 0.3% Nb_2O_5 are estimated to be present in the wall zone of a calcic pegmatite. The wall zone contains pyrochlore, zircon, apatite and sulfides in an intergrowth of pegmatite and granitoid rock. A biotite-rich intermediate zone and a 4-5 foot wide calcite core are also present.

- B -

- B-24. Byers, V. P., 1978, Principal uranium deposits in the world: U. S. Geol. Survey Open-File Report 78-1008, 308 p.

Extensive compilation of information on the major uranium deposits of the world. Bancroft deposits are the only "pegmatite-type" mentioned.

- C -

- C- 1. Cameron, E. N., and others, 1949, Internal structure of granitic pegmatites: Econ. Geology, Mon. 2, 115 p.

A definitive text on the zoning and internal structures of pegmatites. Abundant examples and numerous diagrams illustrate the mineralogy, petrology and structures which have led to the recognition of border, wall, intermediate and core zones.

Radioactive materials are not discussed and only rarely mentioned.

- C- 2. _____, and others, 1954, Pegmatite investigations 1942-45, New England: U. S. Geol. Survey Prof. Paper 255, 352 p.

Describes mica, feldspar and beryl pegmatite resources in Maine, New Hampshire, Connecticut and Vermont. Geologic setting of various pegmatite districts is discussed as well as spatial relations and internal structure of individual pegmatites. A description of mines and prospects is provided. Occurrence of radioactive minerals is reported in some deposits.

- C- 3. Carpenter, R. H., Gallagher, J. R. L. and Huber, G. C., 1979, Modes of uranium occurrences in Colorado Front Range: Open-File Report GJBX-15(79), U. S. Dept. of Energy, Grand Junction, Colo., 307 p.

Included in an exhaustive discussion of uranium in the Front Range are several pages on uranium in pegmatites. In addition to detailed descriptions, the author makes many generalizations and observations. (1) Uranium is found in uraninite or as an ionic substitute in rare-earth minerals in simple pegmatites

in the Front Range. Uraninite-bearing complex pegmatites have not been reported. (2) Pegmatites will not be an important source of uranium ore except during emergency periods. (3) The most favorable areas to explore are along the fringes or in the hood zone of Silver Plume and Pikes Peak age intrusives.

- C- 4. Černý, P. and Trueman, D. L., 1978, Distribution and petrogenesis of lithium pegmatites in the western Superior Province of the Canadian Shield: *Energy*, v. 3, p. 365-377.

Discussion of pegmatitic terranes in Canada, Finland and the U. S. in regard to search for concealed deposits. Emphasis is on lithium.

Table 1 (p. 370) shows minor elements and accessory minerals in four pegmatite areas in Winnipeg River Area. The Lac du Bonnet quartz-monzonite contains allanite, monazite and zircon. The associated pegmatites of the Shatford Lake Group contain garnet and topaz as typical accessories and contain Be, Nb, Ta, REE, Zr, U, Th, Sn. Very high Th/U ratio.

- C- 5. Conley, J. F., 1958, Mineral localities of North Carolina: North Carolina Dept. Conserv. and Devel. Div. Mineral Resources Inf. Circ. 16, 83 p.

Guide to mineral localities of North Carolina. Includes radioactive mineral occurrences. Sites shown on county index maps.

- C- 6. Cooper, Margaret, 1953a, Bibliography and index of literature on uranium and thorium and radioactive occurrences in the United States - Part 1: *Geol. Soc. America Bull.*, v. 64, p. 197-234.

This and the following four entries are parts of an early bibliography on uranium and thorium. Pegmatites are not listed separately in the index which lessens the usefulness of these references to the pegmatite research worker.

- C- 7. _____, 1953b, Bibliography and index of literature on uranium and thorium and radioactive occurrences in the United States - Part 2: Geol. Soc. America Bull., v. 64, p. 1103-1172.
See previous page.
- C- 8. _____, 1954, Bibliography and index of literature on uranium and thorium and radioactive occurrences in the United States - Part 3: Geol. Soc. America Bull., v. 66, p. 465-590.
See previous page.
- C- 9. _____, 1955, Bibliography and index of literature on uranium and thorium and radioactive occurrences in the United States - Part 4: Geol. Soc. America Bull., v. 66, p. 257-326.
See previous page.
- C-10. _____, 1958, Connecticut Delaware, Illinois, Indiana, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont and Wisconsin, Part 5 of Bibliography and index of literature on uranium and thorium and radioactive occurrences in the United States: Geol. Soc. America Spec. Paper 67, 472 p.
See previous page.
- C-11. Correia-Neves, J. M., Lopes Nunes, J. E. and Lucas, D. B., 1972, Mineralogy and geochemistry of pegmatites from Mozambique (P.E.A.): Internat. Geol. Cong., 24th, Montreal 1972, Proc. Sect. 10, p. 37-44.
Discusses radioactive minerals found in zoned pegmatites. Minerals studied include euxenite, betafite, fergusonite, allanite, zircon, monazite and xenotime.
- C-12. Cotelto-Neiva, J. M. and Correia-Neves, J. M., 1960, Pegmatites of Alto-Ligonha (Mozambique-Portuguese East Africa): Internat. Geol. Cong., 21st, Copenhagen 1960, Rept., pt. 17, p. 53-62.

General discussion of complex zoned pegmatites. Radioactive occurrences are noted.

- C-13. Crook, W. W. III, 1977, The Clear Creek pegmatite: A rare-earth pegmatite in Burnet County, Texas: Mineralog. Record, v. 8, no. 2, p. 88-90.

Detailed description of zoned rare-element pegmatite on east side of Lake Buchanan. Uraninite occurs in cubes up to 1 cm. on side; commonly shows "gummite" alteration rim. Pegmatite is in Valley Springs Gneiss near the eastern margin of the Lone Grove granite pluton. Other radioactive minerals include allanite, gadolinite, samarskite, euxenite and yttracrasite.

- C-14. Crouse, R. A., Černý, P., Trueman, D. L. and Burt, R. O., 1979, The Tanco pegmatite, southeastern Manitoba: Canadian Mining and Metall. Bull., v. 72, no. 802, p. 142-150.

A detailed and complete description of the geology and mineralogy of the complexly zoned Tanco pegmatite. It is a product of very advanced fractional crystallization of granitic fluids and was intruded into amphibolite facies meta-gabbro and meta-diorite. The Tanco is rich in lithium, rubidium, cesium and beryllium and is a leading source of tantalum. Uranium or thorium minerals are not reported.

- C-15. Cunningham-Dunlop, P. K., 1967, Geology of economic uraniferous pegmatites in the Bancroft area, Ontario: unpub. thesis, Ph.D. Princeton Univ.

Describes in detail the metasomatic origin for the producing granitic and syenitic pegmatites. The uranium minerals were not considered primary and may have been derived from sediments within or underlying the Grenville Series.

- C-16. Curtis, Diane, 1958, Selected annotated bibliography of the uranium geology of igneous and metamorphic rocks in the United States: U. S. Geol. Survey Bull. 1059-E, 262 p.

- C -

An annotated list of 117 selected reports emphasizing geologic features of rocks and minerals for which uranium determinations have been made. Index map shows location of igneous and metamorphic rocks analyzed chemically for uranium.

- D -

- D- 1. Dar, K. K. and Phadke, A. V., 1964, On the occurrence of beryl and other minerals in pegmatites in India: Internat. Geol. Cong., 22nd, New Delhi 1964, Rept., pt. 6, p. 213-221.

Uraninite occurs within cyrtolite in zoned pegmatites. Five zones are commonly present. The uraninite is found in feldspar-rich zones. Several radioactive mineral localities are discussed.

- D- 2. Davis, H. C., 1954, Summary report of reconnaissance and exploration for uranium deposits in northern Nevada: U. S. Atomic Energy Comm., RME-2013 (Pt. 1, Rev.)

Brief description of radioactive deposits including the Deer Lodge area pegmatites which contain allanite, chevkinite and other rare-earth minerals.

- D- 3. DeKun, Nicolas, 1965, The mineral resources of Africa: Amsterdam, London, New York, Elsevier Publishing Co., 740 p.

Describes uranium deposit in soils derived from pegmatitic terrain in Madagascar. Radioactive minerals in pegmatites from Mozambique are also discussed.

- D- 4. DeLury, J. S. and Ellsworth, H. V., 1931, Uraninite from the Huron claim, Winnipeg River area, S. E. Manitoba: Am. Mineralogist, v. 16, p. 569-575.

Uraninite found in crystals one-eighth to one quarter inch diameter embedded in pinkish albite. Associated minerals are yellowish beryl, zoisite, monazite and tantalite. The

pegmatite is a feldspar-quartz pegmatite in andesitic schist. A chemical analysis is given and discussed.

- D- 5. Dietrich, R. V., 1960, Virginia mineral localities: Virginia Polytech. Inst. Bull. vol. 53, no. 7, 84 p.

The report gives localities for a few radioactive pegmatite minerals such as euxenite, samarskite, fergusonite and pyrochlore. Uraninite is not included in the compilation.

- E- 1. Edelman, Nils, 1968, An attempted classification of pegmatite structures: Geol. Fören. Stockholm Forh., v. 90, p. 349-359.

Pegmatites are classified by their shape, contacts, zoning, fabric, and relation to tectonics. Observations made in southwest Finland.

- E- 2. Ehlmann, A. J., Walper, J. L. and Williams, J., 1964, A new Baringer Hill-type rare-earth pegmatite from the Central Mineral Region, Texas: Econ. Geology, v. 59, p. 1348-1360.

Detailed mineralogic discussion which mentions various radioactive minerals including allanite, cyrtolite, fergusonite, gadolinite and thorogummite.

- E- 3. Eid, A. S. and von Knorring, O., 1976, (pub. 1977) Geochemical aspects of the tantalum mineral microlite from some African pegmatites: 20th Ann. Rept. Inst. Africal Geol., Univ. Leeds, p. 56-58; abs. in Min. Abs. v. 28, no. 4, item 77-4598.

Describes uraniferous microlites (UO_2 2-9%), highly radioactive and with specific XRD pattern resembling pyrochlore.

- E- 4. Ellsworth, H. V. and Osborne, F. F., 1934, Uraninite from Lac Pied des Monts, Saguenay district, Quebec: Am. Mineralogist, v. 19, p. 421-425.

Describes a large crystal of uraninite found in an apparently

unzoned pegmatite, 15 to 20 feet thick, containing pink microcline, white albite, quartz, abundant biotite and somewhat less muscovite. Garnet, zircon and monazite are accessories. The pegmatite, described as being coarse granitoid to graphic, cuts hornblende gneiss. Analyses (low Th and REE) and polished section data are provided.

- E- 5. Evans, A. M., 1964, Geology of the Biccroft uranium mine, Ontario: Canadian Mining Jour., v. 85, p. 106-107.

The author advocates a metasomatic origin for the pegmatites. The uranium mineralization is associated with granitic bodies emplaced in graphitic pelitic gneisses which may have been the source for the uranium.

- E- 6. Ewing, R. C. and Ehlmann, A. J., 1973, Yttrialite and uraninite, additional minerals from the Rode Ranch pegmatite, Central Mineral Region, Texas: Am. Mineralogist, v. 58, p. 545-547.

Uraninite occurs as small inclusions in fergusonite. X-ray diffraction patterns of the uraninite are identical to those of uraninite in fergusonite from Baringer Hill.

- F- 1. Fehn, U., Holland, H. D. and Cathles, L. M., 1978, Hydrothermal convection and uranium deposits in abnormally radioactive plutons: Open-File Report GJBX-42(78), U. S. Dept. of Energy, Grand Junction, Colorado, 51 p.

Hydrothermal uranium deposits may develop via fluid convection generated by abnormally high radioactive plutons.

- F- 2. Fersman, A. E., 1931, Les pegmatites, leur importance scientifique et pratique: Acad. Sci. U.R.R.S.; Translated from the Russian into French under the direction of R. du Trien de Turdonck and J. Thoreau, 3 vols., 675 p., Univ. of Louvain, Belgium, 1951.

Important early work in which the author describes his classification of pegmatites based on mineral composition

and a decreasing temperature gradient. Fersman's classification is still followed by some European geologists. Text gives paragenetic data on many pegmatites containing radioactive minerals and discusses the occurrence of uraninite.

- F- 3. Foord, E. E., 1977, The Himalaya dike system: Mineralog. Record, v. 8, no. 6, p. 461-474.

In addition to a history of gem mining in the district, the article gives geologic setting, mineralogy and paragenesis. Radioactive minerals are rare and include djalmite, uranmicro-lite-microlite, monazite and uraniferous zircon. The djalmite, which occurs in grains less than 0.01 inches across, contains about 32 percent uranium.

- F- 4. Ford, R. B., 1955, Mineralogy of a uraninite-bearing pegmatite, Lac La Ronge, Saskatchewan: Econ. Geology, v. 50, no. 2, p. 196-205.

A zoned granitic pegmatite in which uraninite occurs both contemporaneous with massive perthite in the wall zone and as late stage fracture filling in aplitic phases of the pegmatite.

- F- 5. Fowler, A. D. and Doig, R., 1979, Origin of uraniferous granitoids, Grenville Province, Quebec and Ontario (abs.): Geol. Assoc. Canada, Mineralog. Assoc. Canada, 1979 Ann. Meeting, Quebec, Program with Abstracts, p. 50.

Age determinations of uraniferous granites from Bancroft, Mt. Laurier and Johan Beetz areas show that these rocks are younger than ages normally associated with the Grenville orogeny. Some of these granites are spatially and in part temporally related to abundant alkalic rocks which occur from Bancroft to Mt. Laurier. Origin by anatexis or melasomatism discounted.

- F- 6. Fratta, M., 1969, Study of pegmatitic uranium deposits in the Grenville Province: in Report of Activities, pt. A, Canada Geol. Survey Paper 69-1A, p. 110-111.

Two areas of the Grenville Province in southern Quebec containing uraniferous pegmatites are described.

Features related to uranium-bearing pegmatites are as follows: (1) pink to gray color, (2) medium coarse grain size (1-4 cm), (3) accessory mineral is usually biotite, sometimes hornblende, never muscovite. Muscovite-bearing pegmatites are common in both areas, but are barren, (4) presence of magnetite or unusual concentrations of coarse biotite favorable, (5) uraninite is the most common radioactive mineral, but euxenite, betafite and uranophane may also occur, (6) Th content is low compared to Bancroft deposits, (7) strong structural control is evident.

- F- 7. _____, 1970, Pegmatitic uranium deposits in the Grenville Province, Ontario and Quebec: in Report of Activities, pt. A, Canada Geol. Survey Paper 70-1A, p. 89-92.

Brief descriptions of the Mont Laurier, Baskatong Reservoir and Baie Johan Beetz areas in the Grenville Province are provided. In regard to uraniferous pegmatites in the Baie Johan Beetz area, the author concludes: (1) the pegmatites are genetically related to nearby granites, (2) pegmatites with abundant biotite and or magnetite are abnormally radioactive, but except for local concentrations of radioactive minerals, they are somewhat lower in radioactivity than the parent granite, (3) the magmas of the granite and pegmatites presumably contained the same proportions of uranium.

- F- 8. Frondel, Clifford, 1956, Mineralogy of thorium: U. S. Geol. Survey Prof. Paper 300, p. 567-579.

A comprehensive paper on the mineralogy of thorium in which minerals containing thorium as an essential and vicarious constituent are described.

The association of thorium with uranium, the rare earths, and zirconium is also discussed.

- F- 9. _____, 1957, Mineralogy of uranium: Am. Mineralogist, v. 42, p. 125-132.

Principally a discussion of the history of uranium mineralogy and the problems as apparent in 1957.

The article states that low temperature uraninite has a relatively small unit cell size, hydrothermal vein-type uraninite has somewhat larger cell dimension and pegmatite uraninite has the largest cell dimensions of natural uraninite.

- F-10. _____, 1958, Systematic mineralogy of uranium and thorium: U. S. Geol. Survey Bull., 1064, 400 p.

Detailed description of primary and secondary species giving physical and chemical data including X-ray diffraction data. The occurrence of uraninite in various types of pegmatites is discussed. Unit cell dimensions for uraninites from a large number of pegmatite occurrences are given.

- G- 1. Gabelman, J. W., 1977, Migration of uranium and thorium-exploration significance: Am. Assoc. Petroleum Geologists Bull., Studies in Geology no. 3, 168 p.

A comprehensive study of the behavior of uranium and thorium in the geologic environment.

The volatile fraction of late stage differentiated magmas is enriched in uranium and thorium. In pegmatites the uranium and thorium are concentrated in individual crystals which are sporadic and infrequent and, therefore, of no economic interest. Despite the ubiquity of uranium in pegmatites they are not favorable exploration targets.

- G- 2. Galipeau, J. M. and Ragland, P. C., 1977, A radiometric study of rocks in three selected drainage basins in the Spruce Pine area, North Carolina: Open-File Report GJBX-30(78), U. S. Dept. of Energy, Grand Junction, Colorado., 79 p.

This paper presents results from carborne and foot traverse scintillation counter surveys in the Spruce Pine District. The results correlate with geology, topography and soil. X-ray diffraction data for primary uranium minerals from the McKinney and Webb Mines is provided.

- G- 3. Gallagher, M. J., 1967, Phosphates and other minerals in pegmatites of Rhodesia and Uganda: Mineralog. Mag., v. 36, p. 50-59.

Occurrence of many U-Th minerals in deposits in Rhodesia and Uganda are briefly described. Samarskite and fergusonite are more common than euxenite in Rhodesian pegmatites. A number of radioactive minerals are present in the central lithium mineral units of the Gooddays pegmatite in Rhodesia. Uraninite is found in pegmatites of the Miami district.

- G- 4. Garneau, D. M., 1976, Selected bibliography on the geology of Canadian deposits and occurrences of uranium and thorium: Canada Geol. Survey Paper no. 75-45, 41 p.

Contains many references to published articles and theses, including radioactive mineral occurrences in pegmatites.

- G- 5. Garside, L. J., 1973, Radioactive mineral occurrences in Nevada: Nevada Bur. Mines and Geology Bull. 81, 121 p.

Occurrences include 33 pegmatites reported to contain radioactive minerals.

- G- 6. George, d'Arcy, 1949, Mineralogy of uranium-and thorium-bearing minerals (revised): U. S. Atomic Energy Comm. RMO-563, 198 p.

Discusses occurrence of uranium in pegmatites; gives descriptions and analyses of many radioactive minerals. Information is now outdated in some areas.

- G- 7. Giblin, P. E., 1955, The geology and mineralogy of the Basin property, Faraday Township: unpub. M.Sc. thesis, Univ. of Toronto, Toronto, Ontario.

The uranium mineralization is associated with carbonate bodies in a nepheline-syenite; presumably the result of injection of pegmatitic fluids. The genesis and mineralogy of both these rock types is discussed in detail.

- G- 8. Ginsbourg, A. I., 1960, Specific geochemical features of the pegmatitic process: Internat. Geol. Cong., 21st, Copenhagen 1960, Proc. pt. 17, p. 111-121.

The author discusses the geochemical differentiation of pegmatites. Uranium is, for the most part, in deep-seated Precambrian pegmatites, however, each province is characterized by its own differentiation and composition. Pegmatites derived from a magma enriched in uranium and rare earths are not necessarily enriched themselves. The effect of the enclosing country rock on enrichment may be considerable.

- G- 9. Glass, J. J., Rose, H. J., Jr. and Over, Edwin, 1958, Notes on the mineralogy of an yttrium-bearing pegmatite body near Lake George, Park County, Colorado: Am. Mineralogist, v. 43, nos. 9-10, p. 991-994.

An unzoned pegmatite intrudes the Pikes Peak granite. The yttrium-bearing minerals are associated with fluorite as hydrothermal replacement of feldspar. Minerals include allanite, gadolinite, monazite and xenotime.

- G-10. Grauch, R. I. and Zarinski, Katrin, 1976, Generalized descriptions of uranium-bearing veins, pegmatites and disseminations in non-sedimentary rocks, eastern United States: U. S. Geol. Survey, Open-File Report 76-582, 113 p.

References to and locations of radioactive pegmatites in several eastern states.

- G-11. Greenberg, J. K., Hauck, S. A., Ragland, P. C. and Rogers, J. J. W., 1977, A tectonic atlas of uranium potential in crystalline rock of the eastern U. S.: Open-File Report GJBX 69(77), U. S. Energy Research Development Administration, Grand Junction, Colorado, 94 p.

This atlas provides data on uranium potential in the form of maps and tables for each state. A tectonic index map is provided and briefly discussed. The table includes various categories such as: exploration potential, ore host rock, ore type, type of alteration and minerals present, age, trace element data and important references.

- G-12. Gresens, R. L., 1967, Tectonic-hydrothermal pegmatites. II. An example: *Contr. Mineralogy and Petrology*, v. 16, p. 1-28; abs. in *Min. Abs.*, v. 23, 72-2532.

It is postulated that the Kiowa pegmatites in New Mexico were formed "synkinematically" during regional metamorphism. Spectrographic data for various minerals is provided.

- G-13. Griffitts, W. R., Jahns, R. H. and Lemke, R. W., 1953, Mica deposits of the southeastern Piedmont: Part 3. Ridgeway - Sandy Ridge District, Virginia and North Carolina, Part 4. Outlying deposits in Virginia: *U. S. Geol. Survey Prof. Paper* 248-C, p. 141-202.

The Knight Mica Mine in Rockingham County, North Carolina is in a zoned sill-like pegmatite in biotite-quartz schist. Uraninite, autunite, uranophane (?), other secondary uranium minerals and allanite are reported. The uranium minerals occurring in the hanging wall in oligoclase-quartz-muscovite pegmatite and as stains on fractured pegmatite.

- G-14. Griffitts, W. R. and Olson, J. C., 1953, Mica deposits of the southeastern Piedmont. Part 5. Shelby-Hickory District North Carolina: *U. S. Geol. Survey Prof. Paper* 248-D, p. 203-281.

Zoned pegmatite at the A. F. Hoyle Mine in Cleveland County, contains minor uraninite and autunite in the wall zone of coarse-grained plagioclase, quartz, muscovite and subordinate perthite. Green apatite crystals also occur with the muscovite in this zone. Interior of pegmatite is largely white to light-gray perthite with minor plagioclase, light-to dark gray quartz and mica. Garnet and sulfides occur with green muscovite and quartz as fracture fillings. Host rock is biotite gneiss.

- G-15. Gross, E. B. and Heinrich, E. W., 1966, Petrology and mineralogy of the Mount Rosa area, El Paso and Teller Counties, Colorado. II. Pegmatites: Am. Mineralogist, v. 51, nos. 3-4, p. 299-323.

Describes and compares the Pikes Peak pegmatites and Mount Rosa pegmatites. Various minerals are described and a brief discussion on paragenesis and regional zoning is provided. Mount Rosa pegmatites are mineralogically more complex than the Pikes Peak pegmatites.

- H- 1. Haji-Vassiliou, Andreas, 1974, Uranium mineralization-uraninite: Mineralog. Record, v. 5, no. 2, p. 79-86.

Review paper on uraninite. Discusses cell-edge variation with types of occurrences.

- H- 2. Haji-Vassiliou, Andreas, Puffer, J. H. and Markewicz, F. J., 1974, Uranium-rare-earth mineralization at Charlotte Mine prospect near Cranberry Lake, New Jersey, (abs.): Geol. Soc. America, Abstracts with Programs, v. 6, no. 1, p. 33.

"Paragenetic and chemical analytical data indicate that the ore was probably precipitated from hydrothermal solutions associated with the intrusion of the pegmatite."

Uraniothorite, zircon and fergusonite occur in magnetite-rich contact zone between pyroxenite and perthilic pegmatite.

- H- 3. Hanley, J. B., Heinrich, E. W. and Page, L. R., 1950, Pegmatite investigations in Colorado, Wyoming and Utah; U. S. Geol. Survey Prof. Paper 227, 125 p.

Location, history, maps and geologic data are provided for 114 pegmatites in Colorado, Wyoming and Utah. The report evaluates the pegmatites' potential as a resource for mica, beryllium, tantalum and lithium. Uranium minerals are mentioned only where prominent.

- H- 4. Haynes, C. V., Jr., 1965, Genesis of the White Cloud and related pegmatites, South Platte area, Jefferson County, Colorado: Geol. Soc. America Bull., v. 76, no. 4, p. 441-462.

Zoned rare-earth pegmatites in granite are described in detail. Cyrtolite and fergusonite are found in the outer intermediate zone, whereas, the later-forming allanite is found in the core. The pegmatites were emplaced as liquid segregates of residual fluids late in the history of the Pikes Peak batholith. Uranium minerals were original constituents as evidenced by idiomorphism, simultaneous growth with known primary minerals and replacement by known secondary minerals. Maps and paragenetic sequences are included.

- H- 5. Haynes, Vance, Jr., 1960, The rare earths, in Del Rio, S.M., ed., Mineral Resources of Colorado First sequel: Denver, Colorado Mineral Resources Board, p. 370-385.

The occurrence of euxenite and other radioactive species in pegmatites in Colorado is discussed.

- H- 6. Heinrich, E. W., 1948, Fluorite-rare-earth mineral pegmatites of Chaffee and Fremont Counties, Colorado: Am. Mineralogist, v. 33, nos. 1-2, p. 64-75.

Describes association of fluorite with rare-earth bearing pegmatites in Colorado and various other pegmatite districts in the U. S. Includes descriptions of the Yard, Luella, Colorado Feldspar and Pine Ridge pegmatites.

- H- 7. _____, 1949, Pegmatite mineral deposits in Montana: Montana Bur. Mines and Geology Mem. 28, 56 p.

Minor radioactive occurrences are described in unzoned pegmatites near Janney in Silver Bow County and Lake Delmo, Jefferson County. The Sappington deposit in Madison County is a zoned pegmatite with minor fergusonite.

- H- 8. _____, 1953, Zoning in pegmatite districts: Am. Mineralogist, v. 38, nos. 1-2, p. 68-87.

Using both U. S. and worldwide examples, the author illustrates the relationships between size, shape, internal and external structures, textures and mineralogy with distance from parent batholiths and nature of host rock. Complex pegmatites are emplaced further from parents as they are less viscous and being late differentiates they are often enriched in rare elements.

- H- 9. _____, 1958, Mineralogy and geology of radioactive raw materials: New York, McGraw-Hill Book Co., Inc., 654 p.

A comprehensive discussion of radioactive mineral occurrences including pegmatites. Important world-wide occurrences listed in tables and the characteristics of various types of occurrence are given. Unzoned pegmatites appear to be the most economically significant kind of radioactive pegmatite. The most widespread type of radioactive pegmatite is that in which radioactivity is due to complex oxides notably euxenite or samarskite.

- H-10. _____, 1959, Sphene-allanite pegmatites of Griffith Township, Renfrew County, Ontario: Canadian Mineralogist, v. 6, p. 339-347: abs. in Min. Abs., v. 15, p. 313.

Four unzoned radioactive pegmatites in eastern Ontario are described. Radioactivity is due mainly to sphene and allanite. Unusual composition is due, in part, to syntexis of dolomitic marble.

- H-11. _____, 1960, Some rare-earth mineral deposits in Mohave County, Arizona: Arizona Bur. Mines Bull. 167, v. 31, no. 1 (Min. Tech. Ser. no. 51), 22 p.

Allanite from the Kingman Feldspar pegmatite occurs in the wall zones. The Rare Metals pegmatite in the Aquarius

Range is described in detail. Deposit contains monazite, euxenite, gadolinite and yttrantalite. About 7-8 tons of yttrantalite ore was reportedly produced. The mineral occurs with gadolinite chiefly in a fine-grained aplitic quartz-albite-muscovite "line-rock" on the footwall side of the quartz core. Beryl and bismuth minerals are found in the deposit. The pegmatite occurs in granite. Other occurrences of radioactive rare-earth minerals in the Aquarius Range are mentioned.

- H-12. _____, 1965, Notes on western mineral occurrences: Am. Mineralogist, v. 50, p. 2083-2088.

Euxenite replaces feldspar in a "core margin replacement pod" in an assymetrically zoned pegmatite in Madison County, Montana. Chemical and X-ray data, as well as autoradiographs, are provided.

- H-13. Heinrich, E. W. and Gross, E. B., 1960, Fluocerite and associated minerals from the Black Cloud pegmatite, Teller County, Colorado: Am. Mineralogist, v. 45, nos. 3-4, p. 455-459.

The Black Cloud is a zoned pegmatite with two replacement units, one fluoritic, the other albitic. Most of the rare-earth and radioactive minerals occur in these units. Minerals include those containing Y- and Ce-group elements. The pegmatite intrudes the Pikes Peak granite.

- H-14. Heinrich, E. W., Klepper, M. R. and Jahns, R. H., 1953, Mica deposits of the southeastern Piedmont, Part 9. Thomaston-Barnesville district, Georgia, Part 10. Outlying deposits in Georgia: U. S. Geol. Survey Prof. Paper 248-F, p. 327-400.

Autunite and other secondary uranium minerals are reported to occur in the Amphlette mica prospect, Cherokee County, in quartz-feldspar-muscovite pegmatite. Black tourmaline is abundant and other accessory minerals include garnet, biotite, beryl, pyrite, pyrrhotite, chalcopyrite, calcite and malachite.

Bright-yellow to bright-green gummite (?) occurs with muscovite and autunite and is found as coatings on pale yellow-green beryl. Host rock is biotite-gneiss.

- H-15. Heron, S. D., Jr. and Johnson, H. S., Jr., 1969, Radioactive mineral resources of South Carolina: South Carolina Devel. Board, Div. of Geology, Misc. Rept. 4, 4 p.

Zircons estimated to contain 0.02 percent eU occur in pegmatites cutting vermiculite and biotite schist in Greenville County.

- H-16. Hewitt, D. F., 1967a, Pegmatite mineral resources of Ontario: Ontario Div. Mines, Indus. Min. Rept. 21, 83 p.

A good discussion of pegmatite classification, petrology and internal structure. Sections in the text deal with various commodities including uranium and rare-earth minerals. The important uranium deposits in the Bancroft area are described in detail.

- H-17. _____, 1967b, Uranium and thorium deposits of southern Ontario: Ontario Div. Mines, Min. Res. Circ. no. 4, 76 p.

An alphabetical inventory of uranium and thorium deposits in southern Ontario. The listings include location, development, reference, radioactive mineral species and general geology for each deposit.

Most of the deposits are in the Bancroft district. The most important are pegmatitic granite dikes typical of "catazone ultrametamorphism". Uranium deposition is determined by the nature of the host rocks. Those rich in iron, calcium and magnesium are the most favorable.

- H-18. Hewitt, D. F. and Glass, J. J., 1953, Two uranium-bearing pegmatite bodies in San Bernardino County, California: Am. Mineralogist, v. 38, nos. 11-12, p. 1040-1050.

The Cady Mountain and Pomona Tile Quarry pegmatites were intruded into quartz monzonite. Uranium is present in allanite, euxenite, betafite, cyrtolite, monazite and possibly davidite. Spectrographic analyses of the uranium minerals are given. Euxenite yielded an age date of 150 million years.

- H-19. Hewitt, D. F. and Stone, Jerome, 1957, Uranothorite near Forest Home, San Bernardino County, California: *Am. Mineralogist*, v. 42, nos. 1-2, p. 104-107.

Uranothorite, allanite and zircon are found in a reddish-brown pegmatite intruding a Precambrian granite gneiss.

- H-20. Hitchen, C. S., 1935, Pegmatites of Fitchburg, Massachusetts: *Am. Mineralogist*, v. 20, no. 1, p. 1-24.

Uraninite and allanite occur in quartz stringers in pegmatites in the McCauliff Quarry in Worcester County, Massachusetts.

- H-21. Hogarth, D. D., Moyd, Louis, Rose, E. R. and Steacy, H. R., 1972, Classic mineral collecting localities in Ontario and Quebec: Field excursion A 47-C 47, Guidebook, Internat. Geol. Cong. 24th, Montreal 1972, 79 p.

Guidebook for Geol. Congress excursion. Includes general geology and descriptions of localities. Many radioactive mineral occurrences in pegmatites are noted.

- H-22. Holland, H. D. and Kulp, J. L., 1949, The distribution of accessory elements in pegmatites. I. Theory: *Am. Mineralogist*, v. 34, p. 35-68.

The authors attempt to qualify and express mathematically the probable distribution of accessory elements in zoned pegmatites. The distribution is deemed to be dependent upon similarity of crystal lattices (dependent in turn upon ionic radii), distance from the wall rock-pegmatite contact, and outside effects caused by loss or addition of material, convection, shattering, veining and replacement. No natural examples are cited.

- H-23. Houston, R. S., 1961, The Big Creek pegmatite area, Carbon County, Wyoming: Wyoming Geol. Survey Prelim. Rept. 1, 11 p.

This paper provides a brief description of several Precambrian rare earth-bearing granitic pegmatites. X-ray fluorescence studies of euxenite and monazite from the Platt pegmatite were made.

- H-24. Hriskevich, M. E., 1949, Radioactive occurrences in the Black Lake area: Sask. Dept. Nat. Res., Precambrian Geol. Ser., Rept. No. 2, 29 p.

Allanite, zircon and uraninite (?) are found along with magnetite in microcline, oligoclase and biotite pegmatites in the Black Lake area of northern Saskatchewan. Local granites are anomalously radioactive.

- H-25. Hugo, P. J., 1970, The pegmatites of the Kenhardt and Gordonia district, Cape Province: South Africa Geol. Survey, Mem. 58, 94 p.

Detailed description of deposits and their mineralogy. Theoretical aspects, such as effects of wall rocks, origin of fluids and paragenesis are also discussed.

Listed as "rare accessory minerals" are allanite, gadolinite, monazite, euxenite, fergusonite, zircon, pyrochlore, xenotime and uraninite, of which allanite is the most abundant.

- H-26. Hurley, P. M. and Fairbairn, H. W., 1957, Abundance and distribution of uranium and thorium in zircon, sphene, apatite, epidote and monazite in granitic rocks: Trans. Am. Geophys. Union, v. 38, p. 939-944.

Data is presented on the ratio, abundance and distribution of U and Th in zircon, sphene, apatite, epidote and monazite. These minerals are the principal host for U and Th in crystalline rocks.

- H-27. Hutchinson, R. W., 1955, Regional zonation of pegmatites near Ross Lake, District of Mackenzie, Northwest Territories; Canada Geol. Survey Bull. 34, 50 p.

Pegmatites in the Ross Lake area were derived from the Redout Lake granite. The nature of the pegmatites is directly related to distance from the granite. The temperature-pressure gradient away from the granite was responsible for regional zoning of the pegmatites as regards size, attitude, mineral content and alteration.

Beryllium-rich pegmatites are found near the granite, niobium-tantalum mineralization further out and lithium-bearing pegmatites are furthest removed. It is unlikely that rare-earth minerals will be found in pegmatites within one mile of the Redout granite.

Radioactivity is constant and low. Uranium is not discussed.

- H-28. Hutchinson, R. W. and Claus, R. J., 1956, Pegmatite deposits, Alto Ligonha, Portuguese East Africa: Econ. Geology, v. 51, p. 757-779.

Pegmatites containing columbite, beryl, lepidolite, bismuth and mica occur in belts of metamorphic schists, whereas those in granitic rocks contain only magnetite as an accessory mineral. Internal structure and mineral distribution are very similar to that in U. S. and Canadian pegmatites.

No radioactive minerals reported.

- I- 1. Ingerson, Earl, 1938, Uraninite and associated minerals from Haddam Neck, Connecticut: Am. Mineralogist, vol. 23, no. 4, p. 269-276.

Describes uranium minerals from Rock Landing Quarry; included are uraninite, gummite, autunite and torbernite. Uraninite has also been found in pegmatites at Glastonbury, Portland and Branchville, Conn.

- I- 2. Ivanov, A. N., Shiryaeva, V. A. and Shmakin, B. M., 1974, (Pub. 1976), Allanite as a mineral indicator of the depth of pegmatite formation: Ezheg., Inst. Geokhim., Sib. Otd., Akad. Nauk SSSR 1974, p. 111-115; abs. in Chem. Abs., v. 88, item 155856z, 1978.

Allanite in pegmatites formed at depth under high pressure conditions is enriched in Y and yttrian lanthanides while allanite in shallow pegmatites is enriched in light lanthanides (La and Ce). An increase in La and Ce in total rare earths in Paleozoic pegmatites reflects formation under pressures lower than those of Precambrian pegmatites. In the western Baikal region Paleozoic pegmatites have a greater rare-earth content than Precambrian pegmatites.

- J- 1. Jahns, R. H., 1946, Mica deposits of the Petaca District, Rio Arriba County, New Mexico: New Mexico Bur. Mines and Min. Res. Bull. 25, 294 p.

An excellent detailed geologic report of the pegmatites in the Petaca District. Radioactive minerals, mainly samarskite, occur at the Sunnyside, Fridlund, Cribbenville, De-Aragon and Eureka deposits. Uraninite is rare but occurs at the Pino Verde and Fridlund deposits. Monazite is a common constituent.

- J- 2. _____, 1952, Pegmatite deposits of the White Picacho district, Maricopa and Yavapai Counties, Arizona: Arizona Bur. Mines (Min. Tech. Ser. No. 46) Bull. 162, 105 p.

The definitive study of the pegmatites from this area. A detailed geologic description of the country rock as well as the pegmatites is provided. Allanite, monazite, micro-lite and pyrochlore are rare constituents of some zoned, granitic pegmatites.

- J- 3. _____, 1953a, The genesis of pegmatites. I. Occurrence and origin of giant crystals: Am. Mineralogist, v. 38, p. 563-598.

Detailed discussion of giant crystals of various composition with examples from several localities throughout the world. The paper includes a discussion of the following aspects: crystal shape and habit, distribution within the pegmatite and replacement versus primary origin. The author concludes that giant crystals formed directly from pegmatitic fluids.

- J- 4. _____, 1953b, The genesis of pegmatites. II. Quantitative analysis of lithium-bearing pegmatite, Mora County, New Mexico: Am. Mineralogist, v. 38, p. 1078-1112.

An excellent detailed study of the Pidlite pegmatite. Included is a unique approach for determining the bulk chemical and mineralogical composition of the pegmatite as well as an analytical study of replacement features. The author con-

cluded that the replacement minerals developed from a residual fluid generated within the pegmatite. The deposit contains a wide variety of minerals including several radioactive species.

- J- 5. _____, 1953c, Distribution of rare elements within granites and granitic pegmatites (abs): Geol. Soc. America Bull. 64, p. 1440.

The distribution and mode of occurrence of rare elements is dependent upon magma composition, pressure-temperature conditions during crystallization and various properties of the ions (size, charge, polarizability). Several ways in which ions behave during crystallization are outlined.

- J- 6. _____, 1954, Pegmatites of Southern California, in Geology of Southern California, Chapter VII: California Div. of Mines Bull. 170, p. 37-50.

A comprehensive study of the distribution and occurrence of pegmatites in Southern California in which various types are described in regard to host rock, composition, age and relative abundance. The geochemistry of the pegmatites particularly as related to source rocks is discussed. It is noted that uranium is conspicuously rare in the deposits.

- J- 7. _____, 1955, The study of pegmatites: Econ. Geol. 50th Ann. vol., pt. II, p. 1025-1130.

One of the classic articles on pegmatites illustrating the change from early descriptive studies to fundamental aspects of mineralogy, structure and petrography. The paper summarizes the geology of pegmatites as to classification, age, distribution, wall rock alteration and origin as viewed in 1955. An extensive bibliography is provided.

- J- 8. Jahns, R. H. and Burnham, C. W., 1969, Experimental studies of pegmatite genesis: 1. A model for the derivation and crystallization of granitic pegmatites: Econ. Geol. v. 64, p. 843-864.

A perceptive presentation arguing that pegmatites are formed by crystallization of magma that has essentially filled a closed chamber. Some material may be derived from the surrounding rocks.

The theory is supported by field, laboratory and theoretical evidence.

- J- 9. Jahns, R. H. and Ewing, R. C., 1977, The Harding Mine, Taos County, New Mexico: Mineralog. Record, v. 8, no. 2, p. 115-126.

A summary paper on the history, geologic setting, zoning, wall rocks and mineralogy of the Harding pegmatite. Micro-lite is the dominant radioactive mineral; allanite and thorite are rare.

- J-10. Jahns, R. H., Griffitts, W. R. and Heinrich, E. W., 1952, Mica deposits of the southeastern Piedmont. Part 1 - General Features: U. S. Geol. Survey Prof. Paper 248-A, p. 1-102.

Good discussion of pegmatites in general including paragenesis. Uranium occurs locally in pegmatites in Virginia and South Carolina. The uranium minerals are found in late stage quartz and albite, as fracture filling and as replacement bodies.

- J-11. Januzzi, R. E., 1959, The minerals of western Connecticut and southeastern New York State: The Mineralogical Press, Danbury, Connecticut, 106 p.

An alphabetical listing of nearly 200 minerals with brief notes on the habits of these minerals in the study area. Location maps are provided.

- K- 1. Kalliokoski, J., Langford, F. F. and Ojakangas, R. W., 1978, Criteria for uranium occurrences in Saskatchewan and Australia as guides to favorability for similar deposits in the United States: Open-File Report GJBX-114(78), U. S. Dept. of Energy, Grand Junction, Colorado, 480 p.

Briefly mentions the occurrence of pegmatites in the Proterozoic rocks at Rabbit Lake, Key Lake and Uranium City in northern Saskatchewan.

- K- 2. Kaspar, J. and Hejl, V., 1970, Thermodynamic conditions of the origin of uraninites, in Uranium Exploration Geology: Internat. Atomic Energy Agency, Vienna, 1970 Proc., p. 301-314.

A discussion of the geochemistry and forms of uraninite. There are two uraninites in pegmatites, one formed between 700⁰ and 800⁰ C and a second formed at about 500⁰ C. Uraninites from pegmatites have a greater basic cell dimension than uraninite in veins or sediments. This is a genetic difference due in part to temperature and in part to chemical environment.

- K- 3. Kelly, L., 1956, The Bicroft Pegmatites: Canadian Mining Jour., v. 77, p. 87-88.

The author asserted that wall-rock assimilation and metasomatic replacement predominate over injection as the mode of origin for the pegmatites. Uranium values do not correlate consistently with any physical or chemical parameters.

- K- 4. Kerr, P. F., 1935, U-galena and uraninite in Bedford, New York, crytolite: Am. Mineralogist, v. 20, no. 6, p. 443-450.

Lead in galena found within crytolite is thought to be largely of radiogenic origin on the basis of its low atomic weight. Uraninite occurs in crytolite as disseminated grains and small veinlets.

- K- 5. Klemic, Harry, and others, 1959, Uranium in Phillips Mine - Camp Smith area, Putnam and Westchester Counties, New York: U. S. Geol. Survey Bull. 1074-E, p. 165-199.

Uraninite occurs as subhedral crystals, highly embayed grains and small rounded disseminated grains in an unzoned hornblende pegmatite as well as in hornblende gneiss and diorite and appears to be associated with magnetite. Uraninite from the deposit gave an isotopic age of 920 million years.

- K- 6. Klemic, Harry, Heyl, A. V., Jr., Taylor, A. R. and Stone, Jerome, 1959, Radioactive rare-earth deposit at Scrub Oaks mine, Morris County, New Jersey: U. S. Geol. Survey Bull. 1082-B, p. 29-59.

Radioactive minerals are found in pegmatites adjacent to a magnetite ore body and in the ore body itself.

- K- 7. Knorring, Oleg von, 1970, Mineralogical and geochemical aspects of pegmatites from orogenic belts of equatorial and southern Africa: in African Magmatism and Tectonics, Kennedy vol., p. 157-184.

An excellent report on the pegmatite regions of southern Africa. The pegmatites are genetically related to two orogenic episodes, 1100 ± 200 million years and 550 ± 100 million years. The mineralogy and geochemistry of pegmatite regions within these orogenic belts are discussed. Two main geochemical belts are recognized, a tin belt and a rare-earth belt. Radioactive minerals are more commonly associated with pegmatites from the latter, particularly in Madagascar and in the Alto Ligonha area in Mozambique.

- K- 8. Kober, C. L. and Procter-Gregg, H. D., 1977, Discrimination of uranium alteration zones in selected areas by use of landsat MSS imagery: Open-File Report GJBX-4(77), U. S. Energy Research and Development Administration, Grand Junction, Colo., 88 p.

Describes the theory and procedure involved in discriminating alteration haloes around uranium deposits. The Merikay pegmatite in Washington did not show a halo. Other areas which may have pegmatites did correlate, i. e. Central City-Idaho Springs area in Colorado.

- K- 9. Komarov, A. N. and Shukolyukov, Yu. A., 1966, Forms of uranium occurrence in micas (in Russian): trans. in Geochemistry Internat., v. 3, p. 1065, 1966: abs. in Min. Abs., v. 19, p. 218, 1968.

This paper deals with fission-track studies of uranium distribution in micas.

- K-10. Kretz, R., 1967, Granite and pegmatite studies of northern Indian Lake, Manitoba: Canada Geol. Survey Bull. 148, 42 p.

Except for very minor allanite, radioactive minerals are not found in these simple unzoned pegmatites. The author presents evidence of plastic flowage of granitic rocks and concludes that the pegmatites formed via lateral secretion.

- L- 1. Landes, K. K., 1925, The paragenesis of the granite pegmatites of central Maine: Am. Mineralogist v. 10, p. 353-411.

Describes mineral development of several pegmatites, notably those at Buckfield. Proposes a five stage sequence of events in their development as evidenced by mineralogical suites. Radioactive minerals not discussed.

- L- 2. _____, 1928, Sequence of mineralization in the Keystone, South Dakota, pegmatites: Am. Mineralogist, v. 13, p. 519-530, 537-558.

In a discussion of the mineralogy of the deposits the author mentions a large specimen containing uraninite that was found in the "uppermost Ingersoll pegmatite". The specimen consisted of amblygonite and quartz in part replaced by lepidotite. Several small masses of uraninite, surrounded by

yellow and orange oxidation products, were enclosed in the lepidolite. From the lead-uranium ratio in the uraninite an age of 1,667 million years was calculated.

- L- 3. _____, 1932, The Baringer Hill, Texas, pegmatite: Am. Mineralogist, v. 17, p. 381-390.

Most of the deposit was quartz-perthite pegmatite with feldspar crystals up to 30 feet across; a quartz core occupied the center of the body. The radioactive minerals, chiefly allanite, gadolinite, fergusonite and cyrtotite occur in a zone containing mainly coarse red albite. A rare-earth rich uraninite (nivenite) and autunite are reported. Radioactive minerals were commonly associated with biotite concentrations. The pegmatite intrudes Precambrian granite.

- L- 4. Lang, A. H., Griffith, J. W. and Steach, H. R., 1962, Canadian deposits of uranium and thorium: Canada Geol. Survey, Econ. Geol. Ser. no. 18, 324 p.

Describes the main types of radioactive deposits in the Bancroft area. These include dikes and lenses of pegmatite granite and syenite, zoned granitic pegmatites, metasomatic bodies and calcite-fluorite-apatite veins.

- L- 5. Larsen, E. S., Jr., Phair, George, Gottfried, David, and Smith, W. L., 1956, Uranium in magmatic differentiation: in Geology of uranium and thorium, International Conference, 1955, U. S. Geol. Survey Prof. Paper 300, p. 65-74.

Discusses the concentration of uranium in the evolution of rocks of a comagmatic series.

- L- 6. Leedom, S. H. and Kiloh, K. D., 1978, Preliminary study of the uranium favorability of Mesozoic intrusive and Tertiary volcanic and sedimentary rocks of the central Mojave Desert, Kern and San Bernardino Counties, California: Open-File Report GJBX-24(78), U. S. Dept. of Energy, Grand Junction, Colorado, 86 p.

Swarms of small pegmatite dikes present in the Kramer Hills and Castle Butte areas contain minor amounts of uranium.

- L- 7. Lemke, R. W., Jahns, R. H. and Griffiths, W. R., 1952, Mica deposits of the southeastern Piedmont, Pt. 2, Amelia District, Virginia: U. S. Geol. Survey Prof. Paper 248-B, p. 103-139.

Radioactive minerals are sparse in the Amelia district. Microlite is moderately abundant at the Morefield, Rutherford No. 1 and Rutherford No. 2 mines and is a minor constituent at the Champion. Microlite occurs chiefly in cleavelandite-rich parts of the deposits.

- L- 8. Leonova, V. A., 1965, Geochemistry and origin of Chupa pegmatite range (North Karelia) (in Russian): Vses. Mineralog. Obsch., Zapiski, v. 94, p. 272-287; trans. in Internat. Geol. Rev., v. 8, no. 6, 1966, p. 689-701.

Study of the relationship of wall rocks to composition of pegmatites. Analyses of zircon, apatite, allanite and epidote from pegmatites, migmatites and gneisses suggest that there is a close geochemical resemblance in the composition of pegmatites and their enclosing rocks. Uranium analyses are given for apatite and allanite from pegmatites.

- L- 9. Lesure, F. G., 1968, Mica deposits of the Blue Ridge in North Carolina: U. S. Geol. Survey Prof. Paper 577, 124 p.

Describes in detail the pegmatites within the Blue Ridge area. An extensive list of mica deposits is provided which includes occurrences of radioactive accessory minerals.

- L-10. Little, H. W., 1969, Anhydrite-pegmatite uranium ore at Bancroft, Ontario: Econ. Geology, v. 64, p. 691-693.

The writer favors the conclusion that the anhydrite in the ore is a primary mineral and that it was essentially contemporaneous with the uraninite, uranothorite and cyrtolite. Isotope ages of uraninite found enclosed in anhydrite are essentially those given by uraninite found elsewhere in the deposit.

- L-11. _____, 1970, Distribution of types of uranium deposits and favorable environments for uranium exploration, in Uranium Exploration Geology: Internat. Atomic Energy Agency, Vienna, 1970 Proc., p. 35-48.

This paper discusses, locates and classifies the many uranium occurrences in Canada. Three pages are devoted to pegmatites, (unzoned red, unzoned white and zoned). A small map depicts location of the pegmatites. Red pegmatites in alkalic rocks are deemed most favorable for uranium deposition.

- L-12. Logan, C. and Van Huyssteem, E., 1973 (reissued 1976), The selection of economically mineralized pegmatites according to their border zone characteristics: Rept. Nat. Inst. Metall., So. Africa, no. 1508, 17 p.

Trace-element content of pegmatite border zones is studied as a possible guide to the economic potential of a deposit. Results suggested that economically mineralized pegmatites may have a higher trace-element content in border zones than barren pegmatites. Presence of discrete minerals of these elements in the border zones is also favorable. Uranium was among the elements included in the study.

- M- 1. MacKevett, E. M., Jr., 1960, Geology and ore deposits of the Kern River uranium area, California: U. S. Geol. Survey Bull. 1087-F, p. 169-222.

Pegmatites containing euxenite are present in the area, but no specific deposits are described.

- M- 2. _____, 1963, Geology and ore deposits of the Bokan Mountain uranium-thorium area, southeastern Alaska: U. S. Geol. Survey Bull. 1154, 125 p.

Uranium and thorium mineralization occurs in several types of deposits including pegmatites and is related to a peralkaline granite. The pegmatites contain brannerite and ellsworth-

ite and are commonly rich in zirconium and rare-earths. Most of these pegmatites are in the peralkaline granite. Other pegmatites related to a quartz monzonite-granodiorite, contain only sparse concentrations of radioactive minerals. Spectrographic analyses given for samples of both types of pegmatites. Peralkaline pegmatites are thought to be late Cretaceous or early Tertiary in age.

- M- 3. Mackie, B., 1977, Petrogenesis of the Lac Turgeon Granite and associated uranium occurrences near Baie Johan Beetz, Quebec (abs.): Geol. Soc. America, Abs. with Programs, vol. 9, no. 7, p. 1080-1081.

Uranium mineralization occurs in coarse grained granite and associated pegmatitic rocks concentrated in axial planes and fold noses.

- M- 4. Mawdsley, J. B., 1954, Radioactive, pronouncedly differentiated pegmatite sill, Lac LaRonge District, northern Saskatchewan: Econ. Geology, v. 49, p. 616-624.

Description of a large zoned sill-like pegmatite intruding metamorphosed sediments. Uraninite crystals are found in an oligoclase-quartz border zone containing a little biotite and most abundantly in a roll in the hanging wall where some uraninite has also developed in a biotite-rich selvage. An intermediate zone of microcline-quartz-oligoclase pegmatite contains accessory biotite, muscovite, magnetite and monazite. Salmon-pink microcline and quartz form the core. Author notes that the oligoclase of the uranium bearing zone is chocolate red-brown in color, probably due to hematite inclusions.

- M- 5. _____, 1955, Radioactive pegmatites of northern Saskatchewan: Canadian Mining Jour., v. 76, no. 5, p. 53-56.

Radioactive pegmatites and associated migmatites are found over wide sections of northern Saskatchewan, generally along the contact of bands of metasediments with granite and granite gneiss. A well-zoned pegmatite at Lac LaRonge contains

uraninite in a narrow oligoclase-quartz border zone and in the overlying mica schist. Parts of pegmatites relatively rich in uranium may contain much biotite and dark quartz. Molybdenite is a minor accessory that is often present. The origin of the radioactive pegmatites is discussed.

- M- 6. McCauley, J. F., 1961, Uranium in Pennsylvania: Pennsylvania Geol. Survey Bull. M43, 71 p.

Describes radioactive pegmatite near Pikesville, in Berks County.

Secondary uranium minerals occur in altered pegmatitic pods and stringers in deeply weathered gneiss exposed in a pit prospected for iron. The pegmatites appear to consist of relatively coarse grained quartz and microcline with biotite. No primary uranium oxide minerals were found in heavy mineral separates. Bands of magnetite-ilmenite are also present in the gneiss.

- M- 7. McKelvey, V. E., Everhart, D. L. and Garrels, R. M., 1955, Origin of uranium deposits: Econ. Geology, Fiftieth Anniversary Vol., pt. 1, p. 464-533.

Describes the role of geochemistry in the origin of uranium deposits and of the uranium cycle in nature.

Drawing upon the foregoing, the article briefly postulates the origin of such uranium deposit models as veins, reefs, coals, shales, phosphorites, sandstone, etc.

Pegmatites are noted as being late stage magma differentiates having a wide variety of uranium minerals. Potassium-rich pegmatites are most likely to host uranium.

- M- 8. McKeown, F. A., 1951, Reconnaissance of radioactive rocks of Vermont, New Hampshire, Connecticut, Rhode Island and southeastern New York: U. S. Geol. Survey Rept. TEI-67, 48 p.

Small quartz-feldspar-biotite pegmatites and adjacent gneiss near Bear Mountain, New York show anomalous radioactivity most of which is derived from thorium-bearing minerals.

- M- 9. McKeown, F. A. and Klemic, Harry,]953, Reconnaissance for radioactive materials in northeastern United States (Maine and N. Y. - N. J. - Pa.) during 1952: U. S. Geol. Survey Rept. TEI-317A, 68 p.

Radioactivity noted in magnetite-rich pegmatite in Morris County, New Jersey: pegmatite contains allanite and zircon.

- M-10. Meeves, H. C., Hauer, C. M., Salsbury, M. H., Konselman, A. S. and Shannon, S. S., Jr., 1966, Reconnaissance of beryllium-bearing pegmatite deposits in six western states: U. S. Bur. Mines Inf. Circ. 8298, 34 p.

Report gives location and accessory mineral assemblage of a large number of pegmatites, mostly in Colorado.

- M-11. Mickle, D. G. and Mathews, G. W., 1978, Geologic characteristics of environments favorable for uranium deposits: Open-File Report GJBX-67(78), U. S. Dept. of Energy, Grand Junction, Colo., 250 p.

Six pages of this 250 page text detailing the characteristics of uranium deposits are entirely concerned with "uraniferous" pegmatites. The authors conclude that "uraniferous pegmatites do not differ greatly from non-uraniferous pegmatites". They go on to note that uraniferous pegmatites are:

- found in areas of extreme crustal mobility
- granitic
- characterized by high silica, soda and potash and low iron, calcium and magnesium
- enclosed in albitized and argillicized rocks
- normally tabular discordant dikes
- associated with mesozonal plutons
- of marginal economic importance

There are numerous exceptions to each of the above generalizations.

- M-12. Mitchell, R. S., 1965, Virginia metamict minerals: Comments on a uranium-niobium oxide from Powhatan County: Southeastern Geology, v. 6, no. 2, p. 79-85.

Olive-brown metamict uranium-niobium mineral found in the White Peak No. 1 mica mine is described together with X-ray powder data and semiquantitative spectrographic analyses. Mineral may be undescribed species or a very altered uranium-rich samarskite. Samarskite and euxenite are found in the deposit which is a large zoned body in migmatized biotite gneiss.

- M-13. _____, 1967, Virginia metamict minerals: X-ray study of fergusonite: Southeastern Geology, v. 8, p. 145-153.

Study of fergusonite from Amelia, Amherst and Bedford Counties, Virginia. Fergusonite from four localities in Virginia is described with indexed X-ray powder data obtained from heated material. Pegmatites from which fergusonite has been verified are the Champion and Rutherford in Amelia County, the allanite-rich pegmatite on Little Friar Mountain in Amherst County and the Wheatly in Bedford County.

- M-14. _____, 1970, Virginia metamict minerals: X-ray diffraction study of samarskite: Southeastern Geology, v. 12, p. 121-133.

Study of samarskites from Virginia with indexed X-ray powder data for the phases developed on heating the metamict mineral. Samarskites were from the Morefield pegmatite in Amelia County, the Mitchell and nearby Patterson pegmatites and Thunder Hill in Bedford County and the White Peak No. 1 pegmatite in Powhatan County. Samarskite from the Mitchell pegmatite is commonly anhedral and enclosed in euhedral columbite associated with greenish gray plagioclase, red garnet and muscovite.

- M-15. Mitchell, R. S. and Zulkiewicz, R. J., 1970, Virginia metamict minerals: pyrochlore-microlite series: Southeastern Geology, v. 11, no. 3, p. 173-185.

Detailed study of pyrochlore-microlite from Amelia, Powhatan and Prince Edward Counties. Includes unit cell, X-ray and spectrographic data.

- M-16. Montgomery, Arthur, 1957, Three occurrences of high-thorian uraninite near Easton, Pennsylvania: Am. Mineralogist, v. 42, p. 804-820.

Granitic pegmatites are considered the source of elements that formed radioactive minerals in serpentinized rocks.

- M-17. Morrill, Philip, 1958, Maine mines and minerals. V. 1 Western Maine: Naples, Maine, Dillingham Natural History Museum, 80 p.

Mineral guidebook which provides descriptions and location maps. Localities for radioactive pegmatite minerals are shown.

- M-18. Murdock, Joseph and Webb, R. W., 1966, Minerals of California: California Div. of Mines and Geol. Bull. 189, 559 p.

A detailed listing of mineral species arranged in alphabetical order. Numerous uranium occurrences are mentioned, but pegmatites are not differentiated.

- M-19. Murdock, T. G., 1963, Mineral resources of the Malagasy Republic: U. S. Bur. of Mines Inf. Circ. 8196, 147 p.

Pegmatites in Madagascar rarely contain uraninite. Principal minerals are euxenite and betafite. From 1908-1925, 100 tons of ore were recovered from surface and eluvial deposits. Ore was difficult to treat.

- M-20. Murphy, M., Wollenberg, H., Strisower, B., Bowroun, H., Flexser, S. and Carmichael, I., 1978, Uranium in alkaline rocks: Open-File Report GJBX-78(78), U. S. Dept. of Energy, Grand Junction, Colorado, 185 p.

This paper describes three alkaline-peralkaline pegmatite locations, some with rare-earth and radioactive minerals. Included are Quincy, Massachusetts, Wichita Mtns., Oklahoma and Mt. Rosa, Colorado.

- N- 1. Narten, P. F. and McKeown, F. A., 1952, Reconnaissance of radioactive rocks of the Hudson Valley and Adirondack Mountains, New York: U. S. Geol. Survey Rept. TEI-70, 54 p.

Describes pegmatite debris containing allanite and uraninite on the dump of a talc mine at Talcville, New York and uraninite in a "replacement" albite-microcline-quartz pegmatite in Grenville limestone near Bigelow, New York. Slightly radioactive pegmatites both granitic and basic were reported from Lake George, Graphite, Mineville and Duane, New York.

- N- 2. Nash, J. T., 1979, Uranium and thorium in granitic rocks of northeastern Washington and northern Idaho, with comments on uranium resource favorability: U. S. Geological Survey, Open-File Report 79-233, 39 p.

Two types of granitic rocks are likely hosts for uranium. The more favorable is a peraluminous, two mica granite where the uranium occurs in magnetite and biotite. The less favorable host is calcalkaline hornblende and biotite granites where uranium is in sphene, zircon and allanite.

Fission track method was employed to determine the site of uranium deposition within various minerals.

- N- 3. Nelson-Moore, J. L., Collins, D. B. and Hornbaker, A. L., 1978, Radioactive mineral occurrences of Colorado and bibliography: Colo. Geol. Survey, Dept. Nat. Res., Bull. 40, 1054 p.

An exhaustive compilation of over 2500 radioactive localities in Colorado. Many pegmatites are included. Bibliography with cross indexing by county, host rock. etc.

- N- 4. Neuerburg, G. J., 1954, Allanite pegmatite, San Gabriel Mountains, Los Angeles County, California: Am. Mineralogist, v. 39, nos. 9-10, p. 831-834.

Allanite and rare uranothorite were found in an unzoned pegmatite.

- N- 5. Nishimori, R. K., Ragland, P. C., Rogers, J. J. W. and Greenberg, J. K., 1977, Uranium deposits in granitic rocks: Open-File Report GJBX-13(77), U. S. Energy Research and Development Administration, Grand Junction, Colo., 93 p.

An excellent summary on the nature and distribution of uranium in granitic rocks. Included are: descriptions of deposits found in the U. S., Canada, Australia and Africa; discussion of exploration techniques and areas favorable for uranium; review of theoretical experimental studies on granite crystallization; and a general summary on features of uranium deposits in granitic rocks.

The authors do not differentiate Rössing type deposits from Bancroft or other pegmatitic deposits and conclude ". . . that the immediate source of uranium in these deposits was uraniferous sediments . . .".

- N- 7. Norton, J. J., 1970, Composition of a pegmatite, Keystone, South Dakota: Am. Mineralogist, v. 55, p. 981-1002.

The composition of a geologically simple pegmatite was determined by mapping and diamond drilling. Chemical and spectrographic analyses are given for various pegmatite units and schist country rock. The bulk chemical composition of this pegmatite is at the granite minimum. Uranium and thorium were looked for but not detected in spectrographic analyses.

- O- 1. Olson, J. C., 1941, Mica-bearing pegmatites of New Hampshire: U. S. Geol. Survey Bull. 931-P, p. 363-403.

Provides descriptions of pegmatites chiefly in the Grafton and Keene districts, that were studied for mica resources. Location and geologic maps of several individual deposits are included.

- 0- 2. _____, 1950, Feldspar and associated minerals in New Hampshire. Pt. XIV Mineral Resource Survey: New Hampshire State Planning and Development Commission, Concord, New Hampshire, 50 p.

Describes geology and mineralogy of pegmatites in New Hampshire with particular attention to their economic mineral products, notably feldspar. Relation of the pegmatites to country rocks, zoning characteristics and the distribution of minerals in zoned deposits are discussed. Specific deposits in which uranium minerals have been noted are mentioned.

- 0- 3. _____, 1952, Pegmatites of the Cashiers and Zirconia districts, North Carolina: North Carolina Dept. Conserv. and Devel., Div. Min. Resources Bull. 64, 32 p.

Pegmatites in two nearby districts are thought to be related to a granite of probable Paleozoic age. Uranium minerals are reported from only two of the many Cashiers district pegmatites, but in the Zirconia district rare accessory minerals are more abundant and include several radioactive species. The report includes location and geologic maps, description of individual deposits and spectrographic data for samples from various zones of pegmatites in the Zirconia district.

- 0- 4. Olson, J. C. and Adams, J. W., 1962, Thorium and rare earths in the United States, exclusive of Alaska and Hawaii: U. S. Geol. Survey Mineral Inv. Resource Map MR-28.

Map shows location of many radioactive pegmatite deposits. Latitude and longitude of the deposits and literature references given in accompanying text.

- O- 5. Olson, J. C. and Hinrichs, E. N., 1960, Beryl-bearing pegmatites in the Ruby Mountains and other areas in Nevada and northwestern Arizona: U. S. Geol. Survey Bull. 1082-D, p. 135-200.

Radioactive minerals were found in only a few of the numerous pegmatites described and were most abundant in pegmatites at Gold Butte in Clark County, Nevada.

- O- 6. Ordway, R. J., 1951, Radioactivity of some Maine pegmatites: Rept. of the State Geologist, 1949-1950, Maine Devel. Comm., Augusta, p. 91-106.

Anomalous radioactivity was found in about two-thirds of the pegmatites visited. Radiation was related to black grains, presumed to be uraninite, which were most abundant in wall zones and core margins. Discoloration of feldspar and development of smoky quartz around radioactive minerals was noted. No commercial concentrations of radioactive minerals were found.

- O- 7. Orville, P. M., 1960, Petrology of several pegmatites in the Keystone district, Black Hills, South Dakota: Geol. Soc. America Bull., v. 71, p. 1467-1490.

Study of three simple pegmatites near Keystone, South Dakota. Pegmatites occur in quartz-mica schist and are peripheral to the Harney Peak Granite. These pegmatites have very similar average modal and chemical composition; the latter being close to that of the granite. Both pegmatites and granite may be considered as rock bodies at a similar stage of differentiation.

- O- 8. Ostrander, C. W. and Price, W. E., Jr., 1940, The minerals of Maryland: The Natural History Soc. of Maryland, Baltimore, 92 p.

Gives location of several occurrences of uranium minerals in pegmatites in Maryland, notably Kensington Mica Mine in Montgomery County.

- O- 9. Osterwald, F. W., Osterwald, D. B., Long, J. S., Jr. and Wilson, W. H., 1966, Mineral resources of Wyoming: Wyoming Geol. Survey Bull. 50, 287 p.

Mentions several occurrences of radioactive pegmatite minerals. Most significant appears to be in Carbon County from which 3115 pounds of euxenite were reportedly produced in 1957.

- O-10. Overstreet, W. C., 1967, The geologic occurrence of monazite: U. S. Geol. Survey Prof. Paper 530, 327 p.

A comprehensive report on monazite which includes descriptions of its occurrence in pegmatites throughout the world. Analyses of a large number of monazites from pegmatites and granites show that the ThO_2 content of the average pegmatite monazite will be higher than that in the average monazite from granite. There appears to be no correlation between the ThO_2 content of the monazite in the pegmatite with the metamorphic grade of the wall rock.

- P- 1. Page, J. J. and Larrabee, D. M., 1962, Beryl resources of New Hampshire: U. S. Geol. Survey Prof. Paper 353, 49 p.

More than 200 pegmatites are described in detail or in tabular form in this catalog of beryllium-rich pegmatites in New Hampshire. The richest pegmatites occur in quartz mica schists of the Littleton Formation of Devonian age. Uranium is mentioned as being a minor constituent usually found with masses of mica near the core margins.

- P- 2. Page, L. R., 1950, Uranium in pegmatites: Econ. Geology, vol. 45, p.12-24.

A benchmark article reviewing uranium in pegmatites as viewed in 1950. Potash-rich pegmatites were considered as favorable. Uranium was to be found only in the central quartz core or in the intermediate zones. Uraninite is associated with muscovite and biotite; betafite and allanite with biotite; euxenite and monazite with beryl; and samarskite with columbite and fergusonite.

Several domestic and foreign deposits including those in Madagascar are described.

Page concludes that "pegmatites could not be considered as a major source of uranium".

- P- 3. Parker, J. M., 1952, Geology and structure of part of the Spruce Pine district, North Carolina: North Carolina Dept. Conserv. and Devel. Bull. No. 65, 26 p.

Radioactive minerals are found in very small quantities in a few perthitic pegmatites in the southeast part of the district.

- P- 4. Patchick, P. F., 1960, A rare-earth pegmatite near Nuevo, California: Rocks and Minerals, v. 35, p. 323-327.

Xenotime, monazite, samarskite and cyrtolite are found in a zoned granitic pegmatite.

- P- 5. Peach, P. A., 1950, Some pegmatites from eastern Ontario and their geological environment: unpubl. Ph.D. thesis, University of Toronto, Toronto, Ontario, 87 p.

Detailed description of the geology and mineralogy of the country rocks and pegmatites in eastern Ontario. A discussion of the occurrence and origin of radioactive minerals is provided. The uranium occurs mainly in pegmatites with abundant potassium feldspar.

- P- 6. Pegau, A. A., 1932, Pegmatite deposits of Virginia: Virginia Geol. Survey Bull. 33, 123 p.

Detailed description of pegmatites and their geologic setting. Occurrences of radioactive minerals are limited to a few sites, notably fergusonite and microlite at the Rutherford mine in Amelia County and allanite in Amherst County.

- P- 7. Povarennykh, A. S., 1972, The role of crystallochemical factors in the distribution of rare elements in minerals (abs): Internat. Geol. Cong., 24th, Montreal 1972, Abs., p. 318-319.

Elements will deposit according to several factors including: abundance, effective ionic radius, coordination number, coordination polyhedra, structure of the electronic shell and electronegativity of the atom.

Similarities between elements results in preferential replacement of elements such as calcium by Sr, Y, RE, Th, and U.

Some elements possess certain peculiarities that render them unique so that they prefer to concentrate in their own minerals. Hexavalent uranium is amongst this group.

- Q- 1. Quensel, Percy, 1940, Minerals of the Varuträsk pegmatite. XIX The uraninite minerals, (ulrichite and pitchblende): Geol. Foren., Stockholm Forh. v. 62, p. 291-396.

Very small fragments of uranium minerals occur as black oxides surrounded by orange or yellow alteration products. Chemical analyses are provided. See following item.

- Q- 2. _____, 1956, The paragenesis of the Varuträsk pegmatite, including a review of its mineral assemblage: Arkiv Mineralogi och Geologi, v. 2, p. 9-126.

An exhaustive descriptive article on a complex zoned lithium pegmatite in northern Sweden. Many analyses and photographs are presented. Uranium and thorium are all but absent. Sparse microlite and uraninite formed between 400° and 600° C during a secondary replacement phase.

- Q- 3. Quervain, Francis de, 1965, Uraninit führender Turmalin-Sillimanit Pegmatit aus dem Gotthard-Massiv: Beitr. Geol. Schweiz. Kl. Mitt. no. 36, p. 395-400, abs. in Min. Abs., v. 19, p. 185, 1968.

Uraninite is found in a tourmaline-sillimanite-bearing granitic pegmatite. Other accessory minerals include apatite, garnet, pyrite and zircon.

- Q- 4. Quirke, T. T. and Kremers, H. E., 1943, Rare element prospecting in pegmatites: Econ. Geology, v. 38, no. 3, p. 173-187.

- Q. -

It is suggested that assaying of "test" minerals may aid in prospecting pegmatites for rare element content. Zircon is considered a "test" mineral for thorium.

- R -

- R- 1. Rayner, E. O., 1960, The nature and distribution of uranium deposits in New South Wales: New South Wales Dept. of Mines, Tech. Rept. v. 5, p. 63-101.

This paper describes the Crocker Wells uranium deposit in Australia. The pegmatite deposits grade into quartz veins with a decrease in feldspar content. Davidite has been found in this deposit.

- R- 2. Redmon, D. E., 1961, Reconnaissance of selected pegmatite districts in north-central New Mexico: U. S. Bur. Mines, Inf. Circ. 8013, 79 p.

This report mentions numerous pegmatites in various districts in both the Petaca and Rincon Range districts. Included in the report are locations, history of the deposits, general geology and mineralogy, including radioactive minerals. Good index maps are provided.

- R- 3. Reeve, E. J., 1972, Geochemistry of the Golding-Keene pegmatite and adjacent rocks: unpub. Ph.D. Thesis, University of Toronto, Toronto, Ontario, 197 p.

Describes geochemistry of a very coarse-grained nepheline-albite pegmatite enclosed within a nepheline gneiss. The author asserted that the pegmatite developed from partial melting of the gneiss.

- R- 4. Reyna, J. G., 1960, Las pegmatitas graníticas de Santa Ana, Tlaxiahuaca, Oax., Mexico. (in Spanish): Internat. Geol. Cong. 21st Session, Copenhagen 1960, Proc. Pt. XVII, p. 63-76. (English abs.)

Many radioactive mineral species including fergusonite and allanite are reported from pegmatites within a Paleozoic granite gneiss. Location maps and maps of the pegmatites are provided.

- R- 5. Rich, R. A., Holland, H. D. and Petersen, Ulrich, 1977, Hydrothermal uranium deposits: Elsevier, N. Y., 264 p.

An excellent summary of uranium deposits formed by hydrothermal processes. Pegmatites are briefly mentioned.

The authors note that uraniferous pegmatites at Beaverlodge have been dated at 2200 million years and 1930 million years $\pm$ 40 million years. Uraniferous pegmatites at Rössing were dated at 510 million years.

- R- 6. Richmond, W. E., Jr. 1937, Paragenesis of the minerals from Blueberry Mountain, Woburn, Massachusetts: Am. Mineralogist, vol. 22, p. 290-300.

Paragenetic studies suggest that allanite, orangite and thorite were deposited from hydrothermal fluids in pegmatites and in veins in both pegmatite and country rock.

- R- 7. Rinaldi, C. A., 1969, Uranium-bearing pegmatites of the mountains of Comechingones, Cordoba Province (in Spanish): Argent. Com. Nac. Energ. At. (Informe), CNEA-256, 56 p.; abs. in Chem. Abs., v. 74, item 44229p, 1971.

Many well-zoned pegmatites are found in a Precambrian mica gneiss. The pegmatites are mined for muscovite and contain beryl, tantalum-niobium and uranium minerals as by-products. The uranium minerals are associated with muscovite.

- R- 8. Rivalenti, G. and Sighinolfi, G. P., 1971, The influence of the local pressure gradient and of the metamorphic grade on the composition of pegmatites in metamorphic terrains: Contr. Min. and Petr. v. 34, p. 80-83, abs. in Min. Abs., v. 23, no. 3, item 72-2499, 1972.

Composition of pegmatites in metamorphic terrains is dependent upon local pressure gradient. Pegmatites having a composition similar to that of the host rock are formed in areas of shallow pressure gradient, while the composition of pegmatites that developed under a steep pressure gradient differ from that of the host rock.

- R- 9. Robertson, J. A., 1968, Uranium and thorium deposits of northern Ontario: Ontario Dept. Mines Min. Res. Circ. No. 9, 106 p.

An inventory of all uranium and thorium deposits in northern Ontario as of 1967. The listings include location, development, reference and general geology for each deposit. A number of pegmatites are included, but these are of minor economic significance.

- R-10. _____, 1978, Uranium deposits in Ontario, in Uranium deposits, their mineralogy and origin: Mineralog. Assoc. Canada, Short Course Handbook, v. 3, p. 229-280.

This discussion of uranium deposits includes summaries of the geology and mineralogy of several deposits in Ontario that have been considered to be pegmatites. Many valuable references are cited.

- R-11. Robinson, S. C., 1960, Economic deposits in granitic dikes Bancroft District, Ontario: Canadian Mineralogist, v. 6, pt. 4, p. 513-521.

A detailed study of the geology, geochemistry and mineralogy of the uraniferous pegmatites and surrounding country rocks. The author has noted that all of the productive uranium deposits are in granitic and syenitic pegmatite dikes adjacent to three granitic plutons of anomalously high radioactivity. The minerals present include uraninite, uranothorite, allanite, betafite and minor fergusonite and polycrase. The author concluded that the pegmatites formed mainly by replacement and in part by fissure filling and that the ultimate source for the rare elements was an extensive older sedimentary unit.

- R-12. Rodgers, John, 1952, Absolute ages of radioactive minerals from the Appalachian region: Am. Jour. Sci., v. 250, p. 411-427.

Lead-ratio method used to determine ages of radioactive rocks. Many pegmatite minerals were analyzed.

- R-13. Rodionov, G., 1964, Pegmatite types and some specific features of pegmatite formation: Internat. Geol. Cong., 22nd, New Delhi 1964, Rept., pt. 6, p. 140-156.

The author recognized four types of pegmatites based on depth of formation. Each type is characterized by a specific mineralogic association. Radioactive minerals are most commonly found in pegmatites emplaced at great depths.

- R-14. Rogers, J. J. W. and Adams, J. A. S., 1969a, Thorium in Wedepohl, K.H., ed. Handbook of Geochemistry: Berlin, Springer-Verlag, v. 2, no. 3, chapter 90.

Data on natural occurrence of thorium. Its abundance in minerals and various rock types is presented and high-thorium provinces are discussed. An extensive bibliography is given.

- R-15. Rogers, J. J. W. and Adams, J. A. S., 1969b, Uranium, in Wedepohl, K. H., ed., Handbook of Geochemistry: Berlin, Springer-Verlag, v. 2, no. 3, chapter 92.

Data on natural occurrence of uranium, its abundance in various rocks, behavior during metamorphism and weathering, solubilities, etc. An extensive bibliography is given.

- R-16. Rogers, J. J. W., Ragland, P. C., Nishimori, R. K., Greenberg, J. K. and Hauck, S. A., 1978, Varieties of granitic uranium deposits and favorable exploration areas in the eastern United States: Econ. Geology, v. 73, p. 1539-1555.

Granitic uranium deposits show two end members:

1. Anatectic - Rössing type with low Th/U ratios, rich in surface elements and high $\text{Sr}^{87}/\text{Sr}^{86}$ ratios. This type is formed by remobilization of pre-existing basement rocks.
2. Magmatic - Bokan type with high Th/U ratios, rich in late-differentiating elements and $\text{Sr}^{87}/\text{Sr}^{86}$ ratios. This type is derived directly from the mantle or deep crust as diapiric magma.

Pegmatites may be found in each member.

- R-17. Romberger, S. B., 1978, Hydrothermal transport and deposition of uranium and the origin of vein uranium deposits (abs.): Abstracts with programs, GAC-MAC-GSA, 1978 Joint Annual Meeting, Toronto, Ontario, v. 3, p. 480.

Outlines the transportation and mechanism of deposition for vein uranium. Various aqueous complexes and hydrothermal systems are evaluated.

- R-18. Rossofskiy, L. N., Chmyrev, V. M. and Salakh, A. S., 1976, New fields and belts of rare-metal pegmatites in the Hindu Kush (eastern Afghanistan): Internat. Geology Rev., vol. 18, no. 11, p. 1339-1342.

The authors discuss the mineralogy of the pegmatites and country rocks as well as the distribution of the pegmatites. No mention of radioactive pegmatites.

- R-19. Rowe, R. B., 1952, Petrology of the Richardson radioactive deposit, Wilberforce, Ontario: Canada Geol. Survey Bull. 23, 22 p.

A detailed description of this deposit is provided. The radioactivity is mainly associated with an oligoclase-microcline zone and calcite-fluorite-apatite core, the latter containing large uraninite crystals. Red haloes noted in calcite enclosing uraninite. Author prefers high temperature hydrothermal origin for deposit.

- S- 1. Safiannikoff, A. and Van Wambeke, L., 1967, La pegmatite radioactive à beryl de Kobokobo et les autres venues pegmatitiques et filoniennes de la région de Kamituga - Kivu - Rép. du Congo: Mineralium Deposita, v. 2, p. 119-130.

Detailed description of a large well-zoned pegmatite in which uraniferous cyrtolite and thorian uraninite are found in an albitized zone containing large masses of beryl as well as columbite, phosphate minerals and lollingite. A geologic map and section of the deposit is shown as well as a paragenetic diagram using Fersman's phases. Pegmatite is in mica schist and is dated at 850 ± 10 million years.

- S- 2. Satterly, J., 1957, Radioactive mineral occurrences in the Bancroft area: Ontario Dept. of Mines, Ann. Rept., 56th, v. 65, pt. 6, 181 p.

This report provides a classification and discussion of the various radioactive deposits in the area. The radioactive minerals are described in detail including analyses of thorite, uranothorite, multiple oxides and uraninite. The bulk of the report centers on property descriptions.

- S- 3. Satterly, J. and Hewitt, D. F., 1955, Some radioactive mineral occurrences in the Bancroft area: Ontario Dept. of Mines, Geol. Circ. 2, 62 p.

Detailed descriptions of individual radioactive deposits in the Bancroft district. Deposits fall into 3 groups: pegmatite, metasomatic and vein.

Occurrences in granite pegmatites are most abundant and widespread. There is a definite correlation between uranium content and amount of magnetite in the leucocratic pegmatites. Other favorable guides are hematization, fracturing and color of feldspar. Purple fluorite may be significant in mafic pegmatites.

Geologic and location maps are provided.

- S- 4. Seaman, D. M., 1975, Pegmatite minerals of Maine Pt. 1: Rocks and Minerals, v. 50, p. 147-151; Pt. 2, *ibid.* p. 240-243; Pt. 3, *ibid.* 312-316; Pt. 4, *ibid.* p. 366-369.

A mineral collector's guide to minerals and their sources in the state of Maine. Locations are given, but without index maps.

- S- 5. Serrano, L. G. Morales, 1962, Some manifestations of radioactive minerals and rare earths associated with pegmatites of Corongo, Casma, Chosica and Atico (in Spanish): Bol. Soc. Geol. Peru, v. 37, p. 109-129: abs. in Chem. Abs., v. 66, item 30945 s, 1967.

Occurrences of uraninite, autunite, rutherfordine and allanite are described.

- S- 6. Shainin, V. E., 1948, Economic geology of some pegmatites in Topsham, Maine: Maine Geol. Survey Bull. no. 5, 32 p.

Describes the geology of the area including a description of the internal structure of various pegmatites. Samarskite and monazite from pegmatites gave age dates of 232 million years and 600 million years respectively.

- S- 7. _____, 1949, Preliminary report of the pegmatites on Red Hill, Rumford, Maine: Report of the State Geologist 1947-1948, Maine Development Commission, Augusta (Maine), p. 90-102.

Briefly describes the geology and internal structure of five zoned pegmatites. The percentage of beryl is given for each zone in the pegmatites.

- S- 8. Shannon, E. V., 1926, Some minerals from the Kensington mica mine, Montgomery County, Maryland: Am. Mineralogist, vol. 11, p. 35-37. Pegmatite, which is in a tourmaline-bearing muscovite schist, contained flesh-red feldspar, quartz, mica, albite (some cleavelandite), spessartite garnet, apatite, gahnite, and greenish-yellow beryl.

Small rusty cavities surrounded by radiating cracks and minor autunite, suggest an earlier radioactive mineral.

- S- 9. Sharp, W. N., 1976, Geologic map and details of beryllium and molybdenum, Mount Antero, Chaffee County, Colo.: U. S. Geol. Survey Map MF-810.

Greisenized areas of the Mount Antero granite of Oligocene age contain minor brannerite.

- S-10. Shaub, B. M., 1938, The occurrence, crystal habit and composition of the uraninite from the Ruggles Mine, near Grafton Center, New Hampshire: Am. Mineralogist, v. 23, p. 334-341.

Uraninite occurs as small well developed crystals in albite-rich perthite, solid perthite, apatite-albite rock, in dikes of massive smoky quartz cutting feldspar, or in muscovite;

the muscovite being noticeably darkened. A chemical analysis shows Th and REE's to be noticeably low for pegmatite uraninite. Age determined to be 304 million years. Age data for other New England pegmatites is given.

- S-11. _____, 1940, Age of the uraninite from the McLearn pegmatite near Richville Station, St. Lawrence County, New York: Am. Mineralogist, v. 25, p. 480-487.

The pegmatite occurs in a highly metamorphosed Grenville series limestone. Uraninite occurs chiefly in white quartz, rarely in feldspar and tremolite. Diopside and calcite are found in the pegmatites. Uraninite age given as 1094 million years. Ages of radioactive minerals from eight other pegmatites summarized.

- S-12. Shaw, D. M., 1958, Radioactive mineral occurrences of the province of Quebec: Quebec Dept. of Mines Geol. Rept. 80, p. 1-52.

A brief discussion of radioactive minerals and the geologic environments in which they occur in Quebec. Included are various granitic and syenitic pegmatite deposits in the Grenville province.

- S-13. Sheridan, D. M., Stephens, H. G., Staatz, M. H. and Norton, J. J., 1957, Geology and beryl deposits of the Peerless pegmatite, Pennington County, South Dakota: U. S. Geol. Survey Prof. Paper 297-A, p. 1-47.

This very large complexly zoned pegmatite has been a major source of scrap mica and beryl with a minor production of feldspar, lithium minerals, tantalite-columbite and cassiterite. Authors give a detailed description of the internal structure and mineralogy of the deposit including maps and drill logs. Autunite and torbernite were reported in earlier literature, but were not noted during this study.

- S-14. Shimer, J. A., 1943, Spectrographic analysis of some New England granites and pegmatites: Geol. Soc. America Bull., v. 54, no. 8, p. 1049-1066.

Granitic rocks and associated pegmatites from 18 sites in New England were studied petrographically and analyses made of whole rocks and individual minerals for 12 elements; uranium and thorium were not included. Each granite has a characteristic minor element suite. The granites and granite minerals almost always have a greater variety of minor elements than associated pegmatites; where the same element is present in both granite and pegmatite it is more abundant in the granite. Potassium was noted as the only element richer in the pegmatites. Biotite in granites contained the bulk of the minor elements; in pegmatites, biotite is always richer than muscovite in minor elements. Data is presented graphically.

- S-15. Shmakin, B. M., 1974 (Pub. 1976), Typomorphic minerals and typochemical elements of muscovite and rare metal-muscovite pegmatites (in Russian): Ezhg. Inst. Geochim. Sib. Otd., Akad. Nauk SSSR, 1974, p. 116-120; abs. in Chem. Abs. v. 88, item 155857a, 1978.

Typomorphic accessory minerals associated with muscovite pegmatites include dravite-buergerite tourmaline, garnet and fluorapatite; uraninite, zircon, allanite, monazite and beryl are common. In rare metal-muscovite pegmatites accessory minerals include columbite, cassiterite, spodumene, amblygonite, and samarskite. Beryl is rare.

- S-16. Shockey, P. N., 1957, Reconnaissance geology of the Leesburg quadrangle, Lemhi County, Idaho: Idaho Bur. Mines and Geology, Pamph. 113, 42 p.

Thorium-bearing allanite occurs in small quartz-feldspar-biotite pegmatites in the Big Jureano Creek area.

- S-17. Simmons, W. B., Jr. and Heinrich, E. W., 1975, A summary of the petrogenesis of the granite-pegmatite system in the northern end of the Pikes Peak batholith: Fortschr. Mineralogie, v. 52 (Spec. vol: Papers and Proc. 9th Gen. Meeting, I. M. A. Berlin (West) - Regensburg, 1974), p. 251-264; abs. in Min. Abs., v. 27, no. 3, item 76-2909, 1976.

Fifty well-zoned granitic pegmatites occur near the former town of South Platte. All of the pegmatites are contained within the parent Pikes Peak granite and are characterized by fluorite, abundant rare-earth minerals and the presence of metallic specular hematite. The well-developed zoning with associated secondary replacement is noteworthy in this area. The authors conclude that the pegmatites crystallized from a water saturated magma as an aqueous phase enriched in fluorine, rare earths, iron, and volatiles.

- S-18. Simpson, A. B., 1975, Summary of the mineralogical investigation of pegmatites: Rept. Natl. Inst. Metall., South Africa, no. 483, 4 p.; abs. in Min. Abs., v. 27, no. 2, item 76-1471, 1976.

An examination of the Noumas pegmatite, 60 miles north of Springbok, revealed green and brown varieties of microlite in irregular discordant bodies of relatively fine grained lithium-bearing muscovite, plagioclase, and microcline that cut across normal zonation and are regarded as replacement units. The green variety of microlite contains significant uranium.

- S-19. Sims, P. K., 1954, Radioactive Precambrian pegmatite, in Geologic investigations of radioactive deposits - Semiannual progress report, June 1 to Nov. 30, 1954: U. S. Geol. Survey TEI-490, p. 137-139. Oak Ridge, Tenn.

Radioactive pegmatites are found in Virginia Canyon one mile north of Idaho Springs, Colorado. Uraninite is associated with biotite; uranophane and autunite are present near the surface. The pegmatites are interpreted to be genetically related to a nearby two mica granite which is slightly radioactive.

- S-20. Sims, P. K. and others, 1963, Geology of uranium and associated ore deposits, central part of the Front Range mineral belt, Colorado: U. S. Geol. Survey Prof. Paper 371, 119 p.

An excellent study of the radioactive pegmatites, granites and

Tertiary intrusives of the Idaho Springs area. Two types of unzoned pegmatites are present, one carries uraninite as disseminated crystals in biotite and feldspar and the other contains monazite and xenotime. The ultimate source for the uranium may have been Precambrian metasediments.

- S-21. Sims, P. K. and Gable, D. J., 1964, Geology of the Precambrian rocks, Central City district, Colorado: U. S. Geol. Survey Prof. Paper 474-C, p. C1-C50.

A 1300+ 100 million year radioactive pegmatite occurs in the Russell Gulch area. The enclosing country rock is biotite gneiss. Small uraninite cubes are concentrated in biotite. This pegmatite is similar lithologically to pegmatite found in Virginia Canyon, one mile north of Idaho Springs.

- S-22. Singh, Surinder and Virk, H. S., 1978, Fission track annealing behavior of uraninite inclusions in muscovite pegmatite of Bhilwara area, Rajasthan State, India: Mineralog. Jour. (Japan), v. 9, no. 2, p. 111-114.

Fission track annealing data for various temperatures. Includes track length reduction and track density reduction plots.

- S-23. Slepnev, Yu. S., 1964, Geochemical characteristics of the rare-metal granitic pegmatites of the Sayan Mountains (in Russian): Geokhimiya 1964, no. 3, p. 242-252; translated in Geochemistry Internat., v. 1, no. 2, p. 221-228, 1964.

Describes in detail the distribution of various rare elements in granitic pegmatites and their minerals. Pegmatites found in tectonically active regions are accompanied by sodium metasomatism and greisenization. Such pegmatites are enriched in rubidium, niobium, tantalum, tin and beryllium. Four types of pegmatites are described and their composition compared to granites. Uranium and thorium are not discussed.

- S-24. Smith, R. C. II, 1978, The mineralogy of Pennsylvania, 1966-1975; Spec. Publ. no. 1, Friends of Mineralogy, Pennsylvania Chapter Inc., 304 p.

Uranium minerals in four pegmatites include phosphuranylite, meta-autunite, meta-torbernite, uranophane, clarkeite, uraninite, allanite and thorogummite. Localities are described.

- S-25. Solodov, N. A., 1959, Certain regularities of distribution of rare elements in sharply zoned granite pegmatites (in Russian): Geokhimiya 1959, no. 4, p. 316-327; translated in Geochemistry 1959, no. 4, p. 388-405.

The author discusses the distribution of Ta, Nb, Be, Li, Rb, Cs in pegmatites. He concludes that distribution is determined by 1) zonal structure, 2) by the "EK" values and ionization potential of the elements, 3) by their initial concentration in the pegmatite melt, and 5) by the chemical composition of the medium relative to point 3. If large amounts of REE's present, Be for example, becomes strongly dispersed.

- S-26. _____, 1964, The criteria of evaluation of rare-metal granite pegmatites: Internat. Geol. Cong., 22nd, New Delhi 1964, Report, p. 6, p. 193-212.

Pegmatites are divided into classes and described as to their chemical and mineralogic composition. Using tables and diagrams, the article provides a framework to determine 1) the type of pegmatite, 2) the zone within the pegmatite and 3) the ore potential of the pegmatite for Be, Ta, Nb, Li and Cs. Uranium is not mentioned.

- S-27. _____, 1965, Relationship between ionization potentials of elements and the concentration necessary for the formation of their own minerals (in Russian): Dokl. Akad. Nauk SSSR, v. 165, p. 190-193; trans. in Dokl. Acad. Sci. U.S.S.R., Earth Sci. Sect., v. 165, p. 177-180, 1966; abs. in Min. Abs., v. 19, p. 289, 1968.

A brief discussion of the factors that cause formation of pegmatite minerals. The most critical factors are the content

of the mineral in the original fluid and the ionization potential of the particular element. The higher the ionization potential, the lower the concentration needed for precipitation. For thorium a concentration of 0.008% of the parent solution would result in deposition of thorite. Uranium is not discussed.

- S-28. Sørensen, H., 1970, Occurrence of uranium in alkaline igneous rocks, in Uranium Exploration Geology: Int. Atomic Energy Agency, Vienna, 1970, p. 161-168.

Radioactive minerals are concentrated in late-stage cores of nepheline syenite pegmatites. Ore grade deposits form only where late or postmagmatic deposition has taken place and where the intrusive is rich in Zr, REE and Nb.

There is no simple relation of uranium to Na/K ratio.

- S-29. Southern Interstate Nuclear Board, 1969, Uranium in the southern United States - U. S. Atomic Energy Comm. Rept. WASH - 1128: Washington, D. C., U. S. Govt. Printing Office, 230 p.

General review of uranium occurrences and favorable environments in the southern United States. Pegmatites are not discussed, but several are located on maps and described briefly on tables.

- S-30. Spence, H. S., 1940, Uraninite and thucolite from Pied des Monts, Charlevoix County, Quebec: Am. Mineralogist, v. 25, p. 711-718.

A large pegmatite of largely graphic microcline-albite-quartz composition contained uraninite, thucolite and monazite. Biotite and muscovite are common, the biotite being unusually rich in pleochroichaloes. Accessory minerals include pink garnet, beryl, apatite, zircon and microlite (?). Feldspar noticeably darkened in vicinity of uraninite. Thucolite occurs in discrete masses and as veinlets in uraninite. Pegmatite is in gneiss.

- S-31. Staatz, M. H., Adams, J. W. and Wahlberg, J. S., 1976, Brown, yellow orange and greenish-black thorites from the Seerie pegmatite, Colorado: Jour. Res. U. S. Geol. Survey, v. 4, no. 5, p. 575-582.

A study of this zoned pegmatite concludes that a fracture-filling thorite-fluorite-zircon assemblage was deposited from late stage solutions that had migrated outward from the core zone. Analyses of the thorites given, contained from 3.44 to 14.96 percent UO_3 . Minute uraninite grains are found in the greenish-black thorite. A geologic map of the deposit is given.

- S-32. Staatz, M. H., Page, L. R., Norton, J. J. and Wilmarth, V. R., 1963, Exploration for beryllium at the Helen Beryl, Elkhorn and Tin Mountain pegmatites in Custer County, South Dakota: U. S. Geol. Survey Prof. Paper 297-C, p. 129-197.

Detailed study based on surface and drill data for three dissimilar beryl-rich pegmatites in South Dakota. Dark brown to black microlite occurs in the core of the Tin Mountain pegmatite where it is generally in narrow bands of pale-purple lepidolite, greenish lithia mica and albite that separate large spodumene crystals from black to smoky quartz. The microlite is the only reported possible uranium-bearing mineral in the deposits studied.

- S-33. Staatz, M. H. and Trites, A. F., 1955, Geology of the Quartz Creek pegmatite district, Gunnison County, Colorado: U. S. Geol. Survey Prof. Paper 265, 111 p.

A detailed geologic study of the pegmatites of the Quartz Creek district; mineral assemblage, structure, and host rock for 1803 deposits given. Radioactive minerals found include pyrochlore-microlite, samarskite, monazite, allanite and an unidentified species, but are not common in the district. The origin of the pegmatites and their geochemistry is discussed.

- S-34. Steacy, H. R. and Kaiman, Solomon, 1978, Uranium minerals in Canada: their description, identification and field guides, in Uranium deposits, their mineralogy and origin: Mineralog. Assoc. Canada, Short Course Handbook, v. 3, p. 107-140.

A concise reference to uranium mineralogy. The association of

uranium in pegmatites with dark purple fluorite, smoky quartz and radial fractures is described.

- S-35. Stuckless, J. S., Bunker, C. M., Bush, C. A., Doering, W. P. and Scott, J. H., 1977, Geochemical and petrological studies of a uraniferous granite from the Granite Mountains, Wyoming: Jour. Res. U. S. Geol. Survey, v. 5, p. 61-81.

A discussion of the distribution of uranium in a highly uraniferous granite. The work includes numerous photomicrographs, much analytical data, and an in depth discussion of the bearing of isotope evidence on distribution and loss of uranium in crystalline rocks.

High silica, high alkaline rocks are deemed to be most favorable for uranium. Such rocks should be unmetamorphosed and relatively unweathered if economic deposits of uranium are to be found.

- S-36. Stugard, Frederick, Jr., 1958, Pegmatites of the Middletown area, Connecticut: U. S. Geol. Survey Bull. 1042-Q, p. 613-683.

More than 300 pegmatites were examined to determine the resource potential of this area. The pegmatites are about 260 million years in age and derived from no specific igneous intrusive. Uranium content is low, but uraninite and samarskite have been found in a few deposits.

- S-37. Sverdrup, T. L., 1960, The pegmatite dyke at Romteland: Norges Geol. Undersokelse Skr., no. 211, p. 124-196.

Description of a pegmatite in southern Norway. Wall rock is a hornblende-bearing quartz-monzonite. Uraninite found in zones surrounding amphibolite inclusions and in graphic granite and quartz feldspar zones. Series of secondary minerals enclose uraninite. Other radioactive minerals include allanite, euxenite, orangite and thorite, samarskite and alvite (cyrtolite).

- T- 1. Tan, Li-Ping, 1966, Major pegmatite deposits of New York State: New York State Mus. and Sci. Service Bull. 408, 138 p.

Petrologic and petrographic discussion of pegmatites in New York.

Paper contains much data on zonation, geothermometry and paragenesis of the pegmatites including a few that contain radioactive minerals.

Sketch maps of several deposits are given and many references are cited.

- T- 2. Taylor, S. R., 1965, The application of trace element data to problems in petrology: Phys. Chem. Earth, v. 6, p. 133-213.

The article discusses the geochemical factors that affect the distribution of trace elements in nature. The elements are discussed in general and specifically.

Uranium and thorium behave similarly. The bulk of these elements in igneous rocks is as interstitial material along grain boundaries. The high ionic potential of U^{4+} and Th^{4+} lead to their concentration in residual magmas.

A section reviewing the behavior of trace elements in pegmatites is given in which two basic types are distinguished. The first are commonly small and possibly products of ultrametamorphic processes. The second group originates from residual melts from magmas, and contain large amounts of rare elements concentrated by continued fractional crystallization.

- T- 3. Thurston, W. R., 1955, Pegmatites of the Crystal Mountain district, Larimer County, Colorado: U. S. Geol. Survey Bull. 1011, 185 p.

Uraninite is found in a plagioclase-quartz-muscovite inner intermediate zone at the Hyatt pegmatite and secondary uranium minerals occur in the same zone of the Big Boulder pegmatite. Associated minerals in this zone include beryl, scrap mica, phosphates, columbite-tantalite, smoky quartz and perthite. Author estimates the uraninite content of this zone as exposed in the deposits to be 0.000X percent.

- T- 4. Trites, A. F. and Tooker, E. W., 1953, Uranium and thorium deposits in east-central Idaho, southwestern Montana: U. S. Geol. Survey Bull. 988-H, p. 157-209.

A description of the geology of 39 reportedly radioactive deposits in Idaho and Montana. Only a small number of pegmatites were visited. These contained minor amounts of thorium and even less uranium.

- T- 5. Turner, F. J. and Verhoogen, John, 1960, Igneous and metamorphic petrology: New York, McGraw Hill, 694 p.

Textbook. Pegmatites are discussed principally from the viewpoint of physical chemistry.

Divides pegmatites into simple and complex. Rare minerals are especially concentrated in complex pegmatites associated with intrusions of syenite or nepheline syenite.

- T- 6. Turner, H. W., 1928, Review of the radioactive minerals of Madagascar: Econ. Geology, v. 23, p. 62-84.

A generalized description of the radioactive minerals found in potassic pegmatites in Madagascar. Analyses of the minerals are given. The only minerals mined for uranium were betafite (80.8 tons) and euxenite (6.6 tons).

- T- 7. Tyler, P. M., 1950, Economic importance of pegmatites: U. S. Bur. Mines, Inf. Circ. 7550, 57 p.

A general review of the economics, methods, and products of pegmatite mining. The paper stresses feldspar, mica, quartz, beryl, lithium, niobium-tantalum and gems. The presence of uraniferous materials is noted, but is dismissed as being of no economic interest.

- U- 1. Uebel, P. J., 1977, Internal structure of pegmatites, its origin and nomenclature; derived from petrographic studies of steeply dipping dikes in South-West Africa and extended to gently dipping dikes observed in southern Norway: Neues Jahrb, Mineral. Abh., v. 131, no. 1, p. 83-113.

The author redefines the zoning of pegmatites using a three dimensional model and assuming solidification simultaneously at walls and in the central core. Fabric and distribution of principal minerals are discussed. There is no mention of geochemistry or of uranium and/or thorium.

- U- 2. U.S. Atomic Energy Comm. and U.S. Geol. Survey , 1968, Preliminary reconnaissance for uranium in Maryland and Pennsylvania, 1953-1957: U. S. Atomic Energy Comm., RME-4103, Washington, D.C., 80 p.

A collection of preliminary reconnaissance report forms on reportedly radioactive localities. Some pegmatitic occurrences are included, but very little substantial data offered.

- U- 3. _____, 1969, Preliminary reconnaissance for uranium in Connecticut, Maine, Massachusetts, New Jersey, New York and Vermont, 1950 to 1959: U. S. Atomic Energy Comm., RME-4106, Washington, D.C., 129 p.

A collection of preliminary reconnaissance report forms on reportedly radioactive localities. Some pegmatitic occurrences are included, but very little substantial data offered.

- U- 4. U.S. Atomic Energy Comm., 1970a, Preliminary reconnaissance for uranium in Gila County, Arizona, 1951-1956: U. S. Atomic Energy Comm., RME-156, Washington, D. C., 186 p.

A collection of preliminary reconnaissance report forms on reportedly radioactive localities. Some pegmatitic occurrences are included, but very little substantial data is offered.

- U- 5. _____, 1970b, Preliminary reconnaissance for uranium in Mohave County, Arizona, 1952-1956: U. S. Atomic Energy Comm., RME-158, Washington, D. C., 1973 p.

A collection of preliminary reconnaissance report forms on reportedly radioactive localities. Some pegmatitic occurrences are included, but very little substantial data is offered.

- U- 6. _____, 1970c, Preliminary reconnaissance for uranium in Pima and Pinal Counties, Arizona, 1950-1957: U. S. Atomic Energy Comm., RME-159, Washington, D. C., 100 p.

A collection of preliminary reconnaissance report forms on reportedly radioactive localities. Some pegmatitic occurrences are included, but very little substantial data is offered.

- U- 7. Uytendogaardt, W., 1960, Uranium mineralization in the Västervik area: Rept. 21st Internat. Geol. Cong. Copenhagen, 1960, pt. 15, p. 114-122; abs. in Min. Abs., v. 15, p. 191.

Davidite, thorogummite and rutile are found in pegmatites and aplites in granitized quartzites on the east coast of southern Sweden. These deposits are Th-rich; uranium, being more mobile, is found in ungranitized quartzite further from granitized areas.

- V- 1. Van Wambeke, L., 1967, Étude de quelques venues radioactives des pegmatites du Congo et du Ruanda: Soc. Belge, Géol., v. 76, p. 7-26; abs. in Min. Abs. v. 19, p. 322, 1968.

Uranium mineralogy of certain pegmatites in Central Africa is discussed. As Ta/Nb ratio increases, uranium-thorium content decreases so that Ta-rich microlite is often devoid of radioactivity.

- V- 2. Varlamoff, N., 1972, Central and West African Rare-Metal granitic pegmatites, related aplites, quartz veins and mineral deposits: Mineralium Deposita, v. 7, p. 202-216.

Author's studies lead to conclusions that rare-metal pegmatite types succeed each other in an order unrelated to age of orogenies or nature of enclosing rocks and that the spatial distribution of the pegmatites in or around granitic intrusives depends on the depth at which the parent granites were crystallizing. Comparisons made to studies of pegmatites in U. S. S. R., Canada, and the United States.

- V- 3. Verrow, H. J., 1941, Pegmatite minerals of the Palermo Quarry, North Groton, New Hampshire: Rocks and Minerals, v. 16, no. 6, p. 208-211.

Over two dozen mineral species found at the Palermo quarry are briefly described. Radioactive species include cyrtolite, uranophane, autunite and "gummite".

Paragenetic studies indicate three stages of mineralization. The earliest stage deposited microcline, muscovite and quartz as crystallization from a magma. A second or pneumatolytic stage is represented by beryl, apatite and uranium minerals. The last or hydrothermal stage is one of replacement by various hydrous iron and manganese phosphates.

- V- 4. Volborth, A., 1962a, Allanite pegmatites, Red Rock, Nevada compared with allanite pegmatites in southern Nevada and California: Econ. Geology, v. 57, p. 209-216.

Description of several pegmatites in southern Nevada and adjacent California with special emphasis on the occurrence and distribution of allanite. The author proposes that this Precambrian area is a rare-earth province.

- V- 5. _____, 1962b, Rapakivi-type granites in the Precambrian complex of Gold Butte, Clark County, Nevada: Geol. Soc. America Bull., v. 73, p. 813-832.

Only minor attention is devoted to pegmatites in this article about rapakivi granites.

Complex zoned pegmatites are found near the contact between granite and enclosing gneiss.

The granite has a very high potassium content, is rich in lanthanides, and allanite is found abundantly in both rock mass and associated pegmatites.

- W- 1. Walker, G. W., Lovering, T. G. and Stephens, H. G., 1956, Radioactive deposits in California: California Dept. Nat. Res., Div. of Mines Spec. Rept. 49, 38 p.

Describes and locates radioactive deposits in California. The only pegmatite with a discernible uranium mineral was the Rainbow in San Bernadino County. Uraninite was found associated with magnetite, smoky quartz and sulfides in pegmatite intruding Jurassic granodiorite. Radioactivity was noted at four other pegmatites.

- W- 2. Weis, P. L., Armstrong, F. C. and Rosenblum, Samuel, 1958, Reconnaissance for radioactive minerals in Washington, Idaho and western Montana 1952-1955: U. S. Geol. Survey Bull. 1074-B, p. 4-48.

Review of nearly 50 radioactive occurrences in the north-western United States.

Some occurrences in pegmatites were examined; autunite, monazite and samarskite were among the minerals noted. The source of radioactivity was not always determined, but appeared to be associated with garnet and biotite.

- W- 3. Wenrich-Verbeek, J. J., 1977, Anomalous uranium in the waters of the Rio Ojo Caliente, New Mexico in Short Papers of the U. S. Geol. Survey Uranium-Thorium Symposium: U. S. Geol. Survey Circ. 753, p. 73-75.

Anomalous uraniumiferous waters from a hot spring are postulated to have derived their uranium from samarskite-bearing pegmatites in the region.

- W- 4. Wetherill, G. W., Tilton, G. R., David, G. L. and Aldrich, L. T., 1956, New determination of the age of the Bob Ingersoll pegmatite, Keystone, S. Dakota: Geochim. et Cosmochim. Acta, v. 9, p. 292-297.

A 250 g mass of uraninite from the No. 1 pit gave an age of 1,600 million years.

- W- 5. White, M. B. and Garland, P. A., 1978, Geological and geochemical aspects of uranium deposits. A selected, annotated bibliography: Vol. 1, Nat. Tech. Inf. Service U. S. Dept. of Commerce ORNL/EIS - 121/V1, 307 p.

An annotated and cross-indexed bibliography of 580 pertinent works on uranium geology. The cross-indexing by author, keywords, location, quadrangle, geoformation and taxonomic name is particularly useful.

Only 16 entries are keyed to pegmatites.

- W- 6. Williams, R. L., 1967, Reconnaissance of yttrium and rare-earth resources in northern New Jersey: U. S. Bur. Mines Rept. Inv. 6885, 34 p.

Probably the best description to date of the Cranberry Lake uranium occurrences. Uranium and rare earths occur in magnetite-rich contact zones between pegmatite and granite gneiss. Drilling indicates the pegmatite thins rapidly below surface.

- W- 7. Wilson, W. F. and McKenzie, B. J., 1978, Mineral collecting sites in North Carolina: North Carolina Dept. Nat. Res. and Comm. Dev., Geol. Survey Sect., Inf. Circ. 24, 122 p.

An excellent guide to mineral sites in North Carolina. The data is clearly presented with numerous maps, road directions and cross-indexing.

The volume is intended for the general public. There is little or no discussion of geology, chemistry, or detailed mineralogy.

- W- 8. Wintringham, N. A., 1955, Handbook for a week with Maine minerals: Holiday Hill Press, Mountainside, New Jersey, 176 p.

A layman's guide to mineral localities in Maine, with generalized geologic and mineralogic data. The author provides detailed location and access information as well as numerous sketch maps.

- W- 9. Wood, C. W., 1967, The Charlotte Mine, uranium rare-earths deposit, Cranberry Lake, New Jersey: Rocks and Minerals, v. 42, no. 6, p. 418-419.

A non-technical article with very little geologic data.

- W-10. Wright, L. A., 1948, The Globe pegmatite, Rio Arriba County, New Mexico: Am. Jour. Sci., v. 246, p. 665-688.

A detailed mineralogic description of the Globe pegmatite, New Mexico. Uranium is present in very late stage samarskite in quartz and possibly in slightly earlier monazite and columbite.

The pegmatite is strongly zoned, with uranium being found only in the innermost late-forming areas.

- Y- 1. Yeliseyeva, O. P., 1977, Content and distribution of uranium, thorium, yttrium and the rare earths in accessory minerals in granitoids: Geokhimiya, no. 9, p. 1338-1351 (in Russian): translation in Geochemistry Internat., v. 14, no. 5, p. 37-49, 1977.

The close association of uranium with thorium, yttrium and the rare earths stems from the capacity of these elements to replace one another. This article describes through photographs and chemical assay data, the distribution of uranium as a replacement or inclusion in grains of zircon, apatite, sphene, etc. in Caledonian granitoids of North Kazakhstan. More acid and younger rocks have more uranium and associated elements.

- Y- 2. Young, E. J. and Hauff, P. L., 1975, An occurrence of disseminated uraninite in Wheeler Basin, Grand County, Colorado: Jour. Res. U. S. Geol. Survey, v. 3, p. 305-311.

Cubes and grains of uraninite with a unit cell of about $5.48\text{\AA}$ are found in biotite-rich gneiss and pegmatite in Wheeler Basin, Colorado. The uraninite is concentrated in clots of biotite and is associated with molybdenite, chalcopyrite, hematite, zircon and monazite. Age is dated at $1450\pm$ million years.

A comparison is made with the Rössing deposit.

- Z- 1. Zodac, Peter, 1937, Minerals of the Strickland Quarry: Rocks and Minerals, v. 12, no. 5, p. 131-144.

Gives detailed layman's description of various minerals that were found in Strickland quarry near Portland, Conn. Uraninite crystals were recovered from one small area within the pegmatite, which is described only as being at the 30 foot level. "Practically all the crystals found are in the Wesleyan University Museum."

SUBJECT INDEX

Code numbers i. e. (S-12) refer to coded references in Bibliography.

A-

Africa - see under Locations

Age - B-19, D-4, F-5, F-8, G-15, H-18, J-7, L-2, M-2, R-5, R-11, R-12, R-15,
S-6, S-10, S-11, S-15, S-21, S-22, S-35, S-36, W-4, Y-2

Alaska - see under Locations - United States

Alkalic - B-23, G-15, M-2, M-20, R-3, S-28

Analytical data - see under Geochemistry, Mineralogy

Arizona - see under Locations - United States

Australia - see under Locations

B-

Basic type - K-5, W-6

Bibliographies - A-3, C-6, C-7, C-8, C-9, C-10, C-16, G-4, J-7, N-3, N-5, W-5

Bulk Analyses - see under Geochemistry

C-

California - see under Locations - United States

Canada - see under Locations

Colorado - see under Locations - United States

Complex - see Zoned

Connecticut - see under Locations - United States

Cyrtolite - see under Mineralogy

E-

Europe - see under Locations

F-

Fission track - see under Mineralogy

G-

General - B-2, B-13, B-19, B-21, C-2, C-3, C-4, C-5, E-1, F-2, G-5, G-12,
G-13, H-3, H-9, H-14, H-16, H-27, J-1, J-5, J-7, K-3, K-7, K-9, L-1,
L-7, L-9, M-10, M-11, N-5, N-6, O-1, O-2, O-5, O-7, O-8, P-1, R-2,
R-6, R-11, R-13, R-16, S-3, S-14, S-23, S-26, S-36, T-1, T-5, T-7, V-2,
V-3, W-2

R-13, R-16, S-3, S-14, S-23, S-26, S-36, T-1, T-5, T-7, V-2, V-3, W-2.

Georgia - see under locations - United States

Geochemistry:

Analytical data - A-8, B-7, B-19, D-4, E-4, G-6, G-12, H-25, K-6, K-7,
M-12, M-15, R-4, S-2, S-31, T-6, Y-1

Bulk Analysis - B-20, M-2, N-6, S-23

General - A-1, A-8, B-22, F-8, P-7, R-11, R-14, R-15, R-17, S-10, S-23,
S-25, S-27, S-28, V-1, Y-1

Trace Element - A-9, N-6, O-3, S-14, T-2

Grenville type - G-7, H-21, L-10, R-19

Guides - B-2, E-2, G-8, K-3, K-8, L-3, L-10, L-11, M-5, N-5, O-6, P-3, Q-4,
R-19, S-3, S-26, S-30, S-34, W-3

I-

Idaho - see under Locations - United States

Index Maps - see under Locations

India and Pakistan - see under Locations

Isotopes - see Age

L-

Locations:

Africa - B-1, B-8, B-16, C-11, C-12, E-3, G-3, H-25, H-28, K-7, N-5,
P-2, S-1, S-18, V-1, V-2

Australia - N-5, R-1

Canada - B-3, B-6, C-4, C-14, C-15, D-4, E-4, E-5, F-4, F-5, F-6, F-7,
G-4, G-7, H-10, H-16, H-17, H-21, H-24, H-27, K-1, K-3, K-10,
L-4, L-10, L-11, M-3, M-4, M-5, N-5, P-5, R-3, R-9, R-10, R-11,
R-19, S-2, S-3, S-12, S-30

Europe - A-6, A-7, B-12, Q-1, Q-2, Q-3, S-37, U-7

Index Maps - B-3, B-5, C-2, C-5, D-2, G-11, G-13, H-24, I-1, J-11, L-7,
M-5, M-9, M-17, M-18, N-3, O-1, O-2, O-4, O-8, P-1, R-2, S-3, S-6,
S-29, S-36, W-1, W-7, W-8, W-10

India and Pakistan - D-1

Malagasy Republic - B-2, D-3, M-19, T-6

Mexico - R-4

South America - R-7, S-5

Union Sov. Soc. Rep. - B-15, I-2, L-8, S-15, S-23

United States - C-1, G-10, G-11, H-8, M-7, M-10, M-11, M-20, N-5, R-12
 Alaska - M-2
 Arizona - H-11, J-2, O-5, U-4, U-5, U-6
 California - A-2, F-3, H-18, H-19, J-5, L-6, M-1, M-18, N-4, P-4, W-1
 Colorado - B-9, B-14, B-20, C-3, G-9, G-15, H-3, H-4, H-5, H-6,
 H-13, M-10, N-3, S-9, S-17, S-19, S-20, S-21, S-31, S-33, T-3, Y-2
 Connecticut - B-4, B-5, C-2, G-10, I-1, J-11, M-8, S-36, U-3, Z-1
 Georgia - G-10, H-14, S-29
 Idaho - N-2, S-16, W-2
 Maine - B-5, C-2, G-10, L-1, M-9, M-17, O-6, S-4, S-6, S-7, U-3, W-8
 Maryland - G-10, O-8, S-8, U-2
 Massachusetts - B-5, B-10, B-11, G-10, H-20, R-6, U-3
 Montana - B-23, H-7, H-12, T-4, W-2
 Nevada - D-2, G-5, O-5, V-4, V-5
 New Hampshire - B-5, C-2, G-10, M-8, O-1, O-2, P-1, S-10, V-3
 New Jersey - H-2, K-6, M-9, U-3, W-6, W-9
 New Mexico - J-1, J-4, J-9, R-2, W-3, W-10
 New York - G-10, J-11, K-4, K-5, M-8, M-9, N-1, S-11, T-1, U-3
 North Carolina - B-17, C-5, G-2, G-10, G-13, G-14, J-10, L-9, O-3,
 P-3, S-29, W-7
 Oklahoma - A-4, A-5
 Pennsylvania - G-10, M-6, M-9, M-16, S-24, U-2
 South Carolina - H-15, J-10
 South Dakota - L-2, N-6, O-7, S-13, S-32, W-4
 Tennessee - S-29
 Texas - C-13, E-2, E-6, L-3
 Utah - H-3
 Vermont - B-5, C-2, G-10, M-8, U-3
 Virginia - B-21, D-5, G-13, J-10, L-7, M-12, M-13, M-14, M-15, P-6
 Washington - N-2, W-2
 Wyoming - H-3, H-23, O-9, S-35
 World Occurrences - B-2, B-13, B-18, B-19, B-24, C-1, G-10, H-8, H-9,
 M-7, O-10, R-18

M-

Maine - see under Locations - United States

Malagasy Republic - see under Locations

Maryland - see under Locations - United States

Massachusetts - see under Locations - United States

Mexico - see under Locations

Migmatites - M-5, N-2, Y-2

Mineralogy:

Analytical data - A-8, B-7, B-19, D-4, E-4, E-6, G-6, G-12, H-25,
K-6, K-7, M-12, M-15, R-4, S-2, S-31, T-6, Y-1

Cyrtolite - A-4, A-5, H-15, K-4

Fission track - B-19, K-9, S-22

General uranium and thorium - A-9, F-9, F-10, G-6, H-18, J-10, K-6,
S-2, S-34

Multiple oxides - E-3, E-6, H-11, H-23, M-12, M-14

Paragenesis - B-12, B-18, C-15, F-2, F-3, H-4, H-11, I-2, J-5, J-10,
K-7, R-6, S-1, T-1, W-10

Thorium minerals - F-8, H-23, O-10, S-31

Unit cells - B-7, F-9, F-10, H-1, M-12, M-13, M-15, Y-2

Uraninite - B-7, E-6, H-1, I-1, K-2, K-4, M-6, M-16, Q-1, R-19, S-10, S-11

X-ray diffraction - A-6, E-3, E-6, F-10, G-2

Zircon - A-4, A-5, H-15, H-26, K-4

Montana - see under Locations - United States

Multiple oxides - see under Mineralogy

N-

Nevada - see under Locations - United States

New Hampshire - see under Locations - United States

New Jersey - see under Locations - United States

New Mexico - see under Locations - United States

New York - see under Locations - United States

North Carolina - see under Locations - United States

O-

Oklahoma - see under Locations - United States

Origin - B-14, B-18, C-1, C-4, C-15, E-5, F-2, F-5, F-8, G-8, G-12, H-8,
H-10, H-22, H-25, J-3, J-4, J-7, J-8, K-10, L-1, L-3, L-5, L-9, M-3,
M-5, N-5, O-7, R-8, R-11, R-15, R-19, S-17, S-27, S-33, S-36, S-37,
T-5, U-1, U-7, V-2

P-

Paragenesis - see under Mineralogy

Pennsylvania - see under Locations - United States

R-

Radioactivity:

Due to minerals other than uraninite - A-6, A-7, B-3, B-9, B-12, B-14, B-15, B-17, B-20, B-23, C-11, C-12, C-13, D-1, E-2, F-3, G-3, G-6, G-9, G-15, H-4, H-5, H-6, H-7, H-11, H-12, H-13, H-15, H-16, H-18, H-21, H-23, H-25, I-2, J-9, L-2, L-3, L-4, M-1, M-6, M-12, M-13, M-14, M-15, N-4, O-3, O-9, O-10, P-2, P-4, P-6, R-1, R-4, R-7, S-1, S-8, S-16, S-17, S-18, S-24, S-30, S-31, S-33, S-36, S-37, T-1, T-4, U-7, V-1, V-4, V-5, W-10

Due to uraninite - A-6, A-7, B-3, B-4, B-12, B-13, B-15, B-17, C-13, D-1, D-4, E-4, F-2, F-4, F-6, F-7, G-3, G-6, H-16, H-20, H-24, H-25, L-3, M-4, M-5, M-16, O-3, O-6, Q-3, S-1, S-19, S-20, S-21, S-24, S-30, S-31, S-36, S-37, T-1, T-3, W-1, W-9, Z-1

in granites - B-8, F-1, M-3, M-7, M-20, N-2, N-5, R-15, S-9, S-14, S-35, V-5, Y-1

in rocks other than granites - B-3, G-1, G-11, H-24, L-5, M-7

S-

Simple - see Unzoned

South America - see under Locations

South Carolina - see under Locations - United States

South Dakota - see under Locations - United States

Structure, internal - A-6, C-1, C-11, J-9, S-1

T-

Tectonic setting - C-4, N-5, O-3, R-13, V-2

Tennessee - see under Locations - United States

Texas - see under Locations - United States

Thorium minerals - see under Mineralogy

Trace Elements - see under Geochemistry

U-

Union Sov. Soc. Repub. - see under Locations

United States - see under Locations

Unzoned - B-1, B-6, B-8, F-7, G-9, H-9, H-18, H-19, K-10, N-4, R-10, R-18, S-19, S-20, S-21, S-33

Unit Cell - see under Mineralogy, Radioactivity

Uraninite - see under Mineralogy, Radioactivity

Uraniferous granites - see under Radioactivity

Utah - see under Locations - United States

V-

Vermont - see under Locations - United States

Virginia - see under Locations - United States

W-

Wall Rocks - B-1, B-14, F-2, H-20, H-25, J-9, K-1, L-8, M-5, N-6, R-8, R-13, R-18, S-33, S-37

Washington - see under Locations - United States

World Occurrences - see under Locations

Wyoming - see under Locations - United States

X-

X-ray Diffraction - see under Mineralogy

Z-

Zircon - see under Mineralogy

Zoned - B-18, B-23, C-1, C-14, F-4, H-4, H-11, H-12, H-13, H-28, J-2, J-4, M-4, P-2, P-4, P-5, Q-2, R-10, S-6, S-7, S-13, S-32, S-33, U-1, W-10

ERRATA

Please note the following corrections to the text of
"Uranium- and thorium-bearing Pegmatites of the United States":

<u>Page</u>	<u>Paragraph</u>	<u>Line</u>	<u>Change</u>	<u>To</u>
11	2	8	"Hewett"	Hewitt
66	2	2	"undoubtly"	undoubtedly
76	2	7	"these"	those
109	2	6	"latter"	former
116	3	2	"Matthews"	Mathews
References Cited			"Hewett 1954"	Hewitt 1954

NOTE: Mickle and Mathews (1978) has inadvertently been shown
in the text (especially pages 116-120) as Mickle and
Mathews (1979).