Bibliography of the Geology and Mineralogy of the Rare Earths and Scandium to 1971

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by JOHN W. ADAMS and ELEANORA R. IBERALL

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BIBLIOGRAPHY OF THE GEOLOGY AND MINERALOGY OF THE RARE EARTHS AND SCANDIUM TO 1971

By John W. Adams and Eleanora R. Iberall

INTRODUCTION

PURPOSE AND SCOPE

This bibliography is intended as an aid to researchers interested in the geologic occurrence, geochemistry, and mineralogy of the rare earths and scandium. Although largely restricted to these fields, the bibliography includes some references in areas of analytical chemistry, ore beneficiation, uses, physical properties, and certain artificial rare-earth compounds that resemble minerals.

The compilation is, admittedly, far from complete, particularly in regard to scandium, but an attempt has been made to include at least a sampling of the papers that have been published up to and including early 1971. These papers will themselves contain many additional references that have been omitted from our bibliography.

ARRANGEMENT OF THE BIBLIOGRAPHY

Reports with single authors are arranged alphabetically under the author's last name; those with more than one author are listed under the last name of the first author. The full title of the article follows the name of the author or authors; titles given in the romance languages or German are generally not translated. The source of the article and publication date follow the title. Most of the articles are from journals whose names are abbreviated in the bibliography but which can be identified fully by referring to the list of serial publications.

References to abstracts of the papers are given, where possible, for those papers appearing in journals available only in major libraries, or written in a language not commonly understood by English-speaking readers

USE OF THE INDEX

The index to the bibliography is also arranged alphabetically, and includes both topical and geographic headings. Each first-order heading is followed by second-order and third-order headings. For example, an

abstract by Pabst and Woodhouse about an occurrence of thalenite near Kingman, Arizona, appears under the following headings:

Arizona
  Mineral occurrence
    Thalenite, near Kingman
Mineral data, RE minerals
  Thalenite
    Occurrence, Arizona

All references have at least one set of heading entries, and most have several. Complete indexing of references is, of course, impossible. This may be particularly evident when many topics, or data on samples from many localities, are discussed in a single reference. Indexing of references involving various types of rocks was difficult. We used two broad classifications for most igneous rocks: 1) plutonic rocks for those that are apparently intrusive, and 2) volcanic rocks for those considered to be extrusive. Carbonatites and related alkalic rock complexes are listed under carbonatites. Pegmatites are chiefly granitic pegmatites but may include some alkalic types.

ACKNOWLEDGMENTS

This bibliography was developed from references collected by the senior author in the course of a commodity study of the rare earths. He is indebted to many of his colleagues in the Geological Survey for calling attention to references that might otherwise have been overlooked, and to Jane P. Ohl for assistance in the early stages of the work.

MINERALS OF THE RARE EARTHS

The following glossary of minerals has been included in this report for the convenience of the user. The glossary contains the names and chemical formulas of all the more common rare-earth-bearing species and most of the rarer ones. Some of the mineral names shown are no longer accepted, and some represent rather dubious species, but these have nevertheless been included, because they may be met in titles in the bibliography. No attempt has been made to record all the synonyms that may be found for some of the mineral names. A compilation of synonyms is given in the Chemical Index of Minerals, by M. H. Hey (1962, 1963).

The chemical formula for each species is given where possible. The formula shown is not always satisfactory, as many of the species have not been well studied. For some, the formulas are in dispute, whereas other are members of complex substitution series.

Most rare-earth minerals contain detectable amounts of all the 14 naturally occurring members of the group, but commonly the assemblage in any one species is preponderantly rich in either the cerium or yttrium subgroup elements. It will be noted that the rare earths are shown in most of the formulas by the chemical symbol for either cerium (Ce) or yttrium

(Y); for example, the formula for calkinsite is given as $Ce_2(CO_3)_3 \cdot 4H_2O$. This does not mean that cerium is the only rare-earth element in the mineral, but rather the mineral contains dominantly cerium subgroup elements of which cerium may expectably be the most abundant member. Similarly, the formula for weinschenkite (or churchite) is given as $YPO_4 \cdot 2H_2O$ to indicate that it is a phosphate of the yttrium subgroup of which yttrium is the dominant member. Some formulas, such as that of cordylite $(Ce, La)_2Ba(CO_3)_3F_2$, are written so as to emphasize the presence of other members of the subgroup. In a few formulas, the symbol RE is used as an abbreviation for rare earths, no distinction being made as to the assemblage.

The names and formulas given in the list have been taken from various sources including Heinrich (1958c), Fleischer (1966), Vlasov (1966), Frondel, Fleischer, and Jones (1967), and more recent entries in the New Mineral Names section by Michael Fleischer that is published regularly in the *American Mineralogist*.

Rare-earth group of elements

[Includes the lanthanide elements and yttrium]

Rare-earth element	*Atomic number*
Cerium subgroup:	
Lanthanum (La)	57
Cerium (Ce)	58
Praseodymium (Pr)	59
Neodymium (Nd)	60
Promethium[1] (Pm)	61
Samarium (Sm)	62
Europium (Eu)	63
Yttrium subgroup:	
Gadolinium (Gd)	64
Terbium (Tb)	65
Dysprosium (Dy)	66
Holmium (Ho)	67
Erbium (Er)	68
Thulium (Tm)	69
Ytterbium (Yb)	70
Lutetium (Lu)	71
Yttrium (Y)	39

[1]Promethium is a radioactive element with a very short half-life. Although traces occur in some natural materials, promethium is best known as a synthetic element (a fission product of uranium) and is not commonly considered as a naturally occurring member of the rare-earth group.

Glossary of rare-earth minerals

Name	Composition	Remarks
Absite	Thorian brannerite	
Abukumalite	$(Y, Ce, Ca)_5(SiO_4, PO_4)_3(O, OH, F)$	
Aeschynite	$(Ce, Ca, Fe, Th)(Ti, Nb)_2O_6$	Also eschynite
Agardite	$(Y, Ca, H)Cu_6[(AsO_4)_3(OH)_6] \cdot 3H_2O$	
Allanite	$(Ca, Ce, Th)_2(Al, Fe, Mg)_3Si_3O_{12}(OH)$	Synonym: orthite
Alumobritholite	Aluminian britholite	

Ambatoarinite	$Sr_5 (La, Ce, etc.)_{10} (CO_3)_{17} O_3$ (?)	Not well-defined. May be near ancylite or carbocernaite
Ampangabeite		=samarskite
Ancylite	$(Ce, La) (Sr, Ca) (CO_3)_2 (OH) \cdot H_2O$	
Ashcroftine	$K\ Na\ Ca\ [Y(OH)_2]_2\ [Si_6O_{12}\ (OH)_6] \cdot 4H_2O$	Tentative formula
Barsanovite	Na, Ca, Zr, Mn, Fe, Nb, RE silicate	May be=eudialite
Bastnaesite	$(Ce, La)\ F\ CO_3$	Also bastnäsite
Beckelite		=britholite
Beiyinite	Rare-earth carbonate (?)	Resembles bastnaesite
Belovite	$(Sr, Ce, Na, Ca)_5 (PO_4)_3 (OH)$	Apatite group
Betafite	$(U, Ca)_2 (Nb, Ti, Ta)_2 (O, OH, F)_7$	RE varieties known
Blomstrandine		=priorite
Braitschite	$7(Ca, Na_2)O \cdot RE_2O_3 \cdot 11B_2O_3 \cdot 7H_2O$	Tentative formula
Brannerite	$(U, Ca_2Th, Y) (Ti, Fe)_2 O_6$	
Britholite	$(Ca, Ce)_5 [(Si, P) O_4]_3 (OH, F)$	
Brockite	$(Ca, Th, Ce) PO_4 \cdot H_2O$	
Burbankite	$(Na, Ca, Sr, Ba, Ce)_6 (CO_3)_5$	
Calciogadolinite	Calcian gadolinite	
Calkinsite	$Ce_2 (CO_3)_3 \cdot 4H_2O$	
Cappelenite	$Y_6\ Ba\ B_6\ Si_3O_{25}$	
Carbocernaite	$(Ca, Ce, Na, Sr) (CO_3)$	
Caryocerite	Borosilicate of Ce, Ca, Y, and Th	Near melanocerite; identical with tritomite (?)
Cenosite	$Ca_2 (Ce, Y)_2 Si_4O_{12}CO_3 \cdot H_2O$	Also kainosite
Cerianite	$(Ce, Th) O_2$	
Cerite	Cerium silicate with minor Ca and Mg	
Cerotungstite	$(RE)W_2O_6 (OH)_3$	Cerian analogue of yttrotungstite
Cerphosphohuttonite	$(Th, Ce) (Si, P)O_4 \cdot 1.5H_2O$	
Cheralite	$(Ca, Ce, Th) (P, Si)O_4$	
Chernovite	$Y\ As\ O_4$	
Chevkinite	$(Ca, Ce)_4 (Fe, Mg)_2 (Ti, Fe)_3 Si_4O_{22}$	Also tscheffkinite
Chukhrovite	$Ca_3 Al_2 (Y, Ce) (SO_4) F_{13} \cdot 10H_2O$	
Churchite	$Y PO_4 \cdot 2H_2O$	Identical with weinschenkite
Cordylite	$(Ce, La)_2 Ba (CO_3)_3F_2$	
Davidite	$(Fe^{+2}, La, U, Ca)_6 (Ti, Fe^{+3})_{15} (O, OH)_{36}$	
Delorenzite		= tanteuxenite
Doverite	$Ca\ Y\ (CO_3)_2F$	Yttrium analogue of synchysite
Dysanalyte	$(Ca, Ce, Na) (Ti, Nb, Ta) O_3$	Niobian perovskite
Ellsworthite	Part of pyrochlore-betafite series	
Erikite	Probably rhabdophane or monazite	
Eschynite	$(Ce, Ca, Fe, Th) (Ti, Nb)_2 O_6$	Also aeschynite
Eucrasite	May be a high RE thorite or thorogummite	Poorly defined species

Ewaldite	$Ba(Y, Na, Ca)(CO_3)_2$	Proposed name for mineral intergrown with mackelveyite
Fenghuanglite	Thorian britholite	Synonym: fynchenite
Fergusonite	$(Y, Er, Ce, Fe)(Nb, Ta, Ti)O_4$	Part of fergusonite-formanite series
Fersmite	$(Ca, Ce, Na)(Nb, Ti, Fe, Al)_2(O, OH, F)_6$	High RE variety reported
Florencite	$CeAl_3(PO_4)_2(OH)_6$	
Fluocerite	$(Ce, La)F_3$	Synonym: tysonite
Formanite	$(Y, U, Th, Ca)(Ta, Nb, Ti)O_4$	Part of fergusonite-formanite series
Gadolinite	$Be_2FeY_2Si_2O_{10}$	Calcian variety described
Gagarinite	$NaCaY(F, Cl)_6$	
Hatchettolite	Uranian pyrochlore	May be high in RE's
Hellandite	near $Ca_3Y_4B_4Si_6O_{27} \cdot 3H_2O$	
Hibonite	$(Ca, Ce)(Al, Ti, Mg)_{12}O_{18}$	
Hjelmite	Possibly a variety of yttrotantalite	
Huanghoite	$BaCe(CO_3)_2F$	
Hydrocerite	$(La, Ce, Th)_2(Si, P)_2O_7 \cdot 5H_2O$	May be a variety of rhabdophane
Hydroxylbastnaesite	$(Ce, La)(CO_3)(OH, F)$	
Ilimaussite	$Na_4Ba_2CeFeNb_2Si_8O_{28} \cdot 5H_2O$	
Irinite	Thorian loparite	
Ishikawaite	$(U, Fe, Y, Ce)(Nb, Ta)O_4$	
Joaquinite	$Ba_2NaCe_2Fe(Ti, Nb)_2Si_8O_{26}(OH, F)_2$	
Johnstrupite		=mosandrite
Karnasurtite	$(La, Ce, Th)(Ti, Nb)(Al, Fe)(Si, P)_2O_7(OH)_4 \cdot 3H_2O$	Also carnasurtite
Keilhauite	RE-bearing variety of titanite	Synonym: yttrotitanite
Kemmlitzite	$(Sr, Ce)Al_3(AsO_4)[(P, S)O_4](OH)_6$	Cerian variety
Khlopinite	Titanium-rich samarskite (?)	Also chlopinite
Knopite	$(Ca, Ce)TiO_3$	Cerian perovskite
Kobeite	$(Y, U)(Ti, Zr, Fe, Nb)_2(O, OH)_6$	
Koppite	Cerian ferrian pyrochlore	
Lanthanite	$(La, Ce)_2(CO_3)_3 \cdot 8H_2O$	
Lermontovite	$(U, Ca, Ce)_3(PO_4)_4 \cdot 6H_2O$ (?)	
Lessingite		=britholite
Llallaguaite	Probably monazite	
Lombaardite	May be allanite	
Loparite	$(Ce, Na, Ca)_2(Ti, Nb)_2O_6$	
Loranskite	May be euxenite or polymignite	
Lovchorrite		See mosandrite

Lyndochite	May belong in eschynite-priorite series	
Mackelveyite	$Na_2 Ba_4 Ca Y_2 (CO_3)_9 \cdot 2H_2O$	Also Mc Kelveyite
Magnesium-orthite	Magnesian allanite	
Mangano-orthite	Manganoan allanite	
Marignacite	Cerian pyrochlore	
Melanocerite	Borosilicate of Ce, Ca, and Y	
Mendeleyevite	Titanian betafite	
Monazite	$(Ce, La, Nd)PO_4$	Normally contains Th
Mosandrite	$Na_2 Ca_4 Ce Ti Si_4 O_{10} (F, OH)_3$	
Muromontite	Beryllian allanite	
Nagatelite	Phosphatian allanite	
Ningyoite	$(U, Ca, Ce) (PO_4)_2 \cdot 1\text{-}2H_2O$	
Niobo-eschynite	$(Ce, Ca, Th) (Nb, Ti)_2 O_6$	
Nioboloparite	Niobian loparite	
Nordite	$Na_3 (Sr, Ca) Ce Mn_2 Si_6 O_{18}$ (?)	
Oborite	Reported to be like monazite	Associated with beiyenite
Obruchevite	$(Y, Na, Ca, U) (Nb, Ta, Ti, Fe)_2 (O, OH)_6$	
Orthite		= allanite
Parisite	$(Ce, La)_2 Ca (CO_3)_3 F_2$	
Perrierite	$(Ca, Ce, Th)_4 (Mg, Fe)_2 (Ti, Fe)_3 Si_4 O_{22}$	Dimorph of chevkinite
Pisekite	Complex multiple oxide of Nb, Ta, Ti, U, and RE's	Poorly defined species
Plumbopyrochlore	$(Pb, Y, U, Ca)_{2-x} Nb_2 O_6 (OH)$	
Polycrase	$(Y, Ca, Ce, U, Th) (Ti, Nb, Ta)_2 O_6$	Part of euxenite-polycrase series
Polymignite	$(Ca, Fe, Ce) (Zr, Ti, Nb, Ta)_2 O_6$	Possible formula
Pravdite	Altered britholite	
Priorite	$(Y, Er, Ca, U, Th) (Ti, Nb)_2 O_6$	Part of eschynite-priorite series
Pyrochlore	$(Na, Ca, Ce)_2 (Nb, Ti, Ta)_2 (O, OH, F)_7$	Part of pyrochlore-microlite series
Retzian	$Mn_2 Y (OH)_4 (AsO_4)$	
Rhabdophane	$(Ce, La) PO_4 \cdot H_2O$	
Rinkite	May be mosandrite	
Rinkolite	May be mosandrite	
Risörite		= fergusonite
Röntgenite	$Ca_2Ce_3 (CO_3)_5 F_3$	
Rowlandite	near $(Y, Fe, Ce)_3 (Si O_4)_2 (F, OH)$	
Sahamalite	$(Mg, Fe) Ce_2 (CO_3)_4$	
Samarskite	$(Y, Fe, U) (Nb, Ti, Ta) (O, OH)_6$	
Samiresite	Plumboan betafite	Not well defined species
Saryarkite	$(Ca, Y, Th)_2 Al_4 (Si O_4, PO_4)_4 (OH) \cdot 9H_2O$	
Scheteligite	$(Ca, Mn, Sb, Y)_2 (Ti, Ta, Nb, W)_2 (O, OH)_7$	May be a form of pyrochlore

Silicorhabdophane	Silicatian rhabdophane or monazite	
Sinicite	Uranium-rich eschynite	
Smirnovskite	$(Th, Ce, Ca)(PO_4, Si\,O_4)(OH, F)$	
Spencite	Borosilicate of Y, Th, and Ca	
Steenstrupine	$Ce_4\,Ca\,Na\,Si_3\,O_{12}\,(OH, F)$	
Stiepelmannite		= florencite
Stillwellite	$(Ce, La, Ca)\,B\,Si\,O_5$	
Sulfate-monazite	Sulfatian monazite	
Synchysite	$(Ce, La)\,Ca\,(CO_3)_2\,F$	
Tantalopolycrase	Tantalum-rich polycrase	
Tanteuxenite	Tantalum analogue of euxenite	
Tengerite	$Y_2\,(CO_3)_3 \cdot nH_2O$	
Thalenite	$Y_2\,Si_2\,O_7$	
Thorbastnaesite	$Th\,(Ca, Ce)\,(CO_3)_2\,F_2 \cdot 3H_2O$	
Thorosteenstrupine	$(Ca, Th, Mn)_3\,Si_4\,O_{11}\,F \cdot 6H_2O$	
Thortveitite	$(Sc, Y)\,Si_2\,O_7$	
Titanorhabdophane		= tundrite
Tombarthite	Water-rich silicate of RE's	Y is dominant RE
Törnebohmite	$Ce_3\,Si_2\,O_8\,(OH)$	
Treanorite		= allanite
Tritomite	Borosilicate of Ce, Ca, and Th	May be identical with caryocerite
Tundrite	$Ce_2\,Ti\,(Si, P)\,(O, OH)_7 \cdot 4H_2O$	Also titanorhabdophane
Tysonite	$(Ce, La)\,F_3$	= fluocerite
Ufertite		Synonym: davidite
Vudyavrite	Near $Ce_2\,Ti_2\,Si_4\,O_{15} \cdot 14H_2O$	May be altered mosandrite
Wakefieldite	$Y\,VO_4$	
Weibyite	Mixture bastnaesite and ancylite	Discredited species
Weinschenkite	$Y\,PO_4 \cdot 2H_2O$	= churchite
Wiikite	May be euxenite or obruchevite	
Xenotime	$Y\,PO_4$	
Yttrialite	$(Y, Th)_2\,Si_2\,O_7$	
Yttrobetafite	Cerian uranoan obruchevite	
Yttrocerite	Cerian yttrian fluorite	Also cerfluorite if Ce is dominant. Poorly defined names.
Yttrocolumbite	$(Y, U, Fe)\,(Nb, Ta)\,O_4$	
Yttrocrasite	$(Y, Th, U, Ca)_2\,Ti_4O_{11}$ (?)	
Yttrofluorite	$4[(Ca, Y)\,F_{2-3}]$ or $(Ca, Y)\,(F, O)_2$	Also yttrian fluorite. YF_3 may be 15–20 percent. Poorly defined.
Yttroilmenite		Synonym: samarskite
Yttroparisite	Yttrian analogue of parisite	Not well studied
Yttrotantalite	$(Fe, Y, U)\,(Nb, Ta)\,O_4$	
Yttrotitanite		Synonym: keihauite

Yttrotungstite - - - $Y_2W_5O_{18} \cdot 4H_2O$ - - - - - - - - - - - - - - -

Zirconolite - - - - (Ca, Ce) Zr $(Ti\ Nb)_2O_7$ - - - - - - - - - - - - -

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