



GEOLOGICAL  
SURVEY  
OF  
CANADA

DEPARTMENT OF ENERGY,  
MINES AND RESOURCES

PAPER 69-15

A PROGRESS REPORT ON EXPERIMENTS WITH  
CHEMICAL FIELD TESTS FOR THE DETECTION OF  
THE RARE-EARTH ELEMENTS CERIUM AND YTTRIUM

E. R. Rose

This document was produced  
by scanning the original publication.

Ce document est le produit d'une  
numérisation par balayage  
de la publication originale.



GEOLOGICAL SURVEY  
OF CANADA

PAPER 69-15

A PROGRESS REPORT ON EXPERIMENTS WITH  
CHEMICAL FIELD TESTS FOR THE DETECTION OF  
THE RARE-EARTH ELEMENTS CERIUM AND YTTRIUM

E. R. Rose

DEPARTMENT OF ENERGY, MINES AND RESOURCES

© Crown Copyrights reserved  
Available by mail from the Queen's Printer, Ottawa,

from Geological Survey of Canada,  
601 Booth St., Ottawa,

and at the following Canadian Government bookshops:

HALIFAX  
1735 Barrington Street

MONTREAL  
Æterna-Vie Building, 1182 St. Catherine Street West

OTTAWA  
Daly Building, Corner Mackenzie and Rideau

TORONTO  
221 Yonge Street

WINNIPEG  
Mall Center Building, 499 Portage Avenue

VANCOUVER  
657 Granville Street

or through your bookseller

Price: \$ .75

Catalogue No. M44-69-15

Price subject to change without notice

The Queen's Printer  
Ottawa, Canada  
1969

CONTENTS

	Page
Abstract .....	v
Introduction .....	1
Method .....	2
Preparation of sample .....	2
Tests for cerium .....	3
Hydrogen peroxide test .....	3
Quinalizarin test .....	3
Methylene blue test .....	4
Malachite green test .....	4
Tests for yttrium .....	5
Oxine test .....	5
Potassium ferricyanide test .....	5
Test for cerium and yttrium .....	6
Sulphuric acid test .....	6
Materials required .....	6
Reagents .....	6
Equipment .....	7
Solutions .....	7
Résumé of results .....	8
Conclusion .....	12
References .....	12
Table IA. Colours given by cerium, lanthanum, yttrium, and six other associated elements, using six proposed chemical tests .....	9
B. Colours given by twenty elements at one per cent concentration using six tests .....	10
II. Colours given and elements indicated by the proposed set of six chemical tests on rare-earth bearing minerals and rocks .....	11



ABSTRACT

This report describes a number of proposed chemical field tests developed by the writer for the detection of cerium and yttrium. The tests were developed to assist the writer in his study of the geology of rare-earth deposits in Canada and they may be of help to geologists and prospectors who are also concerned with the rare-earth elements. The tests are not yet specific, and further work is required.

## INTRODUCTION

Cerium (Ce) and yttrium (Y) are the most abundant of the rare-earth elements, heading the 'light' and 'heavy' cerium and yttrium groups respectively. The sixteen elements<sup>1</sup> comprising these groups - yttrium, lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium - are dispersed in a variety of rocks and concentrated in a number of rare minerals in which they are very difficult to detect and identify. Occurrences of these elements may be easily overlooked and pass unrecognized. A simple method for detecting the rare earths is of paramount importance to the geologist or prospector concerned with their occurrence.

Serious difficulties are involved in developing simple chemical tests for detecting rare earths, however, and little progress has been reported in the literature. The complexities of the analytical problems involved in determining rare earths by means of chemical techniques, colorimetry, emission and absorption spectroscopy, X-ray fluorescence and neutron activation methods, which emphasize the need for simple tests, are illustrated in works by Ingles (1959), Sandell (1959), Vickery (1960), Pinta (1962), Furman (1962), Kolthoff and Elving (1963), Topp (1965), Eyring (1964, 1966), and Prakash (1967).

During the summers of 1967 and 1968, the writer, assisted by J. H. C. Charette, made some progress in devising methods for detecting rare earths in rocks and minerals in the field, as a part of the writer's geological investigation of rare earth deposits in Canada. The results of this work, outlined here, are the product of an evaluation of the pertinent literature on the rare earths, the subsequent development of practical tests in the laboratory, and the application of the most promising methods under field conditions. The manuscript has been critically read by J. A. Maxwell, S. Abbey, and J. C. Ingles.

---

<sup>1</sup> In addition to these elements, scandium is also considered by some authorities to belong to the rare earth group. Neither lanthanum nor yttrium are true rare earth elements (lanthanons), but they are grouped with them because of their close chemical similarities. Promethium has not yet been found in nature, but has been produced artificially as a radioisotope.

---

Manuscript received: 13 January, 1969.  
GSC Project: 670028.  
Author's address: Geological Survey of Canada,  
601 Booth Street,  
Ottawa 4, Canada.

It should be noted that exhaustive tests on all possible interfering elements, and on combinations of these elements, have not been completed. The degree of success obtained in detecting cerium and yttrium in materials in which they are known to occur suggests, however, that the tests will work under certain conditions and that they may be of some practical value.

In addition to the sixteen rare-earth elements, six or more other rare elements, including scandium, zirconium, hafnium, niobium, tantalum, uranium and thorium, are commonly associated with the rare earths. Because of the many close similarities between the chemical properties of these elements and those of the rare earths, interferences in the tests for the latter are to be expected, as one or more of these elements may interfere with and mask the specific effect of any one rare-earth element. For this reason no one test is entirely specific for a given element, but by judicious application of a series of tests it is possible to detect the presence of a particular element, i. e., cerium or yttrium, with some assurance. Conversely, when cerium and yttrium are detected, it is probable that many of the other rare-earth elements are also present. Furthermore, with a few additional steps, it is also possible to detect the presence of several other associated elements, such as uranium, thorium, scandium, zirconium, niobium, titanium, vanadium, and phosphorus, while testing for the presence of the rare earths.

One of the best methods leading to the detection of rare-earth elements arises from their common association with uranium and thorium, the radioactivity of which may be detected by a Geiger counter or scintillometer. However, although the presence of rare earths should be suspected in all natural radioactive occurrences, they are also found in rocks and minerals showing little or no radioactivity.

The chemicals required for these tests must be used with caution, and disposed of with care. They should not be permitted to come into contact with the skin. In such an event, the affected area should be bathed immediately with water, washed with soft soap and bathed again repeatedly.

## METHOD

### Preparation of Sample

1. (a) A small sample (25 milligrams or more) of the unknown material is powdered as finely as possible, mixed with an equal volume of sodium carbonate ( $\text{Na}_2\text{CO}_3$ ), and the mixture fused<sup>1</sup> with a hot flame such as

---

<sup>1</sup> Many rare-earth-bearing minerals and rocks are sufficiently soluble in hot concentrated nitric acid to give chemical tests for rare earths; some, such as pyrochlore, betafite, fergusonite, euxenite and samarskite, require fusion before they will dissolve in acid.



that of a propane torch or blowpipe. A small steel plate will serve as a convenient base on which to pulverize and heat the sample. Alternatively a mortar and pestle may be used for the grinding, and a small crucible, or a hollowed charcoal or plaster block for the fusion.

- (b) The fusion product is powdered, placed in a small beaker with about 25 millilitres of concentrated nitric acid ( $\text{HNO}_3$ ) [CAUTION!], and the mixture is heated for about five minutes until it dissolves completely or, at least, partly.
- (c) After cooling, the solution is filtered, using a funnel and filter paper, and the filtrate is divided into ten equal portions of about 2 millilitres each in small beakers or test tubes. The solution is now ready for multiple testing, either in the beakers or test tubes, or on a spot plate, where only a few drops are needed.

### Tests for Cerium

#### Hydrogen Peroxide Test

2. (a) To one portion of the above filtrate, concentrated ammonium hydroxide ( $\text{NH}_4\text{OH}$ ) [CAUTION!] is slowly added dropwise (since this is a strong exothermic reaction) until either there is a faint suggestion of a permanent precipitate or cessation of fumes. A white precipitate obtained at this point may be due to the formation of the hydrous oxides of a number of elements, including cerium, yttrium, the other rare-earth elements, scandium, titanium, niobium, aluminum, calcium, magnesium, lead, zinc, tin, thorium and zirconium. A very heavy creamy white precipitate suggests the presence of calcium and phosphorus; a gelatinous orange-brown precipitate, iron; a yellow precipitate and solution, uranium; a dark brown solution and precipitate, chromium or manganese; and a blue colour, copper or nickel.
- (b) A few drops of hydrogen peroxide solution (3-30%  $\text{H}_2\text{O}_2$ ) are then added to the above mixture. If the colour of the solution and precipitate turns yellow-orange, the presence of cerium is indicated. If the precipitate remains white the presence of yttrium or other rare earths is possible, but so is the presence of a number of other elements referred to previously (see Furman, 1962).

#### Quinalizarin Test

3. (a) The quinalizarin test is made in both acid and basic solutions. To a second portion of the nitric acid filtrate, a few drops of quinalizarin ( $\text{C}_{14}\text{H}_8\text{O}_6$ ; tetrahydroxyanthraquinone) solution are added. A pale yellow, pale orange or pale pink colour is suggestive of cerium, yttrium or lanthanum; yellow-orange suggests uranium; and deep blue suggests thorium, copper or chromium.

- (b) The coloured solution is slowly neutralized, made slightly basic as before with concentrated ammonium hydroxide, and examined for changes in colour and appearance. If cerium alone is present, the colour of the solution will turn from yellow to muddy brown and then to blue-violet with a grey or violet-blue precipitate upon addition of two more drops of quinalizarin solution. Lanthanum produces somewhat similar colours. In the presence of yttrium alone, the colour of the solution will change from pale yellow or pink to pale violet or blue with a blue-white precipitate. Solutions containing uranium pass from a shade of yellow-orange (acid), through orange and greenish yellow to a shade of olive green (basic) and those containing iron from very pale amber yellow (acid) to dark brown (basic). Thorium gives deep shades of blue in both acid and basic solutions. Copper, nickel, and scandium give dark shades of blue in basic quinalizarin solutions. When these and other elements are present they may mask, or partly mask, the colours expected for cerium and/or yttrium, but in so doing may indicate their own presence in the solution, a condition which may be verified by another test. Because of the variety of colours given by quinalizarin it is advisable to check them against known solutions from time to time to familiarize oneself with the significant reactions.

#### Methylene Blue Test

4. (a) A few drops of a portion of the nitric acid filtrate are placed on a spot plate or in a test tube, and a drop of aqueous methylene blue solution is added to them. In the presence of cerium in the ceric form ( $Ce^{+4}$ ) in nitric acid solution, the methylene blue colour turns from greenish blue to red. The reddish colour may be partly masked by the bluish or green colour of the complexes formed by most other elements, and the red colour may appear only for an instant as the drop enters the solution, or somewhat later as a dry reddish or violet rim around the solution on the spot plate. This test is sensitive and, if positive, may be considered almost specific for cerium. The violet colour produced by cobalt nitrate solution is the only other similar test noted by the writer.
- (b) When the ceric solution is neutralized and then made basic with  $NH_4OH$  as before, it passes from red (acid) through grey (neutral), to deep blue (basic); uranium passes to dark green, and iron to blue with an orange-brown precipitate (see Eyring, 1964).

#### Malachite Green Test

5. (a) A few drops of a portion of the nitric acid solution are placed on a spot plate or in a test tube, and a drop of malachite green solution is added. A red, brown, or orange coloration is suggestive of cerium, lanthanum, yttrium, uranium, iron, or zirconium; a blue coloration indicates thorium.

- (b) The solution is carefully neutralized and then made slightly basic as before with concentrated ammonium hydroxide. Under these conditions cerium produced a blue or green colour, lanthanum a bright yellowish green or creamy solution, yttrium a green or creamy yellow colour, uranium an orange or yellow, thorium a creamy white colour, iron a brown to orange colour, vanadium a bright yellow colour, cobalt an orange colour, and copper a pale blue colour. Because of masking effects in solutions containing several of these elements this test is of limited usefulness, but in certain instances it may be of assistance in detecting cerium, in differentiating between cerium and yttrium, and in detecting thorium (see Eyring, 1964).

#### Tests for Yttrium

If the presence of yttrium is still in doubt after the foregoing, two further tests may be applied in order to detect or confirm its presence - the oxine and potassium ferricyanide tests.

#### Oxine Test

6. (a) A few drops of oxine solution (8-quinolinol; 8-hydroxyquinoline) are added to another portion of the nitric acid filtrate and the colour is noted. Cerium is indicated by a dark brown or yellow colour; lanthanum, yttrium, thorium and uranium by one that is pale yellow.
- (b) The solution is then carefully neutralized and made basic with ammonium hydroxide. Under these conditions yttrium produced a yellowish orange solution and precipitate, cerium chocolate brown, iron dark brown or green, uranium orange, lanthanum and thorium pale yellow. A small amount of iron may produce a very deep green colour which may partly mask this test for yttrium if both are present in the solution (see Duval, 1954; Eyring, 1964).

#### Potassium Ferricyanide Test

7. (a) The potassium ferricyanide test is done in both acid and basic medium. A few drops of a saturated aqueous solution of potassium ferricyanide [ $K_3Fe(CN)_6$ ] are added to a portion of the nitric acid filtrate. A deep brown solution with orange precipitate is indicative of yttrium or uranium; yellow of lanthanum or thorium; and amber brown of cerium, iron, vanadium, or manganese.
- (b) When the solution is neutralized and made basic, yttrium passes from orange-brown to yellow; cerium from amber brown to yellow, with tan or brown precipitate; and uranium and iron stay brown. The yellow colour produced by yttrium may be partly masked by the dark colours

of the other elements mentioned, but a deep brown solution with orange precipitate which turns yellow in basic solution is indicative of yttrium (see Vickery, 1960).

### Test for Cerium and Yttrium

#### Sulphuric Acid Test

8. (a) If doubt remains as to the presence of cerium and yttrium it is necessary to proceed as follows. (Where circumstances permit, this test may be done immediately after step 2 (b) in order to separate the rare earths from interfering elements.) To another portion of the nitric acid filtrate carefully add ammonium hydroxide until precipitation is complete and the solution is basic. Filter the solution and carefully add 1:1 sulphuric acid ( $H_2SO_4$ ) dropwise to the filtrate in a beaker, bringing it carefully to a pH of 2-3 using pH indicator paper. Filter this solution, using standard filter paper. Any rare earths present in the original residue will have been selectively dissolved and should now be present in the filtered acid solution (the filtrate).
- (b) Heat the filtrate. The cerium group, if present, will be precipitated, but the yttrium group will remain in solution. Filter this solution using standard filter paper.
- (c) Repeat the tests for cerium and yttrium using the above precipitate and solution (see Ingles, 1959; Shaw *et al.*, 1959).

### MATERIALS REQUIRED

#### Reagents

Concentrated nitric acid ( $HNO_3$ )  
Concentrated sulphuric acid ( $H_2SO_4$ )  
Hydrogen peroxide (30%  $H_2O_2$ )  
Distilled water ( $H_2O$ )  
Methanol (methyl hydrate) ( $CH_3OH$ )  
Anhydrous sodium carbonate ( $Na_2CO_3$ )  
Potassium ferricyanide [ $K_3Fe(CN)_6$ ]  
Quinalizarin (tetrahydroxyanthraquinone) ( $C_{14}H_8O_6$ )  
Methylene blue  
Malachite green  
Oxine (8-hydroxyquinoline;  $HO-C_6H_3N:CHCH:CH$ )

### Equipment

Prospectors' pick or hammer  
Small steel plate, or mortar and pestle  
Small crucible, platinum or porcelain  
Plaster or charcoal block  
Propane torch, or blow torch  
2 dozen glass beakers, 30 ml size  
1 dozen pyrex test tubes  
1 test tube rack  
2 glass or plastic funnels, medium size  
filter paper Whatman No. 1, to fit funnels  
1 pair tongs  
1 measuring scoop, spatula, or knife  
1 dozen plastic or glass dropping bottles  
2 medicine droppers  
2 stirring rods  
1 spot test plate, optional  
1 pair rubber gloves, optional  
litmus paper, neutral  
pH indicator paper, range 2-3.5

### Solutions

Potassium Ferricyanide Solution - Stir about 16 g potassium ferricyanide in 50 cc of distilled water until solution is saturated. Filter and store in a dropping bottle. Replenish daily by adding a few grains of potassium ferricyanide to the solution. A drop of this solution in concentrated  $\text{HNO}_3$  turns yellow-green, then brown; in concentrated  $\text{NH}_4\text{OH}$  a yellow solution and brown precipitate forms.

Quinalizarin Solution - Dissolve 0.1 g quinalizarin in 50 cc of methanol ( $\text{CH}_3\text{OH}$ ); store in a dropping bottle. In  $\text{HNO}_3$  a drop of this solution turns very pale pink; in  $\text{NH}_4\text{OH}$ , pale violet.

Methylene Blue Solution - Dissolve 0.2 g methylene blue (water soluble technical grade) in 50 cc of distilled water. Store in a dropping bottle. In  $\text{HNO}_3$  a drop of this solution gives a pale greenish blue colour changing to deep blue in  $\text{NH}_4\text{OH}$ .

Malachite Green Solution - Dissolve 0.1 g malachite green (water and alcohol soluble, technical) in 100 cc of distilled water. Filter and store in a dropping bottle. A drop of this solution in  $\text{HNO}_3$  turns orange; and in  $\text{NH}_4\text{OH}$ , cloudy yellow, with white precipitate.

Oxine Solution - Dissolve 1 g oxine (8-hydroxyquinoline) in 50 cc of methanol (99.9% pure  $\text{CH}_3\text{OH}$ ). Filter and store in a dropping bottle. A drop of this solution is pale yellow in  $\text{HNO}_3$ , and yellow-brown in  $\text{NH}_4\text{OH}$ .

Test Solutions - Test solutions are prepared by dissolving analyzed salts of the various elements in concentrated nitric acid.

### RÉSUMÉ OF RESULTS

Some of the results obtained with these tests are shown in Tables I and II. As may be seen, chemical tests were made on only a limited number of possible interfering elements, but a variety of elements in a number of analyzed minerals and rocks were checked with satisfactory results. In addition, several samples of known, unknown or uncertain rare-earth content were also checked.

Table IA shows the colours produced in individual solutions of cerium, lanthanum, yttrium, and six other allied and interfering elements, both in acid and basic media and at concentrations of 1, and 0.1 per cent of each element. Table IB shows the colours given by acid and basic solutions of twenty different elements at concentration of one per cent. All of the tests are sensitive, and able to detect 0.1 per cent and less of cerium or yttrium, but difficulties may be experienced from combinations of interfering elements and masking colours. For example, the orange colour produced by cerium in basic solution in the Hydrogen peroxide test can be confused with the brown colour produced by iron, or the orange-brown produced by a combination of cerium, iron and uranium, but neither iron nor uranium would give a white precipitate initially in neutralized solution. If uranium is suspected it may be checked by its radioactivity or by its yellow precipitate when NaOH is added to the HNO<sub>3</sub> solution. The orange to yellow colour of cerium and lanthanum produced in acid solution by the Quinalizarin test, may be confused with the yellow of uranium or iron; however, the deep violet or brown precipitate and solution of cerium, and the pale violet of yttrium, in basic solution in the latter test, usually serve to distinguish them from the dark brown of iron, the blue of thorium or scandium, and green of uranium. A cautionary note must be added here however, since Quinalizarin alone in basic solution also has a pale violet colour that may be mistaken for that of cerium in low concentration, or yttrium. In the Methylene blue test, the red colour produced by the ceric ion (Ce<sup>+4</sup>) in acid solution is distinctive, but it may be partly masked by the blues of other predominating elements and the result may be a purple or violet tinge that quickly disappears from the drop or appears later in the dry rim around the drop on the spot plate or in the solution. The red colour is not produced by the cerous ion (Ce<sup>+3</sup>). In the Malachite green test, the green and white produced by yttrium in basic solution might be distinctive if white was not so easily masked by the colours of other elements, but combined with the other tests, the Malachite green test may be useful in distinguishing between cerium, yttrium, and iron. The Oxine test is helpful in distinguishing between cerium and yttrium, but iron may interfere. In the Potassium ferricyanide test, the orange-brown of yttrium in acid solution and yellow precipitate in basic solution are distinctive, but may be masked by the dark browns and green-blacks of other elements.

TABLE IA  
COLOURS GIVEN BY CERIUM, LANTHANUM, YTTRIUM, AND SIX OTHER  
ASSOCIATED ELEMENTS, USING SIX PROPOSED CHEMICAL TESTS

ELEMENT and COMPOUND	REAGENT		Hydrogen Peroxide H <sub>2</sub> O <sub>2</sub>	Quinalizarin	Methylene Blue	Malachite Green	Oxine (Hydroxy- quinoline)	Potassium Ferricyanide	Element Indicated and Test
		% pH	1 - .1	1 - .1	1 - .1	1 - .1	1 - .1	1 - .1	
Nitric acid	a	clear		pale violet	green	orange	pale yellow	dark brown	Reagent Reagent
Ammonium hydroxide	b	clear		pale violet	blue	pale blue	orange- yellow	dark green	
Cerium (Ce <sup>+3</sup> )	a	clear		pale orange	blue	orange	pale yellow	amber	Ce-H <sub>2</sub> O <sub>2</sub>
Cerous nitrate	b	orange ↓		blue-violet ↓	blue (white)	creamy green ↓	pale yellow pale yellow ↓	yellow (tan)	
Cerium (Ce <sup>+4</sup> )	a	amber- clear		orange- yellow	red-wine	brown-red	brown	amber	Ce-Methylene blue
Ceric ammonium sulphate	b	orange ↓		grey-blue (grey) ↓	blue ↓	blue-green ↓	brown ↓	yellow (tan) ↓	Ce-Quinalizarin
Lanthanum (La)	a	clear		pale pink	blue	orange- brown	pale yellow	yellow	La-Quinalizarin
Lanthanum oxide	b	white ↓		violet-blue ↓	blue ↓	green-white ↓	yellow ↓	yellow ↓	
Lanthanum (La)	a	pale amber		pale orange	blue	pale orange	pale yellow	yellow	La-Quinalizarin
Lanthanum chloranilate	b	white ↓		blue ↓	blue ↓	green-white ↓	yellow ↓	yellow ↓	
Yttrium (Y)	a	clear		pale yellow	blue	orange-brown	pale yellow	brown- (orange)	Y-K-ferricyanide
Yttrium oxide Y <sub>2</sub> O <sub>3</sub>	b	white ↓		pale violet ↓	dark blue	green-white ↓	orange - yellow ↓	yellow ↓	Y-Malachite green; ferricyanide
Yttrium (Y)	a	clear		pale orange	blue	red-orange	pale yellow	brown- (orange)	Y-K-ferricyanide
Yttrium nitrate	b	white ↓		violet ↓	blue ↓	green-yellow ↓	yellow ↓	yellow ↓	Y-Malachite green; ferricyanide
Uranium (U)	a	pale yellow		orange	green-blue	brown-green	pale yellow	amber (brown)	U-H <sub>2</sub> O <sub>2</sub>
Uranium octo-oxide	b	orange- yellow ↓		olive-green ↓	green-blue ↓	orange- yellow ↓	orange ↓	amber (brown) ↓	
Uranium (U <sup>+4</sup> )	a	pale yellow		pale yellow	blue	brown-green	colourless	yellow-brown	U-H <sub>2</sub> O <sub>2</sub>
Uranyl nitrate	b	orange- yellow ↓		yellow- green ↓	green ↓	yellow ↓	yellow- orange ↓	yellow- orange ↓	
Thorium (Th)	a	clear		deep blue	blue	dark blue	yellow	amber yellow	Th-Quinalizarin; Malachite green
Thorium nitrate	b	white ↓		pale blue ↓	blue (white)	white ↓	pale yellow	yellow ↓	
Iron (Fe)	a	clear		pale orange	blue	orange- brown	pale yellow	brown	Fe-Malachite green
Iron oxide	b	brown ↓		reddish brown ↓	blue- (orange) ↓	brown-orange ↓	brown ↓	brown- yellow ↓	Fe-K-ferricyanide
Aluminum (Al)	a	clear		clear	green-blue	orange-brown	pale yellow	pale yellow	
Aluminum nitrate	b	white ↓		pale violet ↓	blue ↓	blue-white ↓	yellow ↓	yellow ↓	
Zirconium (Zr)	a	clear		pale yellow	blue	orange-brown	pale yellow	yellow	
Zirconium oxide	b	white ↓		violet ↓	white-blue ↓	yellow-white ↓	orange- yellow ↓	yellow ↓	
Scandium (Sc)	a	clear		very pale	green-blue	orange-brown	pale yellow	yellow	
Scandium oxide	b	white ↓		dark blue ↓	blue ↓	yellow-white ↓	orange- yellow ↓	yellow ↓	

a - indicates acid solution  
b - indicates basic solution  
↓ - indicates precipitate (colour)

TABLE IB

COLOURS GIVEN BY TWENTY ELEMENTS AT ONE PER CENT CONCENTRATION USING SIX TESTS

ELEMENT and COMPOUND	REAGENT		Hydrogen Peroxide H <sub>2</sub> O <sub>2</sub>	Quinalizarin	Methylene Blue	Malachite Green	Oxine (Hydroxy- quinoline)	Potassium Ferricyanide
	% pH		1 - .1	1 - .1	1 - .1	1 - .1	1 - .1	1 - .1
Niobium Niobium oxide	a b	clear white ↓	orange-pink	green-blue blue	pale orange	pale yellow	deep yellow	
Tantalum Tantalum oxide	a b	clear white ↓	pale orange pale violet ↓	pale blue blue ↓	yellow pale orange ↓	pale yellow deep yellow ↓	yellow brown ↓	
Hafnium Hafnium oxide	a b	pale green white ↓	pale orange white ↓	green-blue blue ↓	pale orange pale yellow ↓	pale yellow deep yellow ↓	pale brown dark green	
Silicon Silicic acid	a b	clear clear	pale orange pale violet	green blue	orange yellow	pale yellow brown	yellow yellow	
Magnesium Magnesium oxide	a b	clear clear	pale orange violet	green blue	orange yellow	pale yellow orange- yellow	green-yellow green-yellow	
Calcium Calcium oxide	a b	clear clear	pale orange violet ↓	green blue ↓	orange yellow ↓	pale yellow yellow- green ↓	yellow yellow ↓	
Sodium Sodium nitrate	a b	clear clear	pale violet pale violet	pale blue pale blue	brown white	pale yellow yellow	yellow yellow	
Potassium Potassium nitrate	a b	clear clear	pale orange pale violet	blue pale blue	pale brown white	pale yellow yellow	yellow yellow	
Titanium Titanium oxide	a b	white white ↓	white pale violet ↓	green blue ↓	orange- yellow yellow ↓	pale yellow olive green ↓	yellow green ↓	
Vanadium Vanadium pentoxide	a b	yellow- orange yellow ↓	yellow violet ↓	green blue ↓	dark brown yellow ↓	light brown light brown ↓	dark brown dark green	
Manganese Manganese nitrate	a b	cloudy brown ↓	pale orange violet	blue dark blue	orange yellow-green	pale yellow yellow	light brown dark brown	
Chromium Chromium trioxide	a b	orange brown	blue black	pale brown green	orange orange-yellow	brown brown	orange orange-yellow ↓	
Nickel Nickel oxide	a b	pale green clear	pale green blue	blue blue	orange green-blue	pale green dark green	orange-yellow dark green	
Cobalt Cobalt nitrate	a b	pale blue clear	pink red	violet dark blue	orange pale brown	pale orange red	dark brown dark brown	
Copper Copper oxide	a b	blue dark blue	pale blue dark blue	pale blue dark blue	brown blue	green blue-green	olive green dark blue ↓	
Molybdenum Molybdc oxide	a b	clear pale amber	clear pale violet	blue blue	orange green	pale yellow yellow - green	yellow yellow	
Tin Metallic tin	a b	clear white ↓	clear pink ↓	blue blue ↓	pale brown orange-yellow ↓	pale yellow orange- yellow ↓	yellow yellow ↓	
Lead Lead nitrate	a b	clear cream- brown ↓	pale amber pale blue ↓	blue dark blue ↓	pale brown white ↓	pale yellow yellow ↓	yellow yellow ↓	
Zinc Metallic zinc	a b	clear yellow	clear pale violet	blue dark blue ↓	pale brown	yellow yellow ↓	orange-yellow yellow ↓	
Phosphorous Phosphoric oxide	a b	clear clear	clear pale violet	pale blue pale blue	pale brown	yellow yellow	yellow yellow	



TABLE II  
 COLOURS GIVEN AND ELEMENTS INDICATED BY THE PROPOSED SET  
 OF SIX CHEMICAL TESTS ON RARE-EARTH-BEARING MINERALS AND ROCKS

SAMPLE AND COMPOSITION	HYDROGEN PEROXIDE	QUINALIZARIN	METHYLENE BLUE	MALACHITE GREEN	OXINE (HYDROXYQUINOLINE)	POTASSIUM FERRICYANIDE	ELEMENTS DETECTED
Allanite-R. E., U, Th-bearing silicate (Ca, Ce <sub>2</sub> (Al, Fe) <sub>3</sub> Si <sub>3</sub> O <sub>12</sub> )	a pale yellow b orange c Ce, U, Fe	pale yellow ↓violet-brown Ce, Fe	green ↓green (orange) U, Fe	orange ↓orange Fe, U	pale yellow ↓yellow (green-brown) Fe, U, Ce	dark brown ↓yellow (brown) Fe, U, Y, Ce	Ce, Y, U, Fe
Bastnaesite-Ce fluorocarbonate-(Ce, F)CO <sub>3</sub> 3 samples, 3 localities	a yellow b orange c Ce	amber ↓grey-blue Ce	violet-red ↓blue Ce+4	orange ↓yellow La(?)	yellow ↓green Ca(?)	brownish ↓greenish (orange) Ce(?), U(?)	Ce, La(?), U(?)
Monazite-R. E. and Th-bearing phosphate (Ce, La, Y, Th) PO <sub>4</sub>	a clear b ↓orange c Ce	pale orange ↓deep violet Ce, Th	green ↓blue (white) Th, U(?)	orange ↓green La, Y	yellow ↓yellow (brown) Ce	dark brown ↓yellow Y	Ce, La, Y, Th, U(?)
Euxenite-R. E., U, Ti, Nb, Ta multiple oxide Ce 2%, La 2%, Y 9%, Fe 3%, Nb 13%, U 4%, Th 0.5%	a muddy b ↓yellow (orange) c U, Ce, Fe	pale yellow ↓(violet)↓(brown) Ce, Fe, U	green ↓blue (orange) U, Fe	orange ↓green (yellow) Y, La, U(?)	pale yellow ↓yellow (green-brown) Fe, U, Ce(?), Y(?)	dark brown ↓yellow (orange) Y, U, Fe	Ce, La, Y, U, Fe
Ellsworthite-R. E., U, Ti, Nb, multiple oxide Ce 1%, Y 0.1%	a yellow b ↓yellow c U, Ce(?)	yellow ↓yellow U	green ↓green U	orange ↓green Y, La(?), Ce(?), U	yellow ↓green-yellow Y(?), La(?), Ce(?)	brown ↓yellow Y	Ce(?), La(?), Y, U
Pyrochlore-R. E., Nb, Ti, U, Th, multiple oxide R. E. 6%, Nb 35%, Ti 6%	a pale yellow b ↓yellow (orange) c U, Fe, Ce(?)	pale yellow ↓yellow (orange) Fe(?), U(?)	green blue ↓blue (orange) U(?), Fe(?)	orange ↓green (orange) Y(?), La(?), U(?)	pale yellow ↓green Nb(?), Ti(?), Y(?), Fe	brown ↓yellow (green) Y	Ce(?), Y, U, Fe
Yttrian Garnet (Ca, Y) <sub>3</sub> Fe <sub>2</sub> (SiO <sub>4</sub> ) <sub>3</sub> Y 1%	a clear b ↓orange-yellow c Ce(?), U, Fe	pale orange ↓violet Ce(?)	blue ↓blue (orange) U(?), Fe	orange ↓yellow (orange) U(?), Fe, La(?)	yellow ↓black Ce(?), Fe(?)	brown ↓yellow (orange) Y, Ce(?)	Ce(?)
Green Apatite Ca <sub>2</sub> (PO <sub>4</sub> ) <sub>3</sub> + Ce 0.2%, La 0.1%, Y 0.05%	a clear b ↓yellow c Ce(?)	clear ↓violet Ce, Y(?)	blue green ↓blue U(?)	orange ↓green Y(?), La(?)	yellow ↓deep-yellow La(?), Y(?), U(?)	brown ↓green Ce(?)	Ce, La(?), Y(?)
Brown Apatite Ca <sub>2</sub> (PO <sub>4</sub> ) <sub>3</sub> + R. E., U?	a clear b ↓white c Ca, P, Y(?)	orange ↓violet Ce, Y(?)	blue ↓blue U(?)	orange ↓blue-green Y	yellow ↓green Ca	dark brown ↓green Y, U(?)	Ce(?), Y(?), Ca
Phosphate rock Ca <sub>3</sub> (PO <sub>4</sub> ) <sub>2</sub> + R. E. 0.01% + (U + V)	a amber b ↓yellow-orange c Ce, U, Fe(?)	orange ↓violet Ce, Y(?)	blue ↓blue U(?)	orange-brown ↓yellow U, Y(?), Zr(?), Sc(?)	yellow ↓yellow-green (green) Y(?), La(?), Ce(?)	brown ↓yellow Y	Ce, Y, U, V, La(?)
Granite pegmatite R. E. 0.01-0.1% (4 samples from 1 dyke)	a clear b ↓pale yellow c Ce(faint), U(?)	pale orange ↓violet Ce, Y(?)	blue ↓blue U(?)	orange ↓yellow Zr(?)	yellow ↓green Ca(?)	brown-yellow ↓yellow Y (faint)	Ce (faint), Y (faint), La(?), U(?)

a - acid solution  
 b - basic solution  
 c - elements indicated  
 ↓ - (precipitate)

Table II shows the colours produced by a variety of cerium- and yttrium-bearing minerals and rocks when they were subjected to the six chemical tests. The sensitivity of the tests is indicated by the ability to detect cerium and yttrium in concentrations of less than 0.1 per cent, and the difficulties caused by some interfering elements are shown by the variations in the colours produced. Despite the interferences it seems possible to detect cerium and yttrium in many types of rocks and minerals, including those in which the presence of rare earths is otherwise unknown.

### CONCLUSION

Progress made in initial attempts to develop chemical field tests for detecting the presence of rare-earth elements, particularly cerium and yttrium, in complex geological materials from known occurrences, has been encouraging. The tests require the availability of concentrated acids and bases, pyrex glassware, a propane torch and other simple reagents and equipment, and, although they are best done at a base camp, their use can be extended to the outcrop by means of a portable kit. The time required for making the tests is small, once familiarity with the methods is established.

Because the tests are not yet specific, further efforts will be made to improve them and to extend their range and accuracy of detection. More specific tests for individual rare-earth elements may yet be found as this work progresses.

### REFERENCES

Duval, Clément

- 1954: Inorganic colorimetry; Société d'Édition d'Enseignement Supérieur, Internatl. Union Pure Applied Chem. Monograph; Paris.

Eyring, Leroy (ed.)

- 1964: Progress in the science and technology of the rare earths; vol. 1, Dept. Chemistry, Arizona State University; Macmillan, Pergamon Press, London, New York, Toronto.

- 1966: Progress in the science and technology of the rare earths; vol. 2, Dept. Chemistry, Arizona State University; Macmillan, Pergamon Press, London, New York, Toronto.

Furman, N.H. (ed.)

- 1962: Scott's standard methods of chemical analysis; 6th ed., vol. I., chap. 13, pp. 309-323 by C. J. Rodden; D. Van Nostrand Company, Inc., Princeton, N. J.

- Ingles, John C.  
1959: Manual of analytical methods for the uranium concentrating plant; Can. Dept. Mines Tech. Surveys, Mines Br., Monograph 866.
- Kolthoff, I.M., and Elving, P.J. (ed.)  
1963: A Treatise on analytical chemistry, Pt. II, vol. 8; The rare earths and rare-earth compounds, pp. 1-146, Interscience Publishers, New York.
- Pinta, Maurice  
1962: Recherche et dosage des éléments traces; Dunod, Paris, 726 p.
- Prakash, Satya  
1967: Advanced chemistry of rare elements; Chemical Publishing Company, Inc., New York, 808 p.
- Sandell, E. B.  
1959: Colorimetric determination of traces of metals; 3rd ed., Interscience Publishers, Inc., New York, 1032 p.
- Shaw, Van E., Bauer, Donald, J., and Gomes, John M.  
1959: Extraction of yttrium and rare earth elements from a euxenite carbonate residue; U.S. Bur. Mines, R.I. 5521.
- Topp, N. E.  
1965: Chemistry of the rare earth elements; 165 p., Elsevier Publishing Co.
- Vickery, R. C.  
1960: The chemistry of yttrium and scandium; International Series Monographs on Inorganic Chemistry, vol. 2, Pergamon Press, 1960, 123 p.